Developing, Understanding and Evaluating Augmented Reality Framework for Universities in Saudi Arabia

Muteeb Saad Alahmari
Curtin Business School
School of Information Systems
Perth, Australia
M.alahmari4@postgrad.curtin.edu.au

Abstract— Technology has introduced new tools such as Augmented Reality (AR), the application of which may improve learning outcomes. AR is the integration of digital information with the user environment in real time. Despite the fact that technologies have been implemented in Saudi Arabia's education sector, several issues exist that are associated with the traditional methods of teaching and learning i.e. students' lack of motivation concerning independent learning, collaborative learning, and skills-acquisition, which are a part of the current pedagogy. To resolve the problems associated with traditional teaching and learning methods, the Augmented Reality approach will be examined and assessed in Saudi Arabia's higher education sector, through the development of a new AR model. This research aims to develop, understand and evaluate the AR framework in order to determine the factors (e.g., willingness, perception, motivation, and acceptance) that will have the most influence on AR adoption especially regarding students' learning outcomes in Saudi Arabia. A set of recommendations will be suggested for the adoption of AR in Saudi Arabia's higher education sector. This study will employ a mixed-methods research design (Explanatory Sequential Design), whereby the data will be collected using both quantitative (online survey) and qualitative methods (semi-structured interviews).

Keywords-Augmented Reality; Higher Education; Saudi University; Integration.

I. INTRODUCTION

Schuemie [4] described Human-Computer Interaction (HCI) as a discipline that is concerned with designing, evaluating and implementing interactive computing systems for the use of individuals. User experiences such as satisfaction, motivation, attention, and emotion are essential in HCI to improve the efficiency of these technologies. The effectiveness of new technologies, such as Augmented Reality, has inspired the higher education sector to utilize them for teaching and learning [5]. In the area of learning, the increased learning demands and enhanced learning outcomes have given rise to many issues in university curricula. Consequently, it has now become more challenging to adhere to traditional methods of teaching and learning. Hence, with the increased role of computers in day-to-day activities, it is expected that several computer systems will be integrated into the learning environment. Technological innovations such as AR and Virtual Reality (VR) have a potential use in education. Integrating AR technology into the classroom needs to be evaluated in order to determine its effectiveness for learners. AR technology has become a well-known research topic, and has been widely explored and used in many settings including training and education. Thus, in this study, AR will be examined and assessed in the context of Saudi Arabia's higher education sector, through the development of a new model of AR.

This paper has been organized according to the following sections. In Section II, AR and VR are discussed and compared. Section III explains AR technology. Section IV reviews the extant literature on the use and effectiveness of AR in education. This is followed in Section V by a detailed description of the Saudi education system. The research methods and research question are presented in Section VI. In Section VII, an initial AR framework and the research outcomes are identified based on the literature review. Section VIII discusses future work and concludes the paper.

II. VR AND AR

VR is defined by McLellan [6] as "a class of computer-controlled multisensory communication technologies that allow more intuitive interactions with data and involve human senses in new ways." (p.461). McGlashan and Axling [7] elucidated that VR is a graphical two- or three-dimensional interface that enables the communication between the user and computer, while AR is the next step after VR. Azuma et al. [8] defined AR as a system that enhances the real world with artificial objects by means of computer-generated sensory input such as graphics, video sound, or a Global Positioning System (GPS) data. Azuma [9] identified three advantages of an AR system: it mixes real and virtual; it is interactive in the real world; and it registers in 3-D.

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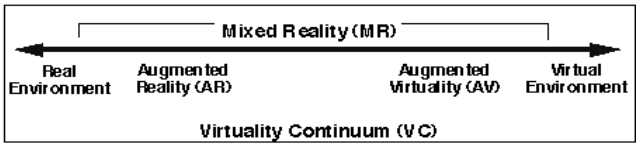

Figure 1. Simplified representation of a "virtuality continuum" [3]

Total immersion is provided in the VR environment while AR integrates the information in the user's existing view. Figure 1 depicts Milgram and Kishino's [3] representation of the real world and virtual world objects combined in a simple display.

