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Mobile Augmented Reality-Based Literacy Enhancement for Deaf Children: A Case Study for Arabic Language

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Declaration:

I Certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this study or any part of the same has not been submitted for a higher degree to any other university or institution.

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Abstract

Literacy is essential for children’s growth as well as to succeed in today's society. Literacy learning requires two related capabilities: language familiarity and decoding. Language familiarity refers to the linguistic wealth acquired, while decoding is the process of transferring that leads to understanding the mapping between the language and the printed text. Regrettably, literacy learning is one of the biggest challenges and difficulties facing deaf people as they are disadvantaged in both capabilities.

Different technological systems were built to support deaf literacy development by using Kinect, Virtual Reality and Leap motion. Most of these systems concentrate on translating written language to sign language and vice versa. This research, therefore, examines the potential of mobile Augmented Reality (AR) to enhance deaf literacy. It further raises the issue of involving intended users in the shaping of technologies to their needs by adopting a User Centered Design (UCD) approach.

To achieve this, a case study was carried out in Palestine through three stages: needs assessments, system design and evaluation. Conducting the needs assessment to identify needs and requirements for a mobile AR prototype for deaf children. Then, a mobile augmented reality prototype for Arabic literacy learning for deaf children combined with flashcards was developed. This prototype helps deaf children to improve their literacy and linguistic wealth, it allows deaf children to view rich augmentative content that covers all the aspects of the learned word where the child can view attractive 3D animation to describe the concept, a 3D avatar to for sign language, videos for finger spelling and lip-reading in addition to audio for the pronunciation for those with hearing residue.

Multiple techniques were used at successive stages of developing the prototype, including in-depth, semi-structured interviews; observations and a questionnaire. The findings have shown that AR has a great potential to enhance deaf literacy, if it is designed and implemented properly. AR-DLE have several advantages such as independent and self-learning as it is easy to use without need of help and it can be used anywhere and not restricted to a particular location. As well, it supports repetition which is very important for deaf, so they can achieve repetition ad they need without efforts. The prototype also supports the visual learning as it takes care of that deaf students depend on visually, interactive, attractive media and this affect positively the deaf children's literacy. Motivation, entertainment and interactivity are another advantage the prototype also have, it provides interactive and attractive rich multimedia contents, it combines between fun and learn which supports the process of education making it more enjoyable, which in turn affect positively the educational achievement.

استخدام الواقع المعزز في دعم وتحسين القراءة والكتابة للصم: دراسة حالة اللغة العربية

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ملخص

إن الإلمام بالقراءة والكتابة أمر ضروري ولا غنى عنه لتطور الأطفال وكذلك النجاح في مجتمع اليوم. يتطلب تعلم القراءة والكتابة قدرات ذات صلة وهي: الإلمام باللغة وفك الشيفرة (تحليل الرموز)، يشير الإلمام باللغة إلى الثروة اللغوية المكتسبة في حين أن تحليل الرموز تعني عملية التحويل التي تؤدي الى فهم الربط بين اللغة والنص المكتوب وتحويل الكلمة المكتوبة إلى كلمة مقروءة (صوت). للأسف، يعد تعلم القراءة والكتابة واحداً من أكبر التحديات والصعوبات التي تواجه الصم، حيث أنهم يعانون من ضعف كبير في هذه القدرات المذكورة نظرا لفقدانهم السمع.

هناك العديد من الأنظمة التكنولوجية التي تم تصميمها لمساعدة الصم ودعم تطور القراءة والكتابة لديهم من خلال استخدام يستخدم Kinect، الواقع الافتراضي، Leap motion. معظم هذه الأنظمة يركز على ترجمة اللغة المكتوبة إلى لغة الإشارة والعكس.

لذلك، هذا البحث يدرس إمكانات وقدرات تقنية الواقع المعزز في تحسين تعلم القراءة والكتابة للصم وتعزيز الثروة اللغوية لديهم. كما أنه يثير مسألة إشراك المستخدمين المستهدفين في تشكيل التكنولوجيات حسب احتياجاتهم من خلال اعتماد نهج "تصميم موجه للمستخدم User-Centered Design (UCD).

ولتحقيق ذلك، تم إجراء دراسة حالة في فلسطين من خلال ثلاث مراحل: تقييم الاحتياجات وتصميم النظام وتقييمه. إجراء تقييم الاحتياجات لتحديد الاحتياجات والمتطلبات لتطوير نموذج أولي لنظام الواقع المعزز (AR) للأطفال الصم. بعد ذلك، تطوير نموذج أولي لنظام الواقع المعزز مدمج مع البطاقات التعليمية لتعليم القراءة والكتابة باللغة العربية للأطفال الصم. يساعد هذا النموذج الأولي الأطفال الصم على تحسين

القراءة والكتابة والثروة اللغوية، يسمح AR-DLE للأطفال الصم بمشاهدة المحتوى المعزز الغني الذي يغطي جميع جوانب تعلم كلمة جديدة حيث يمكن للطفل عرض الرسوم المتحركة ثلاثية الأبعاد الجذابة تصف المفهوم ومعنى الكلمة، كذلك يمكن عرض شخصية ثلاثية الأبعاد تعرض لغة الإشارة لهذه الكلمة، كما أنه يقدم فيديو لهجاء الأصابع وقراءة الشفاه معززاً بصوت للنطق لأولئك الذين لديهم بقايا سمعية.

تم استخدام تقنيات متعددة في المراحل المتعاقبة لتطوير النموذج الأولي، بما في ذلك المقابلات شبه المنظمة؛ الملاحظات والاستبيان. وقد أظهرت النتائج أن النظام فعال ومثير ومحفز وأن للواقع المعزز تأثير إيجابي وإمكانيات في تعزيز وتحسين القراءة والكتابة لدى الصم، إذا تم تصميمها وتنفيذها بشكل صحيح. يتمتع AR-DLE بالعديد من المزايا منها: التعلم الذاتي المستقل حيث انه سهل الاستخدام وليس بحاجة إلى مساعدة كما يمكن استخدامه في أي مكان دون الاقتصار على مكان معين. كذلك، فهو يدعم التكرار وهو أمر مهم للغاية بالنسبة للصم، حيث يمكنهم من تحقيق ذلك كل حسب حاجته وبدون جهد. كما يدعم النموذج الأولي التعلم البصري حيث أنه يأخذ بعين الاعتبار أن الطلاب الصم يعتمدون على وسائل التعليم المرئية والتفاعلية والجذابة وهذا يؤثر بشكل إيجابي على تعلم القراءة والكتابة لديهم. بالإضافة، يعد التحفيز والتسلية والتفاعل ميزة أخرى في هذا النموذج الأولي، حيث أنه يوفر محتويات تفاعلية غنية وجذابة للوسائط المتعددة، فهو يجمع بين المتعة والتعلم مما يدعم عملية التعليم ويجعله أكثر متعة، وهذا يؤثر بدوره إيجابياً على التعليم وتحديدا تعلم اللغة.

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List of Abbreviations

AR	Augmented Reality
HMD	Head Mounted Display
PCBS	Palestinian Central Bureau of Statistics
WHO	World Health Organization
GPM	Graphic Processing Module
GUI	Graphical User Interface
OST	Optical see-though
VST	Video see-through
QR	Quick Response
MAR	Mobile Augmented Reality
PDAs	Personal Digital Assistances
WFD	World Federation of Deaf
SL	Sign Language
ASL	American Sign Language
SMS	Short Message Service

Chapter One

Introduction

1.1 Introduction

Literacy, especially reading and writing abilities, is very important to learning and communicating effectively both in schools, homes and in the society at large. It is very crucial in full involvement in both education and employment. Regrettably, it is one of the biggest challenges and difficulties facing deaf people. For them, hearing loss, which is an important factor in their literacy process, is a major obstacle to literacy and its related, and the problem is exacerbated by the absence of the role of parents in early childhood.

Literacy learning for the deaf can be supported by augmented reality technology, by combining it with the flashcards to present 3D animation, videos of the pronunciation, spelling and 3D signing avatar related to a specific word. This will facilitate the reading process of the deaf, as well as giving them more autonomy in learning. In addition to its being a source of learning sign language for parents, and this will enhance their role in the education of children especially in early childhood and communicate with them.

Augmented Reality (AR) is a modern technology in which means the integration of digital content with the real world real time. It is the ability to augment user's immediate surroundings with electronic data or digital information of diverse types like audio, video, 3D objects etc. [1]. Augmented reality is applied in various fields of human life, like commerce and business, tourism, advertising, military, entertainment and in the most valuable field of AR in education. With AR features it can absolutely transform learning process into a more lively, productive, pleasurable and interactive experience for students [2].

Mobile phones also keep its revolution; it is highly adopted and widely spread among all segments of society at all. The advance of technology in general and the advance of the mobile and its properties, especially mobility converts it from just a communication device (calling) into a computing device and becomes attractive in learning in what is known M-learning (mobile learning). This conversion also makes it greatly adopted in the deaf community as an example the Short Message Service (SMS) [3].

Deafness Constitutes over 5% of the world's population, approximately about 360 million people has disabling hearing loss; about 9% of them are children according to World Health Organization (WHO) [4]. The World Federation of the Deaf evaluated that 80% of Deaf individuals don't get any education at all and only1-2% educate using Sign Language (SL). Deaf Children confront numerous more extraordinary difficulties with language and literacy than hearing peers [5]. The problem of weak literacy and poor comprehension is that it affects their ability to educate, ability to communicate, ability to express himself/herself and integrating into the community.

