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An investigation into the acceptance of augmented reality in Saudi Arabian schools

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Augmented reality (AR) technology has recently begun to be introduced into science classes in Saudi schools. This emerging technology promises many advantages in teaching, like multimedia capabilities, improving content presentation, and enhancing students' learning. Although the Ministry has made it available in all schools, it is not universally used and the reasons for acceptance or non-acceptance of AR technology among Saudi secondary school teachers are unresearched. Thus, this study investigates teachers' perspectives on factors affecting AR technology acceptance and actual adoption. The theoretical framework of relevant factors exploited was the Unified Theory of Acceptance and Use of Technology (UTAUT2), partly with the aim of assessing its suitability in the Saudi educational context where it had not been widely used, adding one construct arising from that context (resistance to change as a personality trait). Qualitative interviews with 25 teachers in secondary schools in the Riyadh region provided data, allowing the teachers' own themes to also emerge. The study revealed that seven types of factors drive Saudi teachers' acceptance of AR technology: performance expectancy, facilitating conditions, social influence, effort expectancy, hedonic motivation, and price in relation to value. This predominantly confirmed the relevance of the UTAUT2 model: only the factor of habit was unsupported, and the evidence was ambiguous with respect to the involvement of resistance to change as a personality trait. Notably both AR users and non-users often had favourable attitudes to the teaching value of AR (its performance expectancy) but it was a variety of facilitating (or rather hindering) conditions that often accounted for non-users not using it. Implications are identified for the Ministry and school authorities who contribute to lack of use of AR by not in all respects providing necessary conditions for

its use, and for the UTAUT2 model where the mediating role of some variables is suggested.

Abbreviations

AR- Augmented Reality technology

BI – UTAUT2 Dependent Variable: Behavioural Intention

DIT – Diffusion of Innovation Theory

EE – UTAUT Independent Variable: Effort Expectancy

FC – UTAUT Independent Variable: Facilitating Conditions

HAB - UTAUT2 Independent Variable: Habit

HM – UTAUT2 Independent Variable: Hedonic Motivation

ICT – Information and Communication Technology

PE – UTAUT Independent Variable: Performance Expectancy

PU – TAM Independent Variable: Perceived Usefulness

PV – UTAUT2 Independent Variable: Price Value

SCT – Social Cognitive Theory

SEM – Structural Equation Modelling

SI – Social Influence

TAM – Technology Acceptance Model

TPB – Theory of Planned Behaviour

TRA – Theory of Reasoned Action

TPD- Teacher professional development

UTAUT – Unified Theory of Acceptance and Use of Technology

UTAUT2 - Unified Theory of Acceptance and Use of Technology version 2

RTC - Independent Variable Resistance to change

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1. Chapter one: Introduction

The inventions produced by the tremendous technological developments that are witnessed today invite decision-makers to examine their possible use in the field of education as potentially invaluable support for the learning process. The introduction of computers to the education field has already constituted a major turning point in the use of technologies in education. This was followed by the development of computer-generated technologies to serve the content of different subjects differently.

Integrating new technologies, or indeed any innovations, into classrooms is however a difficult process because it requires many steps. These span the design and development of ways in which the technology can be used to support the required syllabus and relevant pedagogy (Morrison and Lowther 2001), the evaluation of its effectiveness including assessment of the attitudes to it of key stakeholders (Smaldino *et al.* 2008) and, if it proves beneficial, implementation of its widespread adoption (Froyd *et al.* 2017). The present study focuses on the teacher evaluation and implementation aspects of a particular recent technology - called 'augmented reality' (AR) - which has emerged and has been tried in the field of education, where some studies have shown its feasibility, and some countries have already introduced it into the classroom. Saudi Arabia is one of these countries (Alkhattabi 2017), but is at an interesting stage where higher authorities claim to have made AR available, and indeed expect it to be used in school science teaching, but not all teachers have yet accepted it to the point of actually adopting it for regular use. Note that the term *acceptance* will be used for the evaluative *attitudes* or *intention to use* that a teacher may have with respect to new technology. This may exist whether or not the technology is available to use, or the teacher actually uses it. On the other hand, *adoption* denotes the teacher actually and willingly *using* the technology, or having students use it, in this study in the science classroom. Adoption normally presupposes acceptance, but there are educational contexts, such as the one in this study, where as I shall see there is an attempt to impose use/adoption on teachers.

This study argues, supported by the literature review in chapter 2, that relevant AR resources and ways of using them in classrooms, particularly in school science lessons, have already been developed in many countries, and indeed that evaluation studies have already shown AR to be widely effective in many contexts. The remaining problem is that of the dissemination and adoption of it, especially in contexts such as Saudi Arabian secondary schools where it is relatively new. The present study will therefore argue for, and carry out, a study exploring the factors that affect Saudi secondary school science teachers' beliefs about AR which determine its potential acceptance and consequential actual use (adoption). In particular the factors influencing current non-users will be compared with those apparently affecting users. In this way, it is hoped to provide vital evidence to inform those in whose hands it is to promote up to date and innovative teaching and learning methods in Saudi schools (e.g. the Ministry of Education, school inspectors, teacher trainers/providers of professional development).

Augmented reality (AR) is a notable technological innovation which has emerged in recent years, and which demands substantial research to enable educationalists to understand how it may gain wider acceptance and be actually implemented successfully in classrooms in Saudi Arabia. Research on the integration of new technology in education is particularly important in Saudi Arabia given the Saudi government's commitment to substantial investment and reform in the education field (see further 2.1). AR presents an important opportunity to demonstrate how the dissemination of a new technology might contribute to the changes planned for the educational system.

This chapter presents the study context, the research problem which this study will illuminate, with a discussion of the specific circumstances that dictated the decision to conduct the study. It also explains the significance of the study and the structure of the thesis.

1.1 Statement of the research problem

AR is a remarkable new technology which calls for research attention due to its recognised potential as a tool for improving the education sector. AR is most closely allied to virtual reality (VR), but while VR takes the form of providing the user with a complete virtual environment, AR intermingles virtual elements with the actual reality that surrounds the user. These days it is often implemented through apps on smartphones, which many Saudi secondary school children already possess. A simple example of how this might be used in a science class is the following, as described in this quote from (educationalappstore.com):

> **SkyView**
>
> SkyView app is a free augmented reality (AR) app for both iOS and Android devices that uses your smartphone's camera to uncover different stars, constellations, planets, star clusters and other celestial bodies in the night sky. Using SkyView app, you can also discover coordinates and facts of planets, comets and asteroids, which if you have kids, can turn your stargazing into an educational experience. SkyView Free is a stargazing app allowing users to explore aspects of the night sky and learn more about astronomy. Skyview app download is available for iOS (iPad and iPhone) and Android devices as well as on desktop (PCs, laptops and Mac computers).

As will be described in chapter 2.2, many AR apps have already been created, covering many educational areas, including basic science. The effectiveness of AR in enhancing teaching and learning processes has also been confirmed by many empirical studies conducted around the world (again see literature review in chapter 2). These studies also show that AR positively affects the development of a wide range of students' skills, including not only content understanding and information retrieval but also cooperation and motivation.

Against this background, in the Arab world, studies on AR applications in education are minimal or almost non-existent, particularly in Saudi Arabia. A few articles have been published recently in Kuwait and Egypt, but they are mostly published in the Arabic language (Alkhattabi 2017; Safar *et al.* 2017). Compounding these problems is the fact that teaching and learning in schools in Saudi Arabia often continues to rely on traditional methods and the instructors' discretion in delivering knowledge, with teachers and students making only limited attempts to use information and communication technology (ICT) (Elyas and Al-Ghamdi 2018). Although the country's Ministry of Education has provided schools with many modern technologies, actual ICT implementation remains limited (2.1.5).

The implementation of new technologies in classrooms therefore depends not only on higher authorities providing and encouraging it, but also on teachers' perceptions regarding such innovations and their intention to adopt them (i.e. their acceptance of it). Almaghlouth (2008) found that Saudi science teachers perceive ICT to be beneficial in classrooms but that they are reluctant to use it due to insufficient support. This finding highlights the necessity of considering teachers' perceptions in any initiatives for technology integration, such as the current one involving AR.

Students in the digital age are aware of how to use technological tools for social and entertainment purposes but very often not necessarily to support their learning. Many studies conducted in Saudi Arabia have indicated that the decreasing cost of mobile devices has enabled most Saudi students to possess smartphones or tablets and this can contribute to an increase in the number of students who use mobile devices for learning purposes (Al-Fahad 2009; Nassuora 2012; Alfarani 2016). For example, during the Coronavirus (Covid 19) pandemic, the Saudi Ministry of Education moved school teaching to online instruction with the schools closed. If families did not already possess suitable devices, the MoE supplied them. All students therefore learned more about how to use devices for learning, e.g. by browsing the unified education platform (madrasati.sa), whose popularity is evidence of widespread use of devices by all families. With increasing availability of several apps that have an educational benefit, guiding and encouraging students to these apps is therefore now also urgently required. Thus, Saudi teachers should keep up with this development and with changes in students' awareness and needs.

Studies have found that AR technology can enhance teaching and learning, and plenty of suitable apps are available. However, more research still needs to be conducted about the acceptance of AR as a teaching tool and what teachers in education expect from the technology. An understanding of user expectation is also one of the key foundations for establishing better-designed AR systems and applications that will result in more acceptance of this technology.

Alkhattabi (2017), in her study about the application of AR technology in Saudi primary schools, recommended that continuing research about the acceptance and adoption of AR in classrooms is required in Saudi Arabia, and this thesis is a response to that call. My review of the literature on AR and its application in education (2.2.1) clearly reflects the need for increased investigations into the factors affecting the acceptance and the use by teachers of this technology in Saudi teaching environments. This prompted me to explore the AR resources that Saudi teachers have available to use, and teachers' willingness to use them, in Saudi Arabian schools.

1.2 Significance of the study

A developing country seeks to develop its education system as a corner stone of its overall development plan. In an era where a revolution in technology is taking place, many technological innovations cause huge changes in teaching and learning processes which encourage developing countries to incorporate modern technologies into educational practices with the aim of improving them and creating new opportunities for their citizens to benefit from these innovations.

Hence, the government of Saudi Arabia recently announced a national comprehensive project (Vision 2030) that is aimed at developing the technological capacities of government institutions, including the Ministry of Education, and achieve a full transformation into e-governance. Correspondingly, the Ministry of Education launched a number of e-learning initiatives that are intended to effectively integrate technologies into schools. The implementation of these projects requires studies that investigate the introduction of these changes so as to ensure the best use of modern technologies as teaching and learning instruments in Saudi Arabian schools and accordingly support the managerial decision to adopt such innovations.

In September 2018, the Ministry of Education began to apply augmented technology (AR) seriously in its curricula for schools. New science textbooks incorporating links to specially commissioned AR technology apps became available for secondary school teachers and students. Consequently, this is the first study conducted since the actual introduction of AR technology in Saudi secondary schools. The study will evaluate AR applications in terms of their feasibility for school use, by exploring the acceptance of AR among Saudi teachers, both those who are actually using AR and those not, which will help the MoE to evaluate AR implementation in Saudi educational settings.

This study will therefore provide both decision-makers and teachers with a better understanding of factors involved in determining the *acceptance* of AR use in schools and the challenges that may impede consequent actual technology *adoption*. This research is being conducted at a time when the country is undergoing education reform following increased government investment in such effort (see further 2.1). Ensuring the productive use of investment also necessitates research that explores the implementation of effective teaching and learning methods. Probing into the use of AR in Saudi Arabian schools represents an avenue of research that provides unique contributions to teaching and learning across the country. The findings of the current study, which highlight the teachers' perceptions about the potential for the use of AR, will therefore ultimately contribute to the quality of the teaching methods applied in Saudi schools and bridge the gap in the literature regarding the use of new educational technologies, especially in the Arab context.

Aside from its value for the Saudi educational context, this study has importance and interest for technology acceptance researchers worldwide. In the continual quest to enhance teaching quality, the use of AR in educational environments represents a very current and practical research topic. This study is expected to expand the literature on ICT acceptance and adoption/use in Saudi Arabia and the Arab world. This makes it of interest not only to researchers in other similar contexts but also more widely, since it fills a gap in the current literature. Studies that focus on AR have thus far generally neglected the Arab education sector as an area for research, with the majority of studies on educational technologies being carried out in Western developed countries. Findings in Western schools may not be generalisable to Saudi schools given the tremendous influence of culture on education and individuals. The current work contributes to filling this void in that it researches aspects of AR implementation in the Saudi Arabian cultural context.

It will be seen later that study is also of broad interest to researchers in its specific aim to test out the usefulness of the UTAUT model of factors affecting technology acceptance in a context where it has not already been widely used, and in doing so both considering teachers who use it and those that do not. This comparison, as well as the focus on teacher acceptance rather than learner acceptance, is not so often seen in research studies. Furthermore, this study will propose the addition of a factor not usually included in the model, but prompted by the Saudi context. This is Resistance to change, as a personality trait of the teacher, and not simply as a behaviour prompted by one of the factors already included in the UTAUT, such as a belief that the technology is not cost efficient (see chapter 3). The study includes an account of this and of its value in explaining the data gathered.

1.3 Thesis structure

The thesis is organised as follows. The first chapter introduces the research, including briefly describing the topic, and the context of the study, giving a statement of the research problem, its aim, and why this study is important. The second chapter presents the literature review of the study, including the overview of the education system in Saudi Arabia where the study will be conducted. There are some sections about the culture and school and integrating ICT and science education in Saudi Arabia. This chapter includes many sections about AR technology, including the use of AR in education, its advantages, disadvantages, and challenges. Importantly the chapter ends with three sections linking AR with learning theories. The third chapter addresses the models of technology acceptance and provides the conceptual framework that guides the research questions and the research methodology.

The fourth chapter describes the research design and methodology. In this chapter also there is the presentation of findings from the quantitative questionnaire data, while chapter five gives the qualitative data findings from interviews. The discussion of the study findings is presented in chapter six, followed by chapter seven that provides conclusion of the study including a summary of the research, implications, recommendations for future work and study limitations.

2. Chapter Two: Literature review

This chapter aims to review the literature in two pertinent areas. First it offers a brief background on education in Saudi Arabia including the system of education, science education, ICT use, and the influence of culture on schooling. Second It will present definitions of AR technology, and review its applications and implementation in educational practices, and research on its effectiveness.

2.1 Study context

The study is carried out in the Kingdom of Saudi Arabia (KSA) which was founded in 1932 by King Abdulaziz al Saud. It occupies approximately four-fifths of the Arabian Peninsula in Western Asia and is located at the intersection of three continents: Asia, Africa and Europe. Riyadh is the capital and the most populous city of the kingdom, which occupies about 2,250,000 square kilometres (868,730 square miles). KSA has a total population of about 34.218 million, of which 21.1 million (61.7%) are Saudi citizens, according to the General Authority for Statistics report (stats 2019).

Figure 1 Saudi Map (source: google.com)

KSA has developed rapidly since the discovery of oil in 1938, causing its economy to become the largest in the Arab world. The constitution and law in the kingdom are based on the Islamic religion and are derived from the holy law (Shari'at) and its interpretations. Saudi culture is also clearly influenced by Islam, to a greater extent than many Muslim Arab countries of the Arab world. In terms of social life, 'the moral values are derived from a complex commitment to the interpretation of Quranic principles; this moral code affects a range of areas from personal relations to tribal and extended family values'. In recent times, to keep up with the demands of global development, the Saudi government has begun introducing modern legislation imported from developed countries, as a result of which, amongst other things, its citizens, both male and female, receive many scholarship opportunities to attend prominent universities around the world.

2.1.1 The educational system in KSA

In 1925, formal education began to be officially provided in KSA with the Saudi government's decision to create a general directorate of education, which comprised four elementary schools. In 1932, King Abdulaziz extended the household responsibilities of the general directorate of education to involve all Saudi regions at the time. After the discovery of oil, the government took several steps to improve the education system in the western region in the late 1930s and early 1940s. These efforts led to the official establishment of the Ministry of Education in 1953, which introduced universal state education in the kingdom with the announcement of free, compulsory education provided at the point of use for all children aged between 6 to 15 years (MoE, 1978). About a quarter of the Saudi government's budget is dedicated to the Ministry of Education (Al Sadaawi 2010).

The administration of the education system in Saudi Arabia is centralised, and the educational policies are designed by the government. The curriculum, textbooks and syllabus are uniform throughout the kingdom. The provision of education is segregated by sex, although the same curriculum applies to both sexes. The education system includes three educational grade stages: primary school, intermediate and general secondary school (Alrashidi and Phan 2015). Primary school is intended for students aged 6–12 years; intermediate school for students aged 12–15 years; and secondary school for students aged 15–18 years. Each school has a separate campus in the major cities. The number of students in Saudi schools has increased in recent years, with a total of roughly (6187776) students in 2020. The number of schools across all three levels recently reached 27,000 (MoE, 2020).

With respect to higher education, King Saud University was the first university to be founded in Riyadh in 1957. In 1975, the Ministry of Higher Education was established to supervise the higher educational institutions in the kingdom. In January 2015, the Ministry of Higher Education merged into the Ministry of Education, and the latter became the authority responsible for overseeing all levels of education in the country, including kindergarten, primary and secondary education, special needs education, teacher training, junior colleges and universities.

Institutions of higher education in Saudi Arabia comprise 25 public universities, 9 private, 34 private junior colleges. While these are mainly targeted at both men and women, there is a public women's university which was established recently in Riyadh called the Princess Nourah Bint Abdulrahman University (Ministry of Education, 2017). Most of the universities have a similar curriculum, although there are a few exceptions. Two universities, Islamic University and Imam Muhammad ibn Saud Islamic University, focus on teaching Islamic subjects and the Arabic language to international students. Further, King Fahd University of Petroleum and Minerals (KFUPM) specialises in teaching subjects related to petroleum and mineral sciences, and King Abdullah University of Science and Technology (KAUST) specialises in science and technology studies. In the following section there is a presentation of the contribution of culture in the Saudi education field.

2.1.2 The role of culture in Saudi Education

As mentioned above, Saudi Arabia is conservative nation, with some of its educational policies influenced by Arabic culture and certain interpretations of the Islamic Shari'at. As a result, the complex value system has played a key role in discouraging change and modernisation. This can be seen, for example, in the level of Internet acceptance in the Arab world, which shares a common culture, religion and language with the KSA. Although Arab governments have devoted a significant budget to the transfer of new technologies to their countries, the level of Internet acceptance is still low. Loch *et al.* (2003) interpreted this reluctance to be a result of cultural conflicts with this technology. People have concerns not about the technology itself but about the new international values that it provides access to, which may be in conflict with their personal belief systems (Abunadi 2013). Due to these social concerns, there is a dedicated department in the Communications and Information Technology Commission (CITC) that works to filter Internet content, blocking any material that is inconsistent with societal values (CITC.SA, 2015). A broad list of websites is blocked under these rules, and even the public has the opportunity to introduce additions to the list. Given such constraints, the implementation of ICT in Saudi education is still in the early phases of development (Albugami and Ahmed 2015).

Saudi society has historically experienced much conflict with respect to the introduction of new technology, such as the telegraph, automobiles, the radio, the television (TV), cameras, the Internet and smartphones, which has reduced the effective application of such technologies in many sectors (Al saud 2012) . In the context of schools, ICT was introduced very gradually because the decision makers were keen to avoid any resistance to change or any conflict between the integration of ICT and community values and beliefs. It is unsurprising therefore that the form of modern technology that has perhaps found most acceptance in schools and universities is Microsoft Powerpoint, used primarily by the teacher, and displayed to the class with a digital projector. This is itself a content free application where the user supplies the content, and is often used without associated internet access. Hence it is compatible with delivery of quite traditional class material which formerly would have been written on a blackboard/whiteboard.

The cultural influence can be seen also in gender segregation in Saudi schools, where the female schools are separate and female teachers are not allowed to teach male students, as well the male teachers are not allowed to teach female students. The gender segregation policy is generated from the complex interaction between religious teachings and Arab social traditions, and this policy has in the past saddled women with facilities substantially inferior to those available to their male counterparts (Almohsen 2001). It has also prevented the MoE from benefiting from interaction and cooperation between qualified teachers in both schools whether in teaching students, sharing expertise between genders, or in making decisions or designing curricula. In addition, it is hard for female teachers to attend certain meetings or training courses that are delivered by men due to the gender segregation policy and its effects.

Currently, some of these restrictions have been lifted to allow women to teach students of both genders in the three primary grades and participate in some work meetings to share their experiences with men. There is notable progress in improving the situation of women and some new legislation that relates to female workers. For example, Prince Norah university is open to accepting more than 4000 female students yearly and females have the opportunity to gain senior positions in the MoE. There is also a new act that allows women to drive a car and travel alone to attend professional meetings and training courses which may help in improving the female teacher's performance and support women's participation in development projects. It is worth also mentioning the developments that have taken place in recent years with the launch of the Saudi Vision 2030 initiative, which included empowering women to take up some leadership positions and participate in some activities alongside men.

Regarding the curricula, the culture also has a significant role in the design of the content of the subjects taught. The overall education policy includes some explicit statements about ensuring compatibility with Islamic legislation and societal traditions in all syllabus designing (MoE,2015). There are further some concerns amongst ordinary members of Saudi society about any changes in the subjects or content because some conservative people believe that any modification in the subject content will lead to changing or replacing some of the Islamic subjects or will negatively influence students' thoughts and ideologies. For example, teaching some curriculum content is not allowed, such as principles of philosophy, anything with sexual content, and religious differences, due to the strong influence of Saudi culture on the design of the curriculum. MoE efforts to change or develop the curricula occasionally face some challenges because of community concerns which have a negative impact on the progress of change.

In the aftermath of the 11 September 2011 events in the USA, Saudi Arabia’s education system became the target of widespread criticism in local and international media. This campaign led the political leadership to intervene decisively in curriculum amendment discussions, which resulted in some important modifications being introduced, such as reducing the number of religious subjects (Prokop 2003), increasing the profile of math and science, providing teachers with training courses, and supporting all schools with ICT resources. Although, these moves resulted in improving schools' infrastructure and broke new ground in curriculum modernization, the process of change is still facing some challenges and the MoE is still paying a lot of attention to societal culture in all the steps it takes.

Over the last two years, with the 2030 Vision announcement, dramatic changes in Saudi government policies have been causing some modifications of Saudi society's views on modernization (Topal 2019). This may impact on the acceleration of change in the educational field in the future. At this point, however, it is important for this study to shed some light on science education in the KSA and the history of the introduction of ICT in Saudi education so far.

2.1.3 Science education

Science education in both developing and developed countries has undergone significant changes in recent years with the aim of promoting teaching and learning in an age of fast moving technological change. The many challenges associated with such development (Kaptan and Timurlenk (2012) are of course more prominent in the former. In Saudi Arabia, where this study is conducted, there is widespread concern particularly about the outcomes of science education due to the increasing need for high-grade scientists, technicians, and engineers. These are required specifically in order to meet the requirements of the government's development plans which broadly aim to move the country away from its historical high reliance on foreign experts in key services and industries with a large science/technology component, such as oil, telecommunications and medicine. The impact of this 'saudification' program is seen partly in the great emphasis now placed on English language in the educational system, but is also evidenced of course in special attention to the teaching of math, science and technology. For some decades, in fact, the Ministry of Education has a historical record of concern to improve the science and math curriculum, and began quite early to launch a large-scale science education reform in order to respond to the needs created by accelerating changes in the world (Qablan *et al.* 2015). The most important reform began with King Abdullah's initiative to improve education and schools in 2007 (implemented through a specially set up company called Tatweer). One of the initiative's innovations was the development of a math and science project which was established in 2009. This project focused on importing highly effective educational materials (e.g.

from McGraw-Hill for math and natural science curricula) and translating them into the Arabic language.

The project's philosophy was based on many current educational principles: learner-centered learning, multimedia-based generation of excitement, learning through multiple sensory channels, learning through collaborative work, knowledge exchange, communication and representation in various ways, active learning based on exploration and investigation, improving thinking skills, developing the skills of decision-makers, developing the learner's abilities to present planned initiatives, linking learning to real-life contexts. The project also worked on professional development of teachers, supervisors and curriculum experts in the country through continuous support elicited from international centres of expertise in this field. Further, relevant to the present study, the project aimed to benefit from the output of outstanding international experts and produced educational materials supporting technology as part of the process of delivering the mathematics and natural sciences curricula in schools generally. (MoE, 2009).

Consequently, the MoE began to integrate new technologies into the classroom and science lab to support improvement of the level of science teaching and learning in parallel with the changing science curriculum. Many research studies then indicated that using technological support does indeed help to create an environment where a student is more engaged in the process of learning in contrast with traditional education where the student is only a listener and observer (Albugami and Ahmed 2015).

In the past, the science teacher was using available simple materials to introduce his topics or do his experiments for students. This process required moving students to the lab and waiting for materials to be prepared before starting the teaching process. Moreover, the teaching was centred around the teacher him/herself. The teacher had total control of the learning process without any role for students, which made learning in the class a boring process.

With the technological revolution, integrating digital tools in the teaching and learning of science is playing a significant role in simplifying the explanation of key concepts and making learning a more interactive, active and enjoyable process. For example, the teacher can create an experiment using some computer software and sometimes he can import it from the internet without spending much of his own time or effort (Almaghlouth 2008). He also has an opportunity to share with students more video, PowerPoint slides, sounds and photos which help to deliver knowledge in easy and fun way. The teacher role still exists, but more as a class manager than a controller, so he/she needs to learn this new role. Hence it is important next to discuss the programmes prepared for developing teacher performance.

2.1.4 Teachers' professional development

Effective professional development (PD) is an essential mechanism for maintaining a high standard in science education. It helps teachers to master the requisite knowledge and skills, recognize the specific expertise associated with their work and promote the quality of teaching in school (Heba *et al.* 2015). Thus, science teacher education is receiving more attention in Saudi Arabia than it has ever received before, in particular after the weak performance of Saudi science students in the Trends in International Mathematics and Science Study (TIMSS) test (Mullis *et al.* 2004) 2008.

Attention to teacher professional development programs was initiated as far back as 1975 by the allocated department which is called the General Administration for Educational Training and Scholarships within the Ministry of Education to provide teachers with two forms of professional development program: teacher training and internal and external scholarships for teachers (Heba *et al.* 2015). More recently, the government established a national company (Tatweer) which was allocated funding not only to develop the curriculum and supply schools with new educational materials but also to provide professional development programs for both science teachers and supervisors (Almazroa and Al-Shamrani 2015). This process is promoting a transfer from traditional teaching methods to more advanced, inquiry-oriented, styles which require teachers to adopt a supporting rather than controlling role in student learning and performing of these new activities. As I have indicated, that connects with use of technology such as AR which very often is associated with student centered active learning. However it is not clear if that strong connection is yet made in Saudi professional development programs.

Currently, a training and scholarship centre has been established in each of the 45 local departments of education across the country to provide professional development programs for all teachers and supervisors (MoE, 2019). The national center has specific professional programs for math and science teachers which are part of the Project of Mathematics and Natural Sciences (PMNS) and provides additional programs to train science supervisors to train science teachers.

However, these programs have been criticized by many studies that have been conducted on this matter because the most commonly used methods in these programs are only training workshops (Mansour *et al.* 2013) . Moreover, the goals of PD programs which have been established by the MoE, although supposedly based on determining the needed skills and competences of teachers, were in fact mismatched regarding supervisors' and teachers’ actual needs. A group of studies found that teachers were not called upon to participate in designing and preparing the PD programs that were offered (Sabah *et al.* 2014). Hence a divergence can easily arise between what skills and knowledge teachers actually lack and what higher authorities think they need.

Some departments in the MoE have different priorities according to Sabah *et al.* (2014), that may explain why most PD programs do not actually meet teachers’ needs. That study (Sabah *et al.* 2014) collected and analysed the guidebooks for training programs in several educational districts and found that there is a lack of clear guiding goals for PD programs in Saudi Arabia. The reason for the lack of suitable shared goals can be attributed to the method of formulating the list of programs offered. Essentially, the program providers frame the list of programs based on prioritizing the needs of the science teachers as specified by the MoE. However, in King Abdullah’s project (implemented through Tatweer) there is a different group of goals provided for PD programs. For instance, there are some relevant if rather vaguely worded goals for science teachers such as developing basic teaching skills in order to improve general educational outcomes, and focusing on developing both teachers' and supervisors’ learning capacity (Tatweer Project, 2019).

In contrast with the top down approaches to specifying needs just described, Mansour *et al.* (2014) identified teachers’ needs by actually interviewing them and ascertaining a list of their requirements. There emerged four main themes. 1) Pedagogical, including the sub themes: Deepening pedagogical content knowledge, Responsiveness to the new science curricula reforms, Classroom management, Assessment and Accommodating students’ individual differences. 2) Content knowledge, including the following sub themes: Deepening subject content knowledge, Practical skills and Cultural issues related to science education. 3) ICT, including the sub theme: Technological pedagogical content knowledge. 4) Professional skills, including: Self-development and learning how to learn, Teacher as a researcher, and Leadership. However, some of these themes do not exist in the programs provided (Riyadh Educational Administration, 2014). In particular, in respect of theme 3, the researcher is not aware of any training made available to science teachers in the KSA that specifically targets AR.

2.1.5 ICT in Saudi schools

Merging modern technologies into the Saudi environment, particularly in education, passed through gradual stages. The first efforts to implement technology in the Saudi educational context were characterised by multiple attempts to introduce computing as a subject. The first attempts to introduce ICT in education were made in the mid-1980s when some private schools began to teach a few subjects related to computer science as part of the curriculum, such as: An Introduction to Computer Sciences, Programming in BASIC, Systems Programming and The Use of Information Systems (Oyaid 2009). The success of these attempts led the Ministry of Education to introduce computer studies as a compulsory subject in state secondary schools by 1990 and to equip schools with computer labs. In the next decade, additional subjects were added to the curriculum: Information Technology, Information Systems, Computer Applications and The Information Age.

A next important step occurred when computer labs were made available in all secondary schools with training courses for select teachers to use and integrate computers into the learning process in subjects other than computing or ICT (Al-Aqeely 2001). In addition, many computer training programmes were organised for teachers as well students to improve their technology skills. However, the use of the Internet was still forbidden in schools and in some departments within the Ministry.

At the dawn of the new millennium, the field of education witnessed the wider integration of computers into the teaching process and administrative tasks as a result of the Ministry of Education’s commitment. The government began to increase the budget allocated to ICT by providing schools with ICT equipment that allowed both teachers and students to use the Internet. A study conducted by Almaghlouth (2008) revealed that digital projectors (which of course require a computer or similar device to generate and store what is displayed) were the most common tools available in schools in comparison with computers, scanners, printers, TV monitors, VCR/DVD players and smart boards. In addition, the development of digital learning resource centres in Saudi schools became an important project as part of the Ministry of Education’s efforts in this direction. This project aimed to develop school libraries and equip them with multiple information sources, including digital resources, to enrich the learning environment (Oyaid 2009).

The Saudi government has invested heavily in the education technology sector. For example, the ‘Tatweer’ project (set up by King Abdullah’s Public Education Development) mentioned earlier aims to provide schools with ICT equipment, such as laptops, smart boards and projectors. The budget allocated to this project was about 9 billion Saudi rial over a six-year period (Ministry of Education, 2007).

Saudi Arabia is a pioneer in the Arab World with respect to its experiments with e-learning and its applications. The initiated national project called ‘Watani’ (2000) is designed to encourage the use of computers in the learning process. One of the main objectives of this project is to connect all Saudi schools and educational directorate districts throughout the Kingdom via an extensive network. Through this, teachers, students and parents will be able to access a vast source of reference information. This project has six objectives (www.tatweer.edu.sa): (1) improving student's skills by using various technologies in the learning process, (2) providing an enriched learning environment through multiple sources, (3) improving teachers' potential through promoting information technology (IT) in all educational initiatives, (4) enhancing the outcomes of the educational process by supporting future graduates who have mastered the use of IT, (5) supporting the government's efforts to create a nucleus for an advanced IT industry and (6) enabling a comprehensive awareness of the benefits of employing IT in education. Of these the first two relate most directly to the relevant theme of AR use in science classes.

In terms of higher education, some Saudi universities, such as King Abdulaziz University and King Saud University, provide several courses related to the use of ICT in schools to support the development of education in the country. These universities have designed and offer masters and diploma programmes for teachers, which are focused on developing curricula associated with the use of ICT in education. In its constant pursuit of modern technologies, the Ministry of Education began, in September 2018, to implement some of the newest technologies seriously into its schools and revised the curricula to fit with these technologies. One of these technologies is Augmented Reality technology (AR) which is quickly gaining momentum in the education sector worldwide due to its claimed potential to enable new forms of learning and transform the learning experience. The MoE, with the Tatweer company, created some AR applications specifically dedicated to math and science teaching in Saudi schools, for the Apple and Google apps platforms, and they designed specific books fitting in with those apps to be used in schools. The following section will present some background about AR technology including its advantages and disadvantages in educational practices.

2.2 Augmented Reality technology

Augmented reality (AR) is a relatively new technology that has recently begun to be used in the field of education. It can be defined as a new technology that integrates 3D virtual objects with the real world while the user interacts with all of these components (Chen 2006). Similarly, the definition reported by Höllerer and Feiner (2004) describes the AR system as ‘one that combines real and computer-generated information in a real environment, interactively and in real time, and aligns virtual objects with physical ones’ (p. 2). Yuen *et al.* (2011) explained AR as a technology that shows the actual physical world enhanced by digital content created by a computer, such as images, video and textual information. AR enables the content to be seamlessly overlaid onto users’ perception of the real world. 2D and 3D virtual objects can be utilised to develop user knowledge.

Combining those definitions, this study will adopt the following. AR can be called a technology that overlays digital information onto the user's perception of the real world while that user interacts and engages with the virtual elements surrounding them.

Recently, AR has received increased consideration in educational research as a result of its wider use. A study conducted by Akçayır and Akçayır (2017) found that the number of AR research studies has increased over the last four years. Although the AR concept came after virtual reality, there is a subtle difference in that a user of virtual reality technology is completely immersed inside a virtual setting and separated from the real world. Contrarily, in an AR environment, the user can see and interact with computer generated digital content at the same time as a real setting (Kipper and Rampolla 2012).

As will be seen from the studies described below, the exact implementation of AR can vary immensely in the hardware, software and human interaction that is involved. Although some form of digital display is always involved, with access to both real and virtual information, that can differ in its nature from being individual to public. Some AR systems for instance rely on each person wearing a headset with inbuilt display screen, as for virtual reality. Others display merged real and virtual material on a smartphone or tablet, whose camera has to be pointed at objects or markers in the real environment. Yet other systems use a large smartscreen or digital projection on a wall that a whole class can see and interact with at once. While clearly these differences may in detail themselves impact on the effect of AR, for the most part they are disregarded in the account that follows, which concentrates on what they all share, which is provision of an AR experience of some sort, as defined above.

2.2.1 Using AR in education

The use of AR and its applications has been explored within many disciplines both directly and indirectly connected to education. Yuen *et al.* (2011) listed many studies conducted on AR although at the time of that review only two related to science education - one at primary level and the other at undergraduate level. More recently, Yilmaz (2016) divided AR research related to education into seven sections according to subject: museum education, medical education, biology education, physical education, chemistry education, mathematics and geometry education and astronomy education. Two of those (biology and chemistry) relate to the current study's area of interest: science education.

Several empirical studies have been performed in schools to investigate how AR could be used in teaching and learning. For instance, Barreira *et al.* (2012) conducted a study at an elementary school in Portugal on learning the English names of animals by using an AR game compared to the traditional teaching method. The study used a questionnaire to collect data. The research outcomes indicated that the AR group showed greater progress on their learning and the students considered the AR game easy to use and helpful. Thus, the study indicated that AR had a positive educational impact on the learning process.

There was also a study conducted by Kerawalla *et al.* (2006) with 133 children aged 9–10 years and their teachers from five London schools. The teachers were asked about their previous experiences with AR technology and how they felt about using it in the classroom. Although the sample size of teachers was small, the teachers' feedback was positive, and they considered AR helpful because it made the relationship between the sun and the earth easy to understand. They stated that the subject was difficult to grasp when taught by the traditional method. The study suggested that the AR content could be flexible to help teachers to use it in fulfilling students' educational needs (Kerawalla *et al.* 2006). Chiang *et al.* (2014) also examined the effectiveness of AR systems in aiding learning achievement and motivation at an elementary school in northern Taiwan. The participants were 57 students divided into two classes taught by AR and traditional methods. The study used mixed methods to gather data and pointed out that students taught by the AR system showed significantly higher motivation in terms of attention, confidence and perceived relevance dimensions.

An exploratory study carried out by Cascales *et al.* (2013) aimed to understand parental influence on children's AR use at a preschool for learning natural science unit on aquatic animals and plants. The study used interviews to gather data from the parents of the children. The outcomes of the study suggested that AR use was beneficial for the integration of content components and managing the exercises.

A study conducted by Tanner *et al.* (2014) explored whether the use of AR aided student learning of the task of building Lego™ robots by using an AR application (app) on an iPad tablet compared with a static paper manual. The study indicated that the students' comprehension level in an AR setting was higher, but most of the students preferred the traditional materials and found AR difficult to use.

An experimental research study conducted by Safar *et al.* (2017) in Kuwait—the first of its kind in the Arab World—focused on the effectiveness of using AR apps as a teaching and learning instrument. This study was done in a kindergarten and compared the results of two groups taught by an AR game and the traditional method. The findings indicated that the use of AR in teaching children is more effective than the traditional method. Huizenga *et al.* (2009) tested a location-based augmented reality game called Frequency 1550, developed to help in teaching students in first year of secondary school acquiring historical knowledge of medieval Amsterdam. They concluded that the AR game enhanced students' engagement and they gained significant knowledge regarding the history of the city.

The studies mentioned above all supported the idea that AR technology is a beneficial tool in the field of education, and that it has many benefits to enhance teachers' efforts to explain content to students. However, it can not be overlooked that in many of these studies a comparison was made between an AR game that was new to students, and whatever type of teaching normally occurred, which was typically not a game. It is therefore possible that any beneficial effects on motivation and/or learning were due more to the AR application being new (novelty effect) and/or involving a game, than to its inherent pedagogical characteristics. With respect to novelty, most of the studies reported used AR in more than one session, but not over great lengths of time such as a whole term or semester, which is the span that in real life teaching methods have to function over: it is difficult for any method not to weaken in effect when it occurs regularly over a long period. With respect to the game element, of course it is possible to organise games in traditional teaching without AR, but studies did not generally control for that aspect by arranging game like traditional teaching for the comparison to be made with. Hence there is confounding of the effects of gameplay with the effects of whatever distinctive teaching / learning features AR inherently possesses.

The next section looks at the nature of the collection of features that experts believe AR does possess and which promote instructional success.

2.2.2 The advantages and disadvantages of AR for learning

Some of the main issues discussed concerning the use of AR in education have been related to the claimed pedagogical benefits of AR, such as: providing attractive, effective learning; enhancing interaction; facilitating learning; increasing learner motivation; enhancing engagement; improving student cooperation; triggering creativity; developing imagination and enhancing spatial ability (Yilmaz 2016). Previous research has however found that while using AR could be great for improving the level of student learning in schools it could also negatively affect student learning. This section and the next therefore aim to critically examine the impact of AR on student learning, beginning with four themes or constructs that stand out in Yilmaz' list above.

Better understanding of content

One key part of school learning of anything is understanding whatever is to be learned (the other part is remembering it, see below). Teaching with AR technology has indeed been found to possess educational benefits related to the better understanding of educational content. Previous research has shown that students understand better within an AR system than when learning with other types of media or devices. An AR environment, by blending virtual objects with the real world in real time, may help learners to visualise complex elements of content and understand forces that explain a natural phenomenon, spatial domains or subjects that students cannot possibly experience first-hand in the real world, such as the earth-sun relationship, volcanoes, astronomy, chemical structures and endangered animals (Radu 2014). A study carried out by Hedley (2003) gathered quantitative and qualitative data from 101 participating college students who were required to study a 3D image of mountain scenery and judge things such as the relative distance between points in the landscape. The study investigated the differences between two groups, one studying the scenery using AR and the other on a PC screen, in terms of three outcomes—performance, behaviour and cognitive maps. The study indicated that students using AR constructed more detailed mental representations than the PC group and found that AR had a positive impact on perception, performance and inferred cognitive representation of 3D geographic visualizations. This finding was supported by an experimental study conducted by Kerawalla *et al.* (2006), which was mentioned above, which concluded that using an AR app to build elements helped students to understand the relationships between the earth and sun better. Both studies emphasised that AR may be a suitable medium for delivering complex content especially where it has a spatial component.

Vincenzi *et al.* (2003) conducted a study on teaching four groups about an aircraft oil pump by using four modes of learning: an AR system, printed material, a video tape and interactive text. The comparison results indicated that teaching with the AR system was more effective than teaching with the other media, and students in the AR group recalled more information than others in an immediate recall test. Sin and Zaman (2010) conducted a study using AR which is of particular interest since it involved a science topic, and a secondary school (albeit in Malaysia). 40 students took a pre-test with 15 questions on the students' previous knowledge of astronomy. In the second phase, the students were divided into two groups of 20 students each: the experimental group and the control group. The control group was taught by textbook while the experimental group was taught using AR. Afterwards, the students answered a post-test. The study's findings showed that the AR group exhibited greater understanding of the topic and indeed improved on their pre-test scores by 46% while the control group improved by only 17%. However, it might have been beneficial if the researchers had interviewed the teachers to gain a clearer picture regarding the precise implementation and outcomes of the use of AR.

An experimental study was also carried out by Wojciechowski and Cellary (2013) in a secondary school science context, in Poland. However, this focused on evaluating 42 learners' attitudes towards understanding (and other aspects) rather than their actual increase in understanding, such as was measured in the studies cited above, and did not have a control group. An ARIES augmented reality setting was used to display the reaction between hydrochloric acid and sodium hydroxide. The study found that learners had a positive response toward the content in this experience and judged AR to be useful. However, it would have been beneficial if the study had used interviews to gather detailed information about how exactly they thought AR impacted on their understanding, and had tested the students' actual growth in understanding so as to obtain a clear picture about the effect of AR on content understanding.

The above studies have shown that AR technology has been shown to have a beneficial influence on content understanding, especially for science topics, which are this study's focus of attention. AR technology provides the use of virtual objects merged into the physical world, which may help students to visualise and imagine the relationships between complex content elements and better understand them.

Improving students' motivation

Motivation is an important factor in education. It often has an effect on student academic achievement because it directs their behaviour (e.g. attention, persistence and effort) during the learning process. Motivation has many dimensions and is the subject of much theorising but can be simply defined for present purposes as the desire of a learner to engage in an educational environment (Keller and Litchfield 2002).

The adoption of AR technology into the classroom may enhance student motivation to participate and engage with class activities. Many empirical studies using AR have indicated that students who participated showed a high level of motivation and they had the desire to engage with the AR experience (Radu 2014). For example, a study was conducted by Freitas and Campos (2008) and performed with many classes at a local primary school in Portugal. It aimed to investigate whether using an AR system (SMART) could increase children's grades and motivation levels. Although the findings showed no difference in the students' learning rates, the researchers noted that the use of AR was effective in maintaining high levels of motivation. All of the students had a desire to participate, and they enjoyed using the AR system.

An empirical study was also carried out by Juan *et al.* (2010) at a Summer School of the Universidad Politecnica de Valencia. Forty-six children played two games. One was based on AR and the other was based on the real world. In the post-game questionnaire results, researchers discovered that the children thought that playing the AR game was more enjoyable than playing the real game, and they were very keen to play the AR game again. They did note however that a head-mounted AR game was much harder to use.

In addition, a study conducted by Di Serio *et al.* (2013) in Madrid explored the impact of AR on the motivation of middle school students by using the Instructional Materials Motivation Survey (IMMS) to measure four factors of student motivation: attention, relevance, confidence and satisfaction. Using mixed methods, the results indicated that students who were taught within the AR environment were more highly motivated than students taught within the slides-based learning environment. Moreover, the findings from quantitative and qualitative data showed that the features of AR had an impact on students' motivation, in that they were more confident about what they had learnt, and also remembered the information. It should be note however that many experts would not regard memory or confidence as aspects of motivation itself (defined as desire or effort etc.) but rather as distinct constructs that may however correlate with motivation.