In order to process the scene, the VR system presents an entirely artificial environment; whereas, AR processes the information from different resources and superimposes it onto the users' environment [5]. Nevertheless, Di Serio et al. [10] reported that involvement, navigation, and interaction are features that AR and VR have in common.

III. AR TECHNOLOGY

There are two main AR software application types, both of which have recently become available to educators: (a) a marker-based or vision-based AR and (b) a markerless or location-based AR**.** The marker-based AR presents the virtual object and digital media (i.e., text, 3D models, graphics, video, and audio) to the users when they point a camera at a visual marker (e.g., 2D target, Quick Response code (QR)). The markerless AR uses the user's location, like GPS, and then the application integrates the virtual content with an exact location on or within the users' real environment. The marker-based AR type will be addressed in this research.

A. *Marker-based AR System process*

This process uses a software application to recognize images, such as a QR or a physical object, then generates the augmented virtual content, and enhances this information onto the recognized object (see Figures 2 and 3).

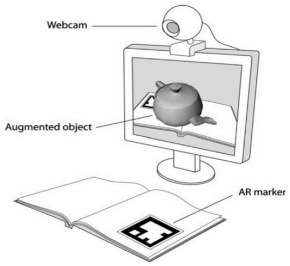

Figure 2. The concept of AR- based [2]

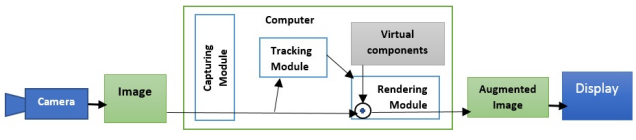

Figure 3. AR Marker-based AR architecture [1]

Mainly, an AR system captures the real world or images, analyzes them and compares them with features identified by the designer and displays the results to the end user.

B. *AR displays*

AR displays can be categorized into three types based on their position between the viewer and the real environment: Head-Worn Displays (HWD), handheld displays, and Projection displays. HWD is worn on the head, allowing images to be displayed in front of users' eyes**.** Projection displays are used to direct chosen virtual information to the real objects to be augmented. Handheld is a flat-panel Liquid Crystal Display (LCD) that some AR systems use by connecting a camera to run a video see-through-based augmentation. The handheld display is used as a magnifying glass or a window that shows the real objects with an AR overlay. Zhou et al. [11] suggested "Handheld displays are a good alternative to Head Mounted Display (HMD) and Head-Mounted Projective Display (HMPD) systems for AR applications, particularly because they are minimally intrusive, socially acceptable, readily available and highly mobile"(p.198).

IV. AR IN EDUCATION

In the literature, AR has been acknowledged as an effective technological tool that assists students to understand a range of science-based domains, such as environmental science [12]. The study has shown that AR has a strong positive emotional impact on the student. Moreover, a study on the use of AR has produced significant results and encouraged researchers to investigate its use in the field of education [13]. The result indicated that no studies have investigated the "educational" field (teacher training). A study by Bujak et al. [14] which compared AR with traditional computer devices inside and outside a mathematics classroom suggested that AR as a collaborative learning tool will better motivate students to learn. AR allows learners to interact with virtual objects in the real world. Combining the educational content with AR technology builds new automated applications to enhance the effectiveness of learning and teaching. Bujak et al. [14] discussed how AR allows students to interact naturally, which can improve learning by attaching data to objects and locations in the students' surroundings. Another study by Kamarainen et al. [15] assessed the use of AR technology as a means of facilitating students' understanding and interpretation when measuring water quality. Results indicated that AR allows students to interact in real time and that leads to improvement in interpretation flexibility. However, the use of AR in education has limitations. According to Bacca et al. [13], common limitations of applying AR in education are the students' attitudes and the difficulty of using AR applications. Hsiao et al. [12] reported that students need to pay much more attention when using AR for the first time. Environment constraints, such as inadequate infrastructure and lack of AR equipment, are common obstacles that educators need to be aware of when integrating AR and VR into education. Therefore, accessibility and usability factors are important issues that need to be considered in future work [10]. Addi-

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tionally, Dunleavy and Dede [16] found that cognitive overload, culture, and type of institute are important issues that play significant roles in the adoption of AR in education.