This thesis concentrates on the role that augmented reality technology can play in improving deaf literacy with concentrating on Arabic language; there are two researches on the AR literacy for deaf, one concern with Chinese language which is still in its initial stages, and the other concerns with the German language. In Arabic, no real work on the augmented reality for deaf literacy has been done, only a preliminary study without actual implementation. This thesis concentrates on the AR in Arabic literacy for deaf in Palestine. In this thesis, a prototype - AR-DLE- of the proposed system has been designed and evaluated which is the first in this field.

1.2 Motivation

Many applications of different technologies are founded for deaf students, including augmented reality, but not for supporting their literacy especially in Arabic language.

According to the Palestinian Central Bureau of Statistics (PCBS), the percentage of disability in Palestine ranges between 2.7% and 7% of the total population whereas the percentage of hearing disability is 14.2 % amongst other disabilities; their number is between 17000 and 42000 persons. The total number of deaf and hard of hearing who have access to education is 2618 students in both public and private schools in the scholastic year 2015/2016 according to ministry of education (MOE). Some of those didn't complete their education and withdrew from schools and some of them enroll schools late.

In Palestine people face a more difficult reality in the presence of the occupation, and the private deaf schools are located only in the centers of basic cities, making it difficult for many to enroll in these schools. In addition to the difficulties faced by these schools such as lack of support and potential. All these factors and others negatively affect the level of Arabic literacy of the deaf in Palestine.

1.3 Thesis Objectives and Questions

The main aim of this thesis is to develop a mobile augmented reality prototype combined with flashcards for deaf children and to assess its potential to enhance their Arabic literacy skills.

Therefore, the main research questions are:

Q1: What is the current situation of teaching deaf in Palestine?

Q2: How should AR-DLE application be design so as to meet the needs of deaf?

Q3: How useful is AR-DLE in teaching deaf? In terms of:

Q3.1 How does the use of .AR application combined with flashcards improves the deaf children’s literacy learning and enhance it?

Q3.2 Can this technology play an active role in increasing the linguistic wealth of the deaf which help them develop their literacy abilities?

1.4 Thesis Contribution

Two main contributions of this thesis:

- Design a mobile augmented reality prototype to enhance and support deaf literacy skills, and asses the AR potential in enhancing deaf literacy. The prototype targeted the Arabic language and it is the first in its field.
- Using User Centered Design (UCD) approach that involves intended users in the shaping of technologies to their needs.

1.5 Thesis Organization

The thesis is organized in the following manner: Chapter two presents the literature reviews on the emerging topic of Augmented Reality and its potential application, specifically to enhance Death Learning. Furthermore, the chapter reviews the various research works that address death learning topic. Chapter three explains the research methodology used in this thesis. Chapter four introduces the prototype and the stages of developing the system, the technologies used in the implementation, the system design and implementation. Chapter five provides the analysis of the experiment and presents the archived result. Chapter six provides the discussion of the results achieved in addition; in this chapter the research questions were answered. The last Chapter, Chapter seven summarizes the work in this research, discusses the limitation of the study and highlights the recommendation for the future work.

Chapter Two

Literature Review

2.1 Deaf learning and technology in deaf learning

In this section an overview of deaf learning and education is presented with concentration on deaf literacy and its difficulties, effects on the individual's learning and other aspects of life especially in communication. The section also presents the impact of technology in deaf learning and views some of these technologies.

2.1.1 Deaf Learning and Education

Hearing impairment is an umbrella term that encompasses the range of hearing loss. It varies from hardly hearing to totally deaf [56]. Deafness is the term of losing the hearing. Deafness influence can vary highly depending onset of it's happening, before or after speech development. According to this, deafness is categorized to pre-and post-lingually deaf. Pre-lingual deafness happened before the development of the language and learning to speak. Post-lingual deafness happened after the one already had learned to speak [57]. People with pre-lingual deafness have a different mother language which is the sign language and the written language is considered as the first foreign language for them. It is attributed to the fact that his language was not developed by hearing and speaking in childhood. By contrast, hearing peers know how to speak and have the ability to do so. Usually, they retain this ability and do not lose it by hearing loss. Their mother language is the same as in hearing people [57].

Research in to the academic achievement of deaf students often finds that the performance of many children is significantly lower than their hearing peers on many measures and across many domains [58]. This low academic achievement is mainly due to lack of literacy. There is an achievement gap between deaf and their hearing counterparts [59]. This lack poor of academic achievement affects many aspects of deaf life, high education, employment opportunities and others. According to [59], two main factors contribute to this gap and its aggravation, learning opportunity and assessment system, the provided services may be not suitable and effective enough for them and don't take into account their needs. The achievement tests may be biased against this population group. Often the combination of the two factors together causes the gap.

To raise the efficiency of their education and increase their educational achievement to achieve a better life and provide better opportunities must choose appropriate methods of effective teaching and taking into account their needs. In the following paragraphs main deaf education methods are mentioned.

Among the Ancient Greeks and Roman deaf lives and circumstances were bad. They were marginalized and humiliated. Aristotle says, "Those who are born deaf all become senseless and incapable of reason." [60]. He believes that hearing is a requirement for learning. Aristotle belief doesn't depend on any scientific facts, but this belief prevailed for a long time and due to this there were only few tries in deaf education. A first challenge to this belief was in the 16^{th} century when Girolamo Cardano was the first physician to recognize the ability of the Deaf to reason, he emphasizes on deaf education and suggests teaching them concepts by signs. The first teaching of a deaf student has been attributed to Pedro Ponce de Leon approximately at 1550, he was the first teacher of deaf history, he teaches successfully Spain deaf from the birth speaking, writing and reading. The first books on deaf education was published by Juan Pablo Bonet at the beginning of the 17th century specifically at 1620, the book title was 'Simplification of the Letters of the Alphabet and Method of Teaching Deaf-

Mutes to Speak'. In 1700 a method to teach speech and lip-reading to deaf people was devised by the doctor Johann Ammons. The first oral school for deaf in the world was started by the German teacher Samuel Heinicke at 1755. Abbe Charles-Michel de l'Épée of Paris founded the first free school for the deaf with sign language as a method of communication at 1760 and at the same year the first British Academy for the deaf founded by Thomas Braidwood. At 1864 Gallaudet University became the first deaf university to offer higher education. Alexander Graham Bell Promotes Deaf Education and opens a deaf school at 1872. At 1931 The Central Institute for the Deaf (St. Louis) begins teacher training program.

In 1960 William Stokoe wrote the first linguistic book in defense of American Sign Language (ASL) as a language, and he together to Dorothy C. Casterline, and Carl G. Croneberg wrote the first sign language dictionary, ‘A Dictionary of American Sign Language on Linguistic Principle’. At 1965 the National Technical Institute for the Deaf. NTID was established which is the first technological college for deaf students in the world. Then a bilingual education was applied using the sign language and the hearing people language. Since 1960s until today, Deaf education has developed significantly specially with the development of ICT. [60-63].

There are three main communication approaches used in deaf education. These three ways of teaching deaf are: Oral, Total communication and Bilingual/bicultural (bi-bi).

Oral approach: this approach emphasizes auditory training and lip-reading. It emphasizes on stimulating and using the residual hearing that approximately all deaf children have, to learn listening and speech and understand the spoken language and depends on amplification technology and electronic implant like hearing aids and cochlear [64,66]. In this approach sign language is completely absent. This approach is divided into two methods first Auditory Verbal which depends on the residual hearing to learn without any visual. The second is

Oral/Aura which is similar to the first, but it teaches the deaf speaking and lip-reading and use visual cues such as facial expression and gesture [64-66].

Total communication approach: this approach uses the combination of the oral and sign language including sign language, lip-reading, voice, fingerspelling, gesture and visual cues [66]. In this approach, the deaf child is exposed to all communication techniques without exception, and it doesn't consider that there is a better technique than other [65, 66].

Bilingual-bicultural approach: in this method, deafness is approached as a cultural, not a medical issue [67], they are a part of the community have their own culture, language, history, school and other special things belong to them. In this approach the deaf learn to read and write the written spoken language through a signed language [68]. And it perceives the importance of both hearing and Deaf cultures. It considers that sign language is the first language taught and the spoken language which is the mother language of hearing people is the second language. This is based on the principle that the previous two approaches oral approach and total communication are not suitable and do not meet the deaf linguistic needs and consider that sign language is more appropriate and efficient for them. This approach is the most common one of teaching deaf and the most applied in deaf schools [69].

2.1.2 Literacy and its difficulties

As mentioned in the previous section, the academic achievement of deaf student often is less than their hearing peer. One of the most important reasons for this problem is the literacy weakness of the deaf student.