In a study carried out by Chiang *et al.* (2014) , using mixed methods to collect data from 57 participant, findings also indicated that the learners had positive learning motivation toward using an AR-based mobile learning system. Sumadio and Rambli (2010) also concluded that students enjoyed using AR software for learning.

In short, many studies support the role of AR in enhancing learners' motivation (in some sense) in a learning environment. However, it needs to be pointed out once again that in many studies AR is a new experience for the participants, and it is common in research to find that any new experience, game or method is found to be more interesting and engaging than the existing one purely because it is new (novelty effect). Also, as in Freitas and Campos (2008) above, greater motivation is not always associated with greater achievement or performance, so AR cannot be judged to be useful for learning simply because it raises motivation.

Furthermore, there have been some converse findings on motivation. Kerawalla *et al.* (2006) found a negative result related to students' engagement in AR settings. In this study, the students taught by AR were less engaged than their peers who were taught in role-play sessions.

Overall however the majority of these findings indicate that AR technology may play a significant role in enhancing students' engagement, desire to learn and enjoyment of content.

Enhanced student collaboration

Collaboration among students is often seen as making learning easier and is a key element in social theories of learning (Topping and Ehly 1998). Previous experimental studies have shown that an AR setting may enhance collaboration in the classroom. For instance, a study carried out by Chen (2008) explored the use of AR in helping students to learn chemistry. The 96 participants were split into three groups. The first group did individual learning with AR, the second did peer learning with AR and the third group did individual learning with a textbook. A questionnaire was used to obtain data. The result of this study found that peer learning in an AR environment was reported to be helpful and may facilitate learning. However, there was no condition where students did peer learning with the textbook, so it cannot be sure if it was AR or just peer learning regardless of medium that had the effect. Peer learning is after all not a necessary feature of use of all AR but may be implemented or not with it, just as traditional classroom learning based on a textbook may be implemented either in peer or individual mode. The findings also indicated that it takes more effort to understand the content in a peer learning setting. That might have a harmful effect if the outcome understanding was damaged, but might have a beneficial effect in that greater effort exerted in the initial learning process has been seen by psychologists as related to better retention/memory (Salomon 1983). For a deeper insight into the whole process, it must be noted again that using interviews to investigate the student's perception might have been a more informative way to collect data.

Another study, involving whole class peer collaboration, was conducted by Freitas and Campos (2008) to investigate the potential of AR in a classroom, using a quantitative observation method to collect data. The sample was composed of 54 students from three primary schools divided into two groups. The control group studied by traditional methods and the experimental group studied with an AR system (SMART). SMART leads children to explore concepts like methods of transport, kinds of animals and other semantic categories by the use of a set of racquets that are employed to manipulate a game in the style of a TV show which runs in a real time video feed to the whole class. For example, they have to use the racquets to indicate what category (aerial or terrestrial) a 3D model of a motorbike (superimposed on the video feed) belongs to. If they are correct, they hear applause, if not they hear a buzzer, like in a game show. The findings showed that the AR system had a positive impact on the whole class's collaboration compared with classes that played the same game without the AR element. However, again it may have been more useful if the researchers had used interviews to gain a better understanding of the effect of SMART on the students' collaboration.

There was also a study carried out by Morrison *et al.* (2009) with 26 participants who used an AR map (MapLens) to play a location-based game in a city centre. The data was collected using a triangulation of quantitative and qualitative methods. In the findings, researchers discovered that students' collaboration in the AR group was more effective than the collaboration that took place in the non-AR group.

Overall then, from the above it can be seen that there is some evidence that when collaborative tasks or games are performed with AR, the collaboration is greater or more effective than when the same tasks are done without the AR element. However, once again it cannot be always certain how far novelty effect might be responsible for this.

Better long term memory

Some investigators have examined the effects of AR on retention and retrieval of information. They notably discovered that students taught in an AR setting can memorise the given information better than their peers taught through other means. A study conducted at Embry-Riddle Aeronautical University (ERAU) in the USA by Valimont *et al.* (2002) included 64 participants aged 18–30. They used an immediate a post-test and interview followed by a delayed test to measure retention levels. Interestingly, the study indicated that students taught by AR were able to recall more information correctly in both in the immediate recall test and the later recall test performed seven days later. However, like in many studies of this sort, seven days does not involve very great long-term memory. In education usually the aim is for people to remember things for more than just seven days. It may have been valuable therefore if they had increased the length of the time before the delayed post-test, to obtain more valid data regarding the effectiveness of AR as a beneficial means for retention of knowledge.

A study conducted by Vincenzi *et al.* (2003) examined the effectiveness of AR on learning with four groups of undergraduate students at ERAU. The data was collected again from a post-test and delayed test. The results of the comparison between the four groups indicated an interesting instructional advantage for those taught by AR. The data indicated that participants who received instruction through AR again demonstrated significantly better recall in a test administered after one week than those who received print instruction or an interactive instructional video.

There was also a study carried out by Macchiarella and Vincenzi (2004) on using AR as a training medium for aviation. They used mixed methods, including a recall test, with a randomly selected sample of 96 participants from ERAU. The study again indicated that learning with an AR system had a positive influence on students' retention. This research determined that AR-based learning affected long-term memory by reducing the amount of information forgotten after a seven-day intervening time between the immediate recall test and the long-term retention recall test.

It is clear that all of the mentioned studies were carried out at the same US university and the focus was on undergraduate students. That means the findings cannot be generalised to the secondary level Saudi context of interest in the present study. The limitation of these studies to one field also means that generalisation is difficult. In addition the short retention period means that information about true long-term memory for the content was not obtained.

2.2.3 The disadvantages of using AR in education

Although many studies show educational benefits from use of AR, with provisos mentioned above, some negative effects have also been recorded. These are of special interest since they might well be reflected in teacher attitudes about technology and reluctance to accept it, which are more the focus of attention of this study. In 2.2.4 there is separate consideration of disadvantages which are associated more with prerequisites for AR use, such as cost and need for technical support and teacher training which would not arise for non-AR aids.

Usability difficulties

One of the main issues associated with the use of AR in learning and teaching is the difficulty of use, whether with older AR applications or in modern apps. Participants in some studies stated that the AR system was more difficult to use than other teaching aids. For instance, Morrison *et al.* (2009) used quantitative and qualitative methods to discover that the team who played a location-based game in the street found that using AR while walking in the street or waiting at traffic lights was difficult. Since the present study is concerned with classroom use, however, that may not be an issue in that context.

Juan *et al.* (2010) carried out a study on using AR to learn about endangered animals in a fun way. The study included 46 children aged 7–12 (26 boys and 20 girls) who studied at the UPV Summer School (Valencia). The study results indicated that the children who played the real game found it easier to play than the AR game. This could be because for the AR version they had to wear a headset and manipulate physical cubes which themselves showed only symbols over which the AR system presented images of animals; the non-AR players however simply worked directly with physical cubes showing animal pictures on the faces.

Akçayır and Akçayır (2017) also indicated that while there is a great increase in the development and usage of AR technology in many fields, the use of AR can still be problematic for people. More studies are needed to illuminate this issue and users' opinions about AR usability and implementation should be examined.

Munoz-Cristobal *et al.* (2015) study presented their evidence concerning what they call 'orchestration', by which they refer to the ability of the teacher to keep track of what students are doing with some digital teaching aids such as AR and so integrate them properly with the rest of the teaching activities. They studied use of an AR system with a sample of 18 students about 12 years-old from a primary school in Valladolid, Spain. They were particularly interested in the educational affordances offered by ubiquitous learning using AR. However, they concluded that the use of the AR system in a nearby park and school's playground was not easy. Its use was hampered by orchestration difficulties, such as that teachers lost awareness of what the students were doing across the multiple devices and spaces involved. Again, in the present case, however, limiting consideration to AR for use in the classroom could reduce the likelihood of this problem.

Not surprisingly, as with most digital aids, technical problems can also arise. Kaufmann and Dünser (2007) stated that although the AR educational application (Construct3D) was a highly usable system, there were still some technical issues that affected usage. Thus overall potentially there exist usability problems both for students and for the teacher, and indeed for both where technical problems are the cause.

Attention Tunnelling

A cognitive feature of AR, which arguably could be regarded as a negative feature, is its effect on attention. A comparative study carried out by Morrison *et al.* (2009) involved 26 participants using AR (MapLens) to play a location-based game in a city centre. The data was collected with triangulation of quantitative and qualitative methods. In the findings, students taught by AR reported that the task and technology 'took all our attention'. They had to pay exclusive attention while playing the game.

Billinghurst *et al.* (2003) analysed communication behaviour in face-to-face collaboration using an AR interface. Participants were 14 students. The study included two experiments and compared participants' collaboration with three different AR displays to their collaboration when using three different non-AR learning methods: traditional, unmediated and screen-based. The study found that the AR system had a limited field of view and low resolution which may have caused tunnel vision for participants who reported experiencing that in their answers.

These types of tunnelling effect may in fact be good or bad depending on the context. In the street it is not desirable for AR users to be so engrossed that they walk into the road and get run over. However, in a safe environment like the classroom, it may benefit learning to be engrossed in a learning task and not distracted by other students who are misbehaving or the like.

Overall, although most of the evidence for the beneft of AR comes from contexts other than Saudi Arabia, the vast majority of evidence shows that it is beneficial rather than the opposite. For that reason in the present study it was deemed relevant to focus efforts on its acceptance rather than demonstrate again its benefits.

2.2.4 Challenges for the use of AR

Integrating AR technology into the education sector is still a challenge because there are many barriers to its introduction that require a variety of flexible solutions. Some obstacles are related to technological and physical issues, and others are related to sociocultural issues (Martins *et al.* 2015). Safar *et al.* (2017) classified the challenges of using AR into four groups: (1) physical obstacles related to environments, the difficulties of integrating ICT into the field of education and the way to use apps; (2) obstacles related to humans, including the role of teachers and learners; (3) technical obstacles related to the AR content and how to design it and (4) social obstacles related to the acceptance of AR in the educational community. Essentially these are prerequisites for its use that are not all met in many areas at present. Alternatively, they can be seen as areas where, if the problems were solved, use of AR would be facilitated.

Physical factors include cost and availability of equipment and technical support. Technological issues also include the fact that some kinds of AR technology are not yet very reliable or user friendly for use in education. There is need for improvement of this technology to accommodate the educational content in a simpler way (Sommerauer and Müller 2014). Di Serio et al. (2013) provide an example of this with the AR software that they used. There were serious problems during an AR class related to how to maintain the visibility of the digital content superposed on the image of the real environment, and the shaking of the image during use. However, students found that changing the position of the real image solved the first problem.

The second category of obstacle is illustrated by the need for training of teachers in the use of AR. Clearly that is necessary in order to avoid considerable obstacles to its implementation in the educational field. Teachers should learn how to use this technology in order to effectively utilise AR in the classroom (Martins *et al.* 2015).

Thirdly, another important obstacle is the lack of existence, for many topics in many subjects, of AR applications with appropriate content for use in the classroom. Creating AR apps with such content demands effort and time and the following of some educational strategies that enhance the use of new technology in teaching (Ibid). Furthermore, the designers of AR technology are usually computer programmers with a lack of understanding of people's educational needs. That may lead to the production of AR apps that discerning teachers would not want to use.

Safar et al.'s (2017) fourth category focuses on the need for acceptance. Acceptance is needed both by teachers and students, if AR is to be exploited fully and effectively. However, in the present study the concern is with teacher acceptance and since that is a major issue of its own and is the subject of this study it will be left for full discussion below.

2.2.5 Teaching with AR in light of theories of learning

As an educational tool, AR can be associated with many learning theories, such as constructivist learning theory, situated learning theory, flow theory and self-determination theory (Antonioli *et al.* 2014). Martín-Gutiérrez *et al.* (2010) showed that AR follows the major principles of constructivist learning theory, which puts learners at the centre of learning, by integrating new knowledge with existing knowledge in their minds. This theory encourages learners to learn in collaborative groups rather than competitively. As has been seen, AR can indeed be used to support students in working collaboratively in traditional classrooms (Antonioli *et al.* 2014). In constructivism, the teacher's role is also changed, from controller to that of a learning facilitator; students themselves have the responsibility for analysing, organising and synthesizing information (De Lucia *et al.* 2012).

Dunleavy *et al.* (2009) on the other hand argued for the possible relationship between AR and situated learning theory, which states that learning happens naturally throughout activities conducted in a realistic context, with social co-participation. In an AR environment, this is found since students have the chance to use experiences close to real-life experiences for the purpose of promoting their learning. AR uniquely does this because it ties simulated/virtual material to the actual real life context. Some learning will happen naturally, and students will also learn from one another using interaction and collaboration.

Flow theory (Csikszentmihalyi 1997) states that learners acquire knowledge from learning experiences when they engage in meaningful activities and become fully immersed in them, with energized attention. The AR tool is related to flow theory insofar as students can become totally engrossed in AR activities, to the exclusion of everything else, as noted above. The flow state yields not only learning but also a deep feeling of satisfaction so connects with intrinsic motivation of a task. The study conducted by Bressler and Bodzin (2013) found that the average student experienced ‘flow’ during a science game in which the student played on a mobile phone. This is because the AR application connected students’ real-world surroundings to learning in a new and attractive way.

AR can also be related to self-determination theory, which is a theory of motivation based on the idea that people have certain basic psychological needs that should be met (Ryan and Deci 2017). The study conducted by Rigby and Przybylski (2009) found that students who won in a game were engaged because they were responsible for their own learning, which is one of those needs (autonomy). In educational AR settings, learners tend to be free to do what is interesting, effective and important and to master it, fulfilling another basic need (competence).

Some AR studies pointed out that AR can be linked to many other learning theories. Bressler and Bodzin (2013) for example indicated that using an AR app which includes multimedia components allows learners to use their cognitive abilities for retaining knowledge more efficiently based on cognitive load theory, which focuses attention on the appropriate distribution of a learner's limited working memory capacity. Collins and Halverson (2009) used the just-in-time learning theory with educational AR app. This theory suggests that learners obtain knowledge best when they are provided with it just at the moment when they need to know it, not by some structured program delivered in advance.

2.2.6 AR implementation in Saudi Schools

As was indicated at the end of 2.1.5, in September 2018, the Saudi Ministry of Education (MoE) began to apply AR technology seriously in its schools and curricula. AR apps and textbooks designed for educational purposes were sent to schools with the link to the National education portal IEN platform, which contains AR materials for both teachers and students.

The MoE with Tatweer designed AR apps to allow users to scan targeted marks and pictures in textbooks in order to see the associated digital content. For example, most of science textbooks became enhanced by AR codes and have a list of contents that contains AR photos or marks. Those apps are also available common stores Apple and Android.

Applications of AR in Saudi schools became easy even for untrained users to use. Converting the curricula to incorporate digital content in the above ways made it easy to use AR technology without any experience or need for training courses. On the National education portal platform (IEN) (https://ien.edu.sa/#/lessonAR), there are many resources available to support the usage of AR technology in teaching and learning. Teachers can download additional content to use in classroom. There is also an illustration video to explain how to use AR apps to exploit the marks in textbooks. Table 1 shows some random examples of science subject content areas for which the MoE provides AR materials to schools, from the available materials on the IEN platform.

Table 1. Examples of science subjects' content which is AR-supported

Year	Subject	Content	Availability
7	Science	Sponges, Solar eclipse, Constellations	Apple store Google play https://ienbooks.t4edu.com/#/lessonAR All AR content already available on IEN platform
8	Science	Inhalation and exhalation, Digestive organs	
9	Science	Photosynthesis, Voltage and resistance	
10	physics chemistry	Arm strength, Center of mass Modern Periodic Table	
11	physics chemistry	Convex mirrors, Electrical voltage Intermolecular forces, Gas pressure	
12	physics chemistry	Magnetic fields, galvanometer Gases	

According to Tatweer, most Saudi schools have received AR materials including textbooks and apps and have access to the support resources on the IEN platform. The MoE with Tatweer are planning to develop AR technology experiences further every year, and there is a plan to collect helpful feedback from teachers and students to evaluate the AR experience.

2.3 Conclusion

This chapter presented a brief background on education in Saudi Arabia including the system of education, science education, ICT use, and the influence of culture on schooling. In addition, It provided definitions of AR technology, and reviewed its applications and implementation in educational practices. The chapter demonstrated the benefits of AR as shown by research on its effectiveness and thus justified the value of investigating factors affecting its adoption.

3. Chapter Three: Literature Review on Acceptance and Use of Technology

This chapter aims to review the literature in the acceptance of technology by reviewing the technology acceptance theories, leading up to the theoretical basis relied on for the current study. It also addresses the conceptual framework of the study and the research model that will be employed in this study.

3.1 Technology acceptance

Technology acceptance is defined in general as the extent to which users perceive, accept and use modern technology (Dillon and Morris 1996). More specifically, user acceptance can be defined as “the demonstrable willingness within a user group to employ information technology for the tasks it is designed to support” (op. cit. p.4). Consequently, in the present study, user acceptance can be understood as teachers' willingness to use AR apps in their teaching and learning practices. I adopt a definition focusing more on the willingness to use technology as a sign of acceptance, rather than on the actual use of it, since as seen above, in the Saudi context, the MoE has already accepted AR and is introducing it to schools through prescribed textbooks and apps. Therefore, its use, at least minimally, is more or less guaranteed. However, it is still possible for teachers to have different degrees of acceptance of it, in the sense of willingness to use it, and that is the target of this study.

User acceptancer is one of the important educational issues in the last decades, since integrating modern innovations into the education field requires studying innovation acceptance among users, as part of evaluating any innovation. However potentially effective a new innovation is, it will not be fully successful unless it is also accepted by those who (have to) use it. With the increase in technological innovations in many areas including the education field, assessing the acceptance of technology is a significant factor when judging whether this technology can be successfully utilised within any environment (Šumak *et al.* 2011). Users' early attitudes toward any new technology need to be understood because they will influence the later use of this technology. Clearly, the acceptance of such technology among users can influence its adoption and lead to an increase (or not) in demand for it (Park 2009).

Two clarifications need to be made at this point. First, as was seen in 2.2.4, there are also other more objective factors that may hinder adoption of an innovation (e.g. cost, lack of availability, tech support, or training) but any study of the integration of information technology successfully into educational practices needs to consider first user acceptance as a significant factor that determines the success or failure of any application of technology (Yang *et al.* 2008). It is that which the theories considered below mostly focus on, though the one that was finally chosen does in fact include some coverage of those wider obstacles or, if they are dealt with, facilitating conditions. Second, it should be noted that in an educational context of course student acceptance of innovation is equally important with teacher acceptance. However, it was beyond the feasible scope of this project to undertake studying that as well. In any case it is my personal experience that it is teachers and not students in my context who are much more likely to have some reservations about innovation involving technology.

It follows that investigating the influential factors in teachers' acceptance (or not) of AR technology will help understand better its implementation in Saudi schools. Furthermore, it may suggest possible interventions that would improve the success of that implementation. Technology acceptance research can also predict how teachers in schools will react to new technologies that they have not yet been exposed to. Practitioners and researchers therefore seek to understand why people accept or reject technology so as to help to improve technology design and implementation and predict what technology will be used in the future (Dillon and Morris 1996).

As stated in chapter 1, this study therefore aims to find out what factors influence teachers' acceptance of use of augmented reality technology in schools in Saudi Arabia. With respect to its causes, Straub (2009) concluded that "technology adoption is (a) a complex, inherently social, developmental process; (b) individuals construct unique (but malleable) perceptions of technology that influence the adoption process; and (c) successfully facilitating a technology adoption needs to address cognitive, emotional, and contextual concerns" (p.626). The present study will therefore range quite widely in considering factors that affect acceptance. In order to deepen understanding of user acceptance, many explanatory theories of user acceptance have been suggested. The ones deemed most informative are these, which are reviewed below: Diffusion of Innovation Theory (DIT), Theory of Reasoned Action (TRA), Theory of Planned

Behaviour (TPB), The Technology Acceptance Model (TAM) (Davis *et al.* 1989), and the Unified Theory of Acceptance Use of Technology (UTAUT) (Venkatesh *et al.* 2003) which is the one adopted in this study, with slight modifications.

3.1.1 Diffusion of Innovation Theory (DIT)

The Diffusion of Innovation Theory (Rogers 1995) is established as the foundation for doing research on innovation acceptance and adoption. It derived from reviewing 508 examples of diffusion research. Rogers (2003, p.10) defined diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system”. Part of the theory deals with the pattern that this process of innovation follows, when naturally occurring; part is more concerned with the reasons for diffusion progressing as it does, which is more relevant to my study. Innovation, communication channels, time, and the relevant social system are the key factors in this model.

The distinctive diffusion curve (Figure 2) followed by an innovation was first plotted in 1903 (Toews 2003) then followed by Ryan and Gross (1943) who introduced the adopter categories and Katz (1957) who introduced the notion of opinion leaders, opinion followers and how the media interacts to influence these two groups. Rogers' complete account of this process identified different kinds of people as follows. An initial few are open to the new idea and want to adopt its use. Those play a key role in spreading the idea and then others will be open to adopt it. Rogers also classify adopters of an innovation into five categories: innovators, early adopters, early majority, late majority, and laggards. Sometimes, non-adopters can be added as a sixth group.

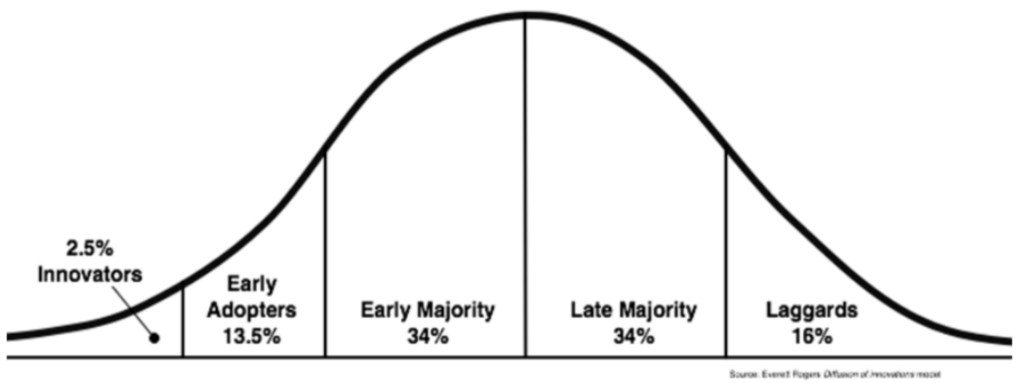

Figure 2.Bell-shaped version of the diffusion curve of an innovation (Rogers, 2003)

This part of the DIT can be considered as a valuable model of gradual change which acceptance of technological innovation may also follow if left to occur naturally following the decisions of the adopter teachers. It could however be that, in a school system where the MoE dictates what occurs in the classroom quite closely, innovation in the sense of actual use could move from near zero to complete adoption almost directly, since it would not depend on teacher acceptance.

The DIT also underlines the importance of communication and peer networking across the natural adoption process. In simple terms, when people adopt a new idea, product, practice or philosophy etc., this communication would be the main mechanism in the DIT. The theory however recognises four components in all: 1) an innovation such as a new idea, practice, purpose that can be perceived by an individual as a new; 2)

Communication channels which are the way of introducing the innovation; 3) Time which is the innovation acceptance rate over time; 4) Social system members, i.e. individuals, groups of people and organizations that are involved in the adoption of an innovation, and their impact on each other. The last is the main concern here, as they are the (potential) technology users.

At the level of the individual adopter/user, the acceptance process has five stages according to Rogers. First comes Knowledge or Awareness, when the individual is exposed to simplified information about the innovation but lacks complete information. Second is the Persuasion or Interest stage when the individual becomes interested in the new idea and is looking for its advantages and disadvantages, searching for further information and more details. Third is the Decision or Evaluation Stage when the individual mentally applies innovation to his present and anticipated future situation, and then decides whether or not to try it. Fourth is the Implementation or Trial Stage when the individual makes full use of innovation. Fifth is the Confirmation or Adoption stage when the individual decides to continue the full use of innovation. It may be imagined that this progression could apply in the minds of Saudi teachers using AR in the classroom even if they are in fact required by the MoE to all actually use it from a certain date when a new curriculum applies and new textbooks and apps arrive. In such a scenario teachers' acceptance of AR would however probably be out of step with their adoption of AR.

In order to examine why some innovations are accepted among users while others never became widely accepted Rogers (2003) further identified five distinct innovation characteristics to explain the reasons for acceptance. Observability is the degree to which the results of an innovation are visible to potential adopters. Relative advantage is the degree to which the innovation is perceived to be superior to current practice. Compatibility is the degree to which the innovation is perceived to be consistent with socio-cultural values, previous ideas, and/or perceived needs. Trialability is the degree to which the innovation can be experienced on a limited basis. Complexity is the degree to which an innovation is difficult to use or understand, its simplicity. Of these, clearly relative advantage, complexity, and compatibility appear to be core factors that will need to be measured for the teachers in the present study, with respect to acceptance of AR. Observability and trialability on the other hand seem to be more ancillary issues that make it easier or harder for a teacher to make a judgment on the first three acceptance areas. It will be seen below that there are however important matters not covered, or at least not highlighted, by this model.

3.1.2 The Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB)

While the DIT is applicable to all innovations, not just technological ones, the TRA and its successor the TPB are basically applicable to all human behaviour that people have any control over, not just acceptance of innovations. They further make the assumption that people make rational choices about their behaviour, weighing up relevant considerations.

The Theory of Reasoned Action (Fishbein and Ajzen 1975) appeared first and has been a popular theory in the technology acceptance domain. It is relatively simple in that it proposes just two prime factors, a person's attitude (in simple terms, how good they think the behaviour is) and their subjective norms (how far the behaviour fits with what they think they ought to do), each with two subcomponents, that affect a person's intention to behave in a certain way (e.g. accept and use AR). Their actual behaviour is then regarded as following more or less automatically in proportion to the intention (Figure 3). Note that in this kind of model the construct of 'behaviour' would typically be thought of as being actual adoption/use of the new technology. However, as justified earlier, it would be better to think of the target in this study as being rather willingness to use new technology, which is closer to intention than behaviour in these models.

The first key factor, attitude to the behaviour, encapsulates the kind of factors labelled by Rogers as relative advantage of some action (using AR). Its precise scope is left open so it might extend to things not very explicitly covered by the DIT such as interest. Any attitude however is seen as having two contributory components: the person's belief about what the outcome of the target behaviour will be and their evaluation of its outcome. Thus if the behaviour is use of AR, their attitude to it is a combination of what they think the outcome of using AR would be (e.g. students understand more, find it interesting, but occasionally get confused), and how good/bad they think that would be (Fishbein and Ajzen 1975).

The second factor is “the user’s subjective norms of what they perceive their immediate community’s attitude to certain behaviour” (Ibid). This again has two components, what they think the existing social norms are, and how much they want to comply with those norms. So for instance in the case of the behaviour of using AR, the subjective norm would be a combination of what they think is expected, e.g. by peer teachers or even by students or the MoE, and how far they want to comply with that. This factor therefore takes into account explicitly what the DIT rather overlooked (although it might be covered under Rogers' notion of compatibility), i.e. the issue of what happens where a teacher is not the main decision maker about use of technology. Attitudes and subjective norms then each contribute to the strength of intention to perform the behaviour. They may however contribute with different weightings, not equally.

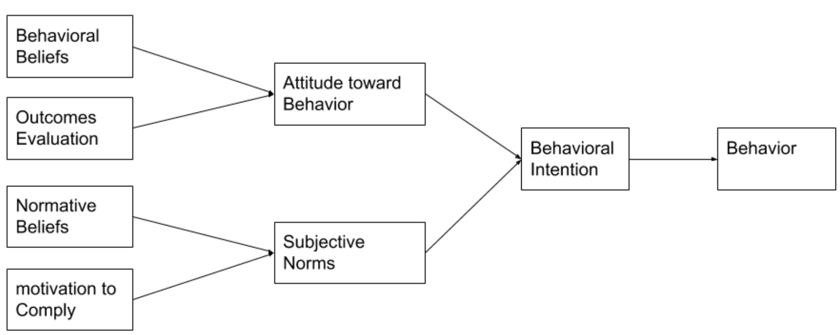

Figure 3. Theory of Reasoned Action (Fishbein and Ajzen, 1975)

Ajzen (1991) later developed Theory of Planned Behavior and added a third factor which is the perceived control of behaviour, which emerged as something missed from the TRA, but which was covered in the DIT to some extent under complexity. It concerns how far people see themselves as actually being able to perform the behaviour successfully. This also affects their intention and the actual performance of a behaviour, alongside attitudes and subjective norms.

Control of behaviour again has two subcomponents which are a person's belief about the control that they have over performing the behaviour and the person's perception of the ease or difficulty of performing the behaviour. In the present case the former is the teacher's belief about how much ability they would have to work AR apps and incorporate their use in lessons. This is similar to the concept of self-efficacy in psychology (Bandura 1982), which resembles a person's confidence in their ability to do something, or perceived proficiency. The second component would then be how easy or difficult for them they think it would be to use AR in lessons. This could differ according to circumstances. For instance, a teacher who thinks they have low computer skills might still consider use of AR easy if they think that the students will know how to use it anyway, or that a technician is always available to help.

The TPB then applies quite well to this study's special case of teacher acceptance of AR. Nevertheless it does not explicitly cover some possibly relevant variables such as those of a more emotional rather than cognitive nature, e.g. perceived interest or enjoyment.

3.1.3 The Technology Acceptance Model (TAM)

Next to be considered are theories that are specific to acceptance of technological innovation. The Technology Acceptance Model is a prevailing theory of user acceptance (Wojciechowski and Cellary 2013; Wu *et al.* 2013; Zhou and Brown 2015). It has been modified by many scholars to apply to user acceptance of specific technologies (Wojciechowski and Cellary 2013; Zhou and Brown 2015). The goal of TAM is "to provide an explanation of the determinants of computer acceptance that is generally capable of explaining user behaviour across a broad range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified" (Davis *et al.* 1989, p.985).The model applies to any users, although the type of users usually considered in actual studies are either people in business locations or, in the educational setting, students rather than teachers.

This model (Figure 4) incorporates from the TRA and TPB above the idea that intention to use something precedes the behaviour of actually using it. It also makes attitudes key constructs that affect the intention. However, it differs from TRA/TPB in the configuration of the main factors. It distinguishes just two factors that predict user behavioural intentions towards using information technology: perceived usefulness and perceived ease of use (Davis *et al.* 1989). Those more or less correspond respectively to what the TPB called attitude towards behaviour (whether it was good/bad) and perceived control of behaviour (whether it was easy/difficult). Thus, the word attitude is used more broadly in TAM than in TRA/TPB. The third factor in TPB (subjective norms) is in TAM demoted from being a third major factor to being disregarded or possibly subsumed under a range of what are termed external variables which are more remote than attitudes from actual behaviour and have an effect only through the two attitudes. In actual studies, however, external variables mostly include only demographics like age and gender as external variables or are omitted altogether. TAM is indeed often adapted in actual studies by omitting parts of it: even the attitudes can be omitted with only intention being focused on (Yousafzai *et al.* 2007). Also, other constructs can be added.

Wojciechowski and Cellary (2013) illustrate an example of an extension of TAM. They employed TAM enhanced with an added emotional/affective construct of perceived enjoyment, and with interface style constructs which might affect ease of use, to evaluate the attitude of learners toward learning in ARIES augmented reality environments.

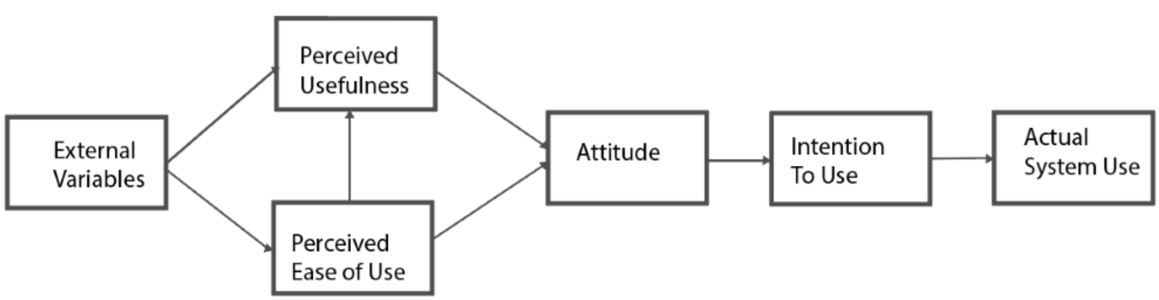

Figure 4. The Technology Acceptance Model (TAM)

They found that perceived usefulness and perceived enjoyment had a similar effect on overall attitude toward using AR technology. Haugstvedt and Krogstie (2012) also implemented an extended version of the technology acceptance model (TAM), adding perceived enjoyment, to study the acceptance of an AR application with cultural heritage content. Olsson *et al.* (2012) employed a version of TAM to measure acceptance by early adopters of using a mobile AR system. They concluded that perceived usefulness (content relevance and saving of time and effort) were significant reasons for AR acceptance.

Although the original TAM attitudes of usefulness and ease of use have been shown by studies to be relevant to intention and use, further versions of TAM (TAM2 and TAM3) have been developed incorporating into the model some of the additional constructs that researchers tested in empirical studies. As Figure 5 shows, TAM2 mainly elaborates on antecedent variables that might affect the two core attitudes (Venkatesh and Davis 2000). Interestingly perceived enjoyment or the like is not added, but for present purposes it is notable that a number of social influence constructs are. Subjective norms from the TRA/TPB regain an explicit place along with image, in the sense of "the degree to which use of an innovation is perceived to enhance one's status in one's social system" (Moore and Benbasat 1991). Furthermore, voluntariness explicitly recognises the relevance of whether or not the person whose acceptance is of interest actually perceives themself to be in charge of the decision to adopt the technology, which as indicated above may be relevant in the Saudi context.

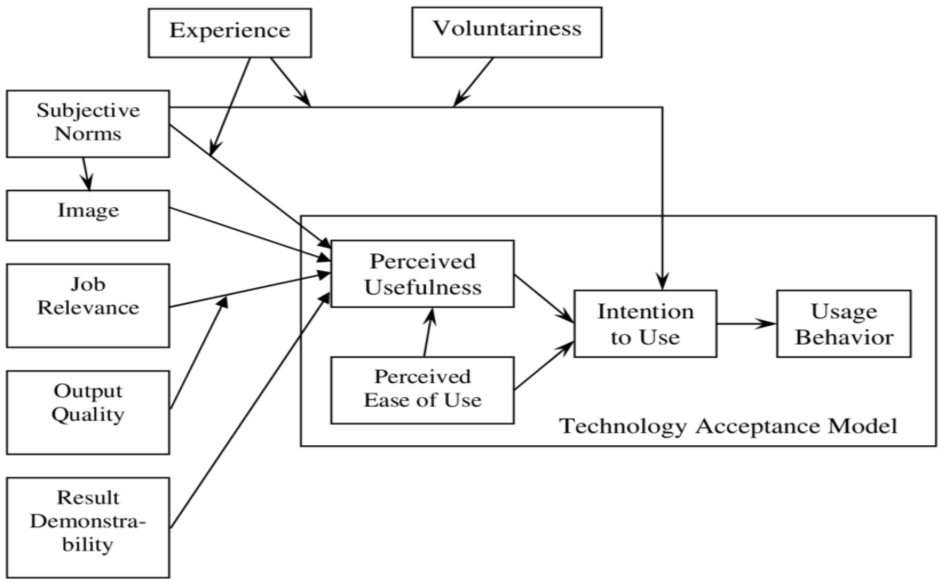

Figure 5. The TAM2 model

3.1.4 The Unified Theory of Acceptance and Use of Technology Model (UTAUT)

As its name implies, the Unified Theory of Acceptance and Use of Technology Model (UTAUT) (Venkatesh *et al.* 2003) claims to unify all relevant previous models of technology acceptance, including those that reviewed above, and in addition: a model combining the technology acceptance model and the theory of planned behaviour (C-TPB-TAM), the motivational model (MM), the model of PC utilization (MPCU), and the social cognitive theory (SCT). UTAUT authors reviewed the technology acceptance literature and compared the eight models before formulating the UTAUT model, then validated it empirically in order to build a unified theoretical basis for studying information technology and its adoption.

This model (Figure 6) still follows the pattern that actual behaviour is preceded by intention which in turn is seen as due to a variety of factors, some of which are attitudinal. The main differences from what was described above are: 1) There are four main antecedent constructs on the left, not three or two, and one of them is diagrammed as directly affecting behaviour, not mediated through intention; 2) There is a further set of four constructs presented horizontally on the bottom that are described as moderators and are not diagrammed as affecting one or more of the four main factors but rather as affecting how those factors affect intention or behaviour (their arrows point to arrows not to boxes).

Of the four key constructs on the left that influence user acceptance of technology, the first three are more or less the same as those in the TPB, under different names, and similarly diagrammed as affecting intention: performance expectancy (cf. attitude), effort expectancy (cf. control of behaviour), social influence (cf. subjective norms). The fourth, called facilitating conditions, essentially covers the wider range of objective non-human factors that are either obstacles or facilitators for technology use (sketched in 2.2.4).

The other models omitted these as they were only concerned with human perceptions. It is understandable why this construct is linked directly to behaviour. The first three constructs are psychological so naturally are direct determinants of behavioural intention which is also psychological, while the fourth can rather be a direct determinant of use behaviour. In other words, a teacher may see great value for students in using AR (performance expectancy) and have confidence in his ability to use it (effort expectancy) plus he wants to please the Ministry inspector coming to the lesson (social influence), all of which boosts his intention to use it, but if a suitable app for the content of his lesson is not available (facilitating condition) he will not end up using it however strong his intention.

The other four constructs, which were largely missing from the models above, other than TAM2, are not seen as causes of intention or behaviour. Indeed, it would not feel entirely sensible to say that being older causes a senior teacher to have less intention to use AR. Rather, it might be felt that it would be harder for an older teacher than a younger one to familiarise with new technology, so their effort expectancy would be higher and that would affect the intention. Hence age is presented in Figure 6 as moderating the link from effort expectancy to intention, but not directly affecting either of those.

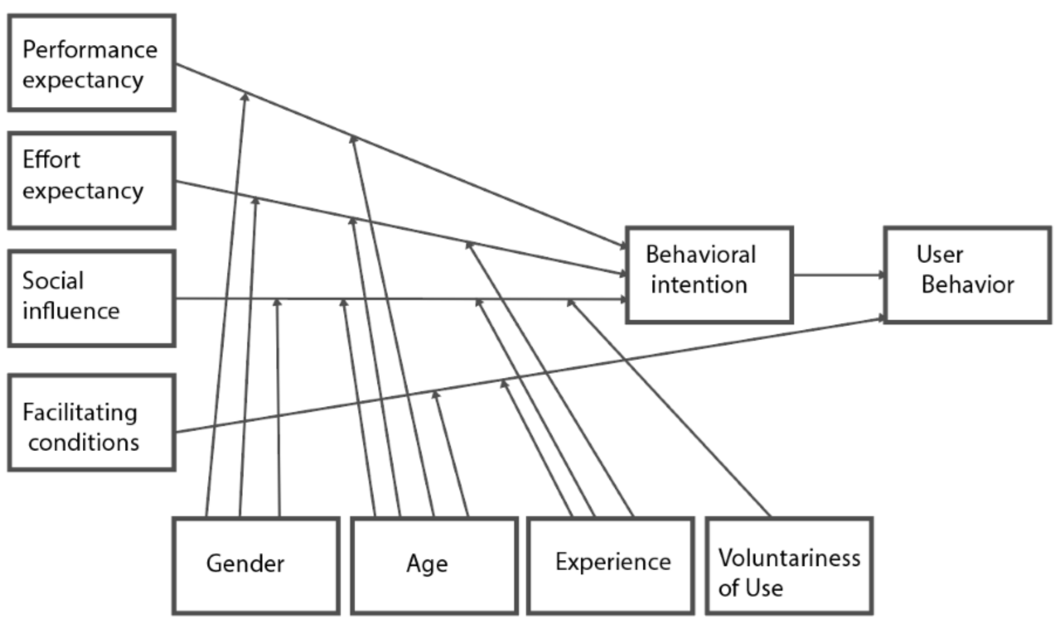

Figure 6. The UTAUT Model (Venkatesh et al., 2003)

The four key factors/antecedent constructs in the model may be described in more detail as follows.

Performance expectancy: Venkatesh *et al.* (2003) define performance expectancy as 'the extent to which a person believes that using a system would enhance his or her job performance'. Performance expectancy in this study refers to teachers finding or expecting to find that AR technology is beneficial for them due to its attributes that enhance their teaching processes and success, e.g. through visualisation, employing photos, video and markers. Many studies have been conducted studying the relationship between UTAUT constructs and user acceptance, and, although most of them focus on students rather than teachers, they have usually found positive relationships between Performance Expectancy and the user's behavioural intention to use technology (Al-Gahtani *et al.* 2007; Alfarani 2016). The exploration of user acceptance of AR in the current work will therefore hypothesise that a key factor that affects AR acceptance by teachers in Saudi schools is their expectation that such implementation will elevate teaching performance, and consequently the student learning that occurs. Alkhattabi's (2017) study in Saudi schools referred indirectly to this as an influential factor (see further below). Other forms of ICT have changed science teaching approaches and provided teachers with a chance to show dynamic processes in real time, such as demonstrating gaseous interactions at different temperatures (Hurwitz and Abegg 1999). If Saudi teachers have had experience of the benefits of other forms of ICT in the science classroom, they may also be favourable to AR on these grounds.

Effort expectancy: This construct refers to 'the degree to which a person believes that using a particular system would be free of mental effort' (Venkatesh *et al.* 2003). That means the perceived ease of use of AR. In this study, using AR in comparison with traditional methods is expected to be easy and to reduce teacher effort in classroom. Nowadays, AR apps are available on a mobile phone which means the teacher can use it easily without any additional effort. Furthermore, the MoE has developed AR technology and provided teachers with all required materials including apps, marked textbooks and guides that help the teacher to use AR technology without spending more effort preparing the content. So, it is expected that teachers will find AR technology easy to use and learning how to use will be easy. Therefore it could be hypothesised that teachers will perceive AR use as easy and this will contribute to their acceptance of it.

Social influence: Social influence pertains to the extent to which a user feels that others believe that they should use a technology (Venkatesh *et al.* 2003). Users, in the present case teachers, would be expected to adopt new technology under the influence of their social group. Many studies have found that the social influence of a user's colleagues plays a key role in his attitude towards using new technology (Wu and Wang 2005). In this study, teacher acceptance of AR may be influenced by factors such as: students' willingness to use this technology, peer appreciation from other teachers, and especially approval from higher authorities such as head teachers or the Ministry of Education who expect/require it to be used.

Facilitating conditions: These conditions mostly revolve around the extent to which a user believes that institutions and infrastructure are available to enable the introduction and enhancement of the use of technology (Venkatesh *et al.* 2003). In this research, the educational support components that might affect the use of AR include Ministry support in the form of supplying, or specifying the use of relevant AR apps, along with training of teachers in how to use this technology, provision of the necessary hardware (smart phones or tablets), and technical support within the school. Previous studies confirmed a positive relationship between such organisational support and actual use of new technology, in contrast with intention to use (Liang *et al.* 2007; Venkatesh and Bala 2008).

Numerous studies across many disciplines have been done adopting the UTAUT as an appropriate model for user acceptance and use of new technology. Furthermore, according to Carlsson *et al.* (2006), UTAUT has been empirically examined and it outperforms all the eight individual acceptance models on which it is based. However, it must be noted that by and large any model with more variables will outperform one with fewer (e.g. TRA) in its ability to explain variance in a dependent variable. As an indication of its predictive power in quantitative studies, Wong et al. (2013) report it explaining 59.6% of the variance of the dependent variable (intention to use new technology).