A. *Effectiveness of AR regarding students' learning outcomes*

Many studies have reported the different effects that these technologies have on students' learning outcomes. A study by Wojciechowski and Cellary [17] showed that AR technology improves students' motivation to learn. Bacca et al. [13] hypothesized that AR is an effective learning tool owing to its combination of actual world and virtual world objects. Its superimposition of information and its enabling of the visualization, exploration, manipulation and interaction with objects within computer-generated surroundings allow learning to take place at the learner's own pace. Findings have confirmed that AR produces positive learning outcomes for students in the faculties of medicine and science [8] [18]. In addition, AR provides enjoyment that significantly influences students' intention to use this technology in the future. Furthermore, Jou and Wang [19] found that teaching approaches, such as AR, have the most effect on students' motivation to learn. From the psychological perspective, Bujak et al. [14] identified the psychological factors that enhance a learning environment that uses AR: students are able to interact naturally, and this can lead to an increase in the transparency of the interface between students and educational content. Additionally, Bujak et al. concluded that the AR environment could enhance learning by attaching data to objects and locations in the students' surroundings. Akçayır and Akçayır [20] demonstrated that most of the advantages of AR in educational settings relate to students' learning outcomes associated with motivation, attitude, and learning achievement.

B. *Influence of students 'characteristics with AR technology.*

According to Cheng and Tsai [2], few studies have taken into account the students' characteristics when students are engaged with AR in science education [21][23]. In the Squire and Jan [22] study, students were divided into three groups according to their age. Older students were found to be more interactive during AR game tasks, whereas younger students rejected the researchers' hypothesis regarding the AR game task. Albrecht et al. [24] investigated the emotional and cognitive impact that AR technology could have on students' learning process compared with the impact of traditional methods. The results showed that there was a significant decrease in student fatigue and a slight increase in student drive. However, despite the scant support from various researchers for the effectiveness of AR, other researchers have stressed its significance in the learning field classroom environment or as an evaluation tool [14][25][26] the classroom environment, or as an evaluation tool. Researchers Ausburn and Ausburn [27] highlighted that there are a few studies that explore and explain the effect of AR regarding theoretical perspectives and models. Several studies [28] [30] also argued that more research on AR is needed to investigate the emotional, social and cognitive dimensions of human experience in the virtual world rather than just technical issues. Cheng and Tsai [2] suggested, "more research is required to explore learning experience (e.g., motivation or cognitive load) and learner characteristics (e.g., spatial ability or perceived presence) involved in AR" (p.449). Various factors such as emotional, social, and personal beliefs, prior knowledge, and cognition have been mentioned in the literature as important issues that need to be examined to determine their influence on student learning outcomes when teaching methods have included technology compared with traditional methods.

V. SAUDI EDUCATION SYSTEM

The process of teaching and learning in the Saudi education system is still lacking vital elements such as enhancing students' personal skills and motivation by encouraging critical thinking, self-learning, and engagement [31]. The current approaches to learning and teaching in Saudi Arabia's higher education sector were reviewed by Alnassar and Dow [32]. They noted the following major challenges: a lack of motivation to develop and improve the teaching methods; the current curriculum does not sufficiently encourage students' critical thinking, self-learning, and problem-solving skills; the lack of adequate teacher training for faculty members. Furthermore, [33] stated that the higher education system in Saudi Arabia encounters difficulties in meeting outcome quality in relation to work needs. Saudi universities are trying to confront these challenges by developing a contemporary curriculum and advanced technological teaching facilities [34]. Despite the learning and teaching issues in the Saudi education system, there are some reasons for optimism. Studies are continuously being conducted by the Ministry of High Education in Saudi Arabia in order to develop an adequate e-learning infrastructure. Alrasheed et al. [35] reported that in developing countries, such as Saudi Arabia, many universities and schools depend on traditional teaching methods and ignore alternative and more effective methods, such as the use of technology in the classroom. Consequently, Saudi Arabia allocated a large budget to support the growth of the education sector and introduce new education programs [36]. One of the largest projects for the redevelopment of the education sector in SA is the King Abdullah University of Science and Technology (KAUST). The aim of this project is to redevelop and improve the learning environments by integrating a digital environment and technologies into the classroom. The Ministry of Education has established twenty-seven technical centers to develop teaching methods and improve teachers' performance in class [37]. The Saudi Arabian government is working hard to reform the education sector in line with sophisticated market needs.