Literacy, especially reading and writing abilities, is very important to learning and communicating effectively both in schools, homes and in the society at large. It is very crucial in full involvement in both education and employment. Regrettably, it is one of the biggest challenges and difficulties facing deaf people. Many researches show that there is a clear difference in literacy achievement of deaf and hearing impairment compared to their hearing peers. For many decades their average literacy outcomes are significantly below of those of hearing [70]. World Federation of Deaf (WFD) pointed out that Illiteracy and semi-literacy are serious problems among Deaf people, WFD also indicate that the enrollment rate and literacy achievement of deaf children is far below the average for the population at large and that there is at least 80 % of the world's 70 million deaf people are illiterate or semi-literate. Internationally, the average deaf students graduate high school with only fourth grade reading level [70] [71]. Several studies have been conducted to assess the ability of the deaf to read and write. Most of these studies have shown that the average reading rate for deaf students aged 14-18 does not exceed the average of hearing students aged 7-9 years. One of these studies was by Pintner and Patterson, who find that the average deaf child at any age never equals the average ability of seven-year-old hearing children [72]. Ronnie B. WILBUR stated in [73] that a study on deaf reading ability applied on deaf students aged 8-10 finds that they performed considerably worse when compared with same aged hearing children. Kyle & Cain also stated in [74] that there is a huge delay between deaf and their hearing counterparts in reading comprehension abilities which in turn leads to that deaf leave school with reading comprehension levels tantamount to those of nine-year-old hearing children. Another study Stanford Achievement Test Reading Comprehension [75] show that deaf between 8-18 years old achieve reading comprehension as a hearing child in third grade or as a hearing child aged approximately nine years old. Another similar result achieved in [76], it finds that a deaf student aged 15 to 16 years had a median reading level equivalent to that of a nine-year-old.

Deaf literacy development is a very prior issue. It is very important to deaf individual to be literate. A set of reasons cited in [77] explain why reading for the deaf deserves special attention:

1. For deaf people, reading provides access to the hearing world.
2. Increasingly daily living (work, entertainment, and poll tax) requires higher levels of literacy than in the past.
3. Many of the technological developments that could benefit deaf people require reading skills-subtitles on television; minicom and computers.

The learning of reading and writing requires two related capabilities, language familiarity and decoding, the learner must be familiar with a language and also must understand the mapping between that language and the printed word [78]. Deaf children are disadvantaged on the two capabilities. Unlike hearing children, deaf children are not exposed to spoken language early in their development, so they do not build language familiarity, and deaf children don't have access to phonological code and have a lack of phonemic awareness, so it is difficult for them to map between the spoken language and the printed words, the second factor also failed.But this doesn't mean that they couldn't learn to read and write, the evidence is that there are deaf people who can read and write even pass successfully the higher education. And they able to be literate, but we should know the way they learn, their abilities and the challenge is to find a way to develop their literacy skills.

Deaf students develop language and literacy skills in comparatively different way than hearing students. Incidental learning is an example of this. where hearing students obtain some of their language from parents and family, the media like TV and radio, whereas this is not available for deaf students, they are less exposed to language during their early years, especially if their parents are hearing and do not learn sign language [79].

An important strategy for deaf and hard-of-hearing children to learn reading is the use of sign language in a process called coding, a process of combining sign, written word, spoken language. Research and studies have shown that Deaf students who use Sign Language and learn through it perform better in written language than students who don't use sign language [80]. Scientifically, there is a different among the brain between deaf who use sign language and who don't, and also different in electrical activities of the brains [81]. Research suggested that deaf with good signing skills may be better readers than whom with poor signing skills [78]. In [78] also mentioned that those deaf, who are learning ASL, learn language naturally and at the same pace that normally hearing children acquire spoken language. In addition, Conrad demonstrate that sign language has a vocabulary that provides the possibility to discuss education topics such as ethics, poetry etc. he recommended that teachers should have sign language skills to effectively deliver teaching and information to deaf students [76].

In scientific term, Bransford et al in how people learn [81] pointed to the emersion of detailed knowledge of brain processes behind language in recent years. For example, there seem to be separate brain regions that specialize in subtasks of the language like hearing words (spoken language of others), seeing words (reading), speaking speech (speech), and generating words (thinking with language). And the independent brain representation of these skills allows to a coordinated practice of skills, which encourage learners to move smoothly between speaking, writing and listening.

He mentioned that educational processes contribute to the organization of brain functions. For instance, language processes are usually more closely associated with the left side of the brain, but certain types of experiments can contribute to other areas of the brain that assume certain language functions. For example, deaf people who learn sign language learn to communicate using the visual system rather than the audio system. The visual perception of sign language is very different of auditory perception of spoken language; it depends on the parallel visual perception of the shape, relative spatial location, and movement of the hands.

He explained the auditory and visual pathways in the nervous system “In the nervous system of a hearing person, auditory system pathways appear to be closely connected to the brain regions that process the features of spoken language, while visual pathways appear to go through several stages of processing before features of written language are extracted. When a deaf individual learns to communicate with manual signs, different nervous system processes have replaced the ones normally used for language—a significant achievement.” (p.123).

In [81] also pointed to the information that specific types of instruction can modify the brain, enabling it to use alternative sensory input to accomplish adaptive functions. Where in all deaf individuals’ brains some cortical areas that normally process auditory information become organized to process visual information.

Many researchers consider that deaf students are extremely visual learners. According to Marschark (2001) [83]:

> “Because most deaf children are dependent on the visual modality for language reception regardless of whether they are acquiring a spoken or sign language, they have to shift attention between their activities and their language partners in order to obtain information both about what is going on around them and about language itself” (p.10).

The term “Visual Literacy” was first coined by John Debes in 1969, he defined the concept: “Visual literacy refers to a group of vision competencies a human being can develop by seeing and at the same time having and integrating other sensory experiences.” [84, 85].

Providing a visually enriched environment to deaf enhances vocabulary acquisition. Lederberg & Spencer [82] hypothesis that deaf children would show three levels of word-learning abilities:

1. Some of deaf preschoolers have difficulty to learn new words rapidly either through direct reference or novel mapping.
2. Some of them would learn new words rapidly just in direct reference strategy.
3. Some of deaf DHH preschoolers would learn new words rapidly through both strategies direct reference and novel mapping.

Many researches explain the role of using multimedia with its various components in education; it provides a rich, intelligent and interactive visual learning environment. Hence it can enhance the literacy by the enrichment of the text with different items of multimedia as images, videos, 3d and animation and other items. This provides students the chance to extract and opportunity to extract and scout learning materials in a way that suits their needs. Examples of these studies mention in the following paragraph.

Nikolaraizi & Easterbrooks [86] examined the using of the visual resources of multimedia software by deaf; the application was built to enhance their reading and comprehension ability. The assessment showed an increasing in their comprehension and it also mentioned that the result indicated that deaf students enjoyed and used most of the visual resources in the software; they use and interact with it independently without following specific teacher guidelines.

Another study [87] Mich et al develop a literacy web tool for deaf children based on stories and comprehension exercises, the assessment also showed an enhancement in their comprehension skills.

As a result, visual learning for teaching deaf must be used as much as possible as vision becomes their primary mean for receiving information.

Technology has become an important instrument in education and it has the powerful to provide interactive environment for learning especially for learner with special needs. In the following section an explanation of importance of technology in learning and especially in literacy is provide and providing samples of deaf learning technologies in general and literacy in particular.

2.1.3 Deaf learning technologies

Technology has become a valuable tool in education; it provides an intelligence learning environment. Bransford [81] mentioned in his book five ways how technology could provide an intelligence and interactive learning environment:

1. Bringing real-world problems into classrooms through the use of videos, demonstrations, simulations, and Internet connections to concrete data and working scientists.
2. Providing “scaffolding” support to augment what learners can do and reason about on their path to understanding. Scaffolding allows learners to participate in complex cognitive performances, such as scientific visualization and model-based learning, that is more difficult or impossible without technical support.

3. Increasing opportunities for learners to receive feedback from software tutors, teachers, and peers; to engage in reflection on their own learning processes; and to receive guidance toward progressive revisions that improve their learning and reasoning.
4. Building local and global communities of teachers, administrators, students, parents, and other interested learners.
5. Expanding opportunities for teachers' learning.

The emergence of information technology sector and its great features has brought new hopes for deaf learner and paly important role in their lives where many assistive systems have been developed that provide supporting to deaf communities.

In this section examples of using technology to help deaf with concentration on literacy and learning reading and writing technologies and applications epically those for Arabic language.

According to Assistive Technology Industry Association (ATIA) [88], assistive technology is defined as any products, equipment, and systems that enhance learning, working, and daily living for persons with disabilities. It can be high-tech or low-tech, it can be hardware, computer hardware or software or other technologies [88].

For deaf people, assistive technologies can be grouped into three main groups, hearing technology, alerting devices and communication technology in addition to the emerging technologies [89] which is the important part for this research.

- **Hearing technology:** this type includes the technologies and devices used to improve level of hearing by improving the level of sound available to a listener and are not made for deaf people with a complete loss of their hearing ability. This technology includes four subtypes: hearing aids devices, assistive listening devices (ALD), personal sound amplification products (PSAPs) and cochlear implants.

- **Alerting devices:** it provides amplification or visual signal or vibration to get attention of deaf person. It can be used for both emergency situation and daily situation. Examples fire and smoke alerts, telephone calls, baby crying and others.
- **Communication support technology:** it is known as Augmentative and alternative communication (AAC), it is the group of tools aimed to improve deaf communication skills. It consists of two main classifications: telecommunication services and person-to-person interactions.

In addition, in [89] the author mentions that there are emerging assistive technologies for deaf. As there is progress in the cochlear implants and another emerging technology the auditory brainstem implant (ABI). The author examines that there are other emerging technologies which are the applications of existing technologies like: Google glasses, various systems to provide real-time captioning, purpose-designed software for laptops and tablets, several smartphone applications.