A systematic review of 450 citations of UTAUT that was conducted by Williams *et al.* (2011) found that 43 articles utilised the theory in empirical research examining technology acceptance and use. Although most previous studies used UTAUT quantitatively, Williams *et al.* (2011) mentioned that there were nine studies that were based on qualitative data gathering (Dadayan and Ferro 2005; Baron *et al.* 2006; He *et al.* 2007; Lee *et al.* 2007; Pappas and Volk 2007; Baumgartner and Green 2008; Van Biljon and Kotzé 2008; Yang *et al.* 2008; Li 2010).

Ifenthaler and Schweinbenz (2013) justified using UTAUT in qualitative research because this approach enables researchers to gain richer detailed qualitative information about the topic. de Vries *et al.* (2017) employed UTAUT in a qualitative study to explore factors influencing the use of a mobile app for reporting adverse drug reactions and receiving safety information. Stigzelius (2011) also stated that UTAUT was an appropriate model to guide the data analysis of his qualitative study.

Moreover, many studies have used UTAUT in mixed methods research, which combines both qualitative and quantitative data gathering in order to benefit from the separate insights that each method can provide (Pappas and Volk 2007; Oye *et al.* 2014; Alfarani 2016). Thus, in order to have the best possible framework and gather the best possible data for exploring factors influencing Saudi teacher acceptance of AR technology, the present study will be based on the UTAUT constructs, using a later version UTAUT2 slightly adapted (see below), and will gather both quantitative and qualitative data.

3.1.5 Non-theory based studies of factors affecting acceptance of AR

A number of studies have investigated factors affecting acceptance of AR and have drawn attention to a wide range of factors. Very often however they have not been framed within the set of constructs provided by any particular recognised theory or model of acceptance such as those above. Furthermore, most are at levels other than secondary school, and/or do not in fact target teacher acceptance but that of students. Still, those are reviewed here to see if they included factors that are already covered by the UTAUT or in fact suggest further variables that it would be prudent to include in the present study.

Quite a number of studies have shown that many factors influence AR technology acceptance. For example, Dalim *et al.* (2017) in a review of 49 articles determined the main factors that had been found in these studies to affect user acceptance of AR technology. The six factors they identified are curriculum, stability of the interaction, self-learning capability, parents' involvement, the student's background and platform. These are worth examination although this review has two limitations. First, it does not specify the criteria for choosing the six factors to talk about: for instance, there is no analysis of how significant they were found to be in the studies reviewed, or whether they all occurred in many of them or only a few. Second, acceptance by users is referred to without saying clearly who they were in the studies: students are mentioned very often, then parents, and teachers or educational levels of any participants hardly at all. It may be suspected therefore that the six factors identified were probably mostly not in studies where school teacher acceptance was measured.

Having said that, the factors identified do feel plausible as things that might affect teacher acceptance if, as is likely, their acceptance would be influenced not only by considerations of themselves but also of what they think might suit their students. Furthermore, two can be regarded as falling within the UTAUT category of performance expectancy. Curriculum refers to greater acceptance where the AR content fits the pedagogical requirements of the course syllabus, which clearly benefits both teacher and student. Stability refers to greater acceptance where AR is reliable and resists hardware or system failures in continuous use. Self-learning capability refers perhaps to a form of effort expectancy, i.e. to greater acceptance where the students can perform AR tasks without help from teacher or parent. The emphasis seems to be on the student interacting with the AR rather than with peers, but still this also fits with the idea that fostering autonomous learning is beneficial, which again might make this a criterion for teacher acceptance.

Parent's involvement falls perhaps in the area of social influence as it concerns parental interest and support which may boost student and teacher acceptance of AR. Student's background, in the sense of demographic features such as lack of disability, good motor control, spatial awareness, or personal innovativeness, all belong perhaps with what the UTAUT regards as moderator variables rather than actual causes of acceptance.

Finally platform refers to the suitability of the device to deliver AR, especially its mobility, so perhaps a facilitating variable.

Rasimah *et al.* (2011), in a study of tertiary level biomedical student acceptance of AR, used the following variables: personal innovativeness (PI), perceived enjoyment (PE), perceived ease of use (PEOU), perceived usefulness (PU), and intention to use (ITU). Of those the last three easily fit the UTAUT while the first two are not explicitly covered by it. In any case, perceived usefulness (UTAUT performance expectancy) emerged as the most powerful predictor.

Rauschnabel and Ro (2016) classified the factors that affect user (student rather than teacher) acceptance of AR smart glasses into six groups Their empirical study demonstrated the particular importance of: functional benefits (performance expectancy again), ease of use (effort expectancy), social norms, and close to that, brand attitudes, since glasses are a fashion item, together with individual difference variables (UTAUT moderators). Alves Fernandes and Fernández Sánchez (2008) also indicated that perceived usefulness is a crucial factor of AR acceptance in the education field. Arvanitis *et al.* (2009) however found that ease of use is an important factor in AR acceptance.

Finally, and closest to the present study, Alkhattabi (2017) examined the acceptance of AR among Saudi primary school teachers. This was a non-model based study entirely conducted with a short questionnaire in Arabic, but with quite a large sample of teachers

(115 female, 85 male). Quite a high percent (>70%) claimed familiarity with the concept of AR, but they had been sent a detailed explanation of it by the researcher to read before they answered the questionnaire! Their practical experience of it is unknown. Quite a high percent (79%) also indicated acceptance of potentially using it, especially females. With respect to factors affecting acceptance, the evidence came from just two items about ease and enhancement of engagement and learning (cf. effort expectancy and performance expectancy), and five questions about perceived obstacles. Both the positive items were answered favourably. In descending order of strength of endorsement, the top three obstacles were: lack of ICT infrastructure, lack of human infrastructure and IT skills, and resistance to change. The first two would fall in facilitating conditions in the UTAUT while the last is a personality trait that has only been mentioned in one other study close to the present one that this researcher has come across (Alfarani, 2016).

From the studies mentioned above, it is apparent that many factors may indeed influence user acceptance. Some of them are related to users themselves, whether students or teachers, and some are related to outside influences, whether social or non-human. As has been shown, most of them fall into the four basic types of factor listed in the UTAUT (Figure 6) as follows:

- Performance expectancy (e.g. perceived usefulness, stability of the interaction, enhancement of productivity, expected functional benefits, fit with the curriculum;

possibly also wider perceived benefits such as for entertainment dimensions, perceived enjoyment, self-presentation).

- Effort expectancy (e.g. perceived ease of use, self learning capability)
- Social influence (e.g. parents' involvement, social norms)
- Facilitating conditions (e.g. ICT support or training infrastructure, platform suitability).

Those are supplemented by moderator variables which may heighten or decrease the effects of the main four factors (e.g. background features of people such as lack of disability, good motor control, spatial awareness, personal innovativeness, willingness to accept change, though UTAUT only includes three such factors).

3.1.6 The Unified Theory of Acceptance and Use of Technology Model (UTAUT2) adopted for the present study

This model is a developed more recent version of The Unified Theory of Acceptance and Use of Technology (Venkatesh *et al.* 2003). The Unified Theory of Acceptance and Use of Technology (UTAUT2) (Venkatesh *et al.* 2012) is an improved version of the UTAUT, adding further explanatory variables and reported by Venkatesh et al. (2012) as explaining 74% of the variance in intention to use new technology (an improvement on the 60% claimed for UTAUT in 3.1.4 above). This is a comparatively high value and UTAUT2 was therefore adopted for the present study. Compared with the original UTAUT, the UTAUT2 model includes three additional main factor constructs: Habit, Hedonic motivation, and Price value.

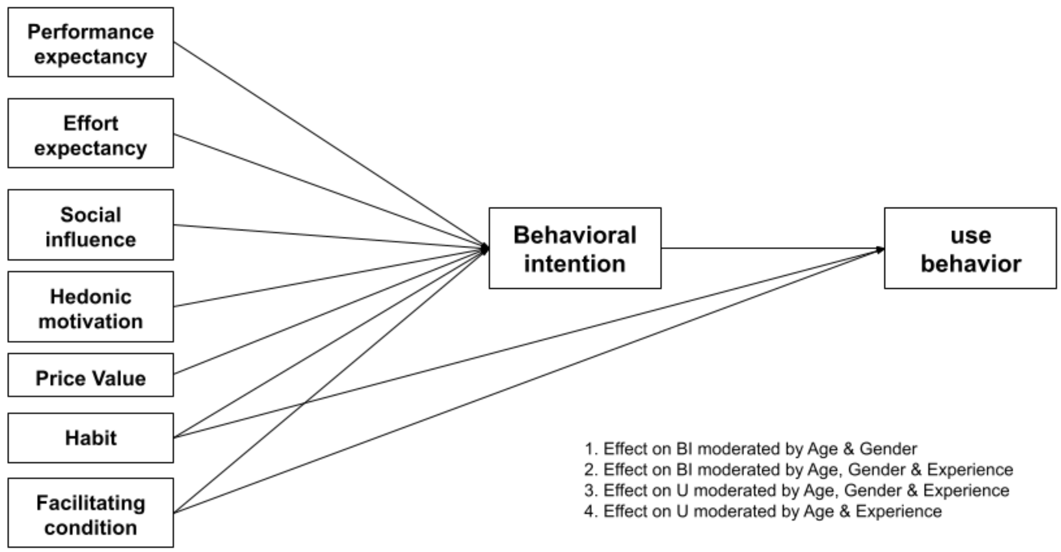

Figure 7. UTAUT2 (Venkatesh et al., 2012)

Habit:

In technology research, it has emerged that experience and habit are additional influential and closely related constructs relevant to user acceptance and behaviour. Experience, refers to the chance to use targeted technology and is operationalized as the passage of time from the first use of a technology by a user. This variable was explicitly recognised in the TAM2 model (Figure 5), and is implicit in the stages recognised by the DIT (Figure 2). It is also included in the UTAUT (both original and second version), but only as a moderator variable, not a main cause of behavioral intention. It is seen not as causing intention but as influencing the strength of other causes.

Habit is a similar construct but has been defined not by time but as the extent to which people tend to perform behaviors automatically because of learning (Limayem *et al.*

2007), which of course would require time. The technology user will perform automatically when he has training and has used targeted technology many times. Thus habit is a personal psychological variable, not just a non-personal objective one, and in UTAUT2 is treated as a main factor not a moderator.

Clearly it is likely that experience / habit will influence a teacher's acceptance. In the Saudi primary school teacher study of Alkhattabi (2017) most of the teachers had probably never used AR, only read about it. It is impossible to say if their acceptance would be different if they had all used it in classes for a few months before the survey and so had an established habit.

In the adapted version of UTAUT2 (Figure 7) used in this study, experience remains treated as a moderator while habit is added to the list of main factors. In the present study there will be teacher participants who have used AR and others who have not, so it will be important to measure factors of this sort. Habit will be defined as the extent to which the teacher believes the use of AR technology has or would become a habit for him.

Hedonic motivation:

This is the unusual name adopted by UTAUT2 for an emotion variable that has appeared in a number of studies cited above (Haugstvedt and Krogstie 2012; Wojciechowski and Cellary 2013), under names such as perceived enjoyment or interest and which is widely measured in educational research on student attitudes to almost anything as it is often assumed to increase effort and learning. In the present study of course it is of interest in relation to the teachers' enjoyment, not the students'.

It was however omitted from the models above, possibly due to its affective rather than cognitive nature, unless it can be assumed that it was regarded as a special type of performance expectation or perceived usefulness. It seems quite appropriate to recognise this construct explicitly and separately as a factor, since when the user finds targeted technology fun and enjoyable, he will continue use it. Some previous research (op. cit.) indeed emphases that hedonic motivation plays an important role in determining technology use and acceptance.

This construct is defined as the fun or pleasure derived from using a technology (Brown and Venkatesh 2005). Students in the digital age are looking for learning in an entertaining atmosphere, so the teacher as well is looking to present the content for his students in an enjoyable way. Hedonic motivation was added in UTAUT2 as a predictor of users' behavioral intention to use a technology (Venkatesh *et al.* 2012). In the present study it will be considered as a teacher variable although the teacher's enjoyment may in fact be influenced by his perception of student enjoyment.

Price value:

Price value has been defined in the first place as the consumer's cognitive trade-off between the perceived benefits of the application and the monetary cost for using it (Dodds *et al.* 1991). This has naturally become a prominent factor in the use of the

UTAUT in business and sales rather than educational research. The price value of technology is then favorable when the benefits of using a technology are perceived to be a greater than the monetary cost. This construct is important for a user or their organization, depending on who pays, and since in the Saudi context the Ministry would be expected to pay, not the teacher, this interpretation of the construct might seem to be barely relevant. The cost in money of using AR will not negatively affect the teacher, but since the AR apps and associated materials are available free in school, that may encourage teachers to try AR and then decide to use it frequently.

However, this construct is usually also usually interpreted understanding the word 'price' metaphorically as a price in terms of effort rather than money. Effort here includes time and attention needed to learn to use it as well as to actually use it. It then becomes a construct that essentially targets the trade-off between teacher effort expectancy and performance expectancy. That was perceived to be relevant to the present study so this construct was included.

3.1.7 UTAUT studies in contrasting contexts

A key feature of the present study is that it examines the application of the UTAUT in a cultural and occupational context where it has not widely been already researched. Therefore, at this point some key findings are reviewed from UTAUT research across a range of cultures so as to provide information as to whether the UTAUT has been found to apply fairly uniformly, or with wide detailed culture-related differences. Based on that then it might be possible to form expectations about whether the present study in the

KSA will reveal variation or uniformity with in comparison with UTAUT studies elsewhere, e.g. in the West.

An immediate problem with this enterprise is that most UTAUT studies have not been conducted with teachers in school but either with students, pre-service teachers, or people in non-school contexts. Therefore, the studies examined here are not occupationally matched to the present study and any differences from the results of the present study later may be due to difference of the type of occupational context as much as national cultural variation.

Al-Ghatani et al. (2007) compared findings in the KSA with those of Venkatesh et al. (2003) in the USA, using occupationally matched subjects. They found a mixture of similar results, e.g. an effect of performance expectancy on intention to use, regardless of age and gender, and different results, e.g. in the KSA no effect of effort expectancy, when interactions with moderating variables were taken into account. The negative effect of the interaction between effort expectancy and experience on behavioral intention showed that, after more years of computer experience, ease of use became less predictive of Saudis' behavioral intentions. However, this research was all conducted on 'knowledge workers' in various major business organisations and not on teachers in the education sector as in the present case.

Nevertheless some parallel results may be expected. For example, in cultures characterized by a strong 'power distance' dimension, such as the KSA, people, regardless of occupational domain, may defer to authority and conform to what superiors expect. Hence, in the present study also, the strong association that Al-Ghatani et al. (2007) found between social influence (termed by them 'subjective norm') and behavioral intention may be expected to be found.

Again, Mehta (2018) conducted a comparative study using the UTAUT with workers broadly matched in occupation, as they all worked in various research organisations, in the Gambia, Uganda and the UK. The quantitative study revealed mostly differences. In fact, of the UTAUT variables only one, Price value, had a significant effect on behavioral intention in all three locations. Effort expectancy was supported only in the UK, Habit and Performance expectancy in the UK and Gambia, Social influence nowhere. Some UTAUT factors were however found to have additional indirect effects on behavioral intention to use technology (e-learning) e.g. in the Gambia Effort expectancy had a significant effect via Performance expectancy. Facilitating conditions had been omitted from the quantitative part but showed up as relevant in the qualitative interview data: negative facilitating conditions in the African context were perceived as preventing e-learning use and needing special efforts to overcome that were not needed in the UK.

In contrast with the above it is possible to find UTAUT studies that are of teachers, but where the cultural context is not the KSA. Wong et al. (2013) for example found considerable applicability of the UTAUT with trainee teachers in Australia (the technology involved being interactive whiteboards). They found both performance and effort expectancies had a strong impact on behavioral intention, but social influence did not. The latter result was explained as possibly due to the young age of the teachers. Although teachers are involved, this study differs from the present one in a number of ways that mean it probably does not afford much insight into its likely findings however (experience of teachers and the technology targeted differ, as well as of course national culture).

Birch and Irvine (2009) also studied preservice teachers, in Canada, which might seem to be a similar cultural context to Australia. However their findings were somewhat different from those of Wong et al. (2013). UTAUT only accounted for a miserly 27% of the variance in intention to use ICT in the classroom and effort expectancy alone, not performance expectancy or social influence, was found to have a significant effect.

A further study of interest is that of Kocaleva et al. (2014), albeit it concerned university teachers in the country now called North Macedonia. Notably for the present study, however, this is reported to be an educational context like that of the present study, in that use of certain technology is mandatory (in that study, use of the university e-learning system). The study does not fully report its findings for the components of the UTAUT, but highlights what apparently was the most notable finding which was that various hindering factors were reported, including lack of time, technical support, training and goodness of fit to the subject.

These one would normally regard as falling within what the UTAUT calls facilitating conditions, albeit they are negative rather than positive conditions, as also reported in

Africa by Mehta (2018) above. Notably, however, this study adds: "Although the use of ICT is mandatory most of the staff says that they have no time, but that means that they don’t want to do that and they have no reason about not using the corresponding systems" (op. cit.. p. 37). Although the researchers do not elaborate on this point, it indicates that they are in fact rejecting the analysis that these are facilitating conditions within the UTAUT and suggesting that instead the respondents simply do not want to use the technology and are offering lack of time etc. simply as plausible excuses for that rather than reporting them as real factors that they believe influence them. In fact Kocaleva et al. conclude their report by saying " other studies may be suggested expanding the factors that affect the theory with other factors that affect the environment similar to ours" (p.38). This, amongst other things, led the present researcher to add a 'resistance to change' factor to the UTAUT model, as will be explained below in 3.2.

Overall, then, it may be concluded that widespread differences have been found in UTAUT studies in different contexts in respect of which UTAUT constructs turn out to significantly affect intention to use new technology. There is also some indication that the list of constructs currently included may not be complete.

3.2 Conceptual framework of the study

The conceptual framework can be defined as a structure of the concepts, assumptions, expectations and theories that enhance and guide the research. It is a significant part of the research design, and it shows the key concepts, factors, and variables and the assumed relations among them (Miles and Huberman 1994). This study, unlike some cited earlier (2.3.5), has a clear basis in the research area of technology acceptance, so the theoretical base comes from the theoretical models of technology acceptance described above.

Determining the factors responsible for teachers' acceptance of technology such as AR is difficult because human behavior is changeable, and may be influenced by many observed or hidden factors. However, as has been seen above, many studies have indicated that there are some key factors that play a consistent role in adoption of technology among users. In this study two theoretical models are chosen as a guide to explore factors that influence Saudi science teachers' acceptance of AR technology: the Diffusion of Innovation Theory (DIT; Rogers, 2003) to understand the process of innovation, and the Unified Theory of Acceptance and Use of Technology (UTAUT2), (Venkatesh *et al.* 2003) to provide a model of causal factors.

As Figure 8 below shows, the seven standard explanatory constructs from UTAUT2 were included to identify the main factors influencing teachers' acceptance, with an additional proposed factor which was resistance to change (see further below). Use behaviour was in this study in fact constructed as reported/perceived use behaviour, not measured objectively. Furthermore, among the standard moderators, experience was split into different types of experience: experience of teaching, experience of using digital devices, experience of using AR. For instance, if Saudi teachers have had experience of the benefits of other forms of ICT in the science classroom, they may be more favourable to accepting AR on the grounds of performance expectancy.

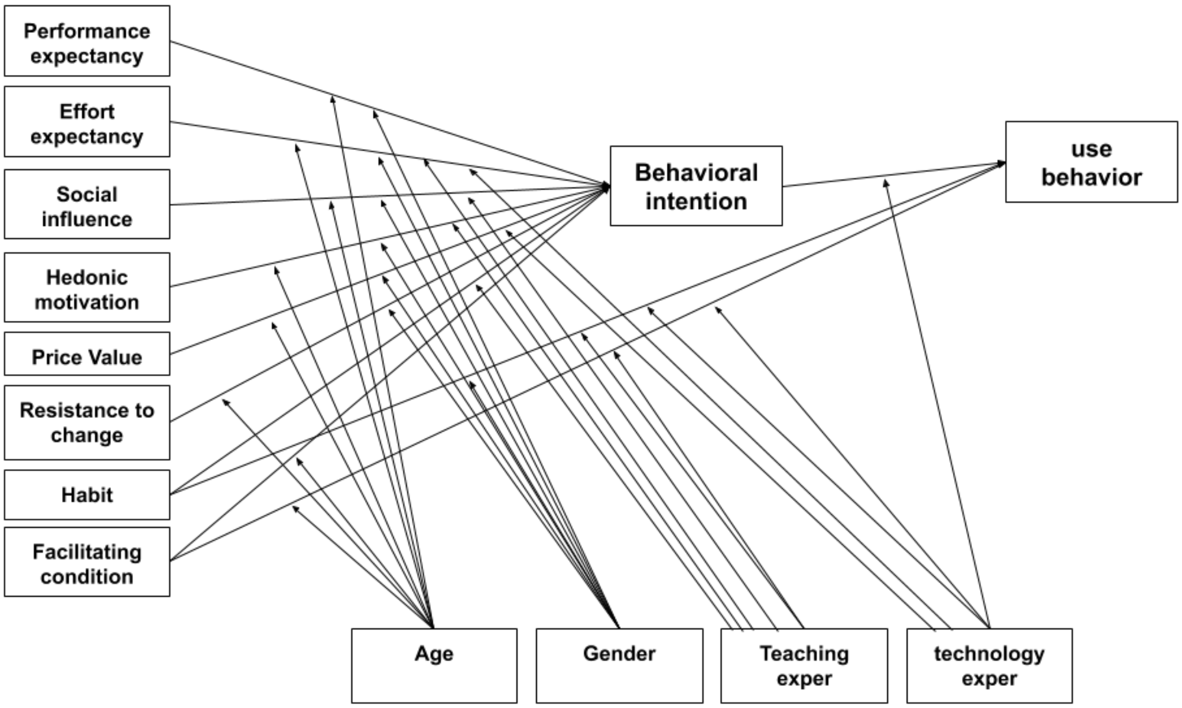

Figure 8. Proposed research Model

Seven of the eight main factors in the model adopted for this study have been already described above. The eighth is change resistance, as prompted by the Saudi literature, from Alfarani (2016) and Alkhattabi (2017).

Resistance to change: This term can be construed simply as the negative side of acceptance: in that case it does not label a cause or reason, but simply the attitudinal response of a person *not* accepting an innovation and, similarly, it is in need of explanation by factors such as those in the UTAUT (Kim and Kankanhalli 2009). Indeed much of the broad literature that exists on teacher resistance to new technology uses it in that sense (Howard 2013).

However that is not the sense in which the term is used in this study. Rather it is used as a label for a conservative personality *trait* which people may possess which would cause non-adoption of innovations regardless of any of the beliefs covered by the UTAUT (e.g. Saksvik and Hetland, 2009). In other words the present study recognises that, along with other personality traits like extraversion or anxiety, a person may be inherently change-resistant and of course that can be a factor affecting behavior such as technology acceptance, alongside the distinct UTAUT factors. For example if a teacher thinks a technology is not beneficial, or that the cost or effort of using it is too great, they may not accept it. However, that is simply the negative side of factors already described (performance effectiveness, price value, effort expectancy). It is not resistance purely and simply because the teacher's personality resists change regardless of benefit, effort and other considerations.

An analysis of this trait is found in Forsell and Åström (2012) where it is shown that resistance was recognised as far back as Freud. Modern studies have shown it to be related to well known personality dimensions: positively to neuroticism and negatively to extraversion. It is seen as an internal state of a person that is of course activated when a change presents itself. Such a change could include contracting an incurable disease, moving to a situation where societal prejudice was experienced, or of course a new externally imposed work condition such as the present study considers. At its strongest it can resemble obsessive compulsive disorder and need therapy although part of the trait can be the belief that therapy cannot help. By contrast resistance to change as a *state* is much more widely evidenced by people as a natural but temporary cautious response to, say, being offered a new food or opportunity to bungee jump.

As was indicated in the previous section, some studies such as Kocaleva et al. (2014) in North Macedonia, have in fact reported such a factor, and even implied that it should be added to the UTAUT, albeit they did not give it a name. Furthermore, such a trait seems intuitively to be relevant in a country such as Saudi Arabia, which is widely understood to be characterised by high levels of conservatism in religion, society and daily life generally. Hence one might expect some teachers not to accept AR, simply because they do not welcome any potential change to teaching practices.

Furthermore a few actual studies in Saudi Arabia have supported this. Alfarani (2016) in a university setting emphasised that general resistance to change is a major obstacle for Saudi teachers adopting new styles of teaching, including use of technology. Alkhattabi (2017), in her study about AR acceptance among Saudi primary school teachers, also found that resistance to change is perceived as one of the three main obstacles influencing AR adoption in primary schools in Saudi Arabia (agreed by 70% of teachers). From my own experience, there are clearly some teachers who simply prefer teaching by traditional methods (textbooks, whiteboard) rather than using modern tools, without any apparent justification other than just that they prefer what is already in place. For these reasons, in the present study, resistance to change as a teacher personality trait is added to the list of main factors.

In conclusion, AR use in Saudi schools is in its initial stages and its acceptance may be limited. Due to a lack of more specific literature and the novelty of AR, this study predominantly relies on a general technology acceptance model (UTAUT2) and assumes the relevance of the eight aforementioned main factors (performance expectancy, effort expectancy, social influence, facilitating conditions, habit, hedonic motivation, price value and resistance to change) as determining Saudi science teachers' acceptance of using AR technology in their classroom. However, the present study, unlike most that have been reviewed, is also interested in richer data on teachers' beliefs concerning these matters so will gather additional qualitative data where teachers are free to mention anything they like. This therefore may uncover issues that have not been reviewed above and are not part of the UTAUT2 model. Furthermore, it may show that some factors in the model play little or no role in the Saudi context.

3.3 Conclusion

This chapter provided a review of literature on technology acceptance and theories from the beginning of emergence of acceptance models. Much has been written about innovation of new technology and various suggested models of factors affecting acceptance, culminating in the UTAUT2 model which this study adopts, with an additional factor added. However, there is quite little on acceptance of AR or new technology in science teaching, especially in Saudi Arabia, which lends support to the value of the present study.

4. Chapter Four: Research Methodology

This chapter will present and justify the research design used for the present study. It includes the study aim, research questions, the description of participants, how both quantitative and qualitative data was gathered, the procedures followed, and how ethical considerations were taken care of.

4.1 Study aim and research questions

As indicated from chapter 1 onwards, the purpose of this research is to determine and explore the factors affecting Saudi science teachers' acceptance of AR use in classrooms in Riyadh province. It aims to gain comprehensive insights into their opinions about the adoption of AR in Saudi Arabian schools. To achieve this aim, the study will address the following questions:

Primary Question:

Which factors do science teachers report as influencing their decision to accept and/or use AR technology in their teaching practices? To answer the main question, the study is guided by the following research sub-questions. The first two were planned to be predominantly answered quantitatively and the third qualitatively:

1. Which of the following independent (UTAUT) variables - if any - are significant predictors of the teachers' behavioural intention to use AR technology in classroom: Performance expectancy (PE), Effort expectancy (EE), Social influence (SI), Facilitating conditions (FC), Hedonic motivation (HM), Habit (HAB), Price value (PV) or Resistance to change (RTC)?

2. Is there a significant moderating relationship between teachers' personal characteristics (age, gender, teaching experience, experience with digital devices, use of AR...) and their intention to use AR technology?

3. What detailed explanations do teachers provide for their beliefs related to the factors affecting acceptance of AR in classrooms?

As already indicated, in answering all three questions special attention was to be paid to the differences between AR users and non users in order to understand how the factors affect them differently and why exactly they differ, since they are all in a context where AR is ostensibly provided and expected to be used. Is it a difference of acceptance? In what way? Or is acceptance similar but something else means that acceptance is translated into adoption by users but not by the non-users?

Recall also that there is a broader purpose to assess the usefulness of the UTAUT2 framework in the Saudi research context, and the value of including the extra factor of Resistance to change.

4.2 Research Paradigm

This study is interested to understand the reality of AR technology acceptance among Saudi teachers and their attitudes toward this technology. The research paradigm provides the ontology and epistemology which form the foundation of social science research and answer questions about how reality can be described and how knowledge can be obtained (Lee 2012). In social science research, the positivist and interpretivist approaches constitute the two fundamental paradigms, and each is based on different ontological and epistemological beliefs (Johnson and Onwuegbuzie 2004).

Positivism takes the view that the truth is 'out there' to be discovered and is an appropriate approach where a theory or model is adopted from the start as a candidate for representing that truth, and data is gathered following its categories to see if it is supported. As indicated in the previous chapter, this is the approach to be taken here with respect to the quantitative data planned to be gathered, where the study follows closely a slightly adapted version of the UTAUT2 model. In accord with that, part of the data in this study is to be gathered through deductive methods by applying a closed response questionnaire, with items based on the UTAUT2, and quantitative analysis.

Interpretivism on the other hand is an approach that values broad data gathering not restricted in advance to categories decided by any theory, where interesting categories may rather emerge inductively. In its view the truth may differ from person to person: it is subjective rather than objective and fixed. Typical data gathering methods are observation and open response questionnaires or interviews where the data is analysed qualitatively. Some open questionnaire items were indeed included in the present study and interviews were conducted where, although the categories of the UTAUT2 were used as a broad guide to the questioning and data analysis, participants were also free to introduce any ideas they thought relevant. Qualitative analysis was then appropriate for this data, where the researcher repeatedly goes through the responses and finds more details and unanticipated ideas (Cohen *et al.* 2011). In this way it was planned to describe and understand users' beliefs in the social world where knowledge is formed bottom up from human experiences (Ibid).

Overall, in this study the purpose was to investigate in depth teachers' perceptions of a specific technology in the classroom and by combining something of both the positivist and interpretivist paradigms it was hoped to achieve that. In particular the aim was to redress the balance in an area where most research tends to be heavily positivist.

4.3 Method overview

A research design is a plan that is adopted to answer research questions accurately, objectively, validly and economically (Orodho 2003). The purpose of this study is to obtain an in-depth understanding of the factors that influence user acceptance and adoption of AR technology. To achieve this, consistent with the paradigms referred to above, data was collected both quantitatively and qualitatively. Teachers' perceptions cannot be successfully evaluated solely by interpreting statistical data (Creswell 2012);

thus, qualitative data was collected to obtain a broader understanding of the factors that influence Saudi teachers' acceptance of AR technology.

At the level of methodology, the gathering of both qualitative and quantitative data on the same research topic, as in this study, is termed a mixed-method approach (Leech and Onwuegbuzie 2009). Such an approach is widely regarded in social science and educational research as strengthening the research data, overcoming the limitations of each method (i.e. achieving greater validity than each would separately provide) and benefiting from the advantages of both approaches. The use of Mixed methods also helps the researcher to investigate the educational issues in their context and obtain a deep understanding of the issue under investigation. It benefits the researcher by allowing generalisation of the results generated with the quantitative method, assuming that representative sampling was used, and enabling understanding of the issue in depth, from the detailed contextualized results produced from the qualitative data (Ibid). This study therefore employed mixed methods with the aim to obtain reliable and valid data that may provide the best answers to the research questions and fulfil the investigation needs.

In order to answer the research questions in the present study, the project was therefore essentially designed to use two methods. The quantitative phase was based on closed response questionnaire items with a large number of participants chosen to represent a population in what is often termed a survey. The second, qualitative, phase was a more intensive open response study of a few teachers who agreed to be interviewed (together with some open item responses from the questionnaire).

Surveys typically have the aim of representing the opinions of quite large populations, as in the present study of a population of several thousand secondary science teachers in the Riyadh region. Surveys often rely on questionnaires and quantitative analysis methods such as correlation (Shaughnessy *et al.* 2000), as was planned for answering RQs 1 and 2. They are suited to finding out participant beliefs and attitudes about a range of predecided issues at a shallow level, but not for in depth exploration of participants' thinking. In this study, therefore caution would have to be exercised when using findings from the questionnaire to speculate about whether AR would become more widely used in future in KSA and what factors might affect this.

The semi-structured interview method fitted the focus of the second phase of the research using a smaller number of science teachers in secondary schools, in order to answer RQ3. They might not be so fully representative, but the aim was for them to be richly informative. Intensive involvement with these teachers in this study should enable the researcher to obtain answers for the ‘how and why’ questions which are hard to deal with in survey questionnaires but typically can be illuminated by in depth interviews with key cases. This part of the study was intended to help the researcher to more deeply understand the perceptions of teachers regarding their acceptance and potential adoption of AR technology.

In this study, then, overall a mixed method survey and in-depth interview approach was planned in order to enrich the research data and gain a full understanding of the teachers' perceptions regarding acceptance of AR technology. This approach then further involved the three steps of conducting research, i.e. collecting, analysing and interpreting, applied both to quantitative and qualitative data (Leech and Onwuegbuzie 2009).

4.3.1 Overview of the study procedure

The intended design of this study paid attention to a number of considerations, in a certain order, which are outlined here and summarised in Figure 9.

First, the survey stage was prepared, with a draft questionnaire based on the UTAUT2 as has been described, to enable an answer to RQ1 to be found, together with relevant demographic items to be able to additionally answer RQ2 (age, experience etc.).

Second, the questionnaire was piloted, and improved, and ethical considerations related to the main study administration were dealt with.

Third, the main study participants were contacted and, since it emerged that some had used AR and some had not (or very little), separate versions of the questionnaire were developed with wording adjusted to suit that. The questionnaire was then administered online to around 400 secondary science teachers.

Fourth, following this stage, the questionnaire data was planned to be quantitatively analysed and a set of questions developed to form the basis of the semi-structured interviews.

Fifth, 25 teachers were to be selected from those who volunteered, and they participated in in-depth interviews to explore their beliefs and attitudes underlying their questionnaire responses. Sixth, the interview data was qualitatively analysed.

The plan was then for an interpreted synthesis of both quantitative and qualitative data to be produced. The qualitative part of the mixed method design would add depth and explanatory insight to complement the bare information provided by the quantitative data. In effect, the quantitative part of the design would yield data answering how much teachers used AR for this or that reason (e.g. PE, etc.), then the qualitative data would help to reveal why they said what they did.

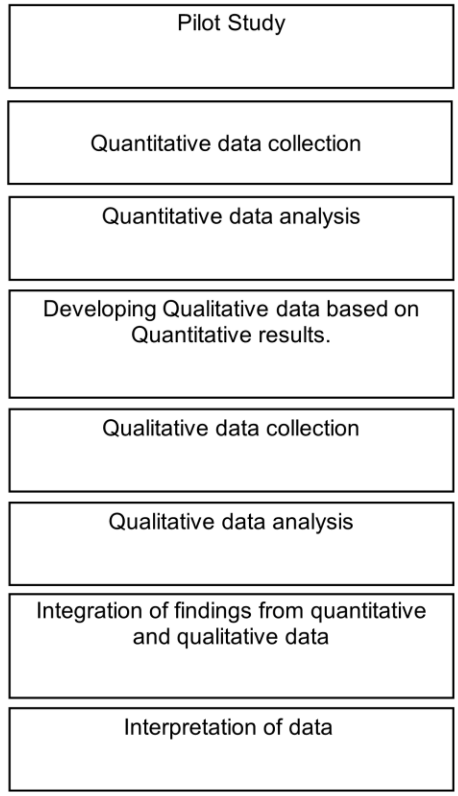

Figure 9.Outline of Sequential Procedure

4.4 Participants

In this study, the targeted participants are current science teachers in Riyadh District (Riyadh City and counties), including both male and female, in all the Ministry of Education public secondary schools. They therefore constitute the population of the study. A population is a group of people who have some shared characteristic in the same organisation or environment, for example, science teachers in secondary schools (Creswell 2012).

The size of the population depends on the nature of the research (Cohen *et al.* 2011). Riyadh is a large region in Saudi Arabia, and it includes the capital city with a diversity of teachers in terms of demographic information: gender, age, teaching experience and technology experience. In the region of Riyadh, there are 1203 secondary schools containing 38261 teachers, 3133 of whom are science teachers (Department of Education in Riyadh, 2018).

Sample size in practice is determined in two stages: before gathering the data, and afterwards, based on the number of valid responses actually received. Although there is no perfect sample number to aim for in most research (Cohen *et al.* 2011), guidance is available for appropriate target sample sizes in quantitative work with large populations where representative samples are required. For the online survey in the main study therefore, since the science teachers in Riyadh region secondary schools number 3133, Krejcie and Morgan (1970) table was followed which recommends an appropriate sample size of at least 300 so as to adequately represent the population which intended to be surveyed. It is to be expected however that many of those who initially agree to participate might not complete the data collection process and this could lead to the need for rearranging for alternative participants.

In qualitative data gathering some authors simply suggest that the sample size should be large enough to gain sufficient data that helps to describe the phenomena in question and the aim of researcher should be to attain saturation (Strauss and Corbin

1967). By that it is meant that the researcher should go on gathering data, in the present case interviewing people, until he starts hearing the same points repeated again and again and no new ones are emerging. Morse (1994) on the other hand gave numerical guidance and recommended for ethnographic studies approximately 30 – 40 participants and 30-50 for grounded theory, while Cresswell (1998) suggests only 20 – 30. For phenomenological studies, Morse (1994) suggests that the sample size should be at least six people while Cresswell (1998) suggests 5 – 25 interviewees.

In the present case, although a broadly interpretivist approach was taken to the interviews, as described above, the interviewing does not fall exactly within any of these specific paradigms and is not totally unstructured. Still, based on these suggestions, it was deemed that 20-30 was a sensible number to aim for and in the end, 25 interviewees were secured.

4.4.1 Description of the questionnaire sample

361 science teachers supplied questionnaire responses. A full description of the nature of this sample was made (similar to that below for the interview participants) but is not detailed here because, as will be explained below, the data from this sample later had to be rejected as invalid and was not analysed to answer the research questions. The questionnaire itself and its mode of delivery will however be described in full below, so that it can be judged whether they were appropriate, and not the cause of this problem.

4.4.2 Description of the interview sample

This section provides a description of the interview participants' demographic and other relevant background information (including use of AR technology). In order to secure teacher confidentiality, individual teachers are referred to as US plus a number for AR users, and NU plus a number for AR non-users.

Demographic characteristics of interview participants

The participants in this part of the study were twenty-five secondary school teachers; the female participants represented more than half of the total sample (n = 14, 56%), while the proportion of males was 44% (n = 11) (See table 2 for detailed data). It is worth noting that female teachers recorded a higher response than males to the researcher's call for interviewees although they were a minority in the survey. Regarding age group, the majority of teachers were between 30 and 39 (n = 15, 60%) at the time of the interview, followed by 24% being under 29 years and 16% being above 40 years. These findings indicate that the sample covered a wide age range.

The highest percentage of participants had a bachelor's degree (n = 24, 96%), but only one teacher had a master's certificate (4%). Twelve teachers had five to nine years of teaching experience (48%), followed by five participants (20%) having between 10 and 14, and five teachers (20%) having less than five years. Three of them (12%) had 15 years or more of teaching experience. These findings further indicate that the majority of the respondents were graduates and most of them were well experienced.

Table 2. Interviewee background information (AR users and non-users combined).

Variable	Category	Frequency	%
Gender	Male	11	44%
	Female	14	56%
	Total	**25**	**100%**
	Prefer not to say	0	
	Total	**25**	
Age	Under 29	6	24%
	30 to 39	15	60%
	40 to 49	2	8%
	50 or over	2	8%
	Total	**25**	**100%**
Education level	Bachelors	24	96%
	Masters	1	4%
	Other	0	0%
	Total	**25**	**100%**
Teaching experience	Less than 5 years	5	20%
	5-9 years	12	48%
	10-14 years	5	20%
	15-19 years	1	4%
	20 years or over	2	8%
	Total	**25**	**100%**
Technology experience	Beginner	0	0%
	Intermediate	15	60%
	Advanced	6	24%
	Expert	4	16%
	Total	**25**	

Teacher reported experience of technology

In relation to teachers' experience with technology, the majority of the interviewees reported that they were familiar with a variety of technologies and had good experiences in using it. Fifteen teachers (60%) reported that they had an intermediate level of experience in using technologies, while six of them (24%) claimed to be advanced and four (16%) experts. These findings are consistent with Bingimlas (2009) who conducted a survey of Saudi Arabian teachers that revealed that the majority of the teachers claimed significant technological knowledge. In that study a majority of the teachers (67%) revealed high confidence levels in their knowledge of technological pedagogy. This therefore suggests that the interview sample in this study, although small, was typical of Saudi teachers more widely.

Devices reported used by participants in class

The projector was reported to be the most used device by participants, which again suggests the sample is representative of the wider population of teachers that is known to favour teacher centred whole class teaching. Table 3 shows that 23 teachers (92%) reported that the projector was the most used device in their teaching practices, followed by mobile phone (56%) and digital camera and TV (8%).

Table 3. Devices reported used by teachers in the interview sample.

Category	Number	%
Mobile Phone	14	56%
Tablet	6	24%
Computer	18	72%
Projector	23	92%
Interactive whiteboard	6	24%
TV	2	8%
Digital Camera	2	8%

Reported AR technology use

About two-thirds of participants in the interview reported that they knew and had used AR technology in the past. Thus the sample, as intended, represented both users and non-users of AR, who it was the intention of the study to compare. As Table 4 below shows, 64% (n=16) reported that they used AR technology in their teaching practices, while 9 of them (36%) reported that they were not AR technology users.

It is worth noting that the user of AR technology in this study is the teacher who knows and uses AR technology many times in his teaching practices, because some of the teachers had used AR technology only once or twice and did not continue to use it or used it for different purposes. The latter were all counted as non-users. One teacher (NU5) for example said, “Perhaps I did (use AR) when the school principal or supervisor attended the classroom,” meaning he knew about AR technology but did not continually use it. The reasons for this will of course be the subject of this study's results later.

Table 4. Users and nonusers of AR technology in the interview sample

Category	Number	%
User	16	64%
Nonuser	9	36%
Total	25	100%

Table 5 below shows the distribution of the use of AR technology by gender at the time of conducting the interviews. In the non-user group, males predominated, while the users were female dominated. In the user group the male teachers were five (n=5, 45.5%) while females eleven (n=11, 78.6%). The females in the non-user group were only three teachers (n=3 ,21.4%) while males dominated (n=6 , 45.5%).

Table 5. Users and nonusers of AR technology in the interview sample, by gender

Gender	Total	User	%	Nonuser	%
Male	11	5	45.5%	6	54.5%
Female	14	11	78.6%	3	21.4%

Total	25	16		9	

Reported frequency of AR technology use by AR users in the classroom

Finally, in order to characterise the AR user subsample more fully, reported frequency of use of AR technology was elicited. Of the 16 teachers who reported using AR technology, eight (50%) reported that they were using AR technology in the classroom at least once a week, while 31% (n = 5) used AR technology 3–5 times per month. As shown in Table 6, three teachers (19%) were using AR technology only a few times a term.

Table 6. Reported frequency of AR usage: AR users in the interview sample

Category	**Number**	**%**
Daily	0	0
Weekly	8	50%
Monthly	5	31%
A few times a term	3	19%
Total	16	

4.5 The Questionnaire phase

This section shows how the quantitative data was collected in this research. It describes the content of questionnaire and the conduct of pilot study and its result. It also shows how the main study quantitative data was collected and analysed.

4.5.1 The survey instrument

The questionnaire allowed for gathering three types of data from a large sample of Saudi science teachers.

First, it covered teachers' personal demographic and relevant background characteristics: age, gender, teaching experience, reported experience of using various general types of devices, reported frequency of use in class of various types of devices, and experience with using AR in class (which was revealed by which version of the remainder of the questionnaire they chose to answer, see below). That was used for two purposes. First it provided an account of the background profile of the sample (4.4 above). Second, most of those variables were moderators in the UTAUT2 model and so were needed to answer RQ2.