A. *Integration of technologies in education in Saudi Arabia*

The integration of technologies in universities is rapidly increasing to simplify the delivery of education. Therefore,

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to enhance student learning, a large number of studies have focused on finding better technological solutions that are compatible with pedagogy [39][40]. Collaborative e-learning is one of the popular pedagogical technologies that were integrated into Saudi Universities to improve education. Al Saif [41] indicated that collaborative e-learning plays a significant role in increasing the number of students enrolling at universities. Smart Tablet technology was introduced in Saudi Arabia's education sector to investigate its potential benefits and enhance student learning outcomes by increasing the level of engagement in the learning process [42]. Also, several studies [43][44] examined the acceptance by students in Saudi Arabia of mobile learning in higher education. The results revealed that more than 65 percent of students are using online learning services and more than 62 percent are learning via electronic resources daily. Also, smartphones, iPads, and Tablets were the preferred learning devices of the majority of students. However, some studies [37] [42] [45] [46] identified several limitations: delay of the integration or rather the implementation of these technologies in SA education institutions; the lack of an adequate infrastructure; and the culture and personal beliefs, which have a significant impact on the utilization of technology in classrooms. Nowadays, new innovative technologies such as AR and VR introduce individuals to a new way of interacting with the world in three dimensions and two dimensions. Universities need to adjust and develop new methods of teaching and learning. In this study, these innovative technologies are introduced into the education system in Saudi Arabia's universities with consideration given to the aforementioned limitations.

B. *Learning Technologies in SA*

A study by Abou-Elhamd et al. [47] examined the adoption of VR in medical education in Saudi Arabia. Students used the Voxel-Man TempoSurg simulator to learn about the anatomy of the temporal bone in three dimensions. They found that teachers and students consider the virtual environment to be a powerful learning tool. Another learning technology used in SA higher education is virtual Avatar to represent a female tutor in online learning [48]. The Avatar technology was used to resolve the issue of a gender-segregated society in online learning. Based on that study, virtual Avatar is considered as a good learning technology for both male and female students. Nevertheless, certain limitations can prevent the adoption of these technologies in SA education; these include technical problems and the acceptance by students of a virtual teacher. However, all the previously mentioned studies have noted that the use of VR has several serious limitations associated with training, time, resources, technical problems, and personal beliefs. These studies would have been more useful if they had focused on suggesting a framework for adopting these kinds of technologies in SA education, and determining the effects of student characteristics on student learning outcomes when using VR technology.

VI. RESEARCH METHODS AND RESEARCH QUESTION

The rapid development of technologies has created difficulties in understanding Information Technology (IT) practices, impacts, usage, and capabilities. IT has become an integral part of individuals' lives and has evolved rapidly. Therefore, Information Systems (IS) researchers often face challenges in identifying sufficient findings and theories that provide essential insights into a phenomenon of interest. Consequently, a mixed-methods design can be employed as a powerful mechanism to help IS researchers to deal with such situations [49]. Given the research purpose and problem statement, this study will adopt a case study approach using mixed-methods research design (Explanatory Sequential Design) wherebythe data will be collected by both quantitative (online survey) and qualitative methods (SS interviews), analyzed separately, and then merged in one study [50] [51].

This research approach has been selected because a general understanding of the research problem can be provided by the quantitative data and their subsequent analysis. The statistical results will then be further refined and explained by eliciting participants' views through interviews (qualitative phase) [52] [54]. Since 2011, most AR studies have used the mixed-methods approach [55] which involves the collection of both quantitative and qualitative data [56][58] to achieve the research objective(s).