In the following paragraphs a review of some of these technologies and application with concentration on education technology especially for literacy and Arabic.

MathSigner [90], an interactive program which is a learning tool to teach American Sign Language (ASL) for K-3 mathematics by interactive media which is 3D animation, The MathSigner contains two programs one is aimed at deaf children and the other is aimed at hearing parents. Each provides two modes learning mode and practice mode. The application was developed using cutting-edge 3D animation technology and based on Maya 2009 (Autodesk), Microsoft XNA [90].

SMILE [90]: Science and Math in an immersive learning environment is a virtual reality immersive environment in which deaf children of age 5–10 able to learn science, technology, engineering and math (STEM) concepts in addition to learn ASL through user interaction with fantasy 3D characters that communicate in ASL and spoken English. SMILE is the first bilingual immersive virtual learning environment featuring interactive 3D animated characters that respond to the user's input in English and ASL. It provides an imaginary town with 3D object, the user can explore the town, enter buildings, interact with objects and learn STEM concepts through the interaction. SMILE can be displayed on different systems: four-wall projection devices, single screen portable projection systems, Fish Tank VR systems, standard desktop computers. And it could be modified to be displayed through HMD [90].

The CopyCat game [91] is an interactive educational game to help deaf children improve their language and memory abilities. The software for the games is written using Flash and runs within a web browser. The child wears different colored gloves in each hand (red and purple) with wrist mounted accelerometers and interacts with the game via American Sign Language. The child sits in front of a camera and computer monitor or laptop. The camera captures continuous video of the signing at 20 fps to track the color gloves and the signer's head are tracked. Vision features which are hand shape features and pose features are computed and combined with Fast Fourier Transform (FFT) based features computed from the accelerometer data that is streamed to the laptop computer via a Bluetooth connection. Then recognition level starts to recognize the signs using Hidden Markov Models.

Arabic Sign Language Alphabets Translator (ArSLAT) system [92] is an automatic translation system for gestures of manual alphabets in the Arabic sign language; the system does not rely on using gloves. It allows the user to interact naturally with the system as it deals with images of bare hands and doesn't need any devices. The proposed ArSLAT system consists of five main phases; pre-processing phase, best-frame detection phase, category detection phase, feature extraction phase, and classification phase. Pre-processing phase receives a video contains the signed words to be translated into text, then prepare it to be ready for use in subsequent phases by extracting frames using segmentation algorithms and convert them to binary and apply smoothing for them. In best-frame detection phase, the system detects the number of words and number of letters in each word that have been signed then it takes snapshots of these letters. Category detection phase considers the Arabic sign language as three categories depending on the direction from which the hand wrist appears, this phase focuses on specifying the category of all letters which increase the accuracy and reducing the matching operation which in turn minimizing the processing time. Feature extraction phase extracts features of each letter. The extracted features are rotation, scale, and translation invariant. Finally, in classification phase, a matching between the unknown letter with all the known letters in the same category in the database and accept the nearest one to this letter and consequently, the system writes the result as text. The extracted features are translation, scale, and rotation invariant in order to make the system more flexible. Experiments revealed that the proposed ArSLAT system was able to recognize the Arabic alphabets with an accuracy of 91.3%.

A real time (ASL) word recognition system [93] developed using artificial neural networks (ANNs) to translate ASL words into English and is capable of recognizing all 50 ASL words used in the testing. The system extracts the gesture features through a sensory glove called the CybergloveTM and a Flock of Birdss 3-D motion tracker. The gloves contain strain gauges sensors, its role to obtain the data about finger joint angle to define the hand shape, and the tracker is to describe the trajectory of hand movements. The data from the gloves and the tracker are processed by a velocity network with noise reduction and feature extraction and by a word recognition network.

Another system in [94] is ARSLEC, which is a software package consisting of sign language translation and chat tools. The translation tool goal is to translate both ArSL To Arabic Language and Arabic language To ArSL, translation is done word by word and via a virtual keyboard, the user presses the sign button he wants, it is then copied to the clipboard then the user presses the translate button to translate the sign to the equivalent word in Arabic and vice-versa. The system also provides a chatting tool.

Avatar-Based Translation System for Arabic Sign Language (ABST for ArSL) [95] is a system to translate Arabic speech directly into 3d avatars. The application receives the input in the form of a speech which is in Arabic. The system captures the speech through a speech recognition system, and then the captured speech is digitized and translated to Arabic sign language. Then it converts the Arabic sign language to animated avatars which are displayed on the computer screen. The system contains a database of the captured 3D motions of Arabic sign language. The sign language motion will be recorded using data gloves. A graphical conversion of the digitized sign language will be re-animated using standard.

Ameiri et al [96] develop a deaf mobile application with several features provide the ability to learn ArSL and communicate through it. The application provides the following features: translating from Arabic text to Arabic sign language and vice versa, video chatting in ArSL, SMS messaging and translating SMS messages to Arabic sign language. The application is downloaded into the mobile and connecting to web server to get the features, videos, archived SMS etc...

Dahmani, D., & Larabi, S [97] proposed a new hand-posture recognition system for Arabic sign language alphabet. This system doesn't require wearing gloves or using other devices, it is user independent operates in complex backgrounds. Hand segmentation is performed using skin color-texture attributes and neural networks.

tuniSigner [98] is an automatic interpreting a SignWriting notation system using avatar technology. It is part of WebSign project which concerned with web application for deaf. tuniSigner main aim is to provide a support to deaf to learn and use the written form of sign language as it is their mother language, this support is by generating avatar animation equivalent to the written form. It takes a SignWriting notation provided in an XML-based variant (SWML) as input and generates the equivalent sign language performed by an avatar animation in a virtual space.

JFakih [99] is android mobile learning game for deaf children to learn Jawi. It contains three main modules: learning Jawi by viewing both Jawi character and the corresponding hand sign, playing quiz games about Jawi, and the last module is a memory game which depends on matching pictures contains Jawi alphabet and hand signs. The result of the evaluation shows that the Learning game application was successful to create focus and enjoyment for the children.

Alsumait, A. et al [100] propose an interactive storytelling prototype, Child Deaf Arabic Storytelling (CDAS). The application aims improve Arabic deaf literacy and communication skills. The CDAS tool is designed on the basis of animated stories. It was developed on portable device to due to its front-facing camera to allow deaf children to record their own hand gestures and save them. It also offers three basic modules: Create My Own Story: allows the deaf student to build his own story by drag and drop objects, using the dictionary of the application to view its appropriate definition in text, images, finger spelling, and ArSL videos.

If the definition doesn't exist it post it on social media to get suggestion, the student recorded the telling of the story through the camera and can save it. The second module: read story, the user can select a story from a list and read along with the story text and/or play a video of an ArSL storyteller. He can use the CDAS's dictionary and hover over words from the story by cursor and see the signing and fingerspelling of a word. The last module: Build a Mastered List, exercises and quizzes are provided to the child to measure his level of comprehension of the story. Preliminary estimates for the first prototype suggest that the approach is suitable and desirable.

Another similar system [101] for the Malaysian sign language translator system, it uses gloves, accelerometer, microcontroller and Bluetooth. The gloves are to capture the finger flexion with sensors in the gloves, the accelerometer for recognizing the motion of the hand and the microcontroller and Bluetooth module to send the interpreted information to a mobile phone.

In [102] an android mobile application to support the Arabic deaf communities was developed]. The application provides an ArSL keyboard to give ability of communication between deaf and hearing. It provides two modes "ArSL keyboard" keyboard with signs and "Standard Arabic Keyboard" people by typing messages each with his own language and the application will convert it automatically to the other's language, where the application converts Arabic text/speech to ArSl and vice versa. Moreover, the application can be used as a tool for learning ArSL for both deaf and hearing people.

Learning version of memory match game for deaf learners (LMMGDL) [103], is an educational game for deaf learners. The aim of this game to enhance vocabulary acquisition for deaf learners in both spoken and sign languages concentrating on learn with fun. The game combines of learning game, 3D human avatar and a sign language written form. The game provides three modes the first the user matches a word with its sign writing, the second he matches a visual content with its sign writing, the last a match between math expression and its signwriting. The game provides another feature, when the learner selects a card that hold SignWriting, then a 3D avatar animation appears viewing the sign.

Tawasol [104] is a free multimedia iOS/Android mobile application, a system for translating Arabic text to Arabic Sign Language. The tool contains three functions: a translator, an ArSL dictionary and fingerspelling editor, it also provides tutorials, quizzes and activities. This educational tool contains 3D animation for sign representation. The application uses Vcommunicator gesture builder, Macromedia flash and Sign Smith Studio. The application is developed with collaboration between university-based research group at King Saud University, and non-profit charitable foundations.

In [105], a real time translation framework to help Arabic deaf people to communicate without needs to get help from others or having specific devices. They build a mobile-based framework that utilizes the power of cloud computing to process the Arabic text. The program first converts the speech to text then after processing the text. It shows a cartoon avatar showing the corresponding Egyptian Arabic Sign Language on the mobile screen.