Second, a set of 37 statements was constructed with responses on five-point Likert scales, covering the eight main factors of the version of UTAUT2 adopted for the present study and the dependent variables of intention to use AR and AR reported actual use in class, which together are essential to answering RQs 1 and 2. Between two and eight statements represented each construct. Through this, the teachers' degree of agreement with a wide range of propositions concerning beliefs about AR technology, which are likely to influence their intention to continue using AR technology in the future, or to start using it if it became available, was determined. These statements include for example 'Learning how to use Augmented Reality technology is easy for me' (Effort expectancy) and 'I will always try to use Augmented Reality technology in my teaching' (Behavioral intention). For the complete listing see

Appendix1.1. These items were based on the enhanced UTAUT2 framework with the eight main factors described at the end of chapter 3 and in Figure 8, and were largely taken from the UTAUT literature (Chang *et al.* 2019), with the additional construct (Resistance to change) where the items used were prompted by its two Saudi sources (Alfarani 2016, Alkhattabi 2017). The items were all presented to participants in the questionnaire organised in their subsets with titles provided for each subset/construct as in Appendix,1.

This part of the questionnaire was designed in two versions, one for teachers who already use AR technology, and the second one for teachers who have not used AR in the past, or very little (see Appendix.1.2). The literature review showed that UTAUT2-based questionnaires, such as the one used in this study, have been used in situations in which the respondents have a wide range of familiarity with the technology about which they are being asked to respond. Indeed, it is not uncommon that respondents are asked about their opinions of technology or software they have not used and possibly do not understand. For example, Sundaravej (2010) reported students' responses to propositions such as 'Using MyGateway enables me to accomplish tasks more quickly', while at the same time it was reported that 51% of the sample had no experience with the application and that 82% had no training. This practice seems entirely inappropriate. Therefore, the present survey came in two versions, to allow non-users to elucidate their opinions in this study in response to items that took account of the fact that they were non-users. For them the questions were worded in a probability wording (e.g. 'Learning how to use Augmented Reality technology would be easy for me' (Effort expectancy)) because they were asked to imagine a hypothetical situation rather than report on actual practices.

Third in the questionnaire, there were some open-ended questions where teachers were invited to respond extensively. Any comments on experiences and beliefs related to AR, especially if they have used it in class, were encouraged. This produced some qualitative data bearing on acceptance, to be treated like the other qualitative data from the interviews, which are described below, and which together help answer RQ3. The topics of the questions include why they would implement AR technology during instruction, how they could be encouraged to integrate the technology into instruction in the future and their views on AR if they had in fact used it in class before. The aim of the open-ended questions was to provide teachers who have experience using AR technology and who will not be participating in the interviews an opportunity to present their opinions regarding the use of AR technology and so illuminate their acceptance of it. The questionnaire ended with an invitation to participants to volunteer to be interviewed.

The questionnaire was created in the English language but translated into Arabic so as not to present any unwanted language problems for the participants for whom Arabic is their language. The Arabic version was sent to a freelance translator to ensure that each item expressed correctly the meaning in the original language. He advised rewording of some statements.

4.5.2 Piloting and expert vetting of the questionnaire

A pilot study was conducted on a group of science teachers from the target population, who were not used in the main study, to ensure that the draft questionnaire was appropriate for research purposes in terms of the survey items being clear and understood and likely to be valid to answer the research questions, and that there were no problems with the online administration or the analysis.

To ensure that the pilot study was conducted in the same conditions as would be used for the main study, Afif city – a small city in the Riyadh region - was chosen to be the pilot study location. The Department of Education in Afif was sent the access letter and all required documents that included the aim of study, the name of university, the researcher details and Saudi embassy approval. The link to the online survey (both versions) was then sent via official email addresses of the Department of Education, together with the information sheet and letter of invitation to teachers to participate (Appendix 3.2 &3.4). Both males' and females' secondary schools participated in the online survey. Participants were given access to the survey for two weeks.

The number of participants was 31. The piloting demonstrated that the survey administration could be executed as intended and there were no infrastructural barriers. The main issue that came to attention first was that of the respondents' behaviour in the form of missing data. Data was cleaned in Excel where the following policy was adopted. Cases that had missing responses only to isolated questions had those responses completed with the mean value for that question. Cases that were missing a whole page of the survey were removed; cases that had more than four item responses missing from either page of the survey were removed. In case a full section had been left completely empty by a participant, the entire questionnaire was again discarded.

A second important issue concerned invariant responses. When a respondent answered most/all the questions with the same answer, their individual data across all items displayed a low standard deviation and such participants were also discarded as this was taken as a sign that the participant had responded unthinkingly and therefore invalidly.

In open questions, absent responses were however not regarded as a problem since the focus would be on the responses to the closed items and it is common in questionnaires with many closed items that participants do not answer the open ones.

Following those principles, eight surveys were discarded because they exhibited invariance of response on the closed items. Therefore 23 responses were converted to SPSS format. While it was not possible to proceed to examine the structural model due to the small number of participants, the piloting demonstrated that the survey instrument was operational.

The main lesson learned from this piloting was that while the items in the questionnaire and its mode of administration seemed to be largely satisfactory, there was potentially a serious problem with the behaviour of the teacher participants. A number of them were not cooperative in the way survey researchers hope for, as evidenced by either omitting many items or answering with a uniform choice. Both these practices are signs that they were not really engaging with the content of the items and hence that although they had agreed to help the researcher by responding, they either did not want to spend the necessary time and effort on considering every item or had some other reason not to reveal their real opinions. Furthermore, all the items in the original piloted version were positively worded. For example, on all the Performance expectancy items greater agreement signalled greater performance expectancy. This meant that it was easy for participants develop an expectation or mental set that what they respond to one item would more or less apply to all of them, and hence that they do not need to actually read all the items, but just duplicate their answer.

Following the experience of the initial piloting, steps were taken to address both missed item and uniform response issues in the main study questionnaire. First, the Bristol online survey (BOS) tool was used to create and administer the questionnaire items for the study due to its successful use in many previous academic studies, and high recommendation by many universities in the UK. It supports the questionnaire design and facilitates its distribution. It also supports the Arabic language and allows use of many techniques to simplify the presentation of questions for the participants. In particular, however, when a questionnaire is administered through BOS, the respondent is not allowed to miss any closed items and cannot progress unless responses are made to all closed items.

In addition, in order to discourage uniform response behaviour, and so strengthen the survey design, four reverse worded items were added to the questionnaire. Using reversed items in the questionnaire is also designed to reduce response bias (Nunnally 1978; Paulhus 1991). For example, in Performance expectancy the item 'Using Augmented Reality technology increases my productivity' was supplemented by the item 'Using Augmented Reality does not increase my productivity' (AR user version). This very obvious clash between nearby items would, it was expected, prompt respondents into realising that all the items were not just variations on the same idea and that they really did need to be all read and responded to separately. These items were also piloted with 19 participants and the Spearman correlations calculated between responses for each related pair of positive and negative worded items. There were no significantly positive correlations. Therefore, it was concluded that the participants were not systematically responding in the same way to both items in these pairs (which would have yielded significantly positive correlations) and the researcher was encouraged to proceed to the main study.

After the piloting, academic faculty feedback on the draft questionnaire was also elicited. Some statements were reworded to be clearer for participants and the four Resistance to change items were changed to three items ('Lack of availability of digital devices in the classroom is a barrier to the use of Augmented Reality technology for teaching and learning', 'Students are distracted by the use of digital devices in the classroom' and 'I prefer teaching using books and board rather than new technologies').

In the nonuser questionnaire, some items were reworded since they needed to be in the conditional future tense.

Finally, translations were sent again to the translator to ensure the survey items were agreed to be clear. He suggested that “Generally speaking the translation is good. However, as in all translations of technical nature there will be some challenges of ambiguity. This is understandable given the disparity of the two languages. The questions I was asked to comment on and give my feedback are 11 to 16. I find some Arabic questions to be unclear and have to be rewritten taking into the consideration the target reader and his knowledge of the relevant field”. This demonstrates that even when questionnaires are given in L1, there can be issues.

4.5.3 Main Study Questionnaire Delivery

In the main study, broadly the same permissions and steps to administer the questionnaire were followed as described for the Pilot study. Participation in the survey was invited from all science teachers in Riyadh secondary schools. After obtaining consent from the Riyadh Education Department, the link to the online survey was sent via email to the educational administration in Riyadh, Alkharj, Alduwadmi, Algwayiyyah, Aldulam, Alzailfi, Alghat, Alhareeg, Al sulayyil, Hotat Bani Tamim, Layla, Rimah, Shagra, Thadig, Wadi Addwair cities to pass it on to their schools.
The principal of every school received the survey email and passed it to science teachers in his/her school and the teachers had the opportunity to participate or not,

after reading the information/invitation sheet (Appendix,3). The online questionnaire was open from 6 May 2019 until 20 September 2019, and two reminders were sent after the first email.

The use of an online questionnaire allowed the researcher to focus more attention on the questionnaire quality, strengthening the questions and improving the design of the survey. This is a type of implementation of technology for data collection and, as such, incidentally, increases participants' awareness of using ICT in their work. It also minimises time spend on printing and distributing the survey to be delivered to a large number of participants. It is only necessary to send an email including the survey link to the local Department of Education to send to the school. With respect to the cost, the online survey is less expensive (BOS is free) than a printed questionnaire (Vehovar *et al.* 2001). Most importantly, sex segregation in Saudi schools makes it more complex to arrange for delivery of hard copy survey instruments from a male researcher to female teachers than male ones. With the use of online delivery, the researcher can access a greater number of participants more easily and quickly.

4.5.4 Main study Questionnaire Data cleaning and response validity checking

Based on the experience of the Pilot, it was important to follow up on the two main issues that emerged concerning participant response. After closing the online questionnaire, the gathered data (N=361) was exported into Excel. Eight respondents who reported being in regions other than the Riyadh region were excluded as not members of the target population. They had presumably either been sent the questionnaire by friends within the Riyadh region or had moved during the time of the survey.

There was, as anticipated, no problem of missing data for the closed items. The administration of the online questionnaire with BOS facilitated the data collection procedure and helped participants to choose their answers by clicking the appropriate icon. Furthermore, the design did not allow for missing values, and it reminded the participants of any missing responses before moving to the next page in the survey. This system therefore contributed to minimising the work in the data cleaning stage and helped in obtaining fully completed questionnaires. As in the Pilot, for open response questions, absent responses were not regarded as important since the focus is on the responses to the closed items.

The issue of uniformity of response by individuals across all or most of the items was then addressed. Three approaches were used. First, as in the Pilot, the individual variances of each participant across all their responses to the 39 items were calculated and means of those generated. Values nearer 0 indicate high uniformity of response and so likely inattention to the content of the items. In fact, the mean variance across all items was only 0.9. Within that there were a number of cases with zero variance in response to the entire set of items, and indeed 20% of the participants had variance less than .5, reflecting a high rate of uniform response across subsets of items.

Second, the four pairs of normal and reverse worded items were each examined to ascertain if the correlation between them was strongly negative, as would be expected if participants were responding with due thought. In all cases the correlations were only weakly negative. For example, on the pair 'People whose opinions that I value prefer that I use Augmented Reality technology' and 'People whose opinions that I value prefer that I do not use Augmented Reality technology' the Spearman correlation was close to zero at -0.005. Since the items were all delivered in Arabic this cannot be interpreted as just due to linguistic misunderstanding. It can only be due to lack of thought about the meaning of the items, which of course carries implications for all the items in the questionnaire, not just this pair. Uniform response is clearly at work here since 117 of the participants (32%) gave an identical response to both.

Finally in order to gain a more sophisticated assessment of uniformity of response, Cronbach's alpha was calculated for the entire data set (39 items and 361 participants), and without reversing the polarity of negatively worded items. Cronbach's alpha is designed to measure the correlational agreement between multiple items, in sets assumed to be all measuring the same thing, and with the same polarity (i.e. high values mean the same thing for every item, e.g. greater performance effectiveness). For that reason, it is widely used as a reliability measure for subsets of items in questionnaires that are supposed to be measuring the same construct. Low values of alpha then are indicative of the subsets not being homogeneous in their focus and/or not all being worded with the same polarity. In the present case, then, using Cronbach on an entire dataset where there are sets of items measuring nine distinct constructs and including four reverse worded items should result in a really low value for alpha (near zero), reflecting the lack of homogeneity of response that should be present. In fact, alpha was .901, which is a quite exceptionally high value (near its effective maximum of 1). This therefore indicates comprehensively that despite there being items included on a range of quite separate issues, and some negatively worded items, the participants gave the sort of response one would obtain if they were all about the same thing. This again must be a reflection of blindly uniform response without attention to the content of the items.

The above findings demonstrate that, despite the researcher's best effort, the problem of uniform / invariant response first seen in the Pilot had not been resolved. Instead there was widespread uniformity and, in the case of reversed items, response far less coherent than would be expected for robust data. This left him with no alternative but to reluctantly discard the entire quantitative data. Hence the standard analyses usually done at this point such as reliability checking for each construct using Cronbach's alpha and assessment of the normality of distribution of the data in preparation for onward calculation of results were not conducted.

4.6 The qualitative phase

4.6.1 The interview instrument

As described earlier, the interview was planned to be a second key instrument in answering the overall question about science teachers' attitudes to, and acceptance of, the use of AR technology. The interview was specifically conducted so as to answer RQ3 by eliciting participants' wider perspectives on the research topic of AR acceptance, and providing a complex picture of the situation (Creswell 2012). In the event, however, as just described, it became the sole instrument used to answer all the research questions.

Interviewing teachers and asking them their viewpoints about educational issues is an appropriate way for a researcher to merge himself in the problem surroundings and helps to provide more meaningful contributions to the study. It informs the researcher about the details, helps him to think deeply about the reasons for acceptance, and leads him to understand the problem in its context (Powney and Watts 2018).

In the interview there are also benefits for the interviewee. He/she can link their personal record with the event and its context which is useful to enrich the study data and helps in uncovering the cause of the problem or answer to the research question (Brown and Sime 1981). In this connection, Young *et al.* (2018) explain that the interview depends really on an interactive method wherein mutual learning takes place between those involved in the interview process. It is an effective and active research process through which a mutually created and contextually bound story is generated between the interviewer and interviewee. Good interviews thus also help the researcher in focusing on the perspectives of the interviewees, rather than any prior theory, to determine what is important or relevant and identify the issues that the interviewer might not have been able to anticipate from the findings of the literature (Young *et al.* 2018).

These aspects of interviews therefore ensured the effectiveness of the interview method to address my research objectives regarding the factors influencing the decisions of the Saudi teachers to accept the use of AR technology into their professional teaching practices. Only some aspects of RQ2 could not be effectively addressed due to the small sample size. Interviewing teachers was necessary for uncovering the full range of reasons that caused teachers' intention to operate (or not) new technologies in their classroom. It helped the researcher to discover latent factors and obtain detailed information about their behaviour, familiarity, engagement and attitudes with respect to the AR technology.

The qualitative semi-structured interviews that were conducted were suited to understanding teachers' perceptions regarding the adoption of AR in depth. In the present case, they helped to explore the influence of critical aspects and allowed important themes to be considered in detail. In addition, since the researcher was present, at least virtually, it was possible to prompt participants to expand their answers where necessary and provide a much better understanding of what was involved in accepting and using AR in class. Furthermore, in this way the interviewee could also immediately ask the researcher about any ambiguities in the questions. The one-to one nature of the interviews also helped to protect against the likelihood of unthinking responses that seemed to have befallen the questionnaire.

The interview questions designed for the new wider role of the interview than that originally intended (see appendix, 2) ranged over issues such as what the AR using teacher thinks of AR now that he/she has actually tried it with a class, whether they will continue using it or not, and why. A core of questions was derived from the items used in the questionnaire to represent the UTAUT2 constructs. At the same time teachers had a chance to speak freely and introduce new ideas or factors that influenced their perceptions about using AR technology.

The skeleton of the interview then was a priori themes derived from the UTAUT2 constructs (PE, EE, FC, SI, PV, HB, HEM), the additional factor (resistance to change) and the demographic and background information, together with the perceived impact of AR technology on teaching and learning. The general sequence of the line of questioning was as follows.

First at the beginning, it was important to ask the teacher about his/her demographic information (I.e., age, teaching experiences, qualifications, technology experiences), his/her knowledge and experiences of AR technology and if he/she uses it or not in class. That introductory information guided the interviewer about what should be pursued in detail later. If the interviewee said they did not use AR technology, then it was clearly not appropriate to ask him/her further about their use of AR, so the questions moved to general ideas about technologies and the potential use of AR.

After this beginning, the teachers who used it were asked to describe their experiences using AR technology: when he/she started using it, why he/she chose AR, whether AR enhances his/her teaching practices and how, students' attitude, and why he/she continues to use it. The aim of those questions was to obtain a comprehensive idea about AR technology use in the classroom and their reasons for it, from the teacher's perspective.

Next, the interview process explored teacher perceptions following the UTAUT2 themes. In this connection, questions were asked covering the benefits of the technology, preparation issues and the effort needed to use it, the infrastructure and AR resources, the role of school staff including the school principal and teacher colleagues in using the technology and their influence on the teacher's decision, teacher personal motivation and habits. There was a part allocated to address the challenges facing the use of AR (e.g.. relevant rules in school, students' distraction, and preference for traditional methods).

Finally, there was a chance for the interviewee to describe any additional factors and engage in conversation about matters not mentioned, but deemed relevant based on the teacher viewpoint.

It should be noted that, like the questionnaire items, the interview questions were mostly worded in terms of factors leading to AR use or non-use, i.e. they directly targeted reasons for AR adoption or non-adoption, their practice, and only indirectly targeted acceptance, their belief, although, as the main research question indicates, the study has an interest in both.

There were several reasons for this. First, it would take too long and be confusing and repetitious to go through two sets of questions, one trying to find out why teachers had favourable or unfavourable attitudes to AR (acceptance) and another trying to find out about teachers' reasons for actually using or not using AR (adoption).

Second, the UTAUT2 model that was being adopted (Figure 8) shows that all the main factors which are of interest first affect 'behavioral intention' (which is, effectively, acceptance) and then, mediated through that, 'use behavior' (i.e. adoption). Only two of the factors (habit and facilitating conditions) may be expected to have an additional direct effect on 'use behavior'. This means that when a user participant is asked 'Why do you use it <AR>?' (appendix 2.1), which asks them to explain their adoption of it, they will almost inevitably cite beliefs in their reply which, in the model, contribute initially to acceptance. On the other hand, when asked 'Are appropriate devices, applications and books available?' their reply will likely give information that evidences the direct link in the model between facilitating conditions and use. In this way it was expected to very often obtain information on reasons both for acceptance and adoption in the same response, and indeed that proved to be the case as the findings later will demonstrate (e.g. table 7).

The original version of the interview questions was written in the English language, but the participants received it in the Arabic language because that is their language. The researcher translated the interview questions into the Arabic version and sent it to a freelance translator to review this version and suggest any change. After reviewing the translator's suggestions, it was sent to an academic faculty member, an expert teacher, and a science supervisor in the Education Department in Riyadh city to obtain their comments about the format of the questions. Their observations were considered before the questions were used with the targeted teachers.

4.6.2 The conduct of the Interviews

After analysing the data gathered from the online questionnaire, the teachers who accepted the invitation to also participate in the interview received an additional email to confirm the invitation, explain the interview and arrange for conducting it. In addition, an invitation email was sent to the Department of Education in Riyadh to be sent to teachers who wanted to take part in this phase. The introductory email for interviewees informed the participating teachers about the researcher's method of recording the interview in Skype and his role in the interview itself.

First, pilot interviews were conducted with three teachers in order to assess the interview question protocol and evaluate the procedure. Three teachers participated in this phase and they were aware of the aim of the study and the type of questions. At the end, they were asked to express their impression of the interview in terms of comfort, voice clarity, and understanding of the questions. The aim of these pilot interviews was to ensure that the method used would produce useful data and so make a valid contribution to the study. Received comments were considered in the main interviews.

In the second stage of the interview data collection, the online survey had been analysed to extract the information of the teachers who initially agreed to take part in the interview phase. A few teachers left incorrect contact details and it was hard to contact them, thus they were excluded. From 38 remaining teachers who volunteered, 8 teachers apologised and withdrew, 13 agreed to participate while 17 teachers did not respond to the second invitation, so they were discarded.

After starting to conduct the interviews, three further teachers withdrew and apologised for various reasons. In order to increase the number of participants a new invitation was therefore sent to some teachers. Two further interviews had to be cancelled because the interviewees only wanted to talk about their situation in school without reference to the interview questions, and were not using any technology in their classroom. Furthermore, one of the participants who agreed was a teacher when he responded to the survey but by the time of doing the interviews, he had moved to a post with a company, so the decision was taken to exclude him because he no longer was a member of the target population.

In addition to these problems the interview appointment times often had to be changed more than once, for reasons such as 'I have new appointment in the hospital, with my family', or 'I will not be in the area covered by an adequate network', and some of the teachers ignored their appointments. To combat this, the invited teachers were sent a reminder (call or message) 15 minutes before the interview appointment. In the end successful interviews were conducted with 25 teachers.

In the interview itself, the teacher was first asked to confirm their consent and was reminded about their rights to confidentiality, to withdraw at any point, refuse to answer any question and so forth, under the ethical guidelines. The Skype interviews took between (28-79) minutes.

After the interviews, all recordings were uploaded onto OneDrive. It was apparent that the weakness of the network connection had impacted intelligibility in a few cases. To overcome this problem, the unclear responses were reviewed with the participant to make sure of what exactly he/she had said.

4.6.3 Transcription and translation of the data

All interviews were transcribed and then handled using Microsoft Word and NVivo qualitative data analysis software.

The transcription process can be considered as a “research activity“, and not just a “technical detail” that precedes analysis (Atkinson *et al.* 1984). It requires the researcher to read the data in detail and begin the process of becoming familiar with it. It also starts the process of understanding it and planning for the next stages. Mergenthaler and Stinson (1992) suggest some principles to follow in the transcription process, which were followed: Preserve the morphologic naturalness of the transcription (word forms; use of punctuation), Preserve the naturalness of the transcript structure (structure the text by speech markers), The transcript should be an exact reproduction. However, filler words such as (ums, ahs, uh, huhs, and you knows) will not be included (McLellan *et al.* 2003).

The .wav files were played on Mac Pro and transcribed into text manually and organised in Microsoft Word files ready to start the analysis proper. The researcher proof-read the textual data to ensure that all sentences had a clear meaning and made some comments on points to check with the participants as mentioned above. Three participants received their responses to check some points and clarify what they said in the interviews.

After that, a freelance translator was engaged to go over all the recorded responses and the transcript to compare them and ensure there were no mistakes in this process. Translation was done by the freelancer translator to ensure that the collected information is accurate and clear. The entire transcribed qualitative data added up to 47200 words.

4.6.4 Thematic Analysis / Coding

Thematic analysis is a form of content analysis widely applied to qualitative interview material in social science research according to Daly *et al.* (1997). It is an approach that involves identifying chunks of text that express distinct themes, looking for *repetitions of the same theme (often expressed in different words) and then classifying those themes into categories at various levels, often called codes, with the aim of illuminating the fundamental characterizations of a phenomenon investigated.

The researcher therefore read the data many times to pick out common themes, ideas, and patterns of meaning that occurred. In detail he followed five steps that assisted him in conducting thematic analysis (Caulfield 2019). Familiarisation with the data was the first step which involved the researcher discovering the data and reviewing it before beginning any proper analysis. This step in fact had already begun during the data collection process. While conducting the interviews, the researcher wrote down some notes about the participant's responses and highlighted some points to facilitate the interviewing itself, e.g. it helped in deciding what sub questions to ask during interview process. However, this also began to familiarise him with the data. That continued during the transcription phase, as noted above.

After the first steps in that process, the textual data was uploaded into Nvivo, version 12.6 where the rest of the steps were executed. The data was submitted to chunking and beginning coding, an important step where the researcher underlines or highlights sections of text, which might be phrases, sentences or even an entire extended utterance constituting a turn in the dialogue with the researcher, and finds provisional shorthand labels for the initial description of each chunk. Next, the researcher reread the content, tracking repetitions of some ideas. Each code and theme corresponds to a specific node in the software, and the sentences or other chunks of text that are assigned to them are highlighted and linked with the appropriate node. The produced sub themes can then be organised and classified into higher main themes.

In the third step, the researcher reread the data, refining the codes using the constant comparison method. The fourth step involved identifying broader themes either based on the UTAUT2 categories or discovered from the data, and so creating a hierarchy of codes, determining patterns of themes. After the theme generation step, at the final step the researcher reviewed the nodes (themes) and the entire coding system to ensure that all themes were useful, and there were no missing themes. After deciding on the final list of themes it was time to also revise the name of each theme to be clearly distinct from other names and capture the essence of the theme correctly.

Potential codes derived from the literature included the following, with examples in brackets of words used by participants that were taken to signal the presence of each category: Performance Expectancy (useful, enhance my work); Effort Expectancy (easy to download, easy to use); Facilitating Conditions (MoE support, school support, providing content, devices, timetable); Social influence (colleagues support, students influence, headmaster support); Resistance to Change (preferring traditional teaching method, devices misuse). These a priori codes were used to facilitate the process of analysis and help understand the relationship between themes (Miles and Huberman 1994). Additional codes were generated from the interviews themselves, bottom up, in a more interpretivist way. They added a number of subthemes to the coding system.

4.6.5 The final coding scheme

Analysis of the participants' responses ultimately yielded seven master themes and their constituent subthemes. The master themes mostly match UTAUT2 constructs and comprise: performance expectancy, effort expectancy, facilitating conditions, social influence, price value, hedonic motivation, and resistance to change. Table 7 shows the output from Nvivo 12.6 of the final coding system, where it is possible to identify all the themes and subthemes that were identified, with example extracts of participants' responses. It should be noted that some subthemes are quite broad and cover a range of different further subthemes, but it was decided not to develop a deeper layer of codes since such categories would only occur quite rarely in the data.

Table 7. Final themes and subthemes of the coding system from Nvivo with examples of quotes

Main theme	**Subtheme**	**Examples of responses**
Performance expectancy	Effectiveness of technology (e.g.. enhancing information retention, advantages offered by multimedia capabilities, reducing content ambiguity, and	"Learning has become more attractive for students, and I noticed when they see things embodied in front of them …. they find images and 3D videos and they look at most things as projects not as traditional education; it is a combination".

	increasing students' interaction)	"…it pushed these students to think deeply, helped them to retain information longer and solved the problem of missing the lessons because these students can access the scientific content at home"
	Efficiency of technology (using the technology whether it is quicker / slower than other methods, e.g. in time spent to deliver content; to arrange the lesson materials, to begin the lesson)	"Surely, the changes are noticeable in the content presentation and information delivery. Teaching with the help of technology is better than the traditional methods". "We use technology to save time, with just one click you are able to display a large amount of content in a short time. This method is better than writing and drawing on the whiteboard… Students sometimes forget their books, and it is a problem, but with the projector the content is there with no such problems".
Effort Expectancy	Easy to use	"It was not difficult. It was easy to use. You download the app and choose the subject which has content for it in the app, you direct the camera towards the image or symbol in the book and then the display is conducted well in front of the students."
	Easy to learn	"There is no nothing hard with YouTube and websites; a lot of explanations are available on those platforms. When I want to use new tool, I search about in the Internet and I find a lot of materials that state how to use it."

Facilitating conditions	Knowledge	"This what we sometimes feel we need. To be honest with you, some people think that knowledge has reached us all, and it has become an old technology that is known. However, when we deal with the practical reality, we feel amazed and surprised as if these technologies have been there for the first time. There is a lack of communicating knowledge to educators and promoting technological programmes and how to deal with them. There is a large percentage of teachers who do not know about this technology
	Resource availability (devices, AR apps, students' ownership, internet, and Localisation	"Sometimes I provide the cable which connects the projector and the HD cable connecting the computer with the projector". "Honestly, the applications of the ministry do not cover all topics of the curriculum. The lessons that do not have the AR codes are problematic".
	Compatibility with other technologies	"... there is no connection cable between the mobile phone and the projector because these are old types of projectors that cannot be connected to mobile phones. How can I use the mobile phone screens then when most of our available projectors are of the old types?"
	Training	"They must be given relevant courses in technology fundamentals so they know how they later can employ it in their work. My colleagues in

		Jordan are compelled by the ministry to take courses for six months to learn computer basic skills and some software that can be used in education. Teachers need many courses to improve their skills, technology is updated and applications increase daily and become more difficult”.
	Lack of time	“The students’ access to the resource room takes time from the lesson and creates other problems. This takes about 15 minutes, and this compels the school to limit the number of the lessons in the resource room”
	Infrastructure (regarding the building, electricity and room capacity)	Sometimes we take the students to another classroom, which has better light, to display the lesson, and sometimes the classroom is too small for a big number of students. Numerous classrooms lack electricity outlets and places to position the projector. The windows have no curtains and we cannot see the projector’s film on the whiteboard.”
	Institutional Support (getting help from school administration, department of education and the MoE)	I tried to communicate with the school administration to help solve the problems but there was no response. In high school, I demanded a projector two years ago and the administration did not respond. The person in charge of the devices in the administration said ‘the administration has all

		devices' but he did not give us any."
Social influence	Colleague influence	"New teachers usually imitate the experts. They look at them and do what they do. If you want to develop your work, you should look at others and try to read and work on the development, rather than staying negative.
	The school principal's influence	"He was interested in applying many teaching strategies in class and has constant monitoring of teachers' performance".
	The supervisor's influence	"Sometimes, the supervisor attends the lesson and sees that I apply the simulation programme and AR technology. He is satisfied and appreciates the fact that I am using this programme.
	Student influence	"but I think the student plays the main role because I come to teach him, so I will do my best to help him to learn".
Price value	Hidden costs (some costs behind using the technology and running related devices)	"I bought some tools for my teaching, I have my own laptop and portable projector because I often move between five classrooms each day, so I use it in teaching. I bought some accessories for these devices. To be honest, it is very expensive, it is about 6000 SR*,* but I am happy because I can do my job in perfect ways and my students can be engaged, they interacted, participated during the lesson, *that's* what *I* am here to do. My students

		deserve that"
	Free and worthwhile apps (availability of apps compared with their benefits in teaching)	"We have numerous free opportunities at our disposal which we can employ and exploit in delivering lessons for students. Similarly, there are many free applications of augmented reality and virtual reality and sometimes those responsible for the content are the ones who decide".
	More valuable apps than those provided (using other apps with higher quality)	*"*There are other applications more exciting than those of the Ministry. Sometimes we say that ready things are better. These are better and more motivating for teachers when they can directly implement them.
Hedonic motivation	Enjoyment (break class routine, create a dynamic atmosphere and a feeling of happiness in students)	It is greatly enjoyable for me and my students, because for instance if you see a fixed image and suddenly there is life in it and it moves and speaks, like a video clip, it is an enjoyable and exciting experience"
	Novelty	"... It is a new thing .... draws attention and is exciting".
Resistance to change	Teacher familiarity with technology	*"S*ome colleagues do not know how to connect devices such as mobile phones to the projectors and do not know how to use the applications or even the process of searching for appropriate applications suitable to the content to be taught to the students*".*
	Preference for traditional methods	There are also more than 40 students in the class, I can't spend more time to apply the technology while explaining all the topic elements for them in

		45 minutes. It is very hard to use technologies with such a number of students".
	Student misuse (damaging devices and violating others' privacy)	"Students can start chatting with each other if they are left with their phones, something that harms their behaviour and causes disruption of the course. Another related problem is the use of the phone camera as they may take shots of the teacher".
	Device bans for students	"The Ministry of Education did not allow students to bring their own tablets and mobile phones into classroom which hindered use of AR technology and other apps. There is an official circular, and no school is allowed to permit mobile phone use inside it.
	Student distraction (using devices to other purpose in the classroom: chatting, gaming)	"This will backfire, students will not pay attention, the girls will use them for browsing irrelevant non-educational activities. They will get distracted".

4.6.6 Reliability and Validity of the Qualitative data analysis

The reliability of the coding was examined by a standard inter-coder reliability method (O'Connor and Joffe 2020). Two faculty members in Saudi universities were chosen with experience of qualitative data coding and some parts of the data were selected randomly (about 5% of the data) and sent to them stripped of any participant information. The second coders were also provided with an explanation of the research aims and questions and theoretical framework, as well as the researcher's final coding scheme fully listed and explained, but not of course the researcher's coding decisions for the specific data sent. They had ten days to review and code the data. They agreed about 75% of codes and advice to refine and add some codes (i.e. localisation, teacher workload, technology anxiety, time to prepare). All differences between the coding of these coders and the researcher were considered and taken into account in a final revision of the coding in Nvivo.

The validity of the data analysis is supported first by the fact that the transcription was double checked by an expert and any unclear passages were also member checked with the relevant participants. Secondly, the coding in part uses established codes from the acceptance literature, which can be assume to be valid, and also benefited from expert input at all stages from the researcher's supervisory board members while the data analysis was being performed.

4.7 Conclusion

This chapter first presented the study aims and research questions, with an account of the research paradigm combining elements of the positivist and interpretivist approaches. It then described the planned mixed-method research methodology collecting quantitative data from a questionnaire and qualitative data from interviews. The sampling of participants was described, followed by the design of the research instruments, how they were administered, and the steps followed to analyse the data. In particular the reliability and validity of the study, especially with respect to the quantitative data, was discussed and reasons provided for the decision not to pursue further the processing of the quantitative data. In the next chapter, the findings obtained from the qualitative data will be presented in detail.

5. Chapter five: Reflections on the Quantitative Survey

As described in 4.5.4, there were compelling reasons to suspect widespread invalid response to the questionnaire, leading to its rejection and, since there was no time to attempt this data gathering again, this entire quantitative part of the study was discontinued. Here an attempt is made to explain this event, and consequent adjustments made to the study are described.

5.1 Possible reasons for the nature of the questionnaire responses

The reasons for this finding could be many. The limitations of questionnaires due to their reliance on participants to self-report diligently and honestly are well known (Creswell, 2012). One specific issue that comes to mind with hindsight in the present study is the way in which the survey was introduced to the participants. The invitation to participate did not come direct from the researcher to the teacher but instead via the official Saudi educational hierarchy. That is to say, as described earlier, the invitation came via the Riyadh Department of Education to the principal of the school and so to the teachers. This means that, despite the wording of the invitation itself, teachers may have perceived the invitation to participate as an official request from higher up in the educational system of which they are a part, rather than as simply coming from a researcher acting independently of that hierarchy and using it only as a convenient way of distributing the invitations. Indeed, it is not always easy to make a clear distinction between educational research done by the government headed educational system (which a teacher is obliged to participate in by virtue of their employment contract) and educational research done by outside academics (which of course they are free to decline to participate in following the usual ethical rules of academic research). In the present case the research was clearly of the second sort but may have appeared to the teachers to be of the first sort. That interpretation might also have been supported by the fact that the teachers would have realised that the topic of the survey, AR, is also the subject of a recent Ministry initiative.

The consequence of the above could have been that teachers interpreted the invitation as official and felt obliged to participate even if they really felt they had little time or interest. The further consequence of that then could have been their less than full cooperation in the questionnaire response: they just rushed through it to get it done.

Such a response is of course also aided by the online distribution of the questionnaire, without a researcher present to notice that some participants are responding very fast or to check the responses. As Buchanan and Scofield (2018) indicate, computers are already beginning to be used to check speed of response to online instruments as an indicator of validity of response, but this was not a feature of the survey software that was used in the present study.

Other possible factors at work, especially if the teachers construed the survey as more official than it was, could be that teachers may avoid extreme, especially negative, responses because it is about a government-supported initiative. That could have encouraged many teachers to just uniformly pick agreement at level 3 or 4 throughout rather than express any negative opinion. This would then be in part a culturally conditioned response related to Saudi perceptions of authority and freedom of expression with respect to the profession and the ministry.

5.2 Revision of the research paradigm

One consequence of the abandonment of the qualitative part of the study is that the relevance of one of the two originally chosen paradigms outlined in 4.2 was necessarily weakened. This study inevitably became dominated by the interpretive stance concerning ontology, epistemology and methods, as implemented by the qualitative interviews and their analysis.

The loss of the more positivist quantitative element made it harder to compare the present findings with those of the predominantly quantitative other studies of UTAUT. However, arguably the increased focus of the present study on discovering participants' views bottom up (Cohen *et al.* 2011), following the interpretivist stance described in 4.2, provides a welcome counterbalance to the many studies that include only quantitative questionnaires presuming and imposing the UTAUT framework top down. Thus the opportunity was provided to explore more fully the different personal realities of the participants (ontology) and gain a richer varied understanding of the nature of their knowledge of the influences on their inclination to use or not use AR (epistemology).

5.3 Revision of the research questions

The other necessary adjustment that had to be made was slight changes to the wording of the research questions to suit an exclusively qualitative approach, as follows.

The main RQ became: What considerations do science teachers report as influencing their decision to accept and/or use AR technology in their teaching practices?

The sub-questions became:

1. Which of the following independent (UTAUT) variables - if any - are reported as prominently influencing the teachers' behavioural intention to use AR technology in classroom: Performance expectancy (PE), Effort expectancy (EE), Social influence (SI), Facilitating conditions (FC), Hedonic motivation (HM), Habit (HAB), Price value (PV) or Resistance to change (RTC)?
2. Do any of the above differ between AR users and non-users, or between genders?
3. What detailed explanations do teachers provide for their beliefs related to the factors affecting acceptance of AR in classrooms?

Notice that the original RQ subquestion 2 had to be now more limited. With the smaller sample, and qualitative data, it was only possible to pursue differences between users and non-users and between genders, not between all the other planned groupings of participants in terms of background variables.

6. Chapter six: Qualitative Findings

The research objective is exploring factors that influence Saudi science teachers' decision to accept AR technology, and adopt it in their teaching practices. It aims to illuminate those factors and address their influence. This chapter presents the findings from the qualitative data. It shows the result of analysing the influential factors on teachers' decision to use or not use the technology. Thus RQ3 as well as RQ1 will be answered. What detailed explanations do teachers provide for their beliefs related to the factors affecting acceptance of AR in classrooms? Since the teachers at times referred to technology other than AR, remarks on that will also be included where it is illuminating to do so.

A further point to be clarified at the start concerns the AR non-users. It will become apparent that they quite often have favourable opinions about AR or other new technology, so show signs of likely acceptance. One might wonder therefore why they are non-users; or indeed one might wonder how, if they are non-users, they know enough about AR to have a valid opinion about it. In fact, as mentioned in 2.2.6, all the participants have been exposed to AR in that their schools received from the MoE the new curriculum, textbooks and links to the apps involving AR some six months before the questionnaire, and would be expected to use them. Therefore, it is safe to say they knew what AR was and had probably tried it out at least for their own benefit, so had formed an opinion of it. The reason why the non-users were non-users is then due to a variety of factors most of which emerge in the account below.

The structure of the chapter follows the main themes as described in 4.6.5. Within each, the accounts of the subthemes are presented in turn.

6.1 Performance expectancy

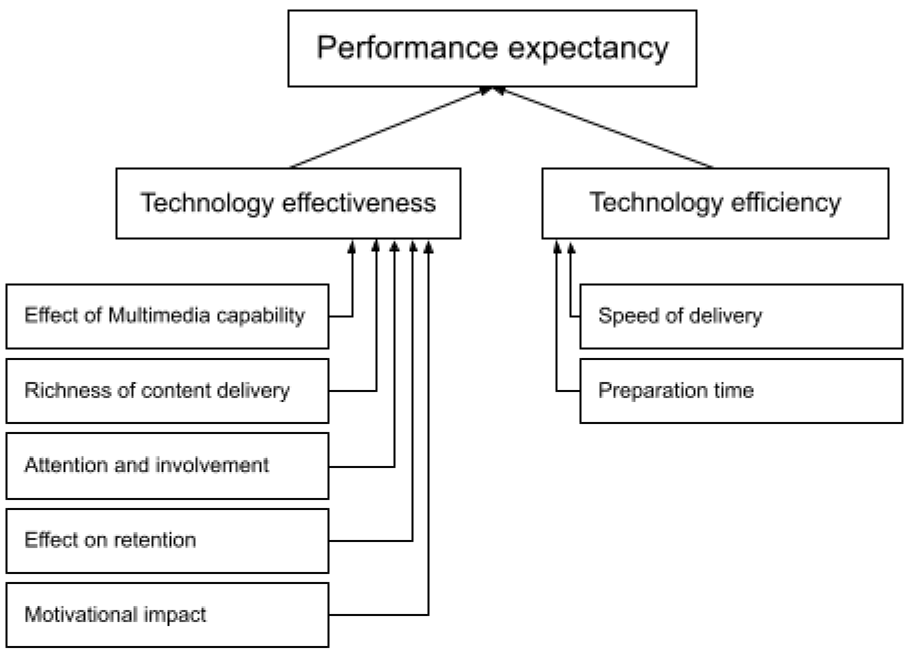

Figure 10. Performance expectancy subthemes

Performance expectancy is the UTAUT name for one of main themes discussed in this study as an important factor in directing teachers to use or not use the technology. It refers to the perceived usefulness (or lack of it) of using AR technology in teaching. The data demonstrated how science teachers perceive the role of using AR technology in their teaching practices almost entirely favourably. The findings show that all participants (n=25), whether they used it or not, expected that using AR or similar technologies in their teaching practices could help them to perform teaching in an effective way and to improve their methods of delivering knowledge to their students. They also suggested that students these days are looking for interactive tools that facilitate knowledge transfer and involve multimedia which can help them to understand the offered content better. The perceptions of participants regarding the performance expectancy theme were classified into two subthemes: technology effectiveness and technology efficiency as discussed in detail below. Each of those includes a number of more detailed aspects or categories.

6.1.1 The effectiveness of technology

This subtheme concerns the effectiveness of using AR/other technology to help teachers accomplish their lesson goals, i.e. getting students to learn, in a more successful way compared to the use of traditional methods in teaching. The AR user participants believed that they used AR and other technologies due to their advantages in improving their job performance. They refer to the role of using AR and other technologies within their classrooms in terms of advantages offered by multimedia capabilities, information retention, reducing content ambiguity, and increasing students' interaction. Only one teacher from the non-user group did not discuss the effectiveness of AR and other technologies in teaching, while the majority of participants (n = 24) from both user (n = 16) and non-user groups (n = 8) discussed capability of AR and other technologies as follows.

Effect of Multimedia capability

First, the teachers drew attention to the value of technologies like AR in terms of the advantages offered by multimedia capabilities which can improve teaching methods and help students to understand the content. Thirteen teachers from both groups discussed this role in their responses. They found that technology that provides picture, video, audio and 3D elements (e.g., AR technology) was more effective in teaching and more readily accepted by students, which encourages teachers to use it to achieve lesson objectives. As a biology teacher (US1, male) who frequently used AR reported:

> *"*I used it to illustrate some details about the cell and presented it as a three-dimensional model in front of the students, which helped the student to visualise it, especially that when we know that the cell is a small thing and difficult to see in nature*"*.

An interpretation could be that it is this sort of perceived benefit that explains his high use (see further Discussion).

Out of thirteen, seven of the user teachers believed that AR technology supported with 3D components facilitates content explanation that could help students visualize the information and ideas provided and learn them clearly. A chemistry teacher (US2, female) who used AR once a week, showed very clearly why she was a regular user in the following extract:

> *"*The example applied in chemistry; I consider one of the things students will not forget. This means if they saw themselves a paper cube they hold in their hands and when they hover their phones on top of it, they see the air element, its

> number and its chemical characteristics. Then they bring another element and combine hydrogen with oxygen and when they mix them together, they transform to water. I consider this as brilliant, there is no technology that can do this, only the AR. Thus, students learned this concept and began to discuss how that has happened. When I asked them about this experiment in future, they will not forget it*".*

From the non-AR user group, six teachers indicated that using modern technologies has a positive impact on their teaching practices because such technologies offered multimedia for students who prefer this type of learning. This then was not their reason for being non-users of AR. Those teachers seem to be flexible about AR acceptance in the future if they know that AR has similar multimedia facilities. For example, a science teacher (NU6, female) commented:

> *"*Imagine, when you watch video, you can listen, visualize and understand the idea clearly... Students want to use modern tools in the classroom. Content delivered by traditional methods is not acceptable in these days. Visual content is more attractive than text or written content."