The purpose of using a sequential mixed-methods approach is to provide a comprehensive picture of a phenomenon by using qualitative data results to deliver a rich explanation of quantitative data and analysis [49][59]. In this study, the mixed-methods approach is used to provide an in-depth understanding of the potential use of AR technology in education, and to unearth more factors. The research philosophy in this study is pragmatism, taking an abductive approach to explore the use of AR in education and then generate a conceptual framework [60]. Pragmatism has been suggested for IS researchers and recommended by mixed methodologists as one of the preferred paradigms for modifying the use of mixed-methods research [49]. Therefore, this study will take a mixed-methods (abduction) approach that is both qualitative (based on deduction) and quantitative (based on induction) in order to examine the use of, and users' attitudes toward, new technology learning methods in Saudi Arabia's universities. This research aims to identify the new factors that must be considered when developing AR for Saudi Arabia.

Firstly, quantitative data will be gathered in order to understand students', teachers', and learning department staff's reactions to the AR teaching method, and to develop a set of new factors from the survey[49]. In other words, survey data will be used to determine the factors influencing the effectiveness of AR as a learning tool. In the the next phase, the qualitative method will be used to explore the quantitative results from the survey in more depth to gain more insights, reasons, deeper understanding, and explanation of these constructed factors.

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A. The participants

The study population will comprise students, teachers (academics) and e-learning department staff from three publicly-funded universities in Saudi Arabia. These universities are an appropriate choice as this study will focus on the introduction of AR technology in the tertiary education sphere.

B. Quantitative online survey

In this study, quantitative data will be used to measure attitude, AR pedagogical contribution, willingness, acceptance, ICT infrastructure, sociocultural factor, etc. and to identify the factors for the proposed framework. Accordingly, an online survey via Qualtrics will be conducted by sending a hyperlink to the all participants (students, teachers (academics), and learning department staff).

This study will use the Statistical Package of Social Sciences IBM SPSS Statistics (version 24) for data analysis and conduct exploratory factor analysis (EFA) for statistical testing of the data collected from the questionnaire in order to identify factors. EFA is commonly used in the domains of psychology and education [61].

C. Qualitative Interviewing

The quantitative data collected via an online survey will be supported/supplemented by qualitative data gathered during face-to-face interviews. The researcher will use semi-structured, face-to face-interviews with a selected number of subjects to collect the data necessary to achieve the research objective and to support the data obtained from the online survey results. The selection of potential interviewees will be based on their knowledge of AR. People who are highly familiar with AR will be able to provide the researcher with rich information and various perspectives on the use of AR in education. The aim of the interviews is to answer the 'why' questions and to better explain the findings derived from quantitative data and analysis, and unearth additional factors.

The qualitative data gathered from the interviews will be analyzed using general qualitative analysis techniques, such as Nvivo software (version 11).

VII. RESEARCH OUTCOMES

Several studies [2] [14] [62] [66] have attempted to show that AR will improve student learning outcomes; however, no study to date has appropriately identified the effect on learning outcomes of the individual's characteristics, such as emotional, personal, social, and cognitive influences in combination with the technology. After comparing these studies, some of the factors were found to be missing in some models, and none would be appropriate for higher education in SA. According to limitations and suggestions offered by related studies [37] [42,] [45] [46] [48] personal and social factors have a significant influence on the utilization of technology in the context of higher education in Saudi Arabia. Compared with other developing regions, this country has solid roots in religious and tribal histories dating back to the eighteenth century. Moreover, Saudi Arabia is one of the most traditional of the Muslim countries, especially regarding the status of women [67]. The religious and cultural restrictions in Saudi Arabian society cannot countenance gender-desegregation [68]. Alturise and Alojaiman [69] indicated that "the strict application of Islamic law has led to its education system being segregated according to gender, which has far-reaching implications for the educational environment which puts it at odds with the open-access culture practiced in many other countries" (p.46). Therefore, the adoption of technology by Saudi Arabia presents a significant cultural challenge to the development of its learning system.

Moreover, cognitive and emotional considerations were identified as important factors that must be dealt with when integrating AR [2] [14] [24] [55] [70] [71].

To the best of this researcher's knowledge, none of the studies reviewed thus far has addressed all of these dimensions comprehensively. Hence, this study will attempt to address the gap in the literature of theoretical frameworks for using AR in learning by including these dimensions: emotional factors (EF), personal factors (PS), social factors (SF), and cognitive factors (CF).