Deaf Talk [106] is software that offers a mechanism through which deaf and hearing-impaired people can communicate naturally with other people. The software is considered as a sign language interpreter and translator to provide a dual mode of communication between deaf and hearing individuals. These modes are Sign/Gesture to speech conversion and Speech to sign language conversion. The software depends on Kinect in both modes, taking advantage that it is able to track motion, depth and gestures and other advanced features. In the first mode the user recorded his gestures through Kinect sensors, the recorded gesture frames then each gesture comprehends by comparing them with the trained gestures already stored in the database. After determining the corresponding key words, it builds the sentence and then sent to text to speech conversion module to play the sentence. In the other mode the speech to sign language conversion module takes natural language as an input, then converts it into text using speech to text API the displays corresponding sign language by 3d animation avatar on the screen in a real time manner.

Sign translator system for Arabic Sign Language (ArSL) [107]. The system translates from Arabic speech into ArSL using the automatic Arabic Speech Recognition module (ASR) integrated with Arabic Signer model to generate the ArSL signs. The system firstly recognizes the speech and translates it into a stream of Arabic written script. Arabic text is generated from the ASR module. Then the generated text is fed then to the proposed system which converts it into animation by the virtual signer. The proposed system consists of three modules Arabic script module takes the recognized Arabic text as an input from the ASR module and tokenizes the text into separate words. The second module converts the Arabic script text into a stream of Arabic Signs. The third module; the Signer generation module converts text streams into animation by the virtual signer. The system was tested on android environment, it based on WordNet lexical database, it used SQL Azure for cloud computing to provide scalability and interoperability. According to the author the evaluation result shows that the system has a sign detection rate of 85 %.

ArSLR [108] is a model for Arabic sign recognition using the leap motion controller (LMC). The system is developed for both static and dynamic gestures. The system composed of five stages, the first stage is pre-processing phase which starts up the leap motion service, receives the hand gestures and performs advanced algorithms on it. The second stage is tracking phase a matching between tracking layer and the data in order to extract tracking information. The third stage concerns feature extraction, a robust feature which is to identify the sign is extracted by analyzing the data obtained from LMC and introduced as a vector. The last stage is the recognition of the gesture using classifier.

Al-Turjuman Arabic Sign Language Translator [109] is a free mobile application developed by Mind Rockets Inc in 2016, it translates written and spoken sentences into Arabic sign language through 3D animated avatar in an instant, it facilitates communication with the deaf community. The application can be used in four ways, converting spoken language to sign language, converting text to sign language, sending message as a video via social media sites, it can also be used to learn sign language by using the dictionary which contains more than 4000 sign languages animations.

The following table provides a summary of these systems.

Author/system	Type	Device or system	Media/characteristics	Notes
MathSigner Adamo-Villani, N., & Wilbur, R. (2010)	Learning- ASL math terminology and concepts	Web/Desktop	3D animations	
SMILE Adamo-Villani, N., & Wilbur, R. (2010)	Learning science and ASL	Projection devices/desktop	virtual reality	
CopyCat game Zafrulla et al (2010)	Improve language and memorize/ sign recognition	Desktop	Flash/ gloves with accelerometers	
ArSLAT El-Bendary et al (2010)	Arabic letters sign language translator	Desktop	Use image processing algorithms to recognize gesture from captured video without needing any device	Accuracy 91.3%
Real time ASL translator Oz, C., & Leu, M. C. (2011)	ASL translation	Desktop	sensory glove/uses neural networks in recognition	Tested for 50 words with accuracy 100% for these words
ARSLEC Al-Dosri et al (2012)	Arabic sign language translation and vice versa/ chatting tool	Web	Provides a virtual keyboard for arabic letters and signs.	
ABST for ArSL Halawani S.M. and Zaitun A.B (2012)	to translate Arabic speech directly into 3d avatars	Desktop	Voice recognition/sensory gloves	
Ameiri et al	Learn ArSL and	Mobile		Translating from

(2012)	communication			Arabic text to Arabic sign language and vice versa, video chatting in ArSL, SMS messaging
Dahmani, D., & Larabi (2014)	Communication hand-posture recognition system for Arabic sign language alphabet.	Desktop	Uses skin color-texture attributes and neural networks in segmentation and recognition	
tuniSigner Bouzid, Y., & Jemni, M. (2014).	automatic interpreting a SignWriting notation	Web	Animated Avatars	
JFakih Hussain et al (2014)	Game- learning Jawi alphabet sign language	Mobile		
CDAS Alsumait et al (2015)	Improving Arabic deaf literacy and communication skills	portable device	Storytelling- animated stories	
Shukor et al (2015)	Malaysian sign language translator	Mobile	Uses gloves, accelerometer, microcontroller and Bluetooth	
Gayyar et al (2015)	Communication with hearing people through ArSL keyboard	Mobile		Converts Arabic text/speech to ArSl and vice versa
LMMGDL Khenissi et al (2015)	educational game for enhancing vocabulary	Desktop (computer game)	3D human avatar	U ser matches a word, visual content or math expression with its signwriting
Tawasol Al-Nafjan et al (2015)	Translating Arabic text to Arabic Sign Language	Mobile	3D animation	uses Vcommunicator gesture builder, Macromedia flash
El-Gayyar et al (2016)	Translate arabic speech to arabic sign language	Mobile	Cartoon avatar. Utilizes the power of cloud computing	
Deaf Talk Ahmed (2016)	Sign language interpreter and translator Speech to sign and vice versa	Kinect	Uses Kinect. Provides 3D animated avatar	
ArTTS Al-Barahamtoshy et al (2017)	Translates from Arabic speech into ArSL	Mobile	Utilizes cloud computing. Virtual signer animation	Sign detection rate of 85 %
ArSLR Hisham, B., & Hamouda, A. (2017)	Arabic sign recognition	Computer	Leap motion	
Al-Turjuman Mind Rockets Team. (2017)	Arabic Sign Language Translator	Mobile	3D animated avatar	Provides dictionary with 4000 sign languages animations. -Video messaging through social media

Table 2.1: Summery of deaf learning technologies previous work

2.2 Augmented Reality (AR)

AR is characterized as innovations that superimpose virtual data on physical environment and permit client communication continuously [6]. It provides the user with a special experience more than from ordinary Graphical User Interfaces (GUIs) by extends user perception and enriches his knowledge without switching between real and virtual environment, but they are integrated by enhancing the real environment with various virtual information.

AR technology has been used in several fields, such as education, medicine, commerce, robotics, manufacturing, maintenance, aircraft simulations, tourism, entertainment and gaming. [6].

In this section, an overview of the AR is provided to explain the background of this thesis. First, introduction of the definition, concepts, characteristic and architecture of AR are presented (Section 2.1.1). Second, key technologies and interfaces of AR are presented (Section 2.1.2). Third, the applications domains of AR are presented (Section 2.1.3). Fourth, the augmented reality in education is investigated (Section 2.1.4). Last, the mobile augmented reality is presented (Section 2.1.5).

2.1.4 Definition and main concepts

The term augmented reality is understood as the enrichment of the real surrounding environment with a virtual computer-generated content as 3D or 2D objects, video, audio text information and others.

The most commonly accepted definition of AR is the technology that allows the overlaying of computer generated information onto alive real environment while being registered in 3D and interactive in a real time [6]. There are three important points in the above definition that attention must be focused on which form the requirements of augmented reality application.

1. It combines real and virtual content.
2. It is interactive in real time.
3. It is registered in 3D.

From these requirements we can extrapolate that the augmented reality is not restricted to special display technology as Head Mounted displays(HMD) as Milgram, et al (1994) noted in [7] "a form of virtual reality where the participant's head-mounted display is transparent, allowing a clear view of the real world" (p. 283). Another fact that augmented reality is not only applied for the sense of sight rather it is applied to all senses including hearing, smell and other. Another point to consider is that some augmented reality application requires the removal of the real object then replace it with the virtual one in what is known as mediated augmented reality; it is considered to be a subset of the whole augmented reality. [8]

Klopfer (2008) confirms in his definition that AR is not limited to a specific technology, it could be applied to any technology that can overlay the real world with meaningful and interactive virtual content, the general definition of AR as indicated by Klopfer and Squire (2008), “a situation in which a real-world context is dynamically overlaid with coherent location or context sensitive virtual information”. (p. 205). [9]

Augmented reality differs from the virtual reality in that the environment the augmented reality deals with is the real environment and the enhancing information is virtual, in contrast to virtual reality in which both the environment and the enhancing information are virtual [10].

According to the Milgram [11], virtuality continuum AR resides between the real environment consisting of exclusively real objects and the virtual environment consisting of exclusively virtual object. As shown in figure 2.1. Mixed reality is an environment where there is a combination of real and virtual scenes and objects, so AR is a part of the whole set mixed reality. [10].

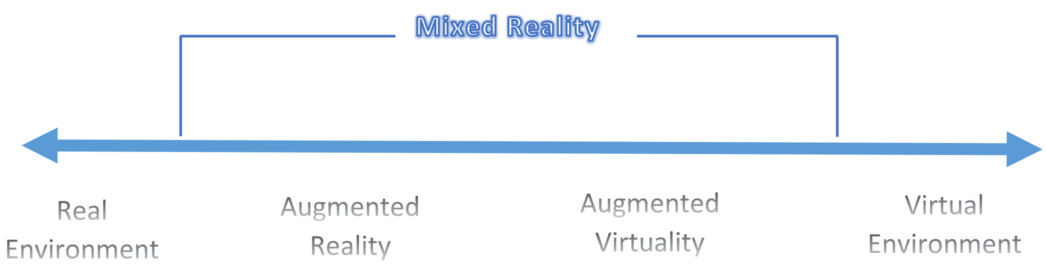


Figure 2.1: A redraw of the virtuality continuum proposed in [10].