Richness of content delivery

The next related aspect of technology effectiveness involves its impact on content delivery, a subject which was discussed by twelve teachers in both groups. The results revealed that ten users continued to use AR technology due to its capability for illustrating content details, and reduction of content ambiguity. The users stated that using AR technology in teaching helps them to deliver varied content in more detail to show some invisible parts in some organisms for their students to discover them. It also provides the opportunity to avoid narration and reduce ambiguity in the content delivered. As an experienced physics teacher, a high user who teaches physics using AR, (US8, Male) reported:

> “students will see for instance this matter is oxygen, they will see the particles inside it, the atomic number. They will move it in all directions with its all dimensions, the six sides of the cube and they will see remarkable things through this element. They can also bring two cubes and they are Hydrogen and Oxygen and attach them to each other and they see the result will be water. This I consider as is the optimal way of benefitting from AR”.

These findings indicated that AR offers numerous effective opportunities to visualise abstract concepts and facilitate student engagement and interaction, which helps in enhancing student learning. As physics teacher who interested in teaching with new technologies (US3, male) stated: “The visual illustration provided by AR app enables the students to watch in front of them what you are talking about and then your explanation is more focused and accurate”.

Agreeing with previous participants, two teachers from the non-user group perceived that using modern technologies helps deliver content easily and to display information visually, which leads to success in the delivery of lesson. An expert non-user teacher (NU1, male) with 29 years teaching experience, also stated, “I am convinced that technology is useful for students, and I hope that all schools have all the required technologies like AR to use in all lessons, because the incorporation of technology in the class makes the explanation easier and better than the traditional methods". Once again this shows that non-users of AR were not non-users because they did not appreciate the richness of content delivery of new technology like AR, but for other reasons which will be explored in the Discussion.

Attention and involvement

Thirdly, comments were found on the role of teaching with the assistance of AR and other technologies in increasing students' interaction with the content of the lesson inside the classroom. The findings indicated that teachers believed that using AR technology to deliver content could be beneficial in attracting students' attention during lesson time and it can help in improving students' involvement, increasing their focus, and create a stimulating atmosphere during lessons.

From the users' experiences the content presented by technologies like AR can also encourage students to participate and discuss the offered content. They observed that students become more attentive and more engaged in the lesson when using AR apps in comparison with the traditional teaching style. Students have opportunities to ask more questions and present their comments regarding the content provided through AR. Therefore, their attention could be increased, which results in more engagement in the classroom. For instance, a math teacher who used AR apps 3-5 times per month (US7, female) highlighted this feature from her own experience in teaching using AR apps:

> "Most importantly, AR makes me a brilliant teacher as it engages the students with the lesson and draws their attention to what I say. Given that there is an informal perception among students about mathematics being boring and complicated, with AR students do not feel bored".

Similarly**,** the findings indicate that teaching with AR technology is believed to be more beneficial than traditional methods because it improves student focus and concentration. As reported by this Physics teacher who used AR a few times per term (US12, female), "It gives an excellent impression about the content, which makes students focused during the lesson explanation and understand information better than explanation on the whiteboard".

This was also reported by the non-AR user group. Five teachers noticed that students are greatly involved with all parts of the lessons when technology is adopted. As a physics teacher who used technologies in his teaching practices (NU8, male) stated "When they are watching the videos and images, they pay attention, and they are absorbed by the content. They become curious and start asking about some details". Once again this shows that non-users of AR were often users of other technology and saw its benefits: therefore their non-use or low use of AR was for other reasons (below). This state of affairs was illustrated repeatedly in the data.

Moreover, it was suggested that other supported technologies that are adopted in the classroom (not AR) could positively affect students' focus on what is displayed in front of them due to not wasting the teacher’s time in writing on the whiteboard (see 6.1.2). This then had an effect of encouraging them to pay more attention. As a general science teacher (NU4, male) asserted “The pupils are focused on what is displayed in front of them without wasting my time in writing on the whiteboard and working hard to draw their attention”.

Effect on retention

Possibly as a consequence of the above aspects of effectiveness, seven teachers from the two groups valued a fourth role of using AR and similar technologies for improving retention of learned information. Five users pointed out that using AR technology helps students both to understand and remember what they have studied by combining the virtual environment with the visual illustration on the device. As well, teaching with AR technology can help the student to readily retrieve information. As a science teacher (US9, female) stated: “…it pushed these students to think deeply, helped them to retain information longer and solved the problem of missing the lessons because these students can access the scientific content at home”.

Considering the results from the non-AR-user group, two teachers out of nine highlighted the value of the features of the type offered by the new apps for their teaching practices saying that they helped their students to remember the learned information during their exams. One participant (NU4, male) introduced his experience with the use of modern apps in general in teaching and their impact on his students' achievement:

> "I noticed in the aptitude test that the results of the students were better than the past years, because I used new applications and technologies instead of the old methods. Hence, their access and retention of information after the end of the academic year have markedly improved".

Motivational impact

Fifth, in addition, the teachers believe that use of AR can result in enhancing students' motivation (see further 6.6), making lessons exciting, stimulating students to participate, developing a sense of competition, passion and creation among students (see further the coverage of HM below). From the users' perspective, the application of AR in teaching educational content has a positive impact on students and stimulates them to follow the information presented during the class. As a science teacher at an advanced level of using technologies (US13, female) stated:

> "It motivates them to study, research, explore and look for information as well as preparing for the lesson… It stimulates learners to participate because it combines learning and enjoyment at the same time… Moreover, it makes students keen to attend and not to miss their classes".

In the non-AR user group, the teachers also believed that the use of technologies had a positive impact on students' attitudes during the lesson, as an experienced math teacher (NU7, male) reported:

> " …I believe that teaching with technology is better and easier both for me and my students who become more active, motivated and engaged with the lesson. The interaction between the students and the teacher lifts his/ her spirit and morale as well as improving his / her performance in the classroom. In contrast, the traditional method makes the students weary and less engaged, which in turn makes the lessons very difficult".

It is inferred from the diverse views gathered from both the users and non-users of AR that the use of AR in teaching practices was predominantly seen as having a crucial impact on student interaction with the content offered. Augmented reality integration in the classroom seems to facilitate the creation of a stimulating environment and foster greater engagement of students in the lesson by allowing real-world users to interact seamlessly with the digital components. This generates motivation and develops positive attitudes to learning among students.

6.1.2 Technology efficiency

The second subtheme within the first main theme (performance expectancy) is technology efficiency. This concerns the issue discussed by teachers of whether using the technology is quicker / slower than other methods. This takes into account not only time spent to deliver content but also to prepare the lesson materials, to set up equipment, and so forth.

Speed of delivery

In total, nineteen teachers (AR user = 14; AR non-user = 5) stated that using recent technologies, including AR apps, has a noticeable positive effect on the speed of knowledge delivery inside the classroom. According to 14 teachers from the AR user group, the use of AR technology could help teachers communicate information speedily to students. As an example, a chemistry teacher (US15, male) stated that: “Using AR serves in consolidating concepts. Showing information in detail, presenting virtual objects that deliver knowledge in a quick way”.

Teachers in the non-user group (n = 5) also indicated that teaching with new technologies improves the techniques of information delivery in terms of delivering the knowledge faster and with multiple presentation options.

Five participants similarly discussed the role of using AR technology in achieving lesson goals in a short time. Four teachers who use AR technology (n = 4) indicated that teaching with AR technology provided by the Ministry of Education helps them to avoid bringing objects into the classroom, which results in saving their time. They agreed that using AR apps for illustrating some topics provided a huge benefit in saving their time during the lesson by minimizing the explanation time and allowing more time for classroom discussion and engaging in different activities. The majority of interviewees (n = 17) highlighted the role of AR technology and other technologies in saving teachers’ time when delivering various kinds of content to students in the classroom. The AR users indicated that using AR technology supports presenting physical objects without going to a lab or resources room that assists them in controlling the class and delivering content without excessive time and effort.

One experienced science teacher who used AR intermittently (US6, female) stated: “However, once they are used to this thing, it saves them time in designing tools, and when they are required to bring objects to display to students, they can just show them through AR, and that will do. If female teachers become used to them, they will not lose time”. This teacher therefore does recognise that there is some expenditure of time initially in learning how to use AR, but suggests that is fully compensated later in saving of lesson time.

The AR nonusers also stated that they prefer using technology generally in order to save their time and avoiding some teaching burdens such as writing on the whiteboard, and bringing some materials to class, as in following comment from a general science teacher (NU5, male):

> “We use technology to save time, with just one click you are able to display a large amount of content in a short time. This method is better than writing and drawing on the whiteboard… Students sometimes forget their books, and it is a problem, but with the projector the content is there with no such problems”.

The way this teacher talks however suggests that he is perhaps thinking of technology only at the level of PowerPoint, which has largely replaced the whiteboard in Saudi schools.

Preparation time

The point was also made that, as US6 said, "it saves them time in designing tools". This is because, as seen in 6.1.1, AR apps help to mix virtual reality components with the reality inside the classroom, which allows students to watch hidden bodies (e.g. the internal organs of the human body, parts of the plant cell) and discover more details. Teachers no longer need to assemble pictures, objects, videos etc. to achieve this, nor design lessons and content for classes so laboriously in advance. This improves on the old system where teachers had to spend a lot of time composing and writing down each lesson plan and assembling the content and exhibits following the traditional educational process.

Nevertheless, it will be seen later (6.5.1) that this benefit was not regarded as so prominent with non-Ministry AR apps.

6.1.3 Summary of Performance expectancy

Performance expectancy was discussed by participants in terms of the performance features of AR technology and other modern technologies in teaching. The teachers who used modern technologies including AR apps valued their benefits in terms of effectiveness of teaching and learning activities: helping students to understand and retain learned information, use of multimedia, content presentation and other impacts on students' learning (e.g. engagement, focusing and stimulation). Also, they discussed the efficiency of using AR and other apps over traditional methods in terms of information delivery while saving class time, and reducing teacher effort. AR users highlighted the role of AR apps in developing their practices and they seemed convinced to continue to use them in the future. The nonusers had a positive attitude toward the technology in general and therefore might be expected to adopt it when other conditions allowed that to happen.

Nevertheless, there were some reservations. A physics teacher who was a keen user (US8, male) made this comment, implying (in the word 'influential') that he used the apps with a feeling that they could be made considerably more effective:

> "Before the introduction of the ministry curriculum, the developers in charge of this matter offered me some applications and listened to my comments in the previous summer before the provision of the curricula. I made my observations which I am sharing with you now. The simulation and interaction are not attractive, but this can be really influential: just switch on and off and watch the picture. This is not a satisfactory level of simulation. The ministry officials explained that the reason for this is that these are the ones that they had developed and .... to use with the books based on the images available to them. I clarified that they are doing a great job: 'you are doing this yourselves'. However I believe that benefitting from the experience of leading companies in this field could be helpful such as the site Vit Phet Interactive Simulation." <PhET simulations at https://phet.colorado.edu › simulations>

It will be seen further below that some beliefs that were coded under Resistance to change (following the sources for this construct) could also be seen as, in effect, negative beliefs of performance expectancy. Also in 6.2.5 some views will be met that AR is more time consuming (so less efficient) than traditional teaching. Still they are a minority and it can be inferred from the above examples that performance expectancy considerations would generally influence the teachers' acceptance to use AR technology.

6.2 Facilitating conditions

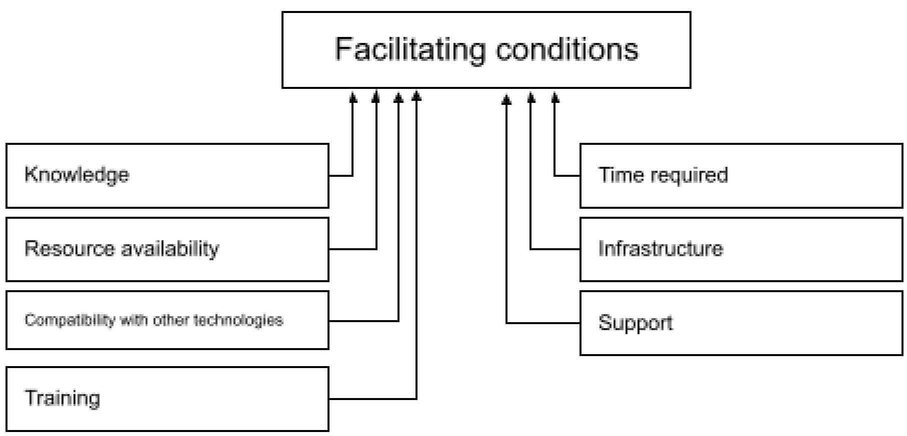

Figure 11.Facilitating conditions subthemes

Facilitating conditions is the second main theme discussed by participants in this study. It again is one of the key constructs of the UTAUT. According to the theory, this construct is concerned with the availability of enough support and resources to individuals utilising technology. Therefore it can also concern obstacles where the conditions are lacking. In the classroom, teachers need Ministry support, as well as local technical support to integrate the use of AR into teaching. In this regard, the results showed that the theme of facilitating conditions was mentioned in one way or another by the whole sample (n = 25), in terms of various subthemes as shown in figure 11: knowledge (n = 23), resource availability (n = 23), compatibility with other technologies (n = 16), training (n = 12), support (n = 10), time (n = 9) and infrastructure (n = 8).

The following sections present the breakdown of the master themes and the relative subthemes with some examples from participants' responses.

6.2.1 Knowledge

The majority of participants (n = 23) stated that receiving new technology with some illustrations about how to operate it and its benefits in teaching them would help them to accept and use it. Some degree of knowledge about AR is therefore clearly a prerequisite for accepting it.

The AR user group members (n = 16) all confirmed their prior knowledge of AR technology before using it. Some teachers in the user-group in fact provided a clear definition of AR technology and how it works, naming some known apps as examples.

For instance, one science teacher with intermediate level in technological skills (US11, female) defined AR technology competently as

> "a technology that converts images or codes to video clips or animations. It is known as technology based on projecting virtual objects and information in a real user environment to provide additional information or act as a guide".

This knowledge came from many sources according to teachers' responses: the Ministry (IEN platform) as well as from searching in websites for new technologies or to obtain more information about such technology.

An experienced science teacher (US9, female) who clearly had obtained prior knowledge of the software was able to clarify at length her position on providing teachers and schools with updated information about desired technologies before asking teachers to use it.

> "This is what we sometimes feel we need. To be honest with you, some people think that knowledge has reached us all, and it has become an old technology that is known. However, when we deal with the practical reality, we feel amazed and surprised as if these technologies have been there for the first time. There is a lack of communicating knowledge to educators and promoting technological programmes and how to deal with them. There is a large percentage of teachers who do not know about this technology….There are not enough efforts in making it known to all. I know some modern technologies which I employ, but when I attend with my colleagues in the training courses and this topic is discussed I have the impression that some have learnt about them for the first time."

That teacher's assessment of the situation seems to be supported by some of the AR non-users. From the non-user group three teachers stated that they had no idea about AR technology. As an example, a science teacher who apparently relied on teaching with projector and laptop (NU9, female) commented: “I have no idea about this technology (AR)…I think teachers need to be updated about new technologies that help them in teaching practices”. Clearly then, this facilitating condition, or rather the lack of it, seems to be one that explains why at least some of the non-users in the study sample were in fact non-users. The later Discussion will take up why the Ministry initiative and IEN website information had not apparently reached all teachers.

From the analysis of different views, there was also lack of updated knowledge even among AR user teachers regarding methods of employment of AR in the presentation of educational content, such as how to involve them in biology lessons. Along with this, some teachers were uncertain about whether there is ready-made content with this technology that is suitable for their classes and can help them deliver the syllabus.

6.2.2 Resource availability

Availability of resources was widely discussed as a significant factor in applying AR and other technologies in schools. Lack of resources can hinder technology implementation, as participating teachers mentioned. This sub-theme was discussed by the majority of participants from both groups (n = 23; user = 14; non-user = 9) in terms of five points: device availability, AR app availability, students’ ownership of devices, internet connection, and app adaptation to local needs (localization), as explained in the following.

Device availability

With regard to device availability, which is an obvious prerequisite for AR use, the teachers indicated that some schools lacked devices, such as computers, tablets and display devices like projectors, screens and an interactive whiteboard, which would enable teachers to apply AR technology and other technologies in school. This is despite the MoE/Tatweer initiatives to introduce new technology into schools described in 2.2.6.

Out of the AR users, six teachers revealed that they used their own mobile phones and laptops to implement technologies in the classroom, but sometimes there was no projector or interactive whiteboard to show the content to all students. In addition, some schools that had devices did not provide some accessories necessary to operate these devices (cable, adapter, HD cable), which would impede exploitation of new technologies in schools. As one science teacher who used AR few times per term (US11, female) commented: “Sometimes I provide the cable which connects the projector and the HD cable connecting the computer with the projector”.

Other teachers indicated that in some schools there is a resource room equipped with several devices like a desktop, projector, TV screen and printer, but their chance to use this room is very slim due to the long queues during the term. As a science teacher (NU9, female) reported:

> “We have only one projector, in the resources room. So, I cannot use this projector every day because the queue is too long…. I think the school needs to provide more devices, a projector in each classroom that will help all teachers to use technology every day without wasting their time to wait in the resources room queue”.

NU9's description provides the information that projectors are not available in normal classrooms in his school.

That picture is confirmed by another AR nonuser biology teacher (NU3, female) who drew attention to this as a reason behind reluctance to use technology like AR in some schools: “The problem is that there are no devices inside the classrooms, just the whiteboard and pencils. Even if I bring my computer with me, not all classrooms have electricity plugs”. It cannot be certain however if the lack of necessary devices in classrooms is due to the lack of sockets or other issues such as fear of theft or because the MoE did not supply them.

The analysis of statements of both the AR user and non-user groups of teachers shows that lack of AR devices like projector or interactive whiteboard, as well as lack of accessories necessary to operate these as AR platforms (cable, adapter, HD cable), are affecting AR integration into the teaching practices in Saudi schools.

Student ownership of devices

This issue closely connects with the preceding. Ten teachers (Male = 6; female = 4) discussed student possession of devices as an important factor in acceptance and use of AR technology both in the classroom and at home. Six teachers who use AR technology agreed that applying AR apps in the classroom requires providing students with tablets to enable them to be involved during the lesson, but the cost of devices may prevent students from owning them. As a physics teacher (US3, male) stated

> "The applications and content are available in the book of the ministry curricula, what we only need is that the students have their mobile phones in order to open the app and book to see the simulation. I think some students are not able to buy iPhone or tablet. It will cost their families about 1500 or more".

That view needs to be unpacked as it raises several issues.

First it shows that some teachers who use AR are determined for it to be associated with individualized autonomous learning, hence the need for devices for each student. Other teachers however were clearly satisfied with a teacher-centred whole class approach which would not require each student to have their own device. As another science teacher (NU4, male) reported: "Instead of standing up, moving a lot and prompting the pupils to focus on the lesson in the book, you just present the lesson to everybody and they face you and the whiteboard". Although an AR non-user said that, it is usually possible for the teacher to implement AR in class also in this way, simply by using his own device and projecting what it shows onto a screen. Indeed all the discussion reported above for device availability concerned devices which the teacher would use for whole class implementation of AR (e.g. projector, screen, interactive whiteboard), not individual use of AR by each student.

Second, if individualized student use of AR is desired, then one would expect that the Ministry supplies enough tablets or phones for the students to use, given that educational policies forbid students bringing their own devices to class, as teachers mentioned in the theme of resistance to change (see below). The six teachers mentioned above however clearly imply that a device for each student is not available from the school/Ministry but only if the student provides it and the usual rule about students bringing their own devices is suspended.

Five participants mentioned another solution, as they observed that the teachers sometimes loan their own mobile or tablet to students to use in the classroom to overcome this problem. However, that only helps one student and using the teacher's tablet may lead students to violate teachers' privacy. Another physics teacher (US8, male) had a better solution:

> "My colleagues and I have many iPads (their own devices), and we all share the same classroom where each group of students has an iPad. We supervise the groups who are watching, and I only have to show the head of the group what to do. Now they are used to this method and as soon as they hold the device, they know what is required from them. I taught them the first time and that was enough, though it is essential that the devices are provided".

In short it seems that many schools not only do not have devices for the teacher but also do not have devices provided for every student, so this is a hindrance to AR adoption. This too may have led to some teachers being non-users.

Furthermore, the above all concerned student use of devices in school. However students need to use devices also at home to learn and search. As a chemistry teacher (US2, female) suggested

> "Secondly, the provision of the devices, what I mean is not providing every student with a tablet, just six or seven tablets in the school given to students who want to use apps in their houses and returned it next day so that students enjoy the learning experience with this technology. I do not expect them to cost much money".

AR apps availability

As stated in chapter 2, AR apps are ready to download and use from the IEN portal in Saudi Arabia and the participants in this study appreciated that. Therefore it might appear that this prerequisite for AR use was thoroughly met.

However, many teachers discussed this subtheme in terms of the availability of AR apps ready made with content that fits the science curricula. 15 AR users and four teachers from the non-user group recounted their experiences relevant to this subtheme. Teachers indicated that some AR apps were available on the IEN platform and downloading them was easy, but the problem they faced was that those apps did not cover all topics in the textbooks. As a math teacher (US7, female) commented: "And I use the apps of IEN portal though they do not cover all the lessons, and this is what drives me to look in Apple store for other apps". Another biology teacher (US16, female) added that: "Honestly, the applications of the Ministry do not cover all topics of the curriculum. The lessons that do not have the codes of AR are problematic". The implication here is that even if a teacher obtains additional non-Ministry apps, they would not connect seemlessly with the textbook because relevant codes would not appear where necessary in the text.

Moreover, some teachers used additional apps that they felt simply had better quality because the AR apps provided by the MoE did not enrich the lesson content as they wanted. This was explained by a physics teacher (US3, male) regarding the existing apps in Saudi schools:

> "However, the applications of the IEN portal are not many compared to other applications, though we use them once every two weeks, and some applications I have, we use them in general, once every two weeks. The ministry's approach requires the production of high-quality output in AR technology; the output produced is good but is not enough. First, they must produce better quality content".

Based on the analysis of the various views above, it is inferred that the AR apps and current technologies do not cover all the academic topics in the curriculum for the classes, and also have quality issues. This again therefore may be a reason for some AR non-users being non-users.

Internet connection

The internet is a prerequisite for use of AR primarily because the Ministry apps have to be downloaded from the IEN site via an internet connection. Once that is done, however, the apps do not require connection to the internet while they are being used by an individual in classroom learning/teaching. The uploaded content on the server can work off-line after obtaining the app on the tablet or smartphone.

Two issues were mentioned involving the internet: first its availability widely in the school and second its reliability/strength of connection. Schools do not usually have hard-wired internet connections so this is really a wi-fi coverage issue. Seven teachers (n = 7) among the AR user group indicated the need for reliable internet networks for employing technologies effectively inside the school. They indicated that in their schools Wi-Fi coverage is limited to some administration rooms, and some schools have weak Wi-Fi networks. As an example, a math teacher (US7, female) stated "There is also an Internet problem as the coverage is limited to the computer room and is far from ours. It does not cover all the school". These teachers regarded the internet as important to operate certain technology, download apps, search for information about their use and find more detailed information to enrich the educational content.

Four teachers from the AR non-user group agreed that the internet network in some schools did not allow them to search or benefit from existing resources on the internet, such as those on the IEN site. As a science teacher (NU1, male) reported “There are some devices in the resource room, but there is a need for stronger Internet network as its coverage is slow preventing the optimal use of these devices”. This could therefore be a factor that explains why NU1 is a non-user.

The analysis of what the teachers say reveals low internet accessibility and poor infrastructure. This facilitating condition is therefore not in place and is creating a barrier to effective AR integration into the teaching practices of schools. This reveals the need for strengthening internet-related infrastructure of the schools (see further 6.2.6).

App adaptation to local needs (Localisation)

The lack of Arabized apps was discussed by six teachers, who suggested that apps should be translated into the teachers’ (and students') native language (Arabic) to be used because the majority of available apps are in a different language (English) which hinders their use. In fact, the MoE apps are in the Arabic language, as the MoE had them specially made/adapted for use in Saudi Arabia, so these teachers are referring to apps available in other languages but which they regard as more valuable.

Six teachers indicated that some valuable apps were not available in their language, so they could not use them and benefit from their advantages. As one science teacher

(NU6, female) commented, “Some iPhone apps used it <AR>, but it was difficult because it needs to be in Arabic language to be easy to use”.

Teachers also experienced this language challenge in another way. It could prevent them from receiving information about technologies that are not available in their native language. As a physics teacher high user (US5, male) said, “Promoting technology in a way enabling teachers to see their benefit and influence on students. As you know, we lack relevant material, and we do not have modern studies regulating our Arabic reality regarding AR to rely on them and add to the existing international related contributions”.

6.2.3 Compatibility with other technologies

This sub theme concerns the technical issues that teachers face when they use AR apps in terms of their compatibility with devices available in school, and the compatibility between different supportive devices.

With respect to the AR apps themselves, it is found that the majority of them are available for tablet computers and smart phones with both Apple and Android operating systems, downloaded via the iTune and Android app stores. The same is true for the Ministry apps from the IEN website. In this respect the majority of teachers in the AR user-group (n = 13) and three teachers (who tried AR apps, n = 3) from the non-user group observed that AR apps were compatible with most devices (tablets, mobile phones, interactive whiteboard and projectors), just some computers did not support app software.

Compatibility issues may also arise however whenever more than one device is used together, which with AR is almost always: the teacher typically has to connect their tablet etc. to a separate display screen, and if the students are using AR at the same time, not just watching the teacher do it, they may need to connect with each other and the teacher. The varied AR apps designed to cater for learning needs these days also may utilise a significant assemblage of sensors, software and devices for displaying media and information on a device concurrently with the real world in the form of digital phantasmagoria (Bitter and Corral 2014).

In this respect, those teachers mentioned above stated that using AR apps by connecting tablets or mobile phones with display devices requires a short cable to carry the content from tablet etc. onto a large screen (projector, interactive whiteboard) or the use of laircasa and Airplay (supported by some modern devices). On the basis of responses obtained it is evident that certain technical issues might emerge here in some schools that have old devices, as a general biology teacher who knew and tried AR technology previously (NU2, male) commented:

> "The only problem though, is that there is no connection cable between the mobile phone and the projector because these are old types of projectors that cannot be connected to mobile phones. How can I use the mobile phone screens then when most of our available projectors are of the old types?"

Overall, however, this category seems to predominantly involve facilitating conditions that do promote AR acceptance and use.

6.2.4 Training

Where teacher knowledge is insufficient, clearly training is one solution. Training was indeed cited by the teachers as a pivotal factor capable of escalating the utilisation of AR technology in the schools of Saudi Arabia. This inference was extracted from the perspective of twelve teachers who acknowledged the importance of training courses that would help them to discover modern educational technologies, their use, and how to operate them successfully in the class.

According to four teachers, there were some training courses in the Riyadh Department of Education about learning strategies, developing teaching practices and some old technologies, but there is a lack of training courses that aim to introduce updated technologies, such as AR technology. A science teacher (NU9, female) reported that

> "They must be given relevant courses in technology fundamentals so they know how they later can employ it in their work. My colleagues in Jordan are compelled by the ministry to take courses for six months to learn computer basic skills and some software that can be used in education. Teachers need many courses to

> improve their skills, technology is updated and applications increase daily and become more difficult”.

The qualitative analysis also showed that offering relevant training courses can refine teachers’ knowledge and keep them updated about new technologies that support their educational practices. This was supported by one math teacher (US7, female) who admitted that she knew about AR technology from attending a training course:

> “I knew about this technology from a training course about the technologies employed in teaching. I attended this course during which they talked to us about AR. When I took part, it was practical and mostly about science; from an image, an animal or a planet emerges through a barcode and so on.”

Training courses of the traditional model mentioned above, where some expert explains and demonstrates to teachers how something should be done, are of course not the only form of professional development though which teachers can gain pedagogical knowledge and learn to improve their practices. One physics teacher (US8, male) embraced the self-development model of teacher education/development: “There is nothing <how-to-guides> in our school, and I do not attend training courses honestly because I learn myself. All I have learned was not in training courses but rather self-learning." She therefore interestingly proposed a different kind of training course, incorporating a self learning element: "We must give female teachers training courses that qualify them and give them an idea about AR as well as explaining its usefulness and asking them for experiments which means they try them and give me their results in classes."

That teacher feels that traditional training should be combined with teachers doing 'experiments' where they try things out in class and report back to the trainer or peer teachers for discussion. Presumably that was part of her own method of self-development. In effect this is adding an element of action research by the teacher, which has become quite popular in some teacher education / professional development programs around the world (Manfra 2019).

Therefore, it seems that there is a lack of suitable training courses such as that which US7 attended, and which presumably facilitated her becoming an AR user. This shortage can have two effects. For a teacher like NU4 it leads to non-use of AR; for a teacher who does not rely totally on top down training like US8, it is compensated for by self development through action research.

6.2.5 Time required

Time was also highlighted as a crucial factor impacting AR adoption by some teachers (n = 9) in this study. This subtheme includes the time required to prepare technology before a lesson (see also 6.1.2, 6.5.1), to try the apps, to check content, etc., and also especially extra time taken out of lesson time when the apps are used. The facilitating (or hindering) condition that affects these is the time effectively made available to teachers by the Ministry in two ways: out of lesson time, through its policy on teacher working hours, and in lesson time, through the time allotted by it to each topic in a course through the official curriculum. For example, each teacher has to teach 24 lessons a week, attending the waiting class, assigning homework, grading tests, and documenting progress. The teacher may already be forced to use their personal time to accomplish some of those out of lesson time duties. Therefore, increasing teacher workload can affect their enthusiasm to apply AR technology in the class if it involves any extra preparation. With respect to in lesson time, a female teacher (US12) also said: "The number of lessons is not enough to finish all the curriculum due to its intensity". Hence teachers may find any perceived extra time taken up by technology during a lesson to be unwanted.

Nine teachers indicated that time was short due to the intensity of the curriculum, and that may influence applying AR technology and other technologies in the classroom because they take up extra time. One science teacher (US6, female) asserted that “Albeit the expected downside is we lose time from the lesson. Any new thing used to be shown and tested with students will take time from the lesson, similar to taking them to the lab. It is the same thing and the only disadvantage”. It must be said that extra time would be needed to explain how to use AR only on the first occasion of use. However, moving rooms, for reasons of limited availability of devices etc in ordinary classrooms as mentioned above, would apply every time AR was used.

Similarly another science teacher (NU4, male) indicated that using some technologies required moving from the usual classroom to the resources room, which reduced the lesson time. “The students’ access to the resource room takes time from the lesson and creates other problems. This takes about 15 minutes, and this compels the school to limit the number of the lessons in the resource room”. This clearly played a role in this teacher becoming a non AR user.

The analysis shows therefore that, whatever its benefits (6.1.1), introducing new technologies demands significant testing time in advance and in some ways reduces the time available to teachers while imparting lessons. That may put some teachers off accepting and using it. However, it was seen in 6.1.2 that many teachers countered this by suggesting other ways in which AR use saves time.

6.2.6 Infrastructure

Infrastructure was discussed by eight participant teachers, out of whom six were from the AR non-user group. They indicated that a lack of essential infrastructure in some schools may hinder or limit use of technological tools e.g. for the AR non users in the sample. Classrooms with large numbers of students (more than 40 students), the number of campus rooms, resource room availability, and hired buildings (which can lack electrical plugs, proper lighting, and safety standards) were mentioned as influential factors when applying technologies to teaching actions. As biology teacher (NU2, male) said “Unfortunately, school’s buildings are deteriorating. Imagine that if one or two air conditioners are run, electricity cuts off from the whole building! These buildings are hired and used to be flats not schools."

Another participant, science teacher (NU4, male) summarized his experience in hired schoolrooms:

> "We take a lot of effort but then also sometimes we cannot run the projector because of low light or there are no curtains. Sometimes we take the students to another classroom, which has better light, to display the lesson, and sometimes the classroom is too small for a big number of students. Numerous classrooms lack electricity outlets and places to position the projector. The windows have no curtains and we cannot see the projector's film on the whiteboard."

6.2.7 Support

The support subtheme (getting help, supplying equipment and doing required maintenance) was cited by more than half of interviewees (n = 13). Getting technical support from the school administration, the Riyadh Education Department, and the MoE was important from teacher perspectives: they said that when teachers faced difficulty in using a technology or wanted technical guidance, the school or education department should provide this information.

However, by far the most important area of support in the teachers' minds seems to concern the supply and maintenance of equipment/devices (cf. 6.2.2 first point). As physics teacher (NU8, male) stated:

> “If we ask them (Department of education) for some resources, they try to provide it, such as devices, equipment, honestly some devices take a long time to be available, some are not available, sometimes I buy small things like wires, mouse to continue working. Waiting for the Education Department to deliver the equipment is tedious; with a large number of schools, the time that or order take it to be delivered to the schools".

Lack of support could even lead school principals to avoid asking teachers to apply modern technology because they cannot provide it, as teacher NU4 commented: “The principal cannot ask us to use equipment that does not exist, although he tried to demand from the education administration to provide devices, there was no response.”

A biology teacher (NU2, male) described his experience regarding accessing help from the school and the Department of Education:

> “In this city, I spent two years asking only for a projector. In the end, the supervisor (Ministry inspector) said, ‘You can pay for the projector from your own money!’ I replied, ‘This is the school’s responsibility and not mine!’ I tried to communicate with the school administration to help solve the problems but there was no response. In high school, I demanded a projector two years ago and the administration did not respond. The person in charge of the devices in the

> administration said ‘the administration has all devices’ but he did not give us any.”

Regarding device maintenance, a few teachers (n = 4) from the AR non-user group indicated that there were broken devices, indicating a lack of regular maintenance. As one biology teacher (NU2, male) reported:

> “The second problem is the projector cable. It can be damaged fast. I think this problem is international like the projector in (…) bookstore. However, the Ministry must buy many cables for all schools. …It is ok, but not all devices are here. Some labs need re-furnishing and supply with new technological equipment.”

Another expert science teacher (NU1,male) described the situation in his school by mentioning that

> “These devices break down frequently due to the heavy use when there are combined classes and no available classrooms for each teacher. Therefore, teachers are faced with multiple problems in this respect. For instance, the interactive whiteboard should have been activated all time and not left without maintenance.”

Overall, clearly lack of support in the area of equipment is a major reason for teachers not being AR users.

6.2.8 Summary of Facilitating conditions

The facilitating conditions theme, designed in alignment with the UTAUT model, was considered important by all teachers for adopting technology in schools. In many areas however there were reported shortcomings, so the conditions were in fact hindering rather than facilitating. The availability of prior knowledge of modern technology, through relevant training, and required resources including devices for both teachers and students, with proper support, apps, internet connection, and localized materials together with improved infrastructure are all crucial factors which must be assured to advance the acceptance of AR in Saudi education.

6.3 Social influence

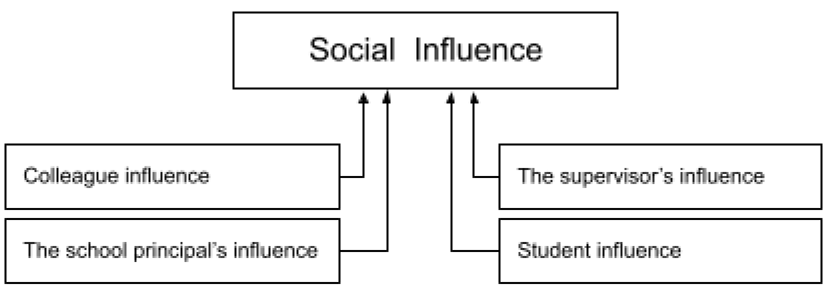

Figure 12. Social influence subthemes

The theme of social influence captures narratives reflecting the idea that the important people in the school environment can influence teacher decisions regarding using AR technology and other technologies. This master theme was discussed by a majority of participants (n = 23) in terms of four subthemes: colleague influence (n = 15), school principal influence (n = 13), supervisor influence (n = 8), and student influence (n = 5). It is worth mentioning perhaps that there were no comments supporting any presence of parent and friend influence.

6.3.1 Colleague influence

The study found that teachers can be influenced by peer opinions about the use of technology. The AR users appreciated their colleagues' role in accepting AR technology as shown in their comments. However, some teachers mentioned some critical comments from their peers which may impact on their decision to use new technologies. Fifteen teachers from both groups (AR user=7, non-user=8) discussed the influence of other teachers on their decision to use the technology in terms of in terms of imitation, encouragement, and discouragement.

In Saudi schools, new teachers are greatly influenced by expert teachers who they talk to or observe. For instance, a physics teacher (NU8, male) revealed this influence regarding available technologies: “New teachers usually imitate the experts. They look at them and do what they do. If you want to develop your work, you should look at others and try to read and work on the development, rather than staying negative. As you know, the teacher who delivers the knowledge for you in easy way will be more respected among his students and colleagues.” He also asserted that a particular teacher positively influenced him to use certain new technologies that were available (which did not however include AR): “If I see the distinguished teacher in our school use this technology and he visit the learning resources room continuously, then that will encourage us to do that.” It is unclear if this teacher is referring just to seeing that another teacher used AR e.g. by the fact that he takes lessons often in the resources room, or whether he actually sat in on lessons and saw how the other teacher used AR in detail. However, in either case what is found here can be interpreted as a form of professional self-development which has been termed the craft model and could potentially be an alternative to training courses, where an inexperienced teacher watches and imitates an experienced one, like an apprentice (Glazer and Hannafin 2006).

Another high user participant (US8, male) revealed from the opposite point of view how colleagues, who looked up to her as an expert to be imitated, motivated her to make herself an even better model user of technology:

> “My colleagues ask me often about the employment of technologies and the uses of certain applications and devices as well as the solutions of the related problems. This drives me to research more and strive to be a good example for them, which is what encourages me to continue”.

The influence of other teachers is not always positive, some of them can hinder other teachers from using new technologies, as one female teacher (NU6) noted: “Honestly, in the beginning there was criticism from teachers like telling us that we are privileged and so on. I was in particular the target of the criticism of many of them”.

Moreover, such criticism may lead some teachers to avoid sharing their experience with others, as another math teacher (US7, female) said when she began to use AR technology:

> “I noticed that this <criticism> happened with other female teachers because some of them will mock anything you do and speak about it in the group. This is how some receive some negative comments. As for me, my work is only between me and my students".

It can be inferred from the above responses that influence of colleagues concerning using the latest technologies was strong among both the AR users and non-users. The majority of the users of AR confirmed that their colleagues motivated them to use new technologies by extending their teaching abilities, while also reducing stress since technologies offer automated and innovative means of teaching without any complications. However, it can also be inferred from the findings that male teachers were more influenced by their colleagues than female teachers.

6.3.2 The school principal’s influence

The school principal has a significant role in Saudi schools to potentially encourage teachers to use new technologies. Therefore, the influence of the school principals was elicited from the teachers’ perspectives in the interviews. Thirteen participants, from both groups (n = 13; AR user = 7 and non-user = 6), considered the role of the school principal to be great in relation to the acceptance of AR technology and other technologies into teaching practices in terms of encouraging teachers to use it, collaborating with teachers to provide the required equipment and countering any lack of encouragement.

Seven users expressed their experiences with their school principals; they agreed that the school principal directed them to use modern technology (e.g. AR technology, virtual experiments and slides) through frequent visits to classrooms, written notices and notifying them of available training courses. As has been seen above (6.2), often teachers needed to bring devices or other equipment to use technology, and the school principal collaborated with them to provide them, although he was not always successful (6.2.7). The reason given for this was that the school principal is convinced of this technology's usefulness and is excited to implement it inside the classroom.

One male participant who teach biology (US1) described his school principal's role in encouraging him to use technology: "He was interested to apply many teaching strategies and new technologies in class and have constant monitoring of teachers' performance". Another physics teacher (US3, male) stated the following: "The school principal and supervisor encouraged me to use it <AR>…they adored it and of course the head teacher was hugely impressed with this, and she is encouraging its use because I use not only AR in teaching but also Skype".

In contrast, some school principals who were not interested in applying technological tools in classrooms or lacked awareness of technology's benefits, did not encourage teachers to use it, as a physics teacher (NU8, male) declared: “He <the school principal> does not focus on the technology, he suggests to me to apply different strategies”. It is not surprising then that he is a non-user.

An expert user physics teacher (US5, male) also gave a broader view of the current reality of school principals’ attitudes towards using technology:

> “It would be unfair to say no. There is a small percentage of them that are interested and there are useful courses for head teachers. I noticed that their inclination towards technology is weak and even if they show an interest once or twice, that is not enough. A school principal is required to motivate the teachers to use technology, and this is weak from the leaders”.

It can be inferred from previous comments that a majority of the respondents agreed that the school principal played a considerable role in encouraging teachers to use the latest technologies in their classrooms. However, the responses from the non-users show that lack of encouragement from the school principal acts as a hindrance towards the use of technology so could contribute to AR non users being non users.

6.3.3 The supervisor’s influence

Another subtheme discussed throughout teachers’ interviews was the influence of supervisors on teachers' attitudes towards using AR and other apps. A supervisor is a person from the local Education Department who observes a teacher's classes unannounced and assesses the teacher's performance, called in some other countries a school inspector. Eight teachers (n = 8) from both groups (user = 3, non-user = 5), discussed this subtheme. The influence of the supervisor can be perceived through their advice, thankful expressions, and encouragement.

All of these teachers (n = 8) stated that their supervisors had attended the classroom and introduced some support in the form of appreciating implementation of technology and suggesting some useful apps. As physics teacher (US3, male) commented,

> “Sometimes, the supervisor attends the lesson and sees that I apply the simulation programme and AR technology. He is satisfied and appreciates the fact that I am using this programme. …The supervisor admires the simulation programme and asked me to give a training course to the physics teachers so that they benefit from this simulation technology in physics”.

The influence of the supervisor however mostly comes from the fact that he/she plays the role of what in the UK would be an Ofsted inspector, from the Education Dept or Ministry. He/she therefore is the channel through which the influence of the Ministry or local Education Department reaches the teacher most directly. They especially check whether the syllabus and textbook are being followed by teachers, as specified, which, since the introduction of the new curriculum including AR, means that they will check that AR is being used. Their influence on use of AR therefore is more that of stick than carrot and can sometimes be short-term or temporary when the teacher uses technology in one lesson per term to coincide with the supervisor's visit.

As a physics teacher (US8, male) reported, “Indeed, we are required to include them <the AR codes in the textbook>, but it happened that the projector is enough if you take it to class and use it to display AR components, images or videos. In all fairness some use it only when the supervisor visits and others like me I have a car where I keep my belongings and technology”. This teacher is clearly indicating that the influence of supervisors not only can be only on one or two days a year but also can favour the weaker use of AR in the classroom that was mentioned before, where the students do not use it, just the teacher uses it and projects it for the whole class to see.

It can be inferred from the interview responses of the teachers that the majority of those who said anything about this theme believed that the influence of the supervisors was low regarding the use of technology. They stated that the supervisors appreciated the usage of technology and also suggested some useful applications that can be used in order to enhance technology usage by the teachers. However there was also some indication that only minimum standards might be fostered by supervisor influence.

6.3.4 Student influence

Students are part of school environment, and they can influence a teacher's decision to use different methods by their acceptance or not of a teaching method, as discussed in this subtheme. Five participants (n = 5; AR user = 4 and non-user = 1) noted that the students’ acceptance of technology could be considered an influential factor in using AR apps or other technologies.

Students' opinions of and reactions to new technology are very important for teachers to decide whether to adopt or continue using this technology, as a math teacher (NU7, male) reported: "but I think the student plays the main role because I come to teach him, so I will do my best to help him to learn". For that teacher it was however not what the student liked that was influential, but whether the student learned better, which might not be the same thing.

By contrast, it was more common for teachers to be influenced purely by what the students liked, without explicit reference to actual learning benefit. For example, one physics teacher (US8, male) expressed her experience with using technology and the influence of students on her use of AR apps as follows,

> "My students are very much in love with this, and they are enjoying and waiting for the moment when we do such things as AR, or with technology in general. Thank God they wish I do not leave the class because they are enjoying the lesson. If they had a free time with no lesson, they also want me to do this with them. It is admirable to introduce these aspects; in other words, the students of the new generation like these technologies".

It can be inferred from the interview responses that some teachers consider the influence of the students to be an important factor that determines their use of AR and other technologies in the school.