A. AR initial Framework

Figure 4 demonstrates the conceptual framework that includes all these factors. The conceptual framework classifies the relevant factors in AR learning system development and acceptance in SA. Based on Gregor [72] theory taxonomy, this theoretical framework is related to theory for an explanation of the phenomena and provides a deeper understanding of why and what a relation between constructs.

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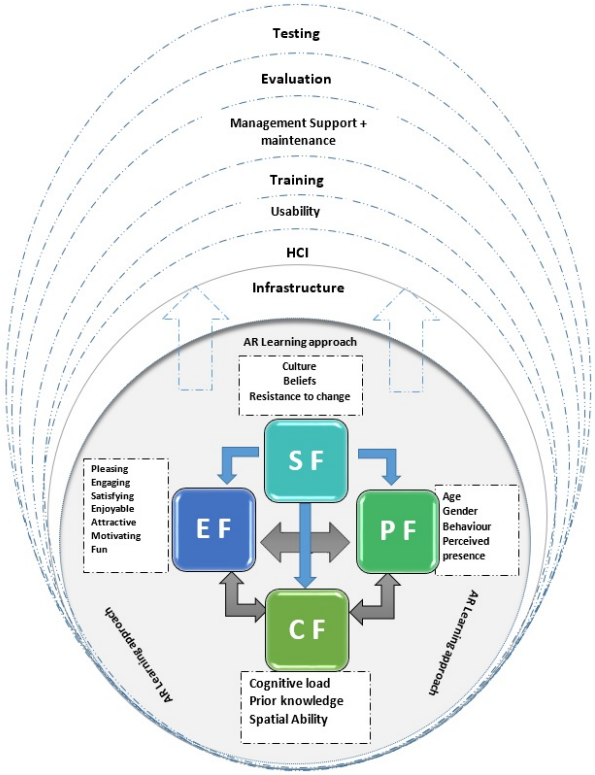

Figure 4. Augmented Reality Framework for Universities in Saudi Arabia

The gray arrows indicate the factors' relationships that were derived from the literature review (INTERACT model) [73], while the blue arrows (the influence of SF on other factors) will be tested in this research via the mixed-methods approach. Until recently, no study has been conducted on the use of AR in Saudi Arabian universities. The initial model will be examined and assessed by several stakeholders in Saudi universities.

B. *Social factor (SC)*

Culture can influence what is learned and how it is learned [74]. From a social perspective, culture is what a society or community share in terms of attitudes, values, and beliefs. Learning and teaching styles differ across cultures and need to be understood. Furthermore, the context of the institutions plays a role in the use of technology. Windschitl and Sahl [75] stated that "The ways in which those teachers eventually integrated computers into classroom instruction were powerfully mediated by their interrelated belief systems about learners in their school, about what constituted 'good teaching' in the context of the institutional culture, and about the role of technology in students' lives" (p.165). Therefore, a different learning approach, such as a new technology can also be influenced by cultures and beliefs.

C. *Personal Factor (PF)*

Personal characteristics such as gender, age, and level of education can influence the attitude toward using technology for educational purposes [76]. Hence, the successful adoption and integration of technology into teaching will be influenced by the personal characteristics of potential users [77]. Consequently, these factors will be considered in the AR learning environment, particularly in this research. Furthermore, case studies conducted by Hayes et al. [78] who investigated students' experience of presence in a mixed reality environment, found that perceived presence may impact on learning outcomes.

D. *Emotion Factor (EF)*

The learning process in higher education can be affected by emotion. Motivated students can confidently demonstrate their level of knowledge. Emotion plays a significant role in both teacher and learner behaviours and in learner motivation and self-esteem [79]. Several studies [80][81] have concluded that the positive impact of a virtual learning environment on emotions would improve students' cognitive processes and performance. According to the findings of previous studies [82] [84], in order to integrate cognitive and affective processes, emotional design research is needed.