2.1.5 Augmented reality system architecture

The main components needed for an AR system are a video camera for scene capture it catches the real surrounding environment image, a tracking module to calculates the position and orientation of the camera to find the correct position of the virtual object to overlay, a Graphic Processing Module (GPM) recognizes the captured image and add the correct virtual content to it, and a display to render the computed image. [13, 14]. Figure 2.2 explores the general architecture of AR system [13].

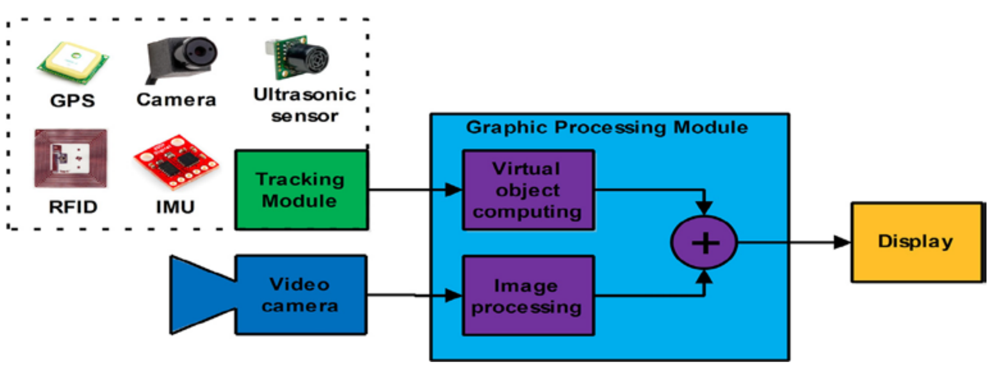


Figure 2.2: General architecture of AR [13].

2.1.6 AR Technologies

Technology has a vital role in developing AR and its research, technology has had a prominent presence in the definition of augmented reality, as most of the definitions refuted the fact that the augmented reality is specific to a particular technology. With the rapid development of technology in all its aspects and the accompaniment of augmented reality to this development in both software and hardware devices, AR has become widespread and applicable in all aspects of life. These technologies are AR displays and AR Tracking.

2.1.6.1 AR Displays

The importance of AR displays viewing the digital content to achieve augmentation. There are three categories of displays: head mounted displays (HMD), handheld displays and spatial displays.

HMD refers to the devices that one wears on his head with a display on front of his eyes. HMDs are categorized either as optical see-though HMD or video see-through HMD [15]. Optical see-though HMD (OST) works by putting optical combiners in front of the eyes these combiners characterized as partially transmissive and partially reflective, the first characteristics enable the user to directly see the real world through them and the second characteristic enable the user to see the virtual content which is projected on the combiners from head mounted monitors. The combiners in turn reflect it on user’s eyes, these combiners may be holographic optical element, half-silvered mirror or other similar technology [12,19-21]. A configuration [19] and an example [17] of optical see-through shown in figure 2.3 a and b respectively.

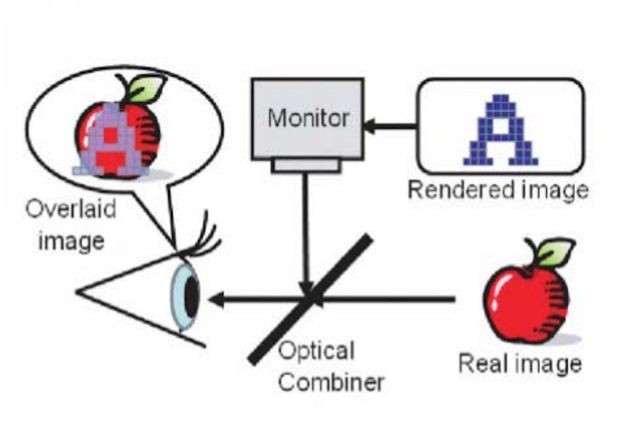


Figure 2.3: a) A configuration of OST [19] b) an example of OST-HMD [17]

Video see-through HMD (VST-HMD) it combines a closed-view HMD with head mounted cameras, the captured video from these cameras is combined with the computer-generated

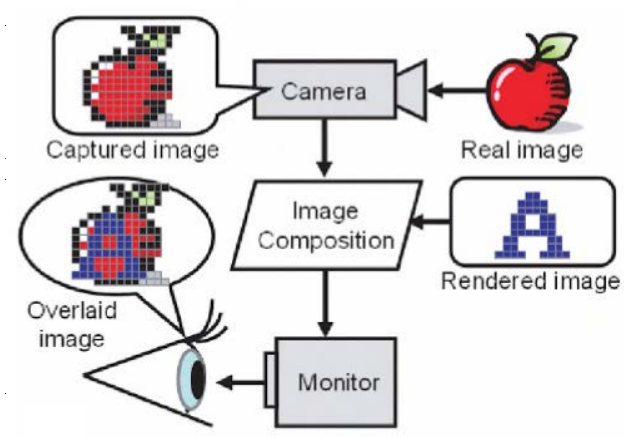


Figure 2.4: a) A configuration of VST [19]. b) an example of VST-HMD [18].

Handheld devices are considered to be a best alternative for HMD display to apply augmented reality, it consists of LCD display that can be held by hand and small built in camera at the back of the display and small computing devices. Handheld displays use the video see-through technique[20], the camera is used to capture the real environment and the computer-generated image will appear on the display as a cover for the real image, the advantage of handheld on the VST-HMD is that in handheld devices it doesn't block out the surrounding environment but rather the user looks at the combination of the real and virtual world through the handheld display and this allow the users to interact with each other and see others non-verbal cues. The most important Handheld Displays are smartphones, PDAs (Personal Digital Assistances) and Tablet PCs [22]. An important feature of these devices that they combine powerful CPU, camera, display and GPS and wireless technology in only one machine that means they doesn’t require any additional hardware to operate AR [19,23]. What makes handheld more convenient for AR their mobility, portability, low cost, flexibility and the widespread of them. Figure 2.5-a [24] shows an example of handheld device.

Figure 2.5: a) Handheld augmented reality display [24]   b) Spatial augmented reality display [25].

Spatial Displays are devices which directly project graphical information onto physical entities in the surrounding environment without the need of wearing or holding any device and instead directly integrate it into the environment, the projection process is performed by using digital video-projectors, optical elements, holograms and other tracking technologies [12], example of spatial display is shown in figure 2.5-b [25].

This display enables multiple users to use it at the same time without each need to wear HMD, and this increase the collaboration between users. There are three different techniques for spatial augmented reality according to the way of augmentation, these techniques are video-see-through, optical-see-through and direct projection [20].

2.1.6.2 Tracking technology

Tracking is the most important process in the AR system of any type, its main function to track, recognize, and localize the position and orientation of the object in the real environment to be overlaid accurately with the virtual contents. There are three main tracking techniques: sensor-based tracking, vision-based tracking and hybrid tracking [22].

Sensor-based tracking: this tracking technique uses different sensors, for example, magnetic, acoustic, inertial, GPS and optical sensors with a specific end goal to localize the position of the target object, the selection among these sensors depends mainly on the type of application and on other factors like accuracy, range, calibration, cost, resolution [22].

Vision-based tracking: this tracking technique determine the position of the camera using an optical sensor, this type also uses image processing of camera images to determine the camera pose relative to real-world objects [22]. There are two fundamental vision-based technologies: marker and markerless vision-based technology. In marker vision-based a predefined small image, often patterns, are being attached to the object to be tracked, this image may have any geometric shape but generally it is square or rectangle, it a predefined geometric and properties like size, color, shape and others, this make it more identifiable and it becomes a physical reference to the interaction of the user [21]. When this marker is detected by the camera and recognized by computer vision algorithm, the correct virtual item can be displayed on the display at the correct position. An example of these marker is Quick Response (QR) code. The markerless vision-based tracker is based on key points detection and recognition, it uses environment features to determine the correct position and orientation of the camera doesn't need any predefined markers or prior information about the environment which makes it have a wider applicability. In this tracking method any part of the real environment may be used as a target, it may use image recognition, GPS or both depending on the application [13].

Hybrid tracking: each of sensor-based tracking and vision-based tracking have advantage and limitation for example sensor based is fast and robust, but because of noise accumulation drifts may happen, and vision-based tracking jitter and drift are very low, but it needs high computational requirements which make it slow, in addition a failure may happen in rabid camera motion. Hence the combination of these two techniques allows embracing the advantage of each and supporting the disadvantage of the other forming a new more efficient and reliable tracking technique hybrid technique [23].

2.1.7 Applications of AR

The development of augmented reality is proceeding rabidly. It has encompassed almost most aspects of life such as tourism and navigation, advertising and promotion, architecture, manufacturing, entertainment and amusement, medicine, military arts, etc. and the most important aspect the education. The following is brief information about some of the most important fields.

Medicine: augmented reality provides various important applications in medical side; the most popular is application that provides helping during surgeries by overlaying real time data pertinent to the condition of the patient as x-ray, ultrasound [26]. Show 3D view of internal anatomy without having to perform open surgery. This development makes it possible to difficult surgeries to become minimally invasive.