6.3.5 Summary of Social influence

The social influence theme was discussed by participants in terms of the influence of other teachers, school principals, supervisors, and students to encourage the teacher to use AR technology or not and try to provide the required support to apply technology in classrooms. Overall, the role of all the important people in teachers' surroundings (apart from parents) was highlighted in the interviewees' responses. Those people can directly or indirectly influence a teacher's decision to use or stop using technology. The role of the school team (the school principal and colleagues) is especially important.

6.4 Resistance to change

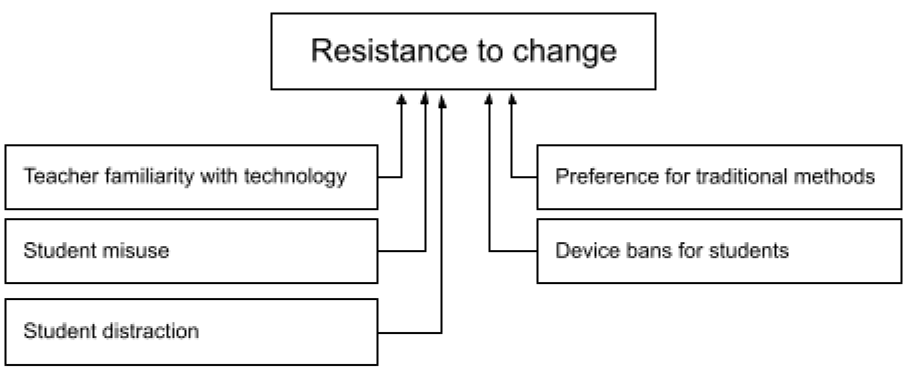

Figure 13. Resistance to change subthemes

This master theme, whose analysis was inspired by its Saudi sources Alfarani (2016) and Alkhattabi (2017), supported by Kocaleva et al. (2014), included five aspects that can hinder or support the use of AR and similar technologies and those aspects were cited as follows, teacher familiarity with technology (n = 8), preference for traditional methods (n = 7), student misuse (n = 6), device bans (n = 5) and student distraction (n = 3)). The following sections present the subthemes and some examples from interviewees' responses.

6.4.1 Teacher familiarity with technology

Teachers' familiarity with technology was cited by a number of participants (n = 8) as one of the challenges for using AR and other technology in the classroom. They indicated that some teachers lacked awareness of the benefits of technology and that this could impact their intention to use it. This was analysed as RTC despite being close to the factors of teacher knowledge and training that were considered as facilitating conditions within the UTAUT scheme above. It was felt necessary here to entertain the possibility that in such reported instances, as in Kocaleva et al. (2014), the non-users who are mentioned are fundamentally just resistant to change and that is the real reason for their not developing their knowledge of AR or general technology literacy.

This could be the case here, where a biology teacher (US1, male) said the following about non-user colleagues, although it is impossible to be certain that RTC is in his mind as the reason for these teachers being in their state of incompetence:

> *"S*ome colleagues do not know how to connect devices such as mobile phones to the projectors and do not know how to use the applications or even the

process of searching for appropriate applications suitable to the content to be taught to the students*".*

From the AR nonuser group, some teachers also indicated that there are teachers who lack technology skills, possibly again due to RTC as a trait. One science teacher (NU4, male) said the following**:**

*"*Some teachers are not familiar with technology. Imagine there are a few teachers who take their mobile phones to their colleagues asking them to carry out a government transaction for them, they are illiterate when it comes to technology. Some teachers spent many years in education and know only a little about technology*".*

Four teachers suggested that teachers need to be updated about new technology that can help them in their teaching practices. The Ministry of Education and the Department of Education should have a plan to encourage experienced teachers (who have more than 20 years in teaching) and support them by offering training courses and providing the required information, which will help them to become familiar with modern technology. However if a teacher is genuinely resistant to change, more effort than this might be needed to generate change.

6.4.2 Preference for traditional methods as a personal trait

This represents the core of resistance to change, as it is defined as a construct. Seven teachers from both groups pointed out that some teachers tended to use conventional teaching methods rather than teaching with technology just because they preferred it or feared change. Some reasons behind the preference for traditional methods were based on reasonable factors that have been covered under UTAUT factors so will not be repeated such as lack of equipment, lack of training, satisfaction with traditional methods, an unwillingness to complicate their work and the number of students in the classroom. Still it seems that RTC may often be an additional contributory factor in such cases.

One science teacher (NU5, female) for example expressed her view on the superiority of the traditional teaching, justifying her non-use of AR: *"*There is a considerable difference; with the traditional method even if the whole burden is on the teacher the students retain the information better*".* Another math teacher (NU7, male) explained how a lack of devices can influence his decision not to use technology: *"*It forces the teacher to change his plan and go back to using traditional methods in teaching. There are also more than 40 students in the class, I can't spend more time to apply the technology while explaining all the topic elements for them in 45 minutes. It is very hard to use technologies with such a number of students*".* In such a case there is always a possibility that the teacher may in fact welcome lack of equipment since that provides an excuse for him then to follow his underlying inclination not to change.

Perhaps the clearest statement of RTC comes from a science teacher (US12, Female):

"My position is that the traditional methods are the best and are irreplaceable. Although the AR technology is excellent, it cannot replace them. It motivates the student to like and enjoy the lesson, and it is a supporting means to facilitate the transmission of the ideas of the lesson as well as keeping up to date with the age of technology."

However, she takes the position not so much of staying only with the old and rejecting the new. She is, after all, an AR user. Rather she wishes to retain the old along with the new which he says he promotes:

"You know that in these days the students know much about devices and technology. I thought that instead of wasting their free time with non-educative games, even at their home, I recommend that they spend it playing with educative games and I have employed this technology in education."

Therefore RTC in this form cannot be assumed to be something undesirable and to be eliminated.

6.4.3 Student misuse

The misuse of devices by students was discussed by six male teachers from both groups. No female teachers discussed technology misuse by students. This sub-theme was perceived in two forms: damaging devices in the classroom and resource room (e.g. a projector or an interactive whiteboard), and invasion of privacy (especially with phones). Once again, these could be classified simply as negative instances of PE, but was regarded by the researcher as likely containing an element of RTC.

A science teacher (NU4, male) clarified why he avoided using a resource room sometimes:

> "We have just one room which hosts the projector and is most of the times closed. The room's key is with the administration out of fear that the devices, which are expensive, are damaged by the pupils. … There is no problem with that as long as we put cameras into all classrooms to ensure the devices are not damaged by the pupils. If something like that happens, who will be held accountable? This is what they fear".

This was regarded as possibly evidence of RTC on the part of the teacher.

Another aspect of technology misuse was violation of the privacy of both teachers and students. For example, when a teacher shared his own mobile phone with the students so that they could see the lesson content, this could allow some students to see his private phone content. Moreover, student use of their own devices could lead to a violation of both teacher and student privacy, as it could enable students to take pictures of the teacher or other students and post them on social media, for cultural reasons these issues would be especially important in the female schools.

One science teacher (NU4, male) presented his experience with this matter as follows: "Students can start chatting with each other if they are left with their phones, something that harms their behaviour and causes disruption of the course. Another related problem is the use of the phone camera as they may take shots of the teacher". Again, math teacher (NU7, male) stated, *"*There is another matter regarding the use of smart phones or tablets in the school, picturing or posting some videos, which may lead to some mistakes. I will not bear the responsibility in this case*".*

It can be inferred from the above interview responses that some teachers were concerned about the use of technologies because some students may damage devices or use them to violate others privacy. Such explanations do mean that this data could alternatively be classified simply as negative performance expectancy, although the position adopted here is that an element of RTC is present.

6.4.4 Device bans for students

Absence of student' devices in classroom can hinder the use of AR as five teachers, from the AR user group, stated. They agreed that students must have individual devices inside the classroom to implement AR technology and other apps effectively. This theme therefore connects with student ownership of devices theme covered earlier under facilitating conditions. However it is included here because it can be seen as perhaps a form of institutional RTC.

A math teacher (US7, female) for example said the following:

> *"*The Ministry of Education does not allow students to bring their own tablets and mobile phones into classroom which hindered use of AR technology and other apps. There is an official circular, and no school is allowed to permit mobile

phone use inside it. You know in our school we must ask for permission to use some apps and technology things such as Skype and things involving photos and so on*”.*

As was seen earlier, this teacher made good use of AR so probably she was doing it in whole class mode, projecting AR from her own device. In any event this example does not evidence any element of RTC on her part. Rather the RTC here is on the part of the authorities.

Ministry AR apps require scanning codes in textbooks and viewing the virtual components either via an individual tablet or phone screen, or by a projector or interactive whiteboard. Sometimes however the latter is not useful, or the teacher simply prefers to teach in a student centred way, but the required devices may not be available. Some teachers were overcoming this challenge by themselves providing some tablets for their students and not just by presenting the content on a large screen (e.g. interactive whiteboard and projector). They pointed out that students should learn by using the AR apps by themselves because this would increase their interaction with the content.

One physics teacher (US8, male) for example had overcome this through personal effort and expenditure: *“*My colleagues and I have many iPads and we all share the same classroom where each group of students has an iPad. We supervise the groups who are watching, and I only have to show the head of the group what to do*”.* The AR app experience with existing student devices would however be more effective and enjoyable for students, as teacher (US8) further reported: “I hope that we can use mobile phones more; in the summer semester I tried to let students bring their own phones because the situation was more relaxed. They were experimenting with this technology through the group system, which made it much more enjoyable than its use at the moment*”.*

What is seen in such examples, then, is pro-active and definitely not RTC teachers who wish to be fully up to date in how they use AR in the classroom. However they find themselves in a struggle with the authorities who, for whatever reason, appear to be in some respects RTC in their policies.

6.4.5 Student distraction

Using AR apps and other apps may distract students during lessons, as noted by three teachers. The present account regards these as at least in part RTC, although once again they could be seen as simply negative PE (reasonable beliefs held by teachers that explain their non-use).

One science teacher (US7, female) expressed her concerns about students using smart devices in the classroom, citing distraction: *“*This will backfire, students will not pay attention, the girls will use the device for browsing irrelevant non-educational activities. They will get distracted*”.* However, as was already seen earlier, this teacher is an AR user despite that. Clearly, she must be using AR in whole class mode e.g. via the projector from her own device, so cannot be RTC with respect to use of AR in that way. Her objection is to use of it in individual student mode. Furthermore, the use of the future tense implies the teacher has not actually tried it in that mode and may be presenting an excuse not to do it (i.e. expressing RTC with respect to AR use by individual students with their own devices), rather than negative PE based on experience of that mode.

However, student distraction can equally occur in traditional lessons, and managing this is part of a teacher's role inside the classroom, as a biology teacher (NU3, male) indicated:

> *"*But in the traditional explanation the students are easily distracted by flipping their books and do not pay attention to the lesson. This puts more pressure on us as we try push to them to focus more and redirect their attention to the lesson itself rather than what distracted them*"*.

This teacher therefore did not see any such distraction when students work individually as a special problem, or indeed as an excuse for RTC.

Teachers further suggested some solutions such as asking the MoE to provide students with devices that included only educational apps and that had restricted internet access, which helped students to focus only on the specific educational content and helped the teacher to handle the learners.

6.4.6 Conclusion on Resistance to change

Although the researcher had diligently followed the pattern of his closest sources for RTC (Alfarani 2016 and Alkhattabi 2017), it emerged that many of the examples illustrating the subthemes were essentially ambiguous, in ways not recognised by those sources. They could be taken as demonstrating RTC supported by plausible excuses, or as simply representing instances of genuine teacher beliefs falling in other UTAUT categories such as negative Facilitating conditions (e.g. lack of teacher knowledge or of institutional support e.g. by banning personal devices in class) or a teacher's negative belief about Performance efficiency (e.g. that student misuse or distraction will occur rather than learning). Hardly any could be argued to be unambiguous indications of a separate factor consisting of conservative personality trait where the teacher apparently did not accept AR just because it was change. This thought will be taken up in the Discussion.

6.5 Effort expectancy

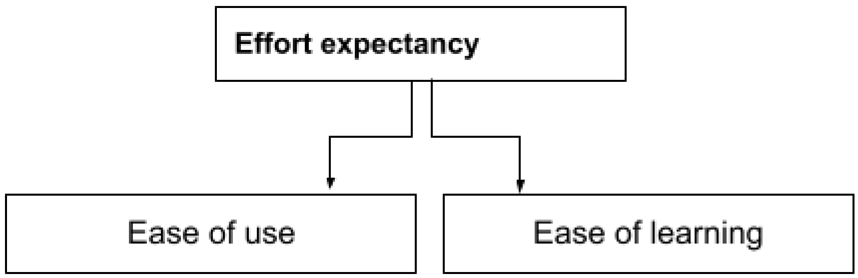

Figure 14. Effort Expectancy subthemes

A majority of teachers in both groups, user (n = 13) and non-user (n = 9), expressed belief that ease of use and ease of learning were important when using AR technology or new technologies when teaching. They indicated that any technological tool should be easy so as to enable teacher application. Majority of participants teachers (n = 22) considered effort expectancy in terms of two subthemes: ease of use (n = 22, female = 12, male = 10) and ease of learning (n = 11, female = 4, male = 7).

6.5.1 Ease of use

The findings show that using the existing AR apps is easy for many teachers and it did not need a high level in technology skills which is a reason for use it by some of them. Most participants (n = 22, female = 12, male = 10) discussed the importance of ease of use in their responses (Figure 14).

Among AR users, a majority (n = 13) stated that available AR technology apps provided by the MoE were easy to use in classroom, especially when a projector or screen was present to display content. These users agreed that the process of running and using AR apps was easy to perform through accumulated usage. As an example, a science teacher (US10, female) described her experience using an AR technology app in her classroom: "It was not difficult. It was easy to use. You download the app and choose the subject which has content for it in the app, you direct the camera towards the image or symbol in the book and then the display is conducted well in front of the students."

Most AR non-user teachers also agreed that any new technology must be easy to use because spending excessive time handling such technology may result in wasted effort and time, causing negative effects on lesson time and teaching quality and leading to teachers avoiding it.

Beyond the AR apps provided by the MoE, an expert physics teacher (US5, male) indicated that other apps were not easy to use for content enrichment in classrooms because they required more time and effort to prepare. He explained this by saying

> "Other times, we believe that the problem lies in the complexity of programmes dedicated to AR and we are faced with two difficulties: the difficulty for the beneficiaries who are far from this technology in terms of how to deal with these programmes with many different technologies, and the other difficulty is the apps

> themselves with regards to how their use can be smooth and simple for teachers."

He seems to be referring here to issues of hardware to run the app on, versus mastering the commands to run the app software itself. He further added that with practice, use becomes easier:

> "The AR courses are among the ongoing programs which I have taken. I feel that there is some difficulty but when you apply technology, this feeling disappears, especially the issue of training. There is difficulty but it is easier with the apps of the Ministry; I just open the app and point it at the image and that is it."

A female teacher (US12) also referred to her lack of using certain AR apps giving a slightly different justification: "However, If I want to use more valuable AR apps (not MoE apps) I have to create, edit and simplify the content for the students in a suitable form. All these take from the teacher more time".

6.5.2 Ease of learning

The results also show that learning how to use AR technology is not considered difficult for most users because it is designed to be used in simple way without losing time or effort on learning how to apply it. A majority of the non-user group (n = 6) however stated that using AR technology or any novel technology required training before being applied in a classroom (cf. 6.2.4). They also reported that learning how to use new technology was not difficult currently with tutorial webpages available online illustrating usage. This was not their reason for non-use, then. Rather they mentioned other obstacles that have already been described (such as time and device availability) that decreased their motivation to try AR technology and learn how to use it.

One biology teacher (NU3, male) for example indicated that YouTube provided several illustrations that supported learning how to use a new technology: “There is nothing hard with YouTube and websites; a lot of explanations are available on those platforms. When I want to use a new tool, I search about in the Internet and I find a lot of materials that state how to use it.”

6.5.3 Summary of Effort expectancy

The effort expectancy theme was discussed by a majority of study participants in terms of related subthemes: ease of use and ease of learning. Participants appreciated the readiness and ease of use associated with AR apps provided by MoE, indicating that novel technologies should be easy to use and easy to learn for effective classroom use. The AR non-users were therefore non-users for other reasons.

6.6 Hedonic motivation

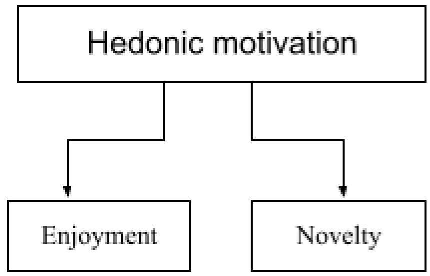

Figure 15.Hedonic motivation subthemes

The findings showed that teachers tend to use AR and similar technologies that provide some entertaining features in the classroom. Participants stated that the pleasure factor and novelty of AR technology influenced their use of AR in teaching. Hedonic motivation was discussed by the entire sample (n = 25) in terms of the the subthemes: enjoyment (n = 17), novelty (n = 7), and modernity (n = 4). The following sections present the subthemes associated with hedonic motivation.

6.6.1 Enjoyment

Enjoyment, arising from a variety of sources, was discussed by interviewees (n = 17, user=14, nonuser=3) in terms of using AR technology or similar technology that can make learning and teaching more enjoyable for both students and teachers. From the user teachers' perspective, teaching with AR technology helps to break class routine and to create a dynamic atmosphere and a feeling of happiness in students. As science teacher (US10, female) explained, the enjoyment can come directly from what the app does "It is greatly enjoyable for me and my students, because for instance if you see a fixed image and suddenly there is life in it and it moves and speaks, like a video clip, it is an enjoyable and exciting experience".

Four users also indicated that when teachers used AR technology in the class, they observed that students became happier and that made them also happy. One of the teachers (US13, female) stated the following: "I even become happy because they are content and impressed. AR helps to attract the attention of students and makes their learning experience enjoyable. They are happy when we brought technology and activated it, which encouraged them to attend all the lessons". This teacher then is happy because his students are happy.

Teaching with AR technology also can create a feeling of amazement among students which also produces enjoyment. As another physics teacher (US8, male) explained,

> "Yes, they are enjoying themselves, and I even become happy because they are content and impressed. They feel a certain amazement, especially given that I was teaching in a far village. This thing was bewildering for them, but there are female students who understand technology and others who do not. They ask me: 'How can we do that? How does this happen? We want to know the name of the app.' I give them the names".

An AR non-user who teach physics (NU8, male) also clarified that "Inside the classroom, technology was always an element of astonishment for students and you notice that they are clearly interacting, laughing and feeling happy." However, clearly in his case this did not make the teacher himself happy enough to lead him to use the software.

In fact several user teachers only mentioned student enjoyment, not their own, but it can perhaps be inferred that student enjoyment played a role in their own enjoyment and hence their choice to use AR. As teacher US9 stated, students also can learn better with content offered by enjoyable AR technology (cf. 6.1.1): "learning has become more enjoyable for students, and I noticed when they see things embodied in front of them, they grasp these things better than with the traditional method. My students are very much in love with this, and they are enjoying and waiting for the moment when we do such things as an AR app". Science teacher (US13, female) also stated,

> "AR is useful. It stimulates learners to participate because it combines learning and enjoyment at the same time. It helps in breaking the routine of a lesson, giving a dynamic atmosphere, better information retention and filling the gap between theoretical and practical education".

6.6.2 Novelty

This theme is reported, since the teachers mentioned it several times. However it was always in relation to student enjoyment and it is not explicit that novelty actually inspired teacher enjoyment and hence use.

Applying modern technologies was said to be accepted by students due to its novelty, as several participants stated in this study, with eight of them from the AR user group. They indicated that AR technology is a novel technology and applying this technology with students is admirable because the students of the new generation like these things. Moreover, introducing AR or new technology with students will draw their attention and be exciting for them. As a science teacher (US14, female) stated, "It makes students keen to attend and not to miss their classes. It is a new thing for students, draws their attention and is exciting".

From the AR non-user group, a science teacher (NU4, male) stated that "The student is excited by any new tools, so I think this technology will lead to change. Any new thing is motivating. It will introduce content via pictures and make it more acceptable, enjoyable*".* So also physics teacher (NU8, male): "I mean when students see something new, they are pleased and relaxed especially since you are providing them with updated technology suitable with the current period".

Of course novelty is expected to wear off over time. The teachers did not report this happening yet, but at the time of the data gathering the teachers and students had only used AR for a maximum of six months.

6.6.3 Modernity

Other teachers focused on modernity rather than just novelty, but again they focused on the student liking for this and not their own. Two teachers indicated that utilising new and amazing apps in the class is required these days and will help students to love school because they prefer today's technology and devices. A science laboratory teacher (US4, male) reported, “We know that in these days our children cannot stay away from the internet and smart devices. Some of them are using these tools in a detrimental manner and I thought we can solve this problem by introducing the educational apps”. In addition, a science teacher (US14, male) stated that “If you deprive them from enjoying themselves and keeping up to date with their time, when will you let them do that? Only after these technologies become outdated, are you willing to try them? No, I do not think this is nice!”

From these teachers’ responses then the students prefer modern technologies inside classroom to match what they experience outside, which encourages their teachers to employ them.

6.6.4 Summary of Hedonic motivation

It can be inferred from the above interview responses that the teachers tend to use AR technology because it provides both students and teachers with an opportunity for fun inside the classroom. They did however mention student enjoyment far more than their own, and seem to regard that as more important. AR helps to create an atmosphere of happiness and amazement which can lead students to interact and involve more with the teacher's explanation. Furthermore, it meets students' desire for novelty and modernity in their classroom experience. Such an environment helps the teacher to make lessons more interesting and interactive so that students learn more effectively (6.1.1). In short, there is an element of performance expectancy present here too. The teachers to some extent enjoy AR (HM) because the students do. However, they also welcome student enjoyment not because it leads to teacher enjoyment but to better attention and learning (PE).

6.7 Price-value

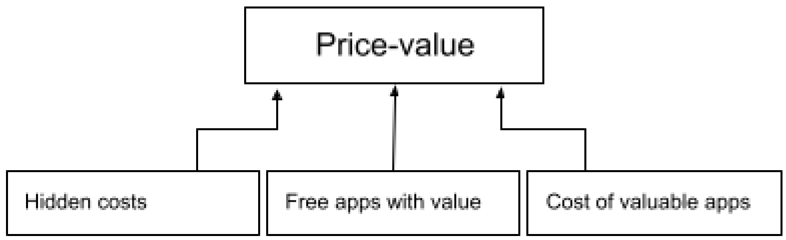

Figure 16. Price Value subthemes

It had been expected that this factor would manifest itself more in terms of a price for teaching benefit (=value) consisting of effort needed (when learning and using AR) rather than a price in money, since the MoE should be paying all the financial costs associated with AR in school. The findings showed however that although AR apps are provided free by the MoE, and designed to cover some topics in the set syllabus, there are hidden monetary costs behind its use and also there are more valuable AR apps that can be useful in teaching science curricula but are not available for free.

The discussion that occurred of the price-value theme by the majority of the participants (n = 23) falls into the three subthemes as shown in figure 17: hidden costs for obtaining immediate value (n = 17), free apps with value (n = 6), and the cost of more valuable apps.

6.7.1 Hidden costs for obtaining immediate value

Seventeen teachers (AR non-users = 8; users = 5), indicated that there was a financial cost to the teacher for using modern technology including AR apps inside the classroom, which may hinder the use of such technology. Sometimes, the school is not equipped with the required technology, as has already been seen, so the teacher who wants to get the value of AR use now has to bring their own device(s) or pay money to provide missing accessories (e.g. a wire or mouse) so that existing devices can be used. Otherwise, he/she has to wait for the school to provide them, so obtaining the teaching value of AR or other technology is delayed.

Six teachers stated that they brought their own devices (e.g. laptop, portable projector or ipad) into the classroom for teaching purposes because they find that it was helpful in their teaching practices; they were willing to buy the required equipment so as to obtain their benefits immediately. As one physics teacher (US3, male) reported, "I have no problem buying them. I believe that when you give such entertaining lessons this price is nothing compared to their positive benefits for the students".

One chemistry teacher (US15, female) described her experience in buying some tools that were necessary in order to effectively use some of the AR apps: "For example, I spent 600 riyals for an Amazon shipment, but later I found a site in Saudi Arabia called Sport and realised it provides these tools for 150 riyals, ...".

From AR nonuser group perspectives, sometimes the teacher was ready to bring his own devices as he faced challenges such availability of display screen or accessories. As math teacher (NU7, male) stated,

> "I bought some tools for my teaching, I have my own laptop and portable projector because I often move between five classrooms each day, so I use it in teaching. I bought some accessories for these devices. To be honest, it is very expensive, it is about 6000 SR, but I am happy because I can do my job in perfect ways and my students can be engaged, they interacted, participated during the lesson, that's what I am here to do. My students deserve that".

However, three teachers stated that they were not ready to buy any equipment because this was the school's responsibility. A biology teacher (NU2, male) clarified his position on this matter:

> "My personal position on this matter is that all these operations of presentation and device connection must be performed by the school administration. I am not ready to use my own devices".

The hidden costs also include the cost of training courses which, as already noted, are not provided by the MoE for AR. These relate to travel to another city and the payment of some registration fees as science teacher (NU1, male) declared.

It is inferred from the interview responses that the majority of the respondents believe that there are hidden costs when using the AR tools and a number of teachers spend their own money instead of waiting for the schools to provide it for them as that is time-consuming. However, some of the teachers refuse to pay such costs as it is the responsibility of the organisation. It is clear that there are various kinds of hidden costs in teaching with the help of technology in the Saudi context and this factor can act as a hindrance for the users and non-users to accept and adopt AR tools for teaching.

6.7.2 Free apps with value

All participants confirmed that AR apps were available for free on the IEN platform. Availability of AR technology for Saudi teachers was considered as an important factor to encourage them to use it in their teaching practices and so add value at no cost for the app. Fourteen teachers discussed this subtheme as follows.

Six teachers (user = 5; non-user = 1) cited the importance of having the free AR apps available for their teaching. Five teachers from the user group stated that they preferred using AR apps because they were available without any additional costs and they were designed to fit with the textbook content and the range of topics. One challenge that occurs in using technology is if the available content does not fit the textbook content, so it is important that the free AR apps were designed by specialists in the Saudi science curriculum.

Both AR users and non-users were aware of availability. One physics teacher (US3, male) who used AR 4-6 times per month said: "As for the applications, they are currently available, and anyone can access the website and download them. There are free applications that can be downloaded by anyone who is interested". A science teacher (NU5, female) said "We have numerous free opportunities at our disposal which we can employ and exploit in delivering lessons for students. Similarly, there are many free applications of augmented reality and virtual reality". This recognition does not in her case lead to use, however, since it was seen earlier that she is a possible case of RTC.

The following statement, from an expert teacher (US7), is also informative about the connection with the textbook:

> "There are other applications more exciting than those of the Ministry. Sometimes we say that ready things are better. These are better and more motivating for teachers when they can directly implement them. The Ministry did well when it took the initiative with respect to this issue − and what is good is that it is in the content of the book, i.e. sometimes when we use the other apps, we will have a content that is partly available and the rest probably unavailable in the syllabus. Yet, these apps are designed specifically for this curriculum, within the book used in the lesson. Sometimes the book or at least the barcode in the book is part of AR."

It can be inferred from the above interview responses that the MoE's free AR is believed to be a cost-efficient technology for the teachers as it provides various benefits at no cost to the teacher for the MoE apps, which acts as a factor that motivates the teachers to use this technology.

6.7.3 Cost of more valuable apps

Findings indicated that sometimes teachers prefer using different AR apps because of their greater value for their teaching practices. Five expert teachers reported that they were using AR apps provided free by MoE only a few times per term because they had found more valuable apps (not MoE apps) that had more options and features. They criticized the quality of the Ministry apps in terms of the poorer interaction, scenario and sequence processes inside these apps.

However, the superior apps came at a price. According to some teachers, there was a cost for paid apps (50 RS = £10) and annual subscriptions (10−40 RS). One teacher (US15) said the following: “Yes, and it is expensive. Some apps require paid subscriptions. It is about 20 SR monthly, so if I want to use 4 or 5 apps that will be costly”. However, they felt the value for delivering knowledge to their students and easing teaching tasks outweighed the cost.

One biology teacher (US16, female) justified why she does not care about the cost of paid AR apps and explained the results of using them:

> “I want my students to learn and enjoy the process of education, although this possibly costs a lot of money, but what I care about is that they learn and I can

do what satisfies me as a teacher. Yes, thank God when I see the result in the end and the level my students reach, I forget everything. This pleasure makes me forget everything and when I receive a message from a student after some time telling me that she has achieved so and so, this is wonderful”.

6.7.4 Summary of Price-value

The price-value theme was discussed by a considerable number of participants in terms of the associated subthemes: hidden costs to obtain immediate value, the value of the free apps, cost of more valuable apps. Participants indicated that the AR apps provided by MoE were available free, but there is a hidden cost with their use in some schools that have a lack of resources. They reported that there are more valuable apps that can serve better than the free apps, but they require payment or subscriptions.

6.8 Conclusion

This chapter presented the findings from the qualitative data drawn from 25 science teachers in Saudi schools. It was divided into sections based on exploration of the themes discussed by the participants as influential factors in terms of their intention to use AR and other modern technologies. The main themes were: performance expectancy, facilitating conditions, effort expectancy, social influence, price-value, hedonic motivation and resistance to change. While the main themes mostly match UTAUT2 categories, many of the subthemes are novel, and much illuminating information was revealed about the detailed teacher beliefs concerning what affects acceptance of AR in the Saudi school context. The interview findings further confirm teachers' view of the predominant effectiveness of using AR/other technology to help teachers accomplish their lesson goals in an effective way compared to using traditional methods in teaching, with a few reservations. Often both AR users and non-users had similar opinions, with the non-users being prevented from becoming users often by unfavourable facilitating conditions.

7. Chapter seven: Discussion

The study aims to investigate the acceptance of AR technology in science lessons in Saudi schools by exploring the factors reported as influencing teachers’ decisions to use (or not use) such technology. Qualitative data was collected from interviewing twenty five teachers in Riyadh district and the high level theoretical frame of the interview questions was all seven UTAUT2 constructs of Venkatash et al. (2012) (PE,EE,FC,SI,HAB,HM,PV), not the more limited set used by Al-Ghatani et al (2007), together with a further construct (resistance to change derived from Alkhattabi 2017 and Alfarani 2016). At lower levels of detail, interviewees were left free to mention whatever they felt to be relevant so that data was gathered also in a more interpretivist way driven by the perspectives of the teachers themselves.

The findings of this study described in the previous chapter will now be discussed, interpreted, and related to the previous studies in this field. However, it must be noted from the start that, as the literature review in chapter 3 showed, there is a dearth of studies of AR that used UTAUT and so are directly comparable. Many existing studies around the world used some version of UTAUT on other technological innovations, often much broader (e.g. use of an entire e-learning system in Kocaleva, 2014), and often not in genuinely educational contexts (e.g. Mehta, 2018). Most of the much smaller number of studies devoted to AR acceptance did not use UTAUT. Thus the novelty of the present project in some ways limits the parallels that can be drawn with findings elsewhere.

7.1 Factors influencing science teachers’ decision to use AR technology

The main aim of this study is to explore factors influencing the decision of Saudi science teacher to accept AR technology into their teaching practices, and to understand in depth their perception of those factors. The findings indicate that the teacher's decision to use or not use AR technology can be affected by seven types of factor in terms of the a priori framework that was used (facilitating conditions, performance expectancy, social influence, resistance to change, effort expectancy, hedonic motivation, and price-value). As far as is known, this is the first time this has been demonstrated in an educational context in Saudi Arabia, so there is no study with which a direct comparison can be made.

As seen in the presentation of the results (chapter 6) six out of seven constructs of the UTAUT2 theory were reported as factors that affect the teachers’ behaviour to accept and adopt AR technology in Saudi schools. Those factors were performance expectancy, effort expectancy, facilitating conditions, social influence, hedonic motivation, and price-value. The only UTAUT2 main factor construct that no evidence was found for in teacher reports was the habit factor (Limayem *et al.* 2007), which will be taken up below. The additional factor derived from the literature in another Saudi context (resistance to change as a trait) was mentioned, albeit not unambiguously. Therefore, in total seven types of factor were identified that influence teachers' decision to accept and maybe use AR technology in their teaching practices.

Although this was not a quantitative study, the findings show that teachers most often in one way or another refer to aspects of the new technology that enhance student learning, and so reflect positively on their professional practices. They accept and (other things permitting) use AR technology especially when the perceived performance expectancy (PE) benefits from its usage in teaching outweigh any disadvantages. This emerges not only where they say things that are straightforwardly classifiable as PE, but also indirectly in RTC and HM coded material. This reflects the high impact of PE found in some quantitative studies across various contexts (e.g. Al-Ghatani et al 2007; Rasimah *et al.* 2011). On the other hand, the availability (or not) of resources (FC) such as devices, AR apps, the internet, localized apps and prior knowledge importantly influences a teacher's behaviour in terms of actually using this technology (consistent with Alfarani 2016).

The findings also indicate that social influence (SI) is quite strong (consistent with Al-Ghatani et al. (2007) and includes school staff influence (school principal, teacher and students) and the presence of a supervisor can encourage the teacher to use technology. In addition, the factor of resistance to change (RTC) includes a preference for teaching using traditional methods and teacher concerns about the misuse of devices by students in the classroom (but see further discussion below). These can be considered as other reasons behind the intention to use AR technology. Furthermore, most teachers prefer a technology that does not require spending a lot of effort to run it, such as Ministry AR apps. This is consistent for example with Arvanitis *et al.* (2009).

In addition, the effort expectancy (EF) and hedonic motivation (HM) behind the use of the technology and the costs of using (PV) technology compared with its feasibility and benefits constituted additional influential factors on the teacher's decision to accept and (other things permitting) use AR technology. The influence of the seven factors on the use of AR technology will be the basis of the discussion in the following sections.

7.1.1 The influence of Performance Expectancy on the use of AR technology

The findings indicate that the users have a positive attitude toward using AR technology in teaching in terms of effectiveness and efficiency of such technology in teaching practices just as has been found in other occupational domains (Venkatesh *et al*. 2012). Although some perceived negative effects on teaching quality were mentioned in other themes, such as students using devices for purposes other than the teaching tasks and even invading others' privacy, these were not widely accepted as reasons for non-use. Notably even some AR non-user teachers acknowledged that modern technologies have a significant role in developing teaching methods. They did not however use AR technology. This can be interpreted as that they may have seen some AR apps and thought they would be beneficial but were stopped from adopting them by one or more of the many other factors mentioned and placed in other themes below (e.g. under FC, lack of tech literacy, lack of devices or other resources in the school). It may be inferred that such nonuser teachers might intend to use AR technology if they were to receive sufficient information about how to use it and/or school support with equipment and a technician.

As a non-user stated in the Training subtheme (below), in order to encourage nonuser teachers to use AR technology, the Department of Education should provide teachers with prior knowledge about new technology that they want them to apply so as to enhance teachers' motivation to try it and discover fully the benefits from its use in teaching. In this study, users had experienced AR technology in the longer term and observed its benefits in developing their teaching performance and so expressed their perceptions clearly. Hence, users' beliefs were based on examining the actual effects of AR technology in the class, which may cause them to continue to use it in their professional practices. Thus, they acknowledged using AR technology as a beneficial tool in their practices and stated they would continue to use it. This is consistent with Venkatesh et al. (2003) who found that performance expectancy positively influences users' behavioural intention to accept and use new technology.

In the present study performance expectancy was regarded as composed of two subthemes, the role of technology effectiveness (perceived usefulness and relative advantage), and technology efficiency (in terms of time) in enhancing teachers' performance. According to the data, AR was perceived to help teachers present content for students in varied types of medium like visual, audio, and virtual presentation that made the explanation quicker and clearer and more memorable. In addition AR offered 3D objects that facilitate the presentation of some science topics that include hidden parts like cells and human body parts. The following two sections explain the aspects of performance that teachers reported from using AR technology.

Technology effectiveness

The users especially consider that with the application of this technology, the information retention, reduction of content ambiguity, students' interaction improved stimulation and focused learning can be secured in teaching practices. This echoes many of the benefits described in Yilmaz (2016) and other studies reviewed in 2.2.1, 2.2.2. Even non-users of AR technology often echoed these views, which they must have formed from perhaps seeing or trying out AR, or thinking of similar applications. A minority of non-users however cited the negative kinds of performance that were not coded under performance expectancy (student distraction and engagement in undesirable off-task activities) which would of course harm the teaching process. For some non-users this could be a reason for their non-use of AR.

Regarding the function of AR technology in retaining the learned information, some non-user teachers applied other apps that aid retention of the learned content, which could be interpreted as showing that for them there was no desire to adopt AR technology because the apps they already used can perform the same functions and gain the same benefits. However, the AR users, consistent with Salomon (1983) and Valimont *et al.* (2002), believed that students could learn better in lessons supported with AR content and retrieve what they learn better in the next lesson, which encouraged them to continue to use AR in their teaching. This evidence can be interpreted as showing that the teacher will continue to use AR apps when he found them helpful in improving students' learning.

As for the advantages offered by multimedia capabilities that distinguish AR technology, the participants' observations highlight the teaching value of multimedia whether in AR technology or other. Presence of a variety of media components can enrich the lesson content and allow students to understand some complex information better than narrative explanation. This chimes with the literature which states that AR is effective in addressing the complications associated with establishing connectivity between imagination and the real system (Iatsyshyn *et al.* 2020).

However, under other themes (especially FC) it did emerge that AR, especially due to its multimedia capability, may demand certain equipment which schools in Saudi Arabia do not keep in ordinary teaching rooms. This may require the class to move to a lab or resources room which could be hard to organise due to many teachers wanting to use the room at the same time and also lost lesson time in walking to a different room.

Nevertheless, multimedia AR itself allowed topics to be expounded through visual presentation that involves 3D objects and video, enhancing students' learning with experiences that they could not have in the physical classroom, as described by Chen (2006). For example, in some chemistry experiments, the teacher uses AR apps to offer a virtual experiment to show the interaction between many chemical compounds which can help avoid performing a real experiment that may involve some risks and need more preparation and resources. From the evidence cited, the multimedia components in AR apps serve to illustrate the complexity in the subject content and enhance students' learning through assisting them to imagine, think and understand the content presented.

In this context, the literature (2.2.1) explains that AR innovation has numerous benefits as an emerging technology in education, as most of the participants echoed. This can be attributed to its features of allowing interaction with two and three-dimensional synthetic objects in a complex reality, developing important practices that could not be otherwise developed and enacted in other technology in enhanced learning settings. The literature highlights that AR can be effectively utilized for learning and education by facilitating collaboration with the present reality (Abu-Dalbouh *et al.* 2020). It allows the students to use virtual learning which enhances a student's learning potential.

AR can also be implemented for improving shared assignments and is relevant for providing an inventive interface that helps in combining real and virtual settings to enhance both individual and coordinated endeavor that helps students in learning. Such enhanced reality applications gain popularity because of their effectiveness for student learning (Ibid). Overall then my findings and the literature (2.2.1) both indicate the effectiveness of AR technology in education because of its multimedia properties, which help increase student performance and learning, so contributing to its acceptance.

It must be commented however that of course the current study did not measure any actual learning done with AR: teachers' perceptions of its effectiveness were relied upon. This is however consistent with the perspective of the UTAUT, which relies solely on measures of teacher perception of all the variables it includes in the model.

Furthermore, much of what is found in the literature about the benefits of AR (2.2.1), assumes that each student has their own device and is using AR for individualised learning, interacting with the content as they personally prefer. In the present study however there are some hints in what the teachers said scattered throughout the data that imply that that was not universal practice. For a variety of reasons classified under other themes, such as teacher preferred style, lack of available devices, or the wish to avoid the problem of student off-task use of devices, it seems there may have been considerable use of the traditional teacher centered whole class mode of teaching where the teacher alone used AR and projected whatever he chose to the class with a projector. For that reason, projectors and projector leads were among the most mentioned hardware in the data. Of course, such a practice does not lose all the advantages of AR, as the teachers in the study testify, but it does limit those that depend on individual use in class. Therefore the teachers were not found talking about AR benefits for learner autonomy or self-education (as does Iatsyshyn *et al.* 2020), for example.

A case in point is the following, where the benefit would not be completely lost through whole class use. The value of teaching with AR apps in illustrating content details, reducing content ambiguity, was expressed by twelve teachers, from both groups. They believed that using AR technology in teaching helps them deliver varied content in more detail to show the invisible parts in some organisms so their students can see them. It also provides the opportunity to avoid so much teacher verbal description and reduce ambiguity in the content provided. AR apps involve many features that allow the teacher to show content attractively and easily for students which may increase the teacher's intention to continue to use it. As Iatsyshyn *et al.* (2020) explained, the implementation of AR provides a user-friendly interface that transforms three-dimensional objects through the use of software and hardware and the computer-aided real-time digital data is enhanced through observable reality, which further helps in increasing knowledge regarding the environment.

The findings also reveal that teachers think that teaching with AR technology can result in increasing students' interaction during lesson time (cf. Yilmaz 2016). They believed that using AR technology can positively impact the classroom environment by enhancing students' motivation to learn and interact and will ignite students' enthusiasm. From the teachers' observations, students become more attentive and more engaged in the lesson. One might think these benefits would be greatest when the students each use AR independently. However, the teachers' wording often shows that they are thinking of whole class use with the teacher in charge, which is in some ways still the traditional teaching style, although when the teachers do it with AR they call it not traditional. Anyway, the students still benefit and have the opportunity to be involved and discuss some ideas when the teacher shows them the content with an AR app. The attractive content offered by AR apps is helpful to overcome student inability to concentrate during the lesson which is one of the teacher concerns in teaching. These consequences of using AR technology in teaching even in a traditional teacher centred style can enhance teachers’ intention to use it and continue to use it in the future. The literature also supports the above interpretation that AR technology users consider that this technology assists in students' real-time interaction with the learning environment, boosts students' engagement and enables collaborative learning so as to improve the learning outcomes (Alahmari 2018).

These findings can be further compared with those in the small existing literature in the Saudi context. This also shows that AR offers numerous effective opportunities to visualise abstract concepts and facilitate student engagement and interaction, which helps in enhancing student learning (Alkhattabi 2017). In the field of education, AR has revealed immense opportunities and advantages, which highlights the high potential of integrating AR in learning and teaching, particularly in science subjects that require visualisation of abstract concepts. Alkhattabi (2017) claims that it also facilitates learning beyond class hours and outside the limits of the school premises and thus can continue a learning experience that is closely associated with the formal classroom. Verifying this was however beyond the scope of the present study which focused only on factors affecting AR acceptance in the classroom. Nevertheless findings of this study confirm teachers' awareness of the immense potential of AR technology in offering effective content and facilitating students to learn effectively and retain successfully as a key factor in their choice to accept it and (subject to other conditions) use it.

These findings may be further considered in light of other literature that confirms that Saudi Arabian teachers believe that AR has numerous positive effects on improving teaching methods (Al-Ahmadi 2019). The adoption of technology and changes in the educational process and pedagogy also created a positive impact on the attendance of the students. It has helped the schools in simplifying the courses and making them more effective and impactful for the students (just as reported for example in Portugal by Barreira *et al.* 2012).

Technology Efficiency

The efficiency of AR technology in teaching was in the present study largely seen as a matter of speed or time. When comparing AR users and non-users, it was noticed that AR users recognise the ability of this technology to facilitate teaching procedures in terms of saving time. Teachers believed that beneficial technology in teaching such as AR helps them to enable students to increase their knowledge by a certain amount in a shorter time than would happen with traditional tools. In effect therefore they regard AR as increasing their productivity (Hanushek and Ettema 2017).