E. *Cognitive factor (CF)*

The thinking processes of students can be supported, guided, and extended when computer technology is involved in the learning process [85]. However, technology may pose additional processing demands and increase students' cognitive load which prevents them from learning [2] [86]. Kalyuga and Liu [87] suggested that the cognitive characteristics of learners should be considered in order to guarantee the instructional effectiveness of any technological innovation; otherwise, students will become frustrated. Moreover, the level of students' prior knowledge can influence student learning outcomes in virtual learning and this should be considered in AR learning. Cai et al. [88] indicated that "With sufficient prior knowledge, whether we use abstract objects in teaching causes no impact on learning; this suggests that the influence of a technological innovation must be closely correlated with the students' prior knowledge".

F. *Technological Infrastructure*

In order to develop, deliver, monitor, test, control or support information technology services in universities, certain hardware, software, networks, facilities, etc. are required to operate and manage an information technology environment. Technology infrastructure is a complex issue and universities' decision-makers need to realize the importance of technology infrastructure as a means of improving teaching and enhancing learning outcomes. Altameem [89] stated that some of the universities in SA still have a weak infrastructure, which makes people reluctant to use the available services and systems.

G. *Human-Computer Interaction (HCI)*

HCI is the study of interactions between computers and people and is an interdisciplinary field comprising computer science, engineering, and ergonomics; its human side includes psychology, physiology, sociology and cognitive

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sciences [90]. According to [91], the purpose of HCI is to design a system that is aligned with users' needs and requirements.

H. Usability

Usability is about assuring users that the system is effective, efficient, safe to use, easy to use and evaluate, enjoyable, and satisfying [91]. To ensure usability, the user should participate in the development process to prevent future user frustration and error and meet the users' requirements. According to Cheng and Tsai [2], usability issues must be considered in AR technology because, without well-designed interfaces, students might encounter difficulties when using AR.

I. Maintenance and Support

After careful planning and hard work, the integrated technologies in organisations need to be updated to ensure that they are running flawlessly. Maintenance and support are required after implementing new technologies to keep the system running efficiently and effectively. The National Center for Education [92] stated that "support services, training, and certification must be ongoing to ensure successful post-implementation use of technology". Thus, the implementation of new technologies such as AR in universities should be supported and maintained by them or outsourced to contractors to achieve the desired goals.

J. Training

Training in the use of technologies should be introduced when universities intend to integrate technology in an educational environment. The main goal of training is to introduce teachers and students to various appropriate technologies that shift the traditional learning method to an efficient learning approach that will enhance learning outcomes. In order to achieve this goal, adequate training is needed to encourage both teachers and students to use the technology. Follow-up training has been acknowledged as a significant factor in integrating technology in the classroom [93]. Finally, in order for new technologies to be used appropriately in education, good in-service training is essential.

K. Testing

The testing stage will allow users to test the new system via a list of web browsers to ensure that the programme code is accurate and meets the intended functional requirement. [63]defined the user test as "a systematic approach to evaluating user performance in order to inform and improve usability design" (p.430). The AR system must be tested to determine whether it meets the expectations of the authorized entity.

L. Evaluation

System evaluation is an important phase when developing or updating a system. When a system is introduced or released, an evaluation should be conducted. Regular evaluation is an important means of identifying the outcomes of using AR in education and improving its efficiency.

VIII. Conclusion

In conclusion, the aim of this study was to develop and evaluate the AR framework in Saudi Arabia's higher education sector. This is a pioneering study in its field in that it attempted to extend the literature by classifying the factors that will have the most influence on AR adoption, especially on students' learning outcomes in Saudi Arabia. The results of this study will create awareness of the potential advantages and the weaknesses of adopting AR technology for teaching and learning purposes in SA universities. It is anticipated that this study will contribute to the theoretical and academic knowledge regarding the important factors that are needed for the successful implementation of AR for teaching and learning purposes in universities. The context of Saudi Arabia's higher education sector presents a set of ambiguities and uncertainties that require careful examination prior to the widespread introduction of AR in university pedagogy. By combining various approaches drawn from extant literature on the implementation of AR in universities globally, this research suggests a framework of factors which could support an integrated and well-considered incorporation of AR in higher education in Saudi Arabia.

In future work, we plan to extend current research by implementing an AR system in Saudi universities and evaluating its impact on student learning outcomes.

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