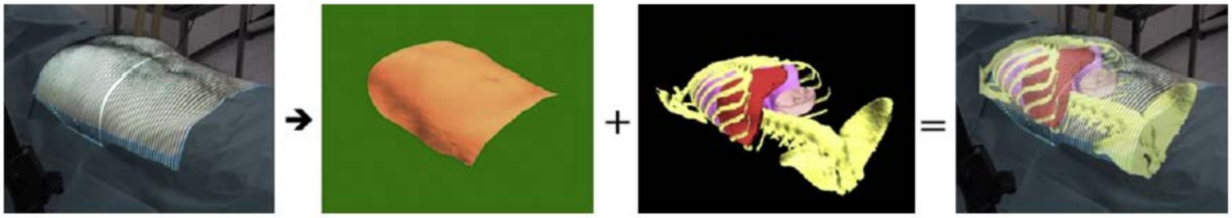


Figure 2.6: Breathing movement simulation for the real-time AR of organs in movement [27].

Tourism: Augmented reality can be used in tourism sector providing the tourists a self-tourist guide, provide historical or valuable information about the place, suggestion of near building as restaurant and other in real-time manner. Example of this application is CorfuAR a tour guide for Corfu city in Greece [28]. Another two-tourism application one provided by Colombia University [29] and the other is ARCHEOGUIDE is about Olympia [30].

Entertainments and media: for example, augmented reality is applied in the TV channels to view augmented news like sport news, weather, advertisements. Another excited entertainment vast field is game developing and the most known Pokémon Go [31] see figure 2.7 a [32].

Manufacturing and Maintenance: Augmented reality has a significant role in the industry field, it provides a virtual prototype superimposed upon real equipment or machine parts [6], showing the user step by step for assembling or maintaining, it may also show instruction or information about specific parts in real time which is better than it was a text manual. Figure 2.7-b shows an example of using augmented reality in manufacturing and maintenance.

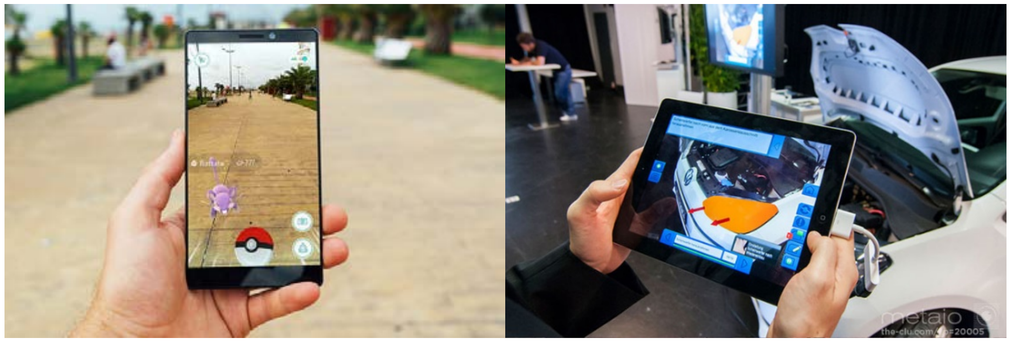


Figure 2.7: a) Pokémon GO AR game [32]   b) Example of AR in maintenance [34]

Augmented Reality in education: AR possesses distinctive and attractive features and unlimited abilities make it a good and interesting learning tool. It turns the learning process into a more attractive, pleasant and fascinating activity [33]. The integration of virtual objects and real environments allows learners to visualize complex spatial relationships and difficult abstract concepts, phenomena that is unattainable in the real environment [35], AR propels students to be more enthusiastic for learning and enhances learning proficiency and concentration student [36]. Some researchers believe that AR has massive potential and various advantages for learning [37]. The same paper [37] mentions that AR has the potential to:

- Engage, motivate and stimulate students.
- Help teach subjects where it is not easy to gain real world experience.
- Enhance collaboration between students and instructors, and among students.
- Foster student creativity and imagination.
- Help students take control of their learning.
- Create an authentic learning environment suitable to various learning styles.

The augmented reality can be implemented for learning in different ways, Yuen et al. [37] also classified augmented reality application for education into five categories: AR Books, AR Games, Discovery-Based Learning, Object Modeling, Skills training.

Indeed, augmented reality has recently applied in diverse domains in the field of education such as history, science, math, art, medical education and so forth. In physics for example [38] augmented reality simulation of magnetic fields interaction with charged particles for first year Physics course at Universidad Carlos III de Madrid. In Mathematics for example in [39], the researcher developed a hands-on spatial geometry learning tool to facilitate the learning of geometry. Another mathematics AR application is in [40], an augmented reality tool is developed and evaluated for mathematics activity of unit conversion and dimensional analysis. In chemistry learning an example of AR system in [41], the researcher developed an AR system for teaching spatial relationships and chemical-reaction problem. In biology for example [42] augmented reality application (ATTech) was built, aim is to enhance students' perception and conception about the complex events and phenomenon in biology. In medical education AR especially applied in anatomy and surgery training for example in [43].

Augmented reality plays a significant role in language learning for example in [44] a study and development description of augmented reality application for learning Arabic in University Sains Islam Malaysia, it aims to solve the problem of difficulties in memorizing the basic Arabic Vocabulary, the application uses AR flash cards to enhance students' knowledge and memorization of basic Arabic Vocabulary. Another example [45] augmented reality application is developed for learning English language.

2.1.8 Mobile augmented reality

In the past decade, mobile technology has evolved from just a simple cell phone to make call into a high technology device with advanced features which gave it the potential to be used as a learning environment. Mobile learning which is known as m-Learning is a new trend in education field [46]. It is an approach in which students use mobile devices in teaching and learning process to accomplish a good interactive learning and this allows students to easily interact with content and teacher any time, any place [47]. However, mobile learning is something beyond just utilizing a mobile device to access content and interact with others it is about the mobility of the learner [48]. Hashemi [49] mention some of the m-Learning benefits:

- Interaction: Student interaction with instructors and among each other.
- Portability: PDAs are lighter than books and enable the student to take notes or input data directly into the device regardless of location either typed, handwritten or using voice.
- Collaborative: Enables several students work together on assignments even while at distant locations.
- Engaging learners: The new generation likes mobile devices such as PDAs, phones and games devices.
- Increase motivation: Owner ship of the handheld devices seems to increase commitment to using and learning from it.
- Bridging of the digital divide: Since handhelds are more affordable than larger systems they are accessible to a larger percentage of the population.
- Just-in-time learning: Increases work/learning performance and relevance to the learner.

- May assist learners with some disabilities.

The most important benefit is the mobility and the personalized learning experiences, it offers the opportunity for learner to learn anything by their own.

This rabid increase of mobile technology makes it possible to have what is known Mobile Augmented Reality (MAR) combining the two concepts together. MAR systems include different mobile devices not just phone devices but also other wireless systems as SixthSense which is gesture-based wearable computer system developed at MIT [50] and Contact Lens [51].

But with the advancement of mobile phones and turning them into smart phones with improved computing power and functionality in addition to handheld MAR become the most appropriate mobile device in AR especially in education filed. Smartphones encompass all needed component for augmented reality in one device, they also have great features for example they are extremely portable, widespread, they have graphics hardware, touchscreens, they encompass a powerful CPU, GPS, camera, compass, accelerometer and they provide wireless access to the internet [52]. Smartphones offer the user the flexibility to use AR application. In 1997 the first mobile augmented reality system was developed, it was Touring Machine system. It uses a see-through head-worn display and a backpack holding a computer [53]. After 3 years AR-Quake augmented reality game was developed it uses HMD and a backpack holding computer. It was the first-person perspective mobile augmented reality application [54]. Mathias Möhring [55] develops the first mobile augmented reality system on a cell-phone. The combination of AR with mobile makes it more flexible, affordable and location independent services without the user being restricted to the geographical location. The MAR revolution is still going on.

2.3 Augmented Reality in deaf learning

In this section a review of augmented reality for deaf in general with concentration on literacy and Arabic language.

PekAr-Mikroogranisma [110] is a science courseware development for 12 years old deaf students. It is a web-based application, it is developed using the following main software Autodesk 3D Studio Max, FLAR Toolkit, Dreamweaver and other software. when the marker is detected a 3D model of organisms is shown, the application also supported with Malaysian SL description video. The development of this application based on a preliminary study to determine the need of deaf science students. The application is evaluated heuristically with education experts and feedback; they encourage the application [111].

Another system [112] aims to help deaf people to communicate with hearing people and vice versa. The system combines difference technologies which are Augmented Reality, Automatic Speech Recognition, Text-to-Speech Synthesis and Audio-Visual Speech Recognition. The system can be used through computer or mobile phone, or HMD. The system uses built-in cameras and microphones to get the video and the speech of the speaker. The ASR and AVSR engines are used to recognize the speech and convert the speech to text. Then the AR engine displays the text as a dynamic object in an AR environment, this dynamic object may be a speech bubble image or a subtitle line which the text loaded on it using a .SWF application. The system uses the face detection to identify the face of the speaking person location in the video frames and then sends this information to the Position and Orientation module. Simultaneously the .SWF file send to this module which in turn places the speech bubble .SWF file to the face information and sends it to the Render module which augments it on AR display, near the speaking person's face. In the reverse process the deaf uses mobiles keyboard or virtual keyboard on to write a text. Then the text is converted into speech using the TTS engine which will be played by the speakers. The testing of the system shows that its accuracy is over 85% on average.