Teachers found AR apps useful technology for them in their teaching practices because AR apps are designed to show many materials in a short time compared to the traditional methods which need more time to prepare materials and write on a whiteboard (Radu 2014). Some non-users of AR technology also recognised this. However, there were also some non-users who, under another theme, mentioned ways in which they perceived AR as losing time compared with traditional teaching because its use had to be explained to students, and required moving to a resources room which lost 15 minutes of lesson time. They might perhaps have discovered that this was compensated by greater time saving in content preparation and delivery if they had persevered and used the app regularly. The findings then revealed that many teachers teaching with AR apps believed this helped them to prepare and explain the content in a shorter time, which allowed them additional time to review and discuss and do further activities during the same lesson. Compared with traditional tools, using AR apps was for them more beneficial in conserving lesson time. The teacher has an opportunity to show the content and move sooner to listen to his students' questions and provide them with appropriate feedback. Using traditional methods, the teacher has to bring some physical materials, write on the whiteboard and control the classroom before starting explanation. With use of AR apps, he will not spend a long time to get control of the class because students will quickly pay attention to the content offered. As confirmed by some teachers in the study, AR facilitates speedy engagement of students by gaining rapid attention of students to the visually appealing presentation of knowledge and information. It provides faster transmission of ideas, information and knowledge, which will help in delivery of lessons in the classroom (Sirakaya and Alsancak Sirakaya 2018).

The literature supports this finding in that AR users in universities in Saudi Arabia have been shown to also consider that the use of AR technology saves student and teacher time, and indeed also reduces the need for additional effort in regard to teaching and learning academic subjects (Alahmari 2019) (see further 6.1.3). Therefore, it has been suggested that in consideration of AR technology's benefits for speeding information delivery, this technology needs to be widely incorporated in teaching practices to enhance learning and teaching outcomes (Ibid).

7.1.2 The influence of Facilitating conditions on the use of AR technology

Facilitation conditions can be defined as “The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system” (Venkatesh et al., p. 2003). In the definition of the present study, it is somewhat broader and also includes background knowledge needed by the teacher about AR and technology and related skills.

Many participants argued that the basic physical and organizational structures and facilities needed to apply AR technology in their teaching practices were critical, but not always fully present in their schools. The availability of knowledge that helps the user to know about and use the technology did not always exist, as well as the availability of AR itself with necessary compatible connected other technologies, supportive devices, training courses that support the use of AR and time and infrastructure. These were all discussed in the interviews to illuminate the relation between the facilitating (or obstructing) conditions and adoption of the technology. The study confirmed that there is a relationship between facilitation conditions and the use of AR technology in terms of availability of those important resources significantly affecting the adoption of AR technology. As Venkatesh et al. (2003) suggest, the existence of the organisational and technical infrastructure to support system use will enhance the user intention to use the system. It could be added that the lack of it hinders acceptance and/or use.

Knowledge and Training

In relation to knowledge about AR technology and incorporating it into teaching, it emerged that users of this technology consider that prior knowledge of the software, learning of projector-based teaching and the use of AR are all considered to be needed and many AR users (and some non-users) possessed it. However, some non-users claimed to lack any knowledge, and this could account for their non-use. Possibly however they were underestimating their technological skills and knowledge: since this was not measured in the present study, their real ability is not known. It has in fact been found that a teacher's perception of their technological ability, their self-efficacy (Bandura 1982), does not necessarily correlate with their actual ability to integrate technology within the classroom (Hickson 2017).

Training courses were therefore considered important to learn lesson delivery through this technology though a few recognised also gaining knowledge through the experience of using it. The teachers who use AR apps in their teaching showed they had prior information about such technology's advantages. With AR technology's trialability (Rogers 2003), they gained more practical information that motivated them to continue to use AR apps. The available knowledge for teachers supported their intention to apply new technologies in their practices. Some of them referred to their self-motivation to improve their performance which guided them to search in educational forums, YouTube and other websites to find supportive information that helped to develop knowledge delivery in the classroom.

Some teachers also discussed the importance of providing the teacher with some information about the emerging technologies in the education field to help them to try it and to keep them updated with developments in their field. Significantly, the MoE provided an illustration video that explains how to use AR apps, but this is not enough as some teachers stated: this echoes the weaknesses uncovered by Sabah *et al.* (2014). The technology needs to be explained in training courses that combine the theoretical and practical aspects. It was claimed that although the Ministry provided some prior information it did not provide training specifically on AR and this was missed. Some AR users had found training online or in courses they personally paid for and attended. The MoE should seek to introduce new technologies to teachers in their school with the necessary instruction, including its benefits and how to use it effectively to help teachers adopt it. This fits with the literature that highlights that workshops and training are necessary aspects for teachers to have knowledge of AR technology for integrating it into the education system of Saudi Arabia (Alahmari 2019).

Both the users and non-users of AR technology then supported the need for training and support for improving knowledge about this technology's use and application in teaching practices. For example, users and non-users highlighted the complex situation of regular updates of AR technology and its complicated nature for which constant training and support provision are necessary for teachers to incorporate it into teaching, as is also emphasized by Alahmari (2019). Even though MoE or DoE training courses increased in recent years, the available training courses did not offer courses about using the latest technologies but rather covered other various teaching strategies as participants reported, so the modern technologies such as AR technology need allocating courses due to their modernity. Al Asmari (2011) also considered the lack of training as a major factor that hampers technology implementation in Saudi schools. As his results revealed, some Saudi teachers have limited knowledge of technology and still use traditional methods.

This all suggests that the teachers predominantly embraced what has been called the applied science model of teacher professional development, where the teacher expects to develop their pedagogical skills and knowledge by an expert explaining to them how things should be done, ideally based on existing research (Wallace and Bau 1991). The teachers found this in paid training courses or online YouTube resources and the like but not from the Ministry. Nevertheless, there was also one teacher who appeared to embrace additionally what has been called the reflective model of teacher education. This teacher referred to the teacher trying out new technology with the class as an 'experiment' that she then learned from. This was in effect referring to action research as a means for the teacher doing their own self-training (Manfra 2019).

Resource Availability and Compatibility with Other equipment

The AR technology users considered that resources like the internet, devices provided by the school, student device ownership, and availability of AR, matter the most for successfully integrating and using AR technology for teaching purposes (as found by Sommerauer and Müller 2014). For example, equipment like an Android or Apple device, projectors and camera are essential for AR incorporation in the classroom environment for teaching purposes. In fact the AR non-users group considered such things to be major barriers if they were not facilitated, and probably they were major causes of non-use. For instance, it was reported that limited internet facilities and weak Wi-Fi connectivity hinder AR technology's implementation in teaching practices in Saudi educational institutions, especially for the initial download of an app from the Ministry site. It is worth also pointing out that the teachers found the availability of AR apps in Saudi schools (which from the IEN site is not a problem if the internet works) was insufficient to ensure its actual use, for which other resources were often lacking such as projectors, cables, students' own devices, and a suitable decent classroom. The literature shows that such problems of inadequate facilities in respect of AR-related equipment and infrastructure (see below) hinder acceptance of ICT in Saudi school (Albugami and Ahmed 2015).

Some users mentioned how supportive resources, and indeed human support in the form of a technician, are vital for applying new technology and enabling teachers to implement it because the lack of necessary tools may hinder some teachers who have an intention to use AR technology. It could be said that teachers may show acceptance of AR, or a positive behavioral intention in terms of the UTAUT2 model, for example by having positive performance expectancy, but not actually use it because of these supportive features not being in place. It is a common finding in research on teacher beliefs in contrast with their practices that this happens. They believe that ideally they would behave in one way, but for practical reasons in the teaching context they actually behave in another (Mansour 2009). Therefore, this can result in absence of actual use in the future. Some teachers in Saudi schools avoid using even simpler technology such as visual and audio in their classroom due to lack of required devices. A study conducted by Alhawiti (2013) found that the lack of suitable equipment is one of the main factors that hamper such technology application in Saudi schools.

Infrastructure and Time

Some AR non-user teachers mentioned that students' movement from classroom to the resource room (required because school policy did not allow devices in normal teaching rooms) reduced the time of lesson delivery. For example, 15 minutes' time was estimated to be lost for the students to walk to the resource room for AR lessons. Therefore, it is noted that, unlike users of the AR technique, who (as seen in 6.1.1) regarded AR as time-efficient, some non-user teachers regarded time-consumption as a hurdle for AR use for teaching purposes. As other studies also indicate, time limitations can hinder technology implementation in the classroom (Bingimlas 2009) and in this respect impact on performance expectancy.

A related view was that the teachers do not have sufficient time to do the necessary preparatory work to integrate the technology due to over-loaded syllabuses that they have to teach. This finding was supported by Al-Alwani (2005) study which found that the teacher schedule in Saudi schools includes 18 lessons (45 Minutes) per week on average. He also has to attend some of the lessons when another teacher was absent and supervise students in break time. All those tasks can influence a teacher's execution of an intention to use AR technology. Therefore, the MoE should work to reduce teacher workload and so promote benefit from the technology to achieve some tasks better with technological tools.

Further, concerning infrastructure (Venkatesh *et al.* 2003), it was mainly non-user teachers who disclosed that inadequate infrastructure with lack of proper projector stations, absence of electricity sockets and improper lighting directly hindered the incorporation and application of AR within Saudi institutions. The literature further supports this view by indicating that Information and Communication Technology-based infrastructure and e-learning infrastructure, are urgently needed to enable integration of technology such as AR into teaching within the educational sector of Saudi Arabia (Alkhattabi 2017; Alahmari 2019).

The study found that there are differences reported between schools regarding adequate infrastructure. Some schools are equipped with all requirements that support the use of AR technology and modern technologies, while some schools suffer from a lack of basic infrastructure. Rented school buildings were reported as still a major weakness in the Saudi education sector. According to an MoE report (2018) the percentage of rented school buildings was as high as 20%. Some of the buildings were designed to be a residential hostel, not a school building. Consequently, it is not a surprise that they do not fit with educational purposes. There are not enough rooms, labs, halls, and items of educational equipment, all of which can harm both teaching and learning processes. However, some schools also have a large number of students; there may be more than 40 students in one classroom. All these issues can hinder AR technology adoption, as Albugami and Ahmed (2015) study also stated.

7.1.3 The influence of Effort Expectancy on the acceptance and use of AR technology

Effort expectancy is defined as “the degree of ease associated with the use of the system” (Venkatesh et al., 2003, p.450). This concept covered discussion of the easiness related to using technology such as AR and easiness related with learning how to use it. In this study, effort expectancy seemed to be an influential factor in the adoption of AR technology. Effort expectancy has a link with facilitating conditions in that where the conditions are not favourable, more effort is needed, e.g. in terms of availability of necessary knowledge about technology use and how to learn about it. Prior knowledge and training courses can reduce the effort needed for the use of new technology and gaining its benefits. However, as noted above, teachers reported in this study's data that Saudi teachers' accessible information on the IEN site is only an illustration video that explains how to use AR apps and not training in the full sense.

Hence that might be a source of need for some effort in that teachers had to seek training elsewhere (as a number said they did).

Moreover, the teachers discussed the ease of using augmented reality technology as a driver for using it. The AR users gave no evidence of AR apps' complexity either of those provided by the MoE or those available on App and Play stores, except for some teachers who did not know the English language. Since the available apps for Saudi schools are ready to be used by any user with a low technological skills level as some users reported, some teachers who are not using this technology must be doing so for other reasons (e.g. those covered earlier such as under-estimation of own knowledge, perceived time involved, lack of devices, infrastructure etc.).

Ease of Use

This key feature (Almaghlouth 2008) was stated by the majority of AR user teachers to be present, especially using the Ministry apps and with use of them through the display of content on screen via a projector. It may be noted however that they were thinking of teacher use in whole class mode, rather than individual (or group) use by students, which might be expected to involve considerably more effort due to many more devices being involved. However, non-user teachers provided a contradictory view that handling and arrangement of AR technology would require a huge time investment that was equated by them with effort.

The literature takes the view that AR techniques assist in saving effort (and time) due to being easily usable (Alahmari 2018; Alahmari 2019; Ingrassia *et al.* 2020). The finding of the current research however is that in the Saudi context there are some aspects of AR use that are easy and some hard, and this would depend on the particular school and teacher. In use, the software may be simple to use in itself, since as one teacher said, he just has to point the device at the code in the textbook, but the arrangements surrounding its use may involve extra effort, such as a resource room having to be booked, and a projector set up with a possible missing cable to be sourced.

Ease of Learning

In relation to ease of learning to use the technology (highlighted for example by Davis *et al.* 1989), AR users generally regarded it as easy and non-user teachers mainly indicated the need for training in AR technology to facilitate integration into the classroom environment. However, a few from the non-user group also highlighted that You-Tube-based tutorials are easily available for learning AR technology and removing obstacles in implementing this technology within the learning environment. Hence even most non-users were not put off by difficulty of learning but rather by other factors that have been mentioned. The literature in fact also adds that training in AR is offered by the Ministry of Education for teachers (Al-Ahmadi 2019), but as mentioned previously, the teachers in the present study did not find that to be the case. In any case, learning how to use the technology becomes easy with many platforms that offer multiple visual explanations like YouTube. However, some of those platforms did not focus on the use of technology in the education field. Training courses and workshops that support teachers in understanding the technology's feasibility and the right way to implement it are still needed for some teachers in Saudi schools. However, it must be admitted that no training course can overcome obstacles to AR learning and use that come simply from lack of resources or infrastructure, which seem to be more prominent issues.

7.1.4 The impact of Social Influence on the acceptance and use of AR technology

Social influence is defined as the degree to which an individual perceives that important people in his surrounding (such as, peers and subordinates) believe that he should use the new system (Venkatesh et al., 2003). This study found that the teacher in Saudi schools is often motivated by his or her colleagues, school principal, students, and supervisor to use a new technology or method in his or her teaching practices. In addition, the influence of others can play a main role in adopting AR technology because the new teacher imitates expert teachers and there are some social norms that impact on teacher behaviour in the school such as avoiding criticism and adverse comments, competition, looking for distinction and job satisfaction, which be motivational factors to change teaching habits. Venkatesh et al. (2003) also observed that the relationship between social influence and behavioural intention to use a new technology is strong.

Colleague Influence, School Principal and Supervisor Influence

Consistent with the Diffusion of Innovation theory (Rogers 1995), it was suggested in the findings that in Saudi schools, new AR non-user teachers mainly get influenced through colleagues, specifically expert teachers, by looking at their way of using AR technology and other methods.Further, it is clear that by visiting the resource room and having assistance from expert teachers, non-user teachers get encouraged to use AR technology for teaching purposes. Moreover, it was reported that females are majorly influenced and encouraged by colleagues, and they significantly get enthusiastic for using technology-based device solutions to mitigate teaching-oriented problems. Further, both male and female users discussed that the principal of the school has a critical role specifically in providing encouragement to teachers to use AR techniques by raising their awareness about benefits of this technology and guiding them to useful courses.

The school principal can encourage teachers to use AR technology because his position allows him to direct teachers to apply new methods. As was predicted in 3.1.7, following Al-Ghatani et al. (2007), in cultures such as the KSA characterized by a strong 'power distance' dimension, such social influence can be powerful. Correspondingly, lack of the school principal’s motivation to implement new technologies can reflect on teachers' attitude since they will then not be excited to use it. Some teachers have a desire to try a new method to improve their practices, but they may be unable do that without the actual support of the school principal who is responsible for materials provision and who has the experience to support new teachers. AR users affirmed that they had been guided by the head of school to apply AR and other technologies and they received support on some issues related to using technologies. The successful implementation of AR technology depends on the school principal's collaboration with teachers in terms of encouragement, support to overcome difficulties, and providing resources. In the Saudi school the principal represents the Education Department, so consequently he has a significant role to promote officially approved new technologies such as AR in school.

In addition, expert teachers have a key role in directing new teachers to use AR technology because a new teacher usually tries to imitate the experts in their professional practices. Due to lack of dedicated teacher training for teaching in Saudi schools, the new teacher tries to observe expert teachers in his school in order to do what they do in terms of how they explain topics, what resources they use in teaching and which methods they use. If the school environment supports the use of AR technology, he likely will use this technology.

In addition, some teachers may be sensitive toward others' comments, and they would try to avoid whatever causes these comments if it involved criticism. A teacher illustrated this when he reported being criticised by colleagues for using AR. Such negative comments may dampen some teachers' enthusiasm to adopt AR technology and other new methods. On the other hand, encouragement phrases could motivate some teachers to apply the technology and continue to use it. Some teachers praised the role of their colleagues in encouraging them to use AR technology in their teaching.

The supervisor can also influence the teacher's determination to use AR technology, by visiting the teacher and evaluating his performance and advising him to implement new strategies involving the use of technology. Similar to the principal, the supervisor has a position of authority that allows him to urge the teacher to apply the technology. Also, he has the experience to guide the teacher in improving teaching practices. AR users in this study indicated the supervisor as one of the important people who directs them to use AR technology and even some nonusers appreciated the supervisor's role in improving their practices. This role can be developed to be more influential when the supervisor increases his visits to the school and participates in the technology implementation which allows him to provide some explanation to the teacher.

Student Influence

The majority of participants considered the students' influence to be the most important factor that determines the use of AR and other technologies in the school. The teacher knows that the student is the beneficiary of the explanation and teaching process, so he will do his best to deliver content. Students also can show their evaluation of the teaching process through their reactions within the lesson. They can accept the teaching method by paying attention to the explanation, interacting with content offered, and discussing. AR users found that teaching with AR apps attracted their students' attention and enhanced their learning which was a reason to continue to use this technology. It is also evident from the literature that technology provides educators with the opportunity to individualise the curriculum and customise it to be desirable by individual students to achieve their learning potential. The student's engagement in their studies is also observed to be enhanced by integrating the latest technology in the studies (Shapley *et al.* 2011). Therefore, students are observed to be the primary focus of using such tools in the classroom, and if they find it effective, tools like AR must be used extensively.

Overall, these findings on social influence echo those of previous studies of social influence in general. They show that the AR user's perception defines their subjective norm that prominent social referents feel he would or would not perform a certain behaviour (Ajzen and Fishbein, 1980). Some teachers are not ready to use new technologies in the school, but might be influenced if the school principal were to encourage them (which was not always the case in the present study data). Often, the teacher wants to comply with the school principal's instructions and satisfy his students' desire to learn by modern technologies so he will apply the technology even he does not prefer this technology, as explained in Shapley *et al.* (2011) study which indicated that if system users believe that people who are important to them will recommend them to use it, then they will use it. When the teacher receives encouragement from his school principal, he will feel a heightened sense of motivation to apply AR technology in his teaching actions (Salleh and Laxman 2014).

Regarding social influence, it is to be seen that many higher education institutions and universities across the globe have increasingly implemented information and communication technology-related tools for curriculum development, teaching and learning and administrative activities. This applies also in schools. To ensure that these technologies are optimally considered for improvising learning potentials of individuals, it is vital to ensure that teachers willingly accept new technologies. This willingness is considerably influenced and determined by attitudes, beliefs, perspectives, and behavioural tendencies of people around them in the school environment (Sharma and Srivastava 2019). Thus, it is argued that to motivate teachers to accept AR technology as a means of strengthening their efficacy and academic performance, it is important to nurture and manage the school settings' positive environment. MoE should inform other people in the schools, including staff members of different departments, about AR's worth. This will help guarantee collaborative work towards AR adoption in the Saudi education sector.

7.1.5 The influence of Resistance of Change on the acceptance and use of AR technology

Resistance to change was an additional factor picked up especially from the Saudi literature. As indicated at the end of 6.4, however, its actual presence in the data became more and more questionable as the study proceeded. It was defined for this study in chapter 3 as a personality trait construct with a cultural dimension involving a person's fixed belief against applying a new method that will change the work setting (e.g. Saksvik and Hetland 2009). A person with this trait then more likely reacts against any change just because it is a change, not motivated by beliefs about UTAUT considerations in its favour or against. Bingimlas (2009) further explained that such resistance to change significantly impedes the effective application of technology in the classroom because applying new technology implies changes in the teaching settings and this will elicit various reactions from the teachers.

In fact, however, the analysis reflected in the categories used in 6.4, which was considerably influenced by that of (Alfarani 2016; Alkhattabi 2017), included a range of reasons given by teachers for non-adoption other than just that they did not welcome change itself or were afraid of it. This therefore raises the question whether these really are instances of RTC or of factors that fall under UTAUT categories which were considered separately. With hindsight, during the qualitative analysis, it would have been better to look directly at the defining features of the construct rather than at the aspects highlighted by the Saudi source studies that were relied on, which muddied the distinction between unwillingness to change due to RTC as a personality trait and unwillingness to change due to negative beliefs that fall under UTAUT categories like performance expectancy or facilitating/inhibiting factors.

On reflection, however, there are two interpretations of such data, but it is hard to be sure which is the correct one. One may take as an example NU4 saying they did not use AR because of the habit of students of chatting with phones instead of using them for the learning task (6.4.3).

On one interpretation the teacher has given a perfectly reasonable explanation for their non-use of AR and this is simply a negative instance of Performance expectancy: the teacher (rightly or wrongly) sees traditional teaching as more effective than AR in holding the students' attention on task. Hence this should really be in the discussion of PE and not RTC. If this line were followed, most of the RTC examples in 6.4 would in fact disappear and be dealt with either as negative examples of PE (those claiming students will actually be distracted by the devices or misuse them rather than learn better) or as negative Facilitating conditions (e.g. teacher lack of familiarity, Ministry device bans and class size).

On the other hand, it is also possible to argue that NU4 does indeed have a personality trait of resisting change and for that reason has not used AR. This for example seems to be the stance of Kocaleva et al. (2014). However, the teacher realises that they may appear to the researcher somewhat inadequate unless they offer a better reason, since the researcher has asked them why they are a non-user. Also perhaps they think what they say may filter back to the Ministry and they had better offer some sort of reason other than 'I just don't like change'. Therefore, they offer the reason that students will be distracted and off task (putting the blame on the students not self or the authorities). In other words, this is not their actual *reason* for non-use, or perhaps only a part of it, but instead what would be better called an *excuse*. Again, this interpretation could be made of most of the examples in 6.4 and, if accepted, would mean that they all are indeed examples of RTC as it was defined in this study.

Unfortunately this researcher was unable to find any way of determining which of those interpretations is correct in any instance though with hindsight this issue could have been addressed by using an objective measure of RTC (Oreg 2003). Therefore, in the discussion of the RTC reasons/excuses below it must be borne in mind that the findings reported in 6.4 have a somewhat ambiguous status. It was quite difficult to find any examples in the data of an unambiguous resistance to change factor, in the narrow sense in which it has to be defined if it is not to overlap other categories in the UTAUT that affect acceptance. Those instances that came closest were where a teacher who was an AR user reported on other, non-user, teachers rather than themself (6.4.1). This indicates that it is widely believed that in Saudi schools, resistance to change is an influential factor in the teacher's decision to use the technology.

The present study then found that there were usually some rational reasons, or excuses, for lack of adoption of AR by non-user teachers in Saudi schools, which might indeed challenge whether adoption was in fact always appropriate. Some of them are related to the teachers and their ability, and some are related to the behavior of students or the rules regarding the use of technology by students.

It was inferred that the main reason for non-acceptance of AR technology involved preference for traditional teaching methods, but it is hard to find teachers saying this without an ostensibly good supporting reason. Students' intention of misusing the technology was for example cited by both user and non-user groups. Teachers' reasons, or perhaps excuses for non-use also included that there was no permission by the MoE for students to use their own tablets or phones in class, although such use would greatly facilitate individualized use of AR in class. This is perhaps more resistance to change on the part of the Ministry than by the teachers. Students' distraction and off task use of devices was also seen as a considerable reason, or excuse, for non-acceptance of AR technology within classroom learning. The literature also shows that using modern devices can lead to students being distracted and not paying proper attention to the taught content. For this reason, it has also been stated in other studies that teachers do not accept integrating modern technology into teaching practices (Goundar 2014).

Participants also indicated that there were fellow teachers (not in the sample) who did not use technology at all, either for teaching or personal purposes and other teachers who were not ready to learn and apply new teaching methods due to their unwillingness to change. These would be more unambiguous cases of RTC, but, perhaps because of that, such teachers may not have volunteered to be interviewed.

Teachers with technology illiteracy and unwillingness to learn can certainly hamper the adoption of AR and other technologies. This type of non-acceptance needs to be investigated further to discover the precise causes and work on finding solutions so as to more fully implement AR technology in the classroom. It remains unclear in the Saudi context, however, how far non-user teachers may have had low AR knowledge and familiarity due to unwillingness to learn (i.e. genuine RTC) or due to the authorities not supplying enough relevant training (Facilitating conditions). Almaghlouth (2008) found that even though some science teachers recognized the value of new technologies in teaching, they would not be ready to use them if they did not receive adequate support. To change this behaviour, the Ministry of Education should intervene by offering professional development programs (cf. 6.1.2) that help teachers move away from using conventional practices toward implementing modern technologies like AR apps in their teaching methods. As Alshumaimeri (2008) suggests, increasing training courses can change teachers’ negative attitude toward using technology and enhance their confidence to integrate technology (see further the implications in ch8).

The misuse of devices by students that some teachers implied as reasons, or excuses, for not adopting AR fell into two main types: damage to the device and use of it for inappropriate purposes. Some teachers avoid using the resources room or bringing devices into the class in some schools because they worry about devices' damage and misuse by students. For example, some teachers indicated that students can damage devices or use smartphones to photograph their teacher or colleagues and post their pictures on social platforms. Those aspects may lead teachers to avoid using devices in the classroom because they will not be ready to bear the responsibility for students' actions.

Alkahtani (2017) refers to the frequency of breakdowns of devices in Saudi schools that may be caused by students who tamper with equipment when the teacher is not looking. In this case, he suggested that the MoE should plan to maintain the damaged devices and provide insurance to cover all damage to encourage the teacher to use the technology without fear of hardware damage. Some legislation related to student behaviour inside the school should be changed to support the safe use of devices and educate students about the cost and significance of devices.

Students sometimes also use the devices to infringe others’ privacy in school. Minor *et al.* (2013) state that students in secondary schools are often unaware of the outcomes of what they post and share on internet websites. Alfarani (2016) discusses cyberbullying as an example of the possible student misuse of devices in Saudi educational institutions, which is increased by widespread use of social platforms such as Twitter and Snap chat. However, the school policy should include specific guidelines to stop such misuse and determine each school member's responsibilities toward the use of equipment. Implementing such actions may reduce the risk of device misuse and encourage teachers to use devices in their classrooms.

The data also indicates that some teachers believe that using devices (i.e., smartphone and tablet) could distract students during the lesson time. For example, some students may pay their attention to the device screen for gaming or chatting with others instead of following the teacher explanation of lesson content. Students can also distract classmates by sharing some text or photo while he should pay attention to the content presented. Student distraction is recognised in the literature as one of the disadvantages of the use of tablet and smartphone in the classroom. Katz-Sidlow *et al.* (2012) assert that even though smartphone devices offer many advantages for users, there is the potential for these devices to distract the user in their work settings. When a student uses the device in the classroom for irrelevant activities, he will distract himself and his colleagues and affect class control, as some participants indicated when voicing their concerns about the use of devices by students. The use of devices inside the classroom can negatively influence the students' learning, and so involve negative performance expectancy (6.1.1), through them paying less attention to the content and undermining classroom discipline. According to Foerde *et al.* (2006), a student cannot learn new things when his mind is distracted by another activity. However, learning supported by smartphone or tablet is enjoyable and desirable and the audio and visual content is more effective in the lesson and enhances explanation content (Milrad and Spikol 2007). Teachers should develop their strategies to control the classroom and control the use of a tablet or smartphone in the class by encouraging students into beneficial use of devices. In addition, to overcome such challenges, teachers can draw student attention by applying didactic methods that enhance students' enthusiasm and attract their attention.

The above concerns with damage and misuse of devices by students, that led some non user teachers not to implement AR, can of course be removed by not giving students devices to run AR apps themselves: only the teacher does it and displays his screen to the whole class. In fact it was found that many of the AR users seemed to adopt that solution, which mixes new technology with quite a traditional approach to classroom teaching. The teachers who raised the damage and misuse issues therefore could be seen as in a sense not traditional, but more progressive than others, in that they understood AR use in class to ideally involve students or groups of students each having a device and using it independently with their textbook. On one interpretation then these teachers are keen to change rather than resistant, but hindered by negative facilitating conditions.

A related theme that was covered under the RTC main theme was the Ministry ban on students using their own devices in class, which interrelates with what has just been discussed. On the one hand it partly deals with the misuses already mentioned, but on the other hand it removes a resource that the teacher could exploit if they wish to use AR in individual student mode, so again was a reason mentioned for teacher non-use of AR since schools were not all reported as possessing sets of devices for students to use in class, or even a projector for the teacher to use in whole class mode. Therefore, in a sense, the Ministry that wants AR to be used is in part also a reason or excuse for teachers not using it.

The ban also fails to exploit the fact that the student, used to using smart devices outside the school, has a high technological skills level (Alshahrani and Al-Shehri 2012). Implementation of AR technology most successfully in the classroom requires allowing students themselves to scan and browse the content offered while the teacher directs them to explore the topic in detail. It is not practical for the teacher to pass his smartphone or tablet to all students in the lesson to use in turn, so the students need to use their personal tablets or smartphones or ones provided by the school. The Ministry decision to prevent students from carrying their personal devices to the classroom is prompted by a school culture that prioritizes teachers' and students' privacy and the fear of distraction above AR related pedagogical considerations.

7.1.6 The influence of Hedonic Motivation on the use of AR technology

Hedonic motivation is defined as the fun or pleasure derived from using a technology. It has been shown to play an important role in determining technology acceptance and use (Brown and Venkatesh 2005). Perceived enjoyment and pleasure aspects from using AR technology can influence AR technology acceptance and use directly and indirectly.

Our study differs from many in the literature, e.g. those considering the introduction of new technology in business workplaces like Al-Ghatani et al. (2007), in that in educational settings there are two kinds of people centrally involved - teachers and students - not one. The data indicated that teachers (our prime focus) in fact paid more attention to student HM than their own. Some AR user teachers agreed that AR-supported teaching fosters teacher happiness because it increases enjoyment among students while they learn new things. However many emphasised what appealed to the students, such as AR's novelty and modernity, and valued their enjoyment for its learning benefits (i.e. for the teachers this is PE rather than HM).

The AR user group of teachers showed more appreciation of student hedonic motivation than the non-user group by expressing the benefit of AR apps in bringing both enjoyment and learning to students in the same instant, in contrast with the traditional method. Participants offered some examples of pleasurable aspects when AR apps were used in the classroom such as breaking lesson routine, creating a dynamic atmosphere and a feeling of amazement among students.

AR apps provide some virtual objects that interact together to show a visual scene. Offering content elements through those objects attracts students to follow the moving elements and enjoy the scenario. In science teaching, some content needs to be presented in detail, which can be boring for both the teacher and students when oral explanation is used. Instead of using the traditional method, using AR apps can present this content in a more attractive and enjoyable way. Juan *et al.* (2010) found that students who play AR games found them enjoyable and wanted to play AR games again.

Further, novelty and modernity are two other motivating features of AR technology which attract students and hence make teachers motivated to use it. This was indicated by the user and some non-user participants who indicated that they adopted this technology because of its hedonic motivation of the students. These findings are consistent with previous studies (Alalwan *et al.* 2017; Herrero and San Martín 2017). It can be inferred that if the teacher finds AR technology features enjoyable and attractive to students, their performance expectancy becomes more positive and the possibility for them to accept and use AR apps is greater.

7.1.7 The influence of Price Value on the acceptance and use of AR technology

The price-value construct (Venkatash *et al*. 2012) is defined as the user understanding of a trade-off between the system's perceived benefits and the monetary (or effort) cost paid for adopting the system. It had been found the most internationally recognised UTAUT factor by Mehta (2018). If the benefits of applying the technology are perceived to be more than the costs, the teacher is more likely to accept this technology.

While it had been expected that the price or cost that teachers perceived would be one of effort rather than money, since teachers are not typically expected to pay for hardware and software needed to do their work, in fact it turned out to be one of money. Both AR non-user and user teachers described the issue of financial costs linked to the use of advanced technology like AR in the learning environment. Teacher expenditure was in practice needed either to hasten the introduction of AR or to improve its quality, and some teachers thought it worthwhile to spend their own money while others did not.

In Saudi schools, the availability of MoE AR apps for free was appreciated by teachers. These AR apps used the Arabic language and were linked to the prescribed textbook and designed to cover topics in the science curricula, so they represented good value for no money from the teacher's viewpoint. That helped teachers use those apps effectively and gain their benefits. The findings revealed that free applications act as one of the major factors that play a significant role in the teachers' decision to accept and use AR. As described in 6.1.1, and in agreement with the literature, the value of AR apps in education comes through bringing increased student participation in the class. They provide the students with effective learning models which result in a better level of student understanding. The more the students understand, the more they have better knowledge about the topic, and that directly has a positive impact on their participation. These apps help the students grasp ideas in a better and faster manner by providing models (Radu 2014). Therefore, free apps played a major role in the selection of AR by the teachers in the classroom.

However, the apps' availability is not sufficient for perfectly applying AR technology, since there is a need for availability of related resources on site where they are used, such as display devices, some accessories and an appropriate classroom. There were reports that these were not always available which is remarkable given the initiatives described in chapter 2 such as the Tatweer project (set up by King Abdullah’s Public Education Development) which spent a huge sum to provide schools with ICT equipment. Nevertheless, trying to order hardware or book suitable rooms through the school could involve a long wait and was not always successful. Some teachers overcame some of these problems by buying and using their own devices, projectors, cables etc. to accomplish their work, and enable them to run AR technology in the classroom straight away. For them the price was worth it for the immediate value received. Others could not or would not do that. The MoE should consider this matter because it can hinder or delay the adoption of AR and other new technology in the future.

The second call on teacher expenditure came from some teachers' views that the free MoE apps are not designed to cover all the content in the science curriculum, and that there are some better apps available on the market than those of the MoE. This led some teachers to search for more valuable apps that could support their teaching. Those apps are however usually not free, and some required paid subscriptions for a month or year. These costs clearly may hinder the use of AR technology as participants clarify. Not all teachers saw the improved value of more and better apps as worth the cost to their own pockets.

AR non-users mostly seemed unwilling to pay additional fees for implementing the technology because they believed that this was the MoE's responsibility. Some of them had tried to apply technology in their practices but felt the cost of providing the required devices was unaffordable. There is a direct relationship between price-value and facilitating conditions in terms of availability of resources that can decrease the potential teacher costs and vice versa. For example, the potential teacher costs may be increased in some schools in the countryside due to lack of infrastructure such as spacious buildings, reliable internet, and required hardware and equipment availability. It is clear that there are various kinds of hidden teacher costs in learning by the help of technology and these are divided into technology infrastructure, administrative applications, and academic applications (Stanley 2013). Thus, this factor can hinder the users and prohibit non-users from adopting AR tools while teaching.

7.1.8 Habit not mentioned as an influential factor

The effect of this was not mentioned by participants. This indicates its absence in a more dramatic way than quantitative questionnaire based studies such as Venkatash et al. (2012) where it would be virtually unknown for any variable to obtain an average report of zero. Furthermore its absence is notable as it had been reported as operative in contexts as disparate as the UK and Gambia by Mehta (2018).

It concerns whether how far a teacher uses AR habitually, and so automatically, influences their continued acceptance or use of it. Unlike most of the main factor themes it is a feature only of more recent models such as UTAUT2 and perhaps that indicates its minor status. The expectation associated with it is that while all the main factors that have been considered are expected to influence initial acceptance or intention to use a certain technology, after use starts, the effects of all those factors through intention gets altered as the force of habit increases through use.

There are several possible reasons for its absence. First, some studies have found that habit does not really play the role of a main factor affecting intention to use new technology, as in UTAUT2, but rather is "a moderating variable of the relationship between intentions and .... continuance behavior, which may put a boundary condition on the explanatory power of intentions in the context of continued IS usage" (Limayem *et al.* 2007 p705). In these interviews any moderating role of a variable has quite a small chance of appearing explicitly in contrast with a role as a main causal factor affecting intention and use.

Second, existing studies of habit generally do not target acceptance of some very specific application such as AR but of broader technological innovations (e.g. use of the internet in general in Limayem *et al.* 2007). Yet clearly habit, in the sense it is used in this study (3.1.6) of the extent to which the teacher believes the use of some technology has or would become a habit for him/her, has more of a chance to build up and become an important influence when the technology is a general application of wide utility. Possibly it is less relevant to a highly specific innovation like AR.

Third, obviously doing something as a habit relates to the construct of experience which in turn is related to for how long and how often the target behaviour (in the present case AR app use) has occurred and so become a habit for the teacher. Although eight users (n=8) reported that they use AR apps weekly, and five users use it monthly, they did not consider this as itself generating habit as a factor. They were not in fact asked for how long they had used AR but the use of AR apps in Saudi schools is still in the initial stages as affirmed by Alkhattabi's (2017) study conducted in Saudi primary schools. The initiative to put AR into schools only began in September 2018 and the interviews took place in February 2020 so the maximum time that any teacher was using AR was probably only 2 terms.

The absence of habit effect could then perhaps be due to the fact that the period of longest use was probably not more than a year and was not high frequency. The available MoE apps were designed to cover some topics, not all topics in the science syllabus. The science teacher in secondary school often has one lesson per week, which does not every time require using AR apps, or the topic is may not be available on the app. Therefore it is perhaps not surprising that no teachers claimed that they used AR simply because it was more or less automatic now for them to use it.

7.2 Inter-related effects of the influential factors

In the models from which the study drew its initial inspiration, the factors affecting intention to use new technology always appear as a list on the left with arrows going to behavioral intention or use, but not to each other. This is apparent in the diagrams of the UTAUT and UTAUT2 in figures 6, 7 and 8. However, from the previous discussion, it is worth noticing that some of the factors influencing AR acceptance and/or use are talked about as inter-related in their effects. This is something rarely highlighted, although Mehta (2018) notably does so, and the present study found several instances.

For example, performance expectancy can affect use of AR. Other things being equal, if a teacher thinks AR will improve student learning, he/she will use it. However, other things often are not equal. If the teacher has (or thinks he/she has) the necessary equipment to apply AR technology, as well as positive performance expectancy, they likely will use it and gain its benefits. On the other hand, if (he/she believes) the resources are not available in school for the teacher, so they cannot use AR technology, then even with high positive performance expectancy they will not use it. Thus the effect of PE on intention to use is not the same in facilitating conditions with different amounts of resource facilitation. The availability of resources in school allows the teacher to use the technology, and it supports the school principal's position when he/she urges teachers to apply it. The teachers however cannot try and use the technology that is not supported in their setting. This is largely what distinguished some AR users from non-users.

Performance expectancy also has a connection with the effect of the price-value factor. The price-value factor has an effect on AR use that depends on whether the value of something related to AR is greater or less than its price/cost. Here the price may be fixed (e.g. the cost to purchase a certain app on the internet), but the value is more subjective and may depend largely on a teacher's PE for the app (and indeed perhaps the effort expectancy he/she has for using it, the hedonic motivation he/she thinks it will generate in students, etc.). Thus one teacher may rate the app of low value so the price seems relatively high and he/she does not buy and use it. Another may rate the app high in value and so buy and use it. For example, some teachers reported that they paid to purchase some devices and accessories to run AR technology for their students. Although the equipment's provision is not their responsibility, those teachers were driven by the perceived usefulness of AR technology in their teaching practices. Features of AR technology led them to overcome the costs of devices to complete their teaching. Interestingly Mehta (2018) also identifies a connection between PV and PE (op. cit. table 14) but conceptualises it the other way round, that PV affects PE rather than the reverse.

Effort expectancy also has a connection with price-value if price is interpreted as a cost in effort rather than money. The teacher may use AR technology due to its effortlessness compared with other technologies and traditional methods: its value exceeds the effort needed. For example, when the teacher perceives that AR apps are easy to use and learn compared with other technologies, he/she will adopt them. The teacher is looking for valuable technology with less effort because he has a heavy workload and is unwilling to apply technology that requires more preparation: in that case the cost in effort exceeds the value. Thus the price-value factor has an effect on acceptance and use that is not the same for different amounts of effort or value involved.

Effort expectancy also has a link with the facilitating condition of availability of necessary knowledge about technology use. Prior knowledge and training courses can accelerate the use of new technology and the procurement of its benefits. However, Saudi teachers' accessible knowledge for the MoE apps is only an illustration video on the IEN portal that explains how to use AR apps, as teachers reported in this data. If teachers' expectancy of the effort of using AR is low, then that amount of information may be enough and he will try using it. However for many teachers the effort expectancy may be higher, so that amount of information will not be enough to trigger attempted use. Those who introduce new technologies need to provide the user with an appropriate amount of information about using it to suit his/her effort expectancy level, if they are to accept and use it.

Finally, there is a connection between the facilitating condition of training and resistance to change. RTC may be associated with lack of knowledge of technology such as AR, and this results in lack of acceptance and use of AR. If, however, teachers join training courses to change their level of knowledge about technology, their RTC may be be reduced and they may be willing to try using AR. Awareness and knowledge are essential for applying a new teaching method, so teachers’ perspectives can be developed when they receive adequate information about the technology and its use in teaching. Advanced training courses can convince teachers to move from using traditional methods to applying new technologies like AR in their teaching, as Alshumaimeri (2008) suggested.

Overall these connections seem important to pursue in future studies, especially since those that seemed prominent in this study's data are mostly different from those that emerged in Mehta (2018), such as SI-PE and HM-PE.

7.3 Gender differences in relation to acceptance and use of AR technology

While the data allowed the researcher to explore the main factors affecting AR acceptance and use quite extensively, including those of the UTAUT2 model, it was not extensive enough to enable him to explore all the moderator variables in the model (Figure 8), except gender. When examining the findings of the interview sample, it was noticed that 16 were users of AR technology and only 9 were non-users, and within that, females predominated in the AR users compared with males, while the gender split was near 50% in the non-users of this technology. In the original large sample that was obtained, which is more representative of the population, 33% of AR users were female and only 19% of non users were female, so again females appear to be more likely to accept AR than males. This is consistent with the literature which shows that female primary school teachers in Saudi Arabia have a higher level of confidence than males with regard to their knowledge and familiarity concerning AR and its application (Alkhattabi 2017). The findings of Alkhattabi (2017) further reveal that 80% of the surveyed female primary teachers highlighted the desire to use AR applications in the classroom in comparison to 76.4% of the male teachers. These finding then also suggest the higher possibility of acceptance by females of the use of AR tools and applications in Saudi Arabian schools. The international literature by contrast does not routinely show gender effects (Venkatash *et al.,* 2012).

In the qualitative data, females were also as vocal as males. This is consistent with Alabbasi (2017) who reveals that the voices of Saudi females are salient in public discussions and they speak confidently and openly in online forums where women and men have equal participation. Saudi women also have their own separate blogs and have the liberty to express their perspectives and opinions on Facebook, Twitter, etc. Access to internet has given an opportunity to them to expose the lives and experiences of other women and men on the virtual platform. This has helped in creating a significant impact on their attitudes and perspectives, which has increased the opportunity for Saudi Arabian women to gain technological knowledge (Alabbasi 2017).
Although the sample was small for a clear judgment to be made, in most areas the views of males and females about factors affecting AR acceptance and use appeared similar. There were however two interpersonal features that seemed to differentiate the genders.

First, all the reports of misuse of devices as an issue came from male teachers, suggesting that female students are more well behaved in this respect. This could be culturally based, since in Saudi Arabia the issue of personal images being captured and disseminated is a concern of females more than males and therefore females might be more sensitive and not engage in this kind of invasion of each others' privacy. On the other hand, it could be interpreted as showing that female teachers tended more than males to use AR in full class teacher centred mode, so for that reason the students had no devices, and this issue could not arise in class.

Second, female teachers seemed to report peer criticism as an issue more than male teachers did. This is not immediately easy to explain and pertinent literature on this issue is hard to find. Still it does accord with some general evidence that women are more critical of other women than men are of men, although the research is mainly in the area of criticism of dress or sexual habits rather than of teaching methods (Meyers 2013). This needs further investigation.

7.4 AR technology in online learning environments

Given the events that overtook the world shortly after my data gathering was completed, it is worth commenting on the use of AR technology in Saudi schools to serve in online learning environments. During the Covid19 pandemic, the MoE has assisted all educational institutions to move to online learning to help deal with this situation. The Madrasati platform (meaning 'my school' in English) was established to manage education procedures and deliver content for students remotely. The MoE announced that AR apps uploaded on the IEN portal were also to be used by both teachers and students to cover some topics during the pandemic.

In this study, some expert teachers recommended developing AR apps design to fit with distance learning to allow students to browse the content and review it in their homes. Some issues raised were related to enabling content to be worked on off-line, increasing the number of topics covered, improving the interaction capability and scenarios of the apps. They also indicated that the server stops working sometimes.

7.5 Conclusion

This chapter has discussed the findings of the previous chapter with respect to the research question concerning teacher beliefs about the factors affecting AR acceptance and use. In sum, the present work adds significantly to the small body of work on AR and/or application of UTAUT in the KSA while it is substantially in line with parallel work internationally, albeit adding some subthemes that are perhaps peculiar to the Saudi context.

In particular the study demonstrates that the UTAUT2 model is relevant in the KSA context. Further it indicates some limitations in the concept of RTC as implemented in Alfarani (2016) and Alkhattabi (2017) where it was dealt with in ways that muddied rather than clarified its distinctiveness from other UTAUT factors, pointing to the need for further work on that in the KSA context and perhaps internationally. With respect to AR it much more richly characterises the considerations that influence teachers than any other study so far in the KSA, including pointing up valuable lessons for stakeholders that will be covered in the final chapter.

In terms of international comparisons, the study confirms the value of UTAUT2 in educational studies as well as business ones. It points to the potential need to add RTC to the list of UTAUT2 factors, but more pressingly to elaborate the UTAUT model into one that models not only predictors and response variables with moderator variables, but also represents how some predictors mediate between others in their influence on dependents. With respect to factors reported as affecting AR in secondary school teachng, much of what was found appears to be universal (e.g. most PE, EE and MH considerations). Factors like game-like appeal, the learning benefit of visual images and ease of use seem to be appreciated the world over. Where potentially context specific factors most occurred were in the realms of SI and FC and RTC, including the ways in which schools support (or fail to support) AR, the role of school and Ministry policies on use of own devices and supply of AR apps, and the local need for Arabization of apps.

8. Chapter eight: Implications and Conclusion

8.1 Research Summary

AR technology has been available for science teaching in Saudi schools since September 2018, when the MoE created the IEN portal and uploaded the specially designed apps to be used by its teachers along with providing new textbooks containing the barcodes needed to trigger the operation of the apps. According to the study findings, the available MoE apps were for specific topics in the textbooks for courses in science, chemistry, biology, math and physics, for the three grades in male and female secondary schools. They reside in the IEN portal (a special website for some educational programs, established by MoE, and also on the Apple App Store, and Google Play Store) and the download process is not hard for the user. However, the apps provided did not cover all the topics in the textbooks, as the teachers in this study stated.

The resources required to use those apps were a smart mobile or tablet (equipped with a camera), and an internet connection. To present the content for students, either each student should have a tablet or smartphone, or the classroom should be provided with a large screen and a projector, or an interactive whiteboard with necessary accessories, for the teacher to display his/her device screen to the whole class. The use of the AR apps varies between Saudi schools in terms of teachers' awareness of the technology and its benefits, availability of supportive devices and internet network, and institutional encouragement and support. Participants in this study indicated that the use of AR technology in Saudi schools is still beginning. The MoE should revise the applications to develop it. Some of the users criticised the interaction and movement scenario features in the available applications. Compared with other apps available from Apple and Google stores, users felt the MoE apps were inferior in quality.

This thesis aimed to investigate Saudi science teachers' acceptance and use (or non-use) of AR technology in their teaching practices. The most substantial issue was the factors that teachers say influence their decision to accept and adopt this technology inside the classroom. The qualitative data came from interviewing 25 teachers based on the same theoretical framework (UTAUT2) constructs with an additional factor derived from the Saudi context literature. The interview data was gathered in the Arabic language and transcribed then translated to the English language by a freelance translator. It was analysed thematically and coded using Nvivo software 12.6.

8.2 Answers to the research question

The main research question is: What considerations do science teachers report as influencing their decision to accept and/or use AR technology in their teaching practices? The study found that seven broad factors can drive teachers' intention to use AR technology in the classroom: performance expectancy was the most mentioned, together with facilitating conditions, social influence, resistance to change (debatably), effort expectancy, hedonic motivation (including of students), and price value. The proposed model of this study also included Habit, which was not mentioned in the participants' responses. Thus, insofar as it was possible to determine without quantitative data and statistical analysis, the UTAUT2 model (Figure 8) was supported as relevant in the Saudi context of the present study, with one only recently added factor (Habit) not represented, and an additional one (Resistance to change) ambiguously supported. Thus, as is often found in social science research, one cannot simply say that the positivist model is competely confirmed, but rather it may take slightly different forms in different contexts, as in a constructivist perspective.

Possibly the most important modification to the model suggested by the data was that there were some reported interrelated effects of the UTAUT main factors on intention to use and actual use which do not form part of the model at present. Whatever main factors are included in versions of the UTAUT or UTAUT2, they are nearly always represented as a set of alternative factors on the left side of a diagram with lines going towards intention to use or actual use on the right. Additional moderating variables may be included but that is not same as representing inter-relations among the four or seven main factors themselves. A rare example that does this is Mehta (2018).

Yet the qualitative data of the present study suggested such inter-related effects exist. In particular interviewees showed that they had a sensitive understanding of performance effectiveness not just as determined by what learning value they believed the students would get out of AR due to what the app does, but other factors as well.

For example their judgment of the effectiveness of AR seems to be additionally conditioned by how good they think the supporting conditions are for its use in their school (FC) and how much they thought the students would find it fun (HM). Thus PE can be seen as, in part, not just another factor in the main factor set on the left of the model diagram but as a variable that mediates between FC and HM and intention to use.

The next sections summarise the answer to the research question in more detail: Considerations influencing teachers' decision to use AR technology.

8.2.1 Performance expectancy

This factor has a widely mentioned effect on teachers' decision to use AR technology in the teaching process, almost always positive. It especially concerned the effectiveness of using AR technology in support of teaching practices—the benefits of using the technology were reported as directing the teacher's intention to apply AR technology in his teaching. The data indicated that using AR technology was perceived as improving teaching practices through producing better information retention, reducing content ambiguity, better student interaction with the content, improved stimulation and focused learning. The capacity of multimedia for diversification of content presentation for students was understood to be more effective. Performance expectancy also covered technology efficiency by facilitating teaching procedures with saving of time. Teaching with AR technology was mostly seen as helping teachers to accomplish their teaching quickly and complete more tasks during the lesson.

8.2.2 Facilitating conditions

This factor has many subparts with a significant influence on teachers' decision to use AR technology in their teaching, which was often reported as negative. Availability of necessary resources can lead the teacher to apply the technology successfully in his classroom while the lack of one of these resources can hinder the technology's adoption. Resources such as AR apps, display devices, internet and appropriate rooms were vital to implementing AR technology in the classroom. Provision of resources is not the responsibility of teachers, so if they had the intention to use the technology, some were prevented by lack of equipment. Furthermore, training and availability of knowledge were reported as key elements for use of the technology.

8.2.3 Social influence

The influence of people around teachers on their decision to use AR technology was reported as strong. Teachers can be excited to use AR technology when they receive appropriate encouragement from other staff in their surroundings. Teachers believed that expert teachers direct new teachers to apply new methods because the new teacher tends to imitate the expert in his professional practices due to lack of experience. Therefore, the role of expert teachers is influential in adoption of AR apps.

Enhancing expert teachers' motivation to adopt AR technology can lead to junior teachers adopting AR apps. The school principal can also encourage teachers to use AR technology and perhaps provide required support for them, which increases acceptance and use of AR among teachers. He also can assess the teacher's accomplishment and add performance evaluation scores in the teacher's record. Students also can have an effective role in encouraging the teacher to use the technology through their interaction with the content presented. Teachers usually aim to fulfil students' needs by applying effective teaching methods, which can lead them to use AR technology that helps the students more.

8.2.4 Resistance to change

This factor is assumed in some literature (though not in UTAUT2) to be one of the influential factors affecting the teacher's decision to adopt new technologies. This research did not unambiguously confirm the existence of this factor, which is a personality trait of teachers who simply do not wish to change. The preference for teaching with traditional methods can be a sign of resistance to change which can hinder the adoption of AR technology in Saudi schools. However, it was hard to find teachers in the present study who did not use AR and who did not report some rational reason for that, making it impossible to decide if these were instances of RTC with an excuse, or of other UTAUT factors and not RTC as it was defined in this study at all (e.g. the necessary devices were not available, the room had too much light for projecting, or the students would use the devices for purposes other than the science task). It remains uncertain how far providing teachers with training courses that educate them about the benefits of technology and its capabilities in teaching would resolve such issues. There were clearly teachers in the non-user group in the sample who had favourable performance expectancy attitudes to AR but did not use it for practical reasons such as lack of devices, so could hardly be said to be resistant to change.

8.2.5 Effort expectancy

This factor was also reported as affecting teacher intentions to adopt AR technology. In other words, the ease of use of the technology can lead the teacher to use it. Easy to use technology is acceptable among teachers rather than technology that needs more effort to handle it in the classroom. Teachers believed that MoE AR apps do not require losing time and effort to run them, so they appreciate that. Learning how to use AR apps is also not hard for teachers, which helps facilitate their application. In addition, the availability of illustration materials and tutorials on YouTube made learning the use of modern technologies easier than before.

8.2.6 Hedonic motivation

This factor concerned the entertainment aspects provided by AR technology in the classroom for both teacher and students which encourage the teacher to use it and continue to use it. Two mechanisms seemed to be in operation. First, the teacher might find AR entertaining him/herself, or enjoy using it simply because the students did (teacher HM). Second, teachers recognised that student enjoyment can change the lesson to be more exciting and increase students' enthusiasm to participate and discuss the content and so improve learning. AR apps involve a type of gaming and interactive objects that show the content in a delightful way and were also regarded as appealing to students due to novelty and modernity. Many teachers therefore approved of AR also because they believed student enjoyment increased performance expectancy.

8.2.7 Price Value

This concerns whether the cost of using the apps, in money or effort, is less than the perceived value of using them, and the effect of that on acceptance and use. Teachers mostly believed that the free MoE AR apps were valuable compared with traditional methods, and could enhance their teaching quality, especially given that they were available free. Indeed, some teachers found that some necessary equipment was not provided by the school and rather than wait for the school to obtain it they were prepared to pay for this themselves in order to obtain the value of these apps immediately. Still others believed that there were better apps available than those of the MoE and in order to enhance their teaching they spent their own money to buy them. When teachers believed in the benefit of technology, some were ready even to bear its costs that the school or MoE should be covering.

8.4 Implications of the research

This study has implications for the theoretical model that was used, for researchers in this field, and for many of the stakeholders in this kind of innovation in the Saudi context.

Implications for the model and researchers. This study contributes to the extant literature. It has unique aims and produced new findings in relation to the acceptance of a technology tool in the study setting (Saudi schools).

Regarding the research model, the framework used in this study supports the use of the Unified Theory of the Acceptance and Use of Technology (UTAUT2) in the technology acceptance field. This study proves the validity of using the UTAUT2 model in a different context like the Saudi context where there is a lack of similar studies. It confirmed the relevance of seven main factors, missing only one (habit) from the model, and added to the literature a new slightly extended model examined in a different context. The extended model involved an additional factor recommended to be considered in future work in developing countries.

The additional factor, Resistance to change (RTC), was derived from a few studies conducted in the local culture together with Kocaleva et al. (2014). It proved informative but also problematic to distinguish clearly from other UTAUT factors where negative beliefs could also result in lack of adoption. Indeed on closer examination it was apparent that the studies used as sources had not really engaged with the ambiguities uncovered in the present study but simply on the researchers' judgment certain data as evidencing RTC. Therefore it needs further work (see below). Although Venkatash et al. (2012) report high satisfaction with UTAUT2 and suggest that, explaining 74% of the variance in intention to use new technology, model building may be at the limit of what can be explained in this area, the present researcher feels there is always room for improvement.

Furthermore, a model is not just a list of relevant variables, it is a hypothesis about how they are related. As was sketched in the research summary above and the earlier Discussion, the present study also supports an elaborated version of UTAUT2 where, for example, PE would not just be a member of a list of factors affecting intention to use, but would be represented as a mediating variable between FC and student HM on the one hand and intention to use on the other (more in the tyle of Mehta, 2018).

By adopting the UTAUT2 model in the context of qualitative research, this study is one of the few studies that have adopted this approach. It demonstrates that it is possible to incorporate a top-down positivist element into qualitative research and may encourage other researchers in the field to try the same. What can be learned from the present study is the message that a qualitative study provides an opportunity for researchers to conduct more studies based on this theoretical framework. It also allows researchers to add and derive additional factors and relationships from their settings prompted by cultural contexts and differences.

The Saudi context differs from other contexts and there is a need for conducting more studies to investigate many social norms. The local culture intervenes in the form of some legislation that hinders technology integration (see MoE below). In this study, conservatism, in the form of resistance to change as a personality trait, may also have impacted on technology adoption. However the data was not unambiguous on this point and further research is needed to discover more clearly the implications of this factor for many aspects in the education field.

Applying a questionnaire to collect data in the Saudi context led to problems in the present case. Caution is therefore advised, and the questionnaire instrument may not be appropriate to collect the data, although previous studies very widely adopted the questionnaire and proved its validity. Nevertheless, from the experience of this study, use of a qualitative approach (i.e., interviews, focus group and broad open response questionnaires) is recommended in Saudi settings where there is lack of awareness of the importance of such research tools and data collection.

Implications for the MoE. This study was conducted after the formal introduction of AR technology into Saudi education, and it stands out as the first study that investigates high school teachers' perception regarding the acceptance and use of that technology. It demonstrates significant factors that influence technology adoption (see 7.2). It is notable that the same factors often influence both users and non-users. The findings of this study can help decision-makers to evaluate the use of AR technology and make appropriate decisions to develop this resource in the future. It can also help them to consider factors that drive teachers' intention to use AR apps.

The study especially provides the MoE with some suggestions by revealing the factors that teacher see as hindering the adoption of AR technology, and which are in the MoE's hands to remedy, such as lack of equipment and devices, lack of training, and poor infrastructure in schools. It is especially important to refer to the current training courses which still need to be improved to involve some courses about new technologies such as AR that support teaching and how to use and benefit from using these technologies. Knowing the technology is not sufficient to use it: the teacher wants to learn how to implement this technology effectively in his practices. Teachers indicated a lack of training courses that aim to show technologies' advantages and how to run these technologies in classrooms. As a participant commented: “There is a lack of communicating knowledge to educators and promoting technological programmes and how to deal with them. There is a large percentage of teachers who do not know about this technology.…There are not enough efforts in making it known to all. I know some modern technologies which I employ, but when I attend with my colleagues in the training courses, and this topic is discussed I have the impression that some have learnt about them for the first time”. Offering certain training courses can encourage teachers to apply new tools like AR technology in their practices and increase teachers’ awareness of advantages of modern technologies which may lead to increase their interesting to be kept updated in this sphere.

Most importantly, this study draws the decision-makers' attention to review some Ministry policies that prevent students from using their own devices inside the classroom. Learning has become dependent on using smart devices and students in this era have a high skills level on such devices. Yet that resource of devices and skill is wasted if the student is not allowed to use their device in class. In some cases it means that AR does not get implemented due to lack of devices, since the school does not have enough for a class. The possible the negative effects of students using their devices in class for other purposes can perhaps be handled by the use of the honor code system such as some schools use to deal with students taking exams at home rather than at school during the Covid crisis.

Implications for app designers. The study provides some suggestions to the designers of AR apps that need to be considered in the future. In particular the following aspects were raised in connection with the MoE apps. Poor interaction, lack of quality and weak scenarios in the available apps should be revised to enrich the AR technology experience.

Implications for school principals. In order to make sure that new technologies are optimally considered for improving the learning potentials of individuals, it is vital to ensure that teachers willingly accept new technologies that have been proved to be beneficial. The willingness of teachers to accept new technology is regarded by some as largely influenced and determined by attitudes, beliefs, perspectives, and behavioural tendencies of people around them in the school environment (Sharma and

Srivastava, 2019) and that was supported by some teacher comments in the present study.

Thus, it can be suggested that to motivate teachers to accept AR technology as a means of strengthening the academic performance of students. it is important to nurture and manage a positive environment in school settings. It is necessary to inform other people in the school, including staff members of different departments, about the worth of AR as this will help in guaranteeing collaborative work towards AR adoption in the Saudi education sector.

It is the school principal who has the role that can bring about the creation of this culture in the school and so should be the leader here. Indeed some teachers in this study commented on the value of the support they received from their principal. It just remains unfortunate that the principal was not always able to turn words into action in the form of actually obtaining needed equipment for the teacher.

8.5 Limitations

This research has several limitations as follows.

Clearly the main limitation is the lack of the quantitative data gathering that was planned, exacerbated by time limitations that prevented gathering more qualitative data of the amount and different types that would have been more ideal. The data collection plan involved mixed methods (quantitative and qualitative) data gathering to enrich the data. After some analysis of the quantitative data, it was found that many participants were still evidencing the behaviour found in the Pilot and giving an apparently unthinking uniform response over many items, despite efforts to prevent this by including blatantly negatively worded items. This led to a reluctant decision to reject the entire quantitative data. Lack of time did not allow for administering the questionnaire again with renewed efforts to overcome this problem, e.g. by attempting face to face rather than online delivery.

The cancellation of this part of the plan meant that the full burden of the study fell on the interview approach to answer the research questions. However, by this point much time had been taken up on the quantitative data so insufficient time was left to considerably expand the qualitative part, e.g. by involving more interviewees. The mixed-method approach that was planned would have supported the generalisation of results from the quantitative data. However the cancellation of the quantitative part of the plan meant that was lost. The number and mode of selection of the interview participants, although quite normal for qualitative interviews, was not such as would support generalisation of the findings to any wider population.

Furthermore, this meant that the assessment of the UTAUT2 theoretical framework was in the end only via qualitative data, not quantitative data. This approach is used in few studies and does not allow for measuring the relationships between variables accurately. Determination of which factor has a significant influence on the teacher behavioural intention to use AR technology or their use of it needs to be examined with quantitative data that allows the correlations to be measured. Furthermore, it was outside the scope of what was possible to do with a small number of interview participants to properly consider the effects of the moderator variables in the model. Apart from considering the user - nonuser differences, and the impact of gender, other background variables could not be systematically taken into account and have their values compared.

However, the semi-structured nature of the interviews, allowing freedom to the participants to introduce their own themes, in great measure compensated for that in that a range of details and issues were mentioned that are not to be found reported in any other study or could possibly be reflected in a set of questionnaire items.

Another kind of limitation is that the study investigates the teachers' perceptions only. Yet clearly the perception of the students is also a relevant factor in the adoption of any new technology. The lack of the students' perspective is due to the time limit and the difficulty of finding or building a suitable theoretical framework that would cater for two viewpoints in the same study. This study also does not address perceptions of decision-makers at various levels (school headmaster, DoE, MoE) regarding the application of AR technology. Yet again, a fully rounded understanding of some factors mentioned by teachers would only be obtained with evidence of the other side of the story from higher policy makers.

There are also other kinds of data that would be valuable. For instance, the study does not include any observation of actual classes taught by the teachers to see if what they say occurs really does occur. Also, it does not assess the success of AR by any objective measures of student improvement in science knowledge to see if the teachers' perceptions of its value are supported. Inclusion of such elements would however have added enormously to the demands of the study, and it must be said that not many studies include them along with a comprehensive collection of data related to UTAUT variables of the perception/belief type. The acceptance of AR apps by teachers needs much more research precisely because it has many dimensions that cannot all be realistically addressed in one study.

Finally, this study was conducted in critical circumstances for the researcher which prevented him from collecting data in normal conditions.

8.6 Recommendations for future work

Many of the limitations just described at once suggest areas where research still needs to be done, not only in the Saudi context but in the wider domain of technology acceptance research. For instance, discussing teachers' perceptions regarding AR technology adoption in the classroom is insufficient to evaluate the acceptance of this technology in the education field. The views of all stakeholders need to be considered. That includes the students' acceptance, and that of the school principal and other staff and indeed officials at higher levels in the educational hierarchy who make the policy decisions that in effect impose acceptance on teachers. It is important for example to obtain the decision-makers' perspective on the reasons behind the classroom devices ban, which appears not acceptable in the digital age and hinders the adoption of AR.

This study focused on exploring the influence of eight constructs on teachers' adoption of AR technology in their teaching practices because it assumed those factors from the literature. It is worth considering extra factors with further theoretical perspectives in future studies. For instance in a few places in the data of the present study a cultural dimension appeared, such as in the matter of females' concern with their images being captured and disseminated unwantedly, which underpinned a few teachers' objections to devices in the classroom and hence to AR. This signals a place for more investigation of a possible cultural factor in the Saudi context.

There is also perhaps room for re-evaluation of some existing factors. In particular the resistance to change factor proved problematic and needs deeper consideration and clarification before it becomes a routine entity within models like the UTAUT. In particular better methods need to be developed to detect RTC as a personality trait factor since in this study's data it did not emerge very clearly at all in the interview responses. If someone rejects an innovation giving a good reason, they surely cannot be automatically regarded as driven by RTC. However it remains difficult to tell when the reason is genuine and where simply an excuse concealing underlying RTC.

Furthermore, AR technology is a new technology widely seen as beneficial. Yet how should it be decided what is beneficial? This study investigated its acceptance by teachers but without considering the impact of using AR apps on students' actual learning outcomes. However, AR should be accepted only if it is actually beneficial, not just judged by teachers to be beneficial. Therefore, this needs to be measured in future work. Indeed evaluation of AR effectiveness in teaching needs to be investigated by conducting real experiments that examine learning with AR in contrast with other methods to obtain a clear picture of its effectiveness that can inform a more valid educational decision about its adoption.

Finally, there remains a need to generalise, not only about school science teachers as a whole but also relevant subdivisions of them that were not in the end able to be systematically pursued, such as groups with different experience, teaching different science subjects, with different class sizes, using teacher centred versus learner centred teaching styles, etc. Although the present study did not succeed in that part of its enterprise, future studies should apply mixed methods with better instruments and increased participant numbers with more representative sampling from schools in many Saudi districts. In that way generalisable results could be obtained concerning AR adoption in different settings and contexts.

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Appendices

Appendix 1:

1.Survey Instruments

Dear teacher

Please read this statement carefully.

Your responses are very important and will help to improve educational practices in Saudi schools. So please try as far as possible to answer every question accurately. The responses will be used as part of my research, evaluating Augmented Reality, and all of your answers are anonymous. It is important that I collect accurate answers to be able to report the findings accurately.

Many thanks, Turki Alroqi.

Do you have experience of using Augmented Reality technology in your teaching?	

1.1 User group questionnaire

	Survey Item	Question/statement
	Please, read the following statements about using Augmented Reality technology in your teaching, and select how much you agree or disagree with each statement:	
	Performance expectancy	
1	I find Augmented Reality technology useful in my teaching	

RV	Using Augmented Reality does not increase my productivity **(RV; Reverse Item)**
2	Using Augmented Reality technology helps me accomplish my task more quickly
3	Using Augmented Reality technology increases my productivity
	Effort expectancy
4	Learning how to use Augmented Reality technology is easy for me
5	My interaction with Augmented Reality technology is clear and understandable
6	I find Augmented Reality technology easy to use
7	It is easy to become skillful at Augmented Reality technology
8	Using Augmented Reality technology is as easy as using any other technologies I have previously used
RV	I do not find Augmented Reality technology easy to use
Qul	Please, write a couple of sentences to justify your answers.
	Social influence
9	People who are important to me think that I should use Augmented Reality technology
10	People who influence my behaviour think that I should use Augmented Reality technology
11	People whose opinions that I value prefer that I use Augmented Reality technology
12	My organisation supports the use of Augmented Reality technology
13	I use Augmented Reality technology because of the proportion of my colleagues who use Augmented Reality technology
14	People in my organisation who use Augmented Reality technology have a high profile
RV	People whose opinions that I value prefer that I do not use AR technology
15	Having Augmented Reality technology is a status symbol in my organisation
16	Using Augmented Reality technology strengthens my position and influence in my organisation
	Facilitating Conditions
17	I have the resources necessary to use Augmented Reality technology
18	I have the knowledge necessary to use Augmented Reality technology
19	Augmented Reality technology is compatible with the other technologies I use
20	I can get help from others when I have difficulties using Augmented Reality technology

	Habit
21	The use of Augmented Reality technology has become a habit for me
22	I am addicted to the use of Augmented Reality technology
23	I must use Augmented Reality technology
	Hedonic Motivation
24	Using Augmented Reality technology is fun
25	Using Augmented Reality technology is enjoyable
26	Using Augmented Reality technology is very entertaining
	Price Value
27	Compared to the effort I need to put in, AR technology is beneficial for me
RV	Overall, Augmented Reality technology is not good value
28	Compared to the sacrifice I need to make, Augmented Reality technology is worthwhile for me
29	Overall, Augmented Reality technology is good value
	Behavioural Intention
30	I intend to continue using Augmented Reality technology in the future
31	I will always try to use Augmented Reality technology in my teaching
32	I plan to continue to use Augmented Reality technology frequently
	Self-reported Usage Behaviour
33	How often do you use Augmented Reality technology in your teaching
34	Do your students have access to digital devices in the classroom which are capable of using Augmented Reality technology?
Qul	Please, write a couple of sentences to justify your answers
	Resistance to change
35	Lack of availability of digital devices in the classroom is a barrier to the use of Augmented Reality technology for teaching and learning .
36	Students are distracted by the use of digital devices in the classroom .
37	I prefer teaching using books and board rather than new technologies

1.2 Nonuser group questionnaire

	Survey items	Question/statement
	Please, read the following statements about using Augmented Reality technology in your teaching, and select how much you agree or disagree with each statement:	
	Performance expectancy	
1	I would find Augmented Reality technology useful in my teaching	
RV	Using AR technology in my teaching would not increase my productivity	
2	Using Augmented Reality technology in my teaching would help me to accomplish tasks more quickly.	
3	Using Augmented Reality technology in my teaching would increase my productivity.	
	Effort expectancy	
4	Learning how to use Augmented Reality technology would be easy for me	
5	My interaction with Augmented Reality technology in my teaching would be clear and understandable	
6	I would find Augmented Reality technology easy to use	
7	It would be easy to become skillful at Augmented Reality technology	
RV	I would not find Augmented Reality technology easy to use	
8	Using Augmented Reality technology would be as easy as using other systems I have previously used.	
	Social influence	
9	People who are important to me think that I should use Augmented Reality technology	
10	People who influence my behaviour think that I should use Augmented Reality technology	
11	People whose opinions that I value prefer that I use Augmented Reality technology	
12	My organisation supports the use Augmented Reality technology	
13	I would use Augmented Reality technology because of the proportion of my fellow teachers who use it.	
14	People in my organisation who use Augmented Reality technology would have a	

	high profile
RV	People whose opinions that I value prefer that I do not use AR technology
15	Using Augmented Reality technology would be a status symbol in my organisation
16	Using Augmented Reality technology would strengthen my position and influence in my organisation
	Facilitating conditions
17	I would have the resources necessary to use Augmented Reality technology.
18	I would have the knowledge necessary to use Augmented Reality technology.
19	Augmented Reality technology would be compatible with the other technologies I use
20	I would be able to get help from others when I have difficulties using Augmented Reality technology.
	Habit
21	The use of Augmented Reality technology would become a habit for me
22	I would become addicted to the use of Augmented Reality technology
23	I would have to use Augmented Reality technology
	Hedonic motivation
24	Using Augmented Reality technology would be fun
25	Using Augmented Reality technology would be enjoyable
26	Using Augmented Reality technology would be very entertaining
	Price value
RV	Overall, Augmented Reality technology would not be good value
27	Compared to the effort I need to put in, Augmented Reality technology would be beneficial for me
28	Compared to the effort I need to put in, Augmented Reality technology would be worthwhile for me
29	Overall, Augmented Reality technology would be good value
	Behavioural Intention
30	I intend to continue using Augmented Reality technology in the future
31	I will try to use Augmented Reality technology in my teaching
32	I plan to use Augmented Reality technology frequently
33	Do your students have access to digital devices in the classroom which are

	capable of using Augmented Reality technology?
	Resistance to change
34	Lack of availability of digital devices in the classroom is a barrier to the use of AR technology for teaching and learning
35	Students are distracted by the use of digital devices in the classroom .
36	I prefer teaching using books and board rather than new technologies

1.3 Demographic information questions

What is your gender?	Male	Female	Other	Prefer not to say	
What is your age group?	Under 29	30 and less than 40	40 and less than 50	Over 50	
What is your highest teaching qualification?	Bachelors	Masters	Doctorate	Other	If you selected Other, please specify
How many years teaching experience do you have?	Less than 5 years.	5-9 years.	10-14 years.	15-19 years.	20 years or over

Please indicate your previous experience of using the following digital devices.

	Beginner	Intermediate	Advanced	I don't know
A tablet				
A smartphone				
A laptop				
A desktop				
A projector				
A television				
VHS tapes				
A smart board				

How often do you use the following digital devices to support your teaching?

	Never	Once a month	Once a week	2-3 times a week	Every day
A tablet					
A smartphone					
A laptop					
A desktop					
A projector					
A television					
VHS tapes					
A smart board					

Appendix 2

2.1 Interview Questions

Part1 :

- Name, gender, age, teaching experiences, level of technology skills?

Part2: AR usage

- What do you know about AR? How do you know about it?
- Did you use it? When? (why?)
- How often do use it in your classroom?

Part 3 : AR In teaching

(PE)

- Describe your experience with using AR apps in teaching?
- Does the AR app help you to deliver the content? How?
- Do you face any educational problems while you present the content by AR app?
- Why do you use it? How does it help students to achieve the intended learning outcomes?
- How to find AR in your teaching?
- Is there a difference between teaching with AR and traditional methods?
- Does AR help you to increase your productivity? How?

- Are your students engaged in the activities that are based on the AR app in their classroom? Could you mention the reasons for both cases, either positive or negative answer?

(EE)

- How do you see the use of AR in terms of easiness and learning how to use it?
- How about the effort you put in?
- If we go back to your efforts in dealing with AR technology, how do you describe the process of learning technology’s use?

(FC)

- Does the school generally support the use of AR technology?
- What about your school environment regarding the use of ICT?
- What are the facilities available for using augmented reality technology in your school?
- Are appropriate devices, applications and books available?
- What about the position of the education department, and the school supervisor regarding supporting the use of augmented reality technology?
- What training opportunities have you had to equip you for effective use of AR technology?

(SI)

- Who encouraged you to use AR technology? How?

- From your perspective, how can other teachers and school staff be supported to integrate AR technology in their pedagogy?

(HM)

- How enjoyable is it to use AR?
- What about enjoyment inside the classroom?

(PV)

- What about the cost, is it expensive?
- What is the incentive that motivates you to spend this amount of money on technology?
- Is the outcome of the teaching process or your students' result worth this money?

(RTC & open ideas)

- What are the obstacles of using AR, and what are your suggestions?
- Why do you think teachers stick with traditional teaching style?
- Who prevent students from using smart devices in their school? Why? Do you think that influence the implementation of AR in the class? How?
- Is there any example of misuse of devices?
- In the future, do you plan to use AR apps in your classroom? Could you give me some reasons as why would you use it?

- Do you think science secondary school teachers are ready to embrace AR applications in their teaching methods?
- How could you be encouraged to implement AR technology in your practice in the future?
- Do you have suggestions for the development of AR technology?

Appendix 3:

Ethics Approvals

3.1 University of Leeds Approval

The Secretariat
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Turki Alroqi
School of Education
University of Leeds
Leeds, LS2 9JT

ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee
University of Leeds

6 November 2018

Dear Turki

Title of study: **An investigation into the use of Augmented Reality technology in Saudi schools**
Ethics reference: **AREA 18-016**

I am pleased to inform you that the above research application has been reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date
AREA 18-016 ethics FINAL.doc	2	29/10/18
AREA 18-016 Fieldwork-Assessment.doc	2	29/10/18

Please notify the committee if you intend to make any amendments to the information in your ethics application as submitted at date of this approval as all changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation and other documents relating to the study, including any risk assessments. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, the Secretariat
On behalf of Dr Kahryn Hughes, Chair, AREA Faculty Research Ethics Committee

CC: Student's supervisor(s)

3.2 Participants Information sheet

Dear Teacher

I am a Saudi research student at the University of Leeds. I have been funded by the Islamic University in Madinah to do this study. The purpose of this study is to investigate the Saudi science teachers' perceptions regarding the use and adoption of augmented reality technology. The study will help to obtain a comprehensive understanding of the research area. Your views and experiences are very important in helping to explore the main factors influencing the adoption and use of Augmented Reality technology in Saudi school. You are invited to participate in this study. Please read and understand why this study will be conducted and what will be involved.

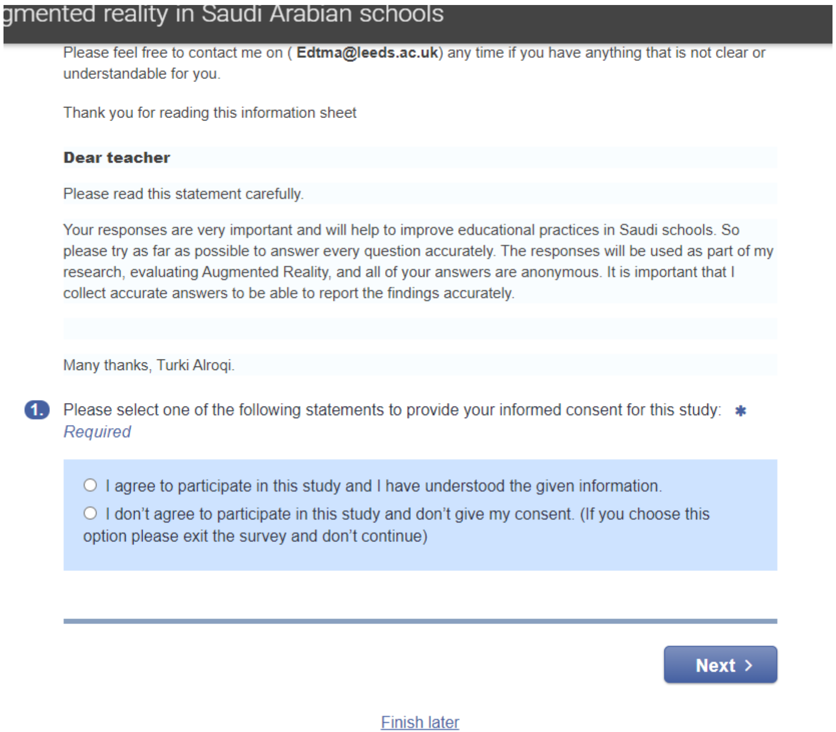
1. The data will be collected by online questionnaire.
2. You will be asked to answer a set of questions related to your opinion about integrating modern technologies into the classroom.
3. All your responses are completely anonymous.
4. Your responses will be used only for research purposes.
5. The access to your responses will be only by the researcher.

6. Your participation in this project will be fully voluntary and you can withdraw from the research any time during data collection.
7. Please note that submitted survey data will not be able to be deleted due to its anonymous nature.
8. The findings of this study will be reported to the researcher university. It will also be presented at conferences and published in academic and professional journals.
9. The gathered data will be saved on the University of Leeds secure servers.
10. The survey will take approximately 15–20 minutes to complete.

Please feel free to contact me on (Edtma@leeds.ac.uk) any time if you have anything that is not clear or understandable for you.

Thank you for reading this information sheet.

3.2 Consent form (online)



gmented reality in Saudi Arabian schools

Please feel free to contact me on (**Edtma@leeds.ac.uk**) any time if you have anything that is not clear or understandable for you.

Thank you for reading this information sheet

Dear teacher

Please read this statement carefully.

Your responses are very important and will help to improve educational practices in Saudi schools. So please try as far as possible to answer every question accurately. The responses will be used as part of my research, evaluating Augmented Reality, and all of your answers are anonymous. It is important that I collect accurate answers to be able to report the findings accurately.

Many thanks, Turki Alroqi.

1. Please select one of the following statements to provide your informed consent for this study: *
Required

- I agree to participate in this study and I have understood the given information.
- I don't agree to participate in this study and don't give my consent. (If you choose this option please exit the survey and don't continue)

Next >

Finish later

3.3 An online invitation letter

Dear teacher

Thank you for your participation in this survey. Your opinion is very important.

The study also includes a second phase involving a follow up interview. If you are willing to take part in the next phase, please leave your name, email address and school name below and I will contact you to arrange a time that is convenient for you.

3.4 Access letter (from the department of education in Riyadh district)

المملكة العربية السعودية
وزارة التعليم
٢٨٠
الإدارة العامة للتعليم بمنطقة الرياض
إدارة التخطيط و التطوير

وزارة التعـليم
Ministry of Education

الرقـــم : ٧٨٧٠٩
التاريـخ : ٩/٩/١٤٤٠هـ
المرفقات : ....

تسهيل مهمة باحث

الاسم		السجل المدني
تركي بن مقعد مطلق الروقي		**١٠٤٥٤٦٦٢٥٥**
العام الدراسي	الدرجة العلمية	الجامعة
١٤٤١/١٤٤٠ هـ	دكتوراه	**ليدز / بريطانيا**
عنوان الدراسة: **استقصاء تصورات المعلمين السعوديين تجاه استخدام وتبني تقنية الواقع المعزز.**		
عينة الدراسة : معلم .		
رابط الاداة الكتروني : **https://leeds.onlinesurveys.ac.uk/sqn-2v432w**		

المكرم قائد المدرسة **وفقه الله**

السـلام عليكم ورحمـة الله وبـركاته ، وبعد:

إشارة إلى قرار معالي وزير التعليم رقم ٣٨٧١٧٠٨٠ وتاريخ ١٤٣٨/٥/١٢هـ بشأن تفويض الصلاحيات لمديري التعليم ، وبناءً على قرار سعادة مدير عام التعليم بمنطقة الرياض رقم ٣٨٩٢٠٧٩٣ وتاريخ ١٤٣٨/٦/٢٣هـ بشأن تفويض الصلاحية لإدارة التخطيط والتطوير لتسهيل مهمة الباحثين والباحثات ، وحيث تقدم إلينا الباحث (الموضحة بياناته أعلاه) بطلب إجراء دراسته، ونظراً لاكتمال الأوراق المطلوبة نأمل تسهيل مهمته ،على أن يبدأ مهمته مع بداية العام الدراسي ١٤٤١/١٤٤٠ هـ .

مع ملاحظة أن الباحث يتحمل كامل المسؤولية المتعلقة بمختلف جوانب البحث ، ولا يعني سماح الإدارة العامة للتعليم موافقتها بالضرورة على مشكلة البحث أو على الطرق والأساليب المستخدمة في دراستها ومعالجتها. وللمعلومية فإن طلب (**إنهاء المهمة**) يتطلب الرفع لنا من الجهات المعنية بتطبيق البحث بأن الباحث قد باشر تنفيذ أدوات بحثه حضورياً.

شاكرين لكم وتقبلوا تحياتي..

مدير إدارة التخطيط و التطوير

سعود بن راشد ال عبداللطيف

3.5 Sample of an email to distribute the online survey

طلب المساهمة في توزيع استبانة بحث علمي لدرجة الدكتوراة

Turki Alroqi [edtma] <edtma@leeds.ac.uk>
Mon 02/09/2019 15:28
To: Qurtubah@riyadhedu.gov.sa <Qurtubah@riyadhedu.gov.sa>

1 attachments (308 KB)
تسهيل مهمة تركي الروقي.pdf;

سعادة مدير مكتب تعليم قرطبة بمنطقة الرياض سلمه الله

السلام عليكم ورحمة الله وبركاته ،، وبعد
نهنئكم بالعام الدراسي الجديد، متمنين أن يكون عام حافل بالنجاحات والتميز.

أتقدم لسعادتكم بطلب التكرم بمساعدتي في توزيع استبانة بحث علمي عن تصورات المعلمين السعوديين عن استخدام تقنية الواقع المعزز، حيث ادرس لمرحلة الدكتوراة بجامعة ليدز بالمملكة المتحدة، ويتطلب البحث جمع بيانات من المعلمين عن تصوراتهم تجاه تقنية الواقع المعزز وكذلك اجراء مقابلات مع من يرغب منهم .
في المرفق ، خطاب تسهيل مهمة باحث من إدارة تعليم الرياض، وكذلك الرابط الالكتروني للاستبانة، آملاً منكم التكرم بتوزيعها على المدارس الثانوية للبنين والبنات التابعة لمكتب قرطبة.\\
شاكراً ومقدراً لسعادتكم الاهتمام والتعاون.\

تركي بن مقعد الروقي
جامعة ليدز

رابط الاستبانة

عزيزي المعلم – المعلمة ، اجابتك مهمة وضرورية بالنسبة لي، لذلك حاول أن تعبر عن آراءك بكل صدق دون استعجال أو تردد، لكي تحقق الدراسة أهدافها، ثقتي بك كبيرة بأن تكون مساهماً في تطوير الميدان التعليمي من خلال تقديم استجابة دقيقة ومعبرة عن الواقع، شاكراً ومثمناً لك اقتطاع جزء من وقتك للمشاركة في هذه الاستبانة. leeds.onlinesurveys.ac.uk/sqn-2v432w

طلب المساهمة في توزيع استبانة بحث علمي لدرجة الدكتوراة

Turki Alroqi [edtma] <edtma@leeds.ac.uk>
Mon 02/09/2019 15:29
To: rwabee1@gmail.com <rwabee1@gmail.com>

1 attachments (308 KB)
تسهيل مهمة تركي الروقي .pdf;

سعادة مدير مكتب تعليم الروابي بمنطقة الرياض سلمه الله

السلام عليكم ورحمة الله وبركاته ،، وبعد
نهنئكم بالعام الدراسي الجديد، متمنين أن يكون عام حافل بالنجاحات والتميز.

أتقدم لسعادتكم بطلب التكرم بمساعدتي في توزيع استبانة بحث علمي عن تصورات المعلمين السعوديين عن استخدام تقنية الواقع المعزز، حيث ادرس لمرحلة الدكتوراة بجامعة ليدز بالمملكة المتحدة، ويتطلب البحث جمع بيانات من المعلمين عن تصوراتهم تجاه تقنية الواقع المعزز وكذلك اجراء مقابلات مع من يرغب منهم .
في المرفق ، خطاب تسهيل مهمة باحث من إدارة تعليم الرياض، وكذلك الرابط الالكتروني للاستبانة، آملاً منكم التكرم بتوزيعها على المدارس الثانوية للبنين والبنات التابعة لمكتب الروابي.\\
شاكراً ومقدراً لسعادتكم الاهتمام والتعاون.\

تركي بن مقعد الروقي
جامعة ليدز

رابط الاستبانة

عزيزي المعلم – المعلمة ، اجابتك مهمة وضرورية بالنسبة لي، لذلك حاول أن تعبر عن آراءك بكل صدق دون استعجال أو تردد، لكي تحقق الدراسة أهدافها، ثقتي بك كبيرة بأن تكون مساهماً في تطوير الميدان التعليمي من خلال تقديم استجابة دقيقة ومعبرة عن الواقع، شاكراً ومثمناً لك اقتطاع جزء من وقتك للمشاركة في هذه الاستبانة. leeds.onlinesurveys.ac.uk/sqn-2v432w

3.6 Sample of the Invitation Email

Subject: Participating in an interview about the Acceptance of Augmented reality technology research

Dear Teacher,

Thank you for your participation in the questionnaire regarding the research entitled: "Investigation of the Saudi science teachers' perceptions regarding the acceptance and use of augmented reality technology", and thank you for your willingness to participate in an online interview to provide the researcher with more details about your opinion on the acceptance and use of augmented reality technology.

I would like to inform you that the interview will be online via the internet, and you need a device, mic and headphone, and the internet, and I will send you the link to the information sheet to your e-mail. Kindly read the research information sheet and give the consent forms.

Could you please also tell me a convenient day and time for you to participate in the interview?

Kind Regards,

Turki Alroqi

PhD candidate at University of Leeds