The paper in [113] introduces a new application of HMD technology in deaf education to enable deaf student to search for the meaning of unfamiliar words. The user wears HMD while reading texts or printed books, the application is waiting the user to points at a word, when this happens it triggers the camera to capture a photo. Then this photo is analyzed to detect the user hand by identifying the region with color in the range of skin-tone then detect the user's fingertip as it is the top area of the hand after that it determines the boundaries of the word directly above the fingertip. After detecting the word, recognition of the world achieved using An OCR algorithm, then it searches for this word in a video ASL dictionary which is developed at the Center for Accessible Technology in Sign (CATS), if it' corresponding ASL video is found then it will be shown on the HMD [113].

Jiang and Kuang [114] developed a desktop application, which target to teach Chinese Literacy and sign language for deaf children by using augmented reality technology. It uses card as input for the AR system, after starting the application, the child puts the card in front of the camera then the program will automatically recognize the identity, shows 3d animated the object and the corresponding animated text of sign language. The application uses the ARToolKit, each card contains a Chinese character. Cards design follows the ARToolKit marker requirement, black border as a frame and in the inner part of the it contains an identification tag which may be tag an image or a binary code with light color usually white, here in this application it is a white Chinese character which forms the identity of the card. The application provides interactivity where the child can move, resize objects and show 3d animation etc.

Parton [115] develops mobile augmented reality lessons for Deaf students whose mother language is ASL. It uses two techniques for creating MAR applications: QR Codes and Auras. The application is built using Aurasma. both QR codes and Auras are used to provide access for deaf children at field trip. The application is for Tiger Creek Wildlife Refuge in Texas, guide booklets were printed with all the tiger names, photos, and QR codes. The visitor can look for the any the tiger's name that matched the nameplate in front of the habitat, and scan the QR code or the image, which in turn triggers it to go to a server and pull down ASL video about that tiger's background story and other information.

Jain et al [116] develop HMD augmented reality application, a system to increase sound awareness for the deaf people, it is designed and evaluated visualizations for spatially localize sound in order to be effectively part of a group conversation epically for group conversations with oral partners. The system contains audio sensor which is a spherical 64-microphone connected to a laptop via USB, the laptop runs a real-time sound source localization and beamforming software. The laptop sent a processed audio packet every 250ms, the packet consists of the intensity, azimuth, and elevation of all co-occurring sounds to android mobile application via Wi-Fi. Which in turn transmit the top four highest intensity sounds to Glass via Bluetooth, which generate the feedback visualizations. The system viewed animated visualization using arrow designs. The system provides more advanced features like: identify who is speaking automatically, perform sound classification and provides real-time captioning.

Live Time Closed Captioning System (LTCCS) [117], is a system combined of two technologies Speech-to-text system and augmented-reality to enhance deaf communication. The system consists of three components: a compact microphone that's clipped onto the user's clothing (as if they're a news anchor), a smartphone-sized Raspberry Pi/Adafruit-powered microcomputer that's kept in a pocket, and a Google Glass-like display. The system translates live speech into captions which are then shown on the display, where the mic is calibrated to pick up human speech, the audio is processed and converted to text and transmitted to the display.

Augmented Reality Letters Cues Recognition Application for the Indonesian alphabets [118]. It aimed to facilitate learning Indonesian letter and sign language, and to facilitate the communication between deaf and hearing people. The system is android mobile application, it was implemented using SDK Vuforia and Unity3D. it uses cards with Indonesian letters as markers, when the camera is directed to the card, the letter marker on the card will be detected by the application and view some 3D animation hand movements for each scanned letter in real-time.

In [119], An Augmented Reality system aimed at improving K-6 deaf children in mathematics skills has been proposed. The System is applied for AR glasses and it was developed using the Meta 1 developer kit and the Unity3D. The project extends the functionality of the previous developed ASL [83]. The system translates the spoken English to 3D signing animated avatars in real time. The 3D avatar displayed through the glasses [119].

Streibl [120] develops and tests a prototype of an augmented reality application in conjunction with flashcards in real-time aimed to enhance reading ability for deaf and also enhance communication. This research was done in collaboration with the ZIS, the center for inclusion and special education in Austria. The application was developed on the basis of Wikitude SDK, it is based on an "image-based tracking" recognize flashcards and augment the appropriate signing video. The flashcards contain word, a matching image based on the Metacom symbols, and a colored tag. The colored frame is to identify the word class according to color representations in Austrian textbooks. This makes it easier for the hearing-impaired children to assign the word to the various word classes. The test result shows that it improved learning reading skills and increased motivation.

IBM and Local Motors [121] are developing a self-driving, electric shuttle bus called “Olli”, it still under development. The bus has a combination of the following technologies artificial intelligence, augmented reality, and smartphone apps to serve people with disabilities as vision, hearing, physical, and cognitive disabilities. For deaf people, the buses could read and speak sign language using their smartphones by employ machine vision and augmented reality; it may also recognize the sign language using machine learning.

Deaf magazine [122] developed by Alexandros Michalakopoulos and Andreas Ruhe, this concept magazine focuses on the culture of the German sign language. It is supplied with augmented reality application which show digital information like video and image, when the printed pages are scanned vie a smart device, providing easy understand of the written pages and enable the deaf to learn new words adds video context to the written content to enhance understand and to teach other people the German sign language.

The paper in [123] provides a preliminary study conducted by using observation and interviews to identify hearing impaired students’ behaviours and the method used to learn Al Quran in order to use the result of this preliminary study as a directive to develop Augmented Reality application that helps hearing impaired students to memorize the surahs of Al-Quran.

Dep et al [124], develop (ASLM Augmented Sign Language Modeling), a real time augmented reality application that converts Hindi (one of the widely-used languages in India) alphabet to sign gestures using 3D animated hand movement. The system aimed to provide an independent learning as well communication facility for deaf/mute.

Another similar work is in [125], where ELRA application were developed, which is an augmented reality application aimed to learn Brazilian sign language by presenting 3D models.

MagicCamera [126], is another augmented reality application used to learn sign language, it concerns with American sign language, it presents a 3D animated signing baby.

MuCy [127] is another sign language teaching model based on Augmented Reality, it presents a 3D avatar for the American sign language, the model was evaluated and showed improvement in children writing, reading and speaking skills.

On the target of this thesis, which is about Augmented reality for development Arabic deaf literacy, there is no work in this field except a report paper which was published after the beginning of working on this thesis. The paper reports an on-going research on the development of AR application for deaf, it is a just Preliminary study to determine the visual needs of deaf Arabic learners. This study uses observation, interviews and questionnaires to achieve these investigations about deaf needs. The author uses two existing AR application in order to clarify the idea behind the research and to hold the observation [128].

Most of the previous works concentrate on communication and learning science and math and other subject but little of them concentrate on literacy. Most of the research these researches just combine word with its corresponding sign language. In term of arabic literacy there is no work in this field, the previous works for other languages. This thesis is the first work for deaf arabic literacy using AR. In addition, this work took care of all aspects of literacy learning terms of pronunciation, spelling and meaning and other aspects that helps in being a good literate. it did not just translate words into sign language and vice versa.

Table 2.2 summarizes the previous work on augmented reality for deaf.

Author/system	Type	Device or system	Media/characteristics	Notes
Zainuddin et al (2011) PekAR-Mikroorganisma	Learning science courseware	Web	• 3D objects and sign language video. • Used interview and observation for evaluation.	Positive feedback
Mirzaei & Mortazavi (2012).	Communication	Computer, mobile phone, or HMD	Used test and surveys	Test, accuracy > 85% Survey, 90% of deaf were very interested
Deaf magazine (2013)	Communication - Germany Language	Mobile	Signing video	
MagicCamera (2013)	learn American sign language	Mobile	3D animated baby avatars	
Jones, M., Bench, N., & Ferons, S. (2014).	Learning Vocabulary acquisition	HMD	video ASL	
Jiang, J., & Kuang, Y. (2014).	Learning literacy-china	Computer	3D objects and animation	Still in the initial stage
ELRA Nazareth eta al (2014)	learn Brazilian sign language	Computer	3D animated avatars	Under development
MuCy Garnica, J. J., & Arrieta, M. A. (2014).	learn American sign language	Computer	3D animated avatars	
Parton, B. (2015).	Learning Augmented fieldtrips	Mobile	ASL video	
Jain et al (2015)	Communication	HMD	animated	

			visualization	
Daniil Frants and team (2015)	Communication	Google Glass and mobile	Captioning text	
Sudana, A et al (2016)	Learning Indonesian sign language for normal people	Mobile	3D animated hand	
Adamo-Villani, N., & Anasingaraju, S. (2016)	Learning- math	AR glasses	3D signing avatar	
Streibl, M. (2016)	Learning Literacy Germany language	Mobile	Signing video	
Almutairi, A., & Al-Megren, S. (2017)	Learning Literacy- Arabic			Preliminary Investigations on
Ahmad et al (2018)	Learning App for memorizing Al-Quran			Preliminary analysis

Table 2.2: Summery of deaf augmented reality previous work

Chapter Three

Research Methodology

In this chapter, the methodology of the research is described and clarified. This chapter consists of three sections: research approach which is described in section 3.1, the second section is research design which is descried in section 3.2 and section 3.3 describes the research method.

3.1 Research approach

In scientific research there are two broad approaches of reasoning, inductive approach and deductive approach. Both deductive and inductive approach have their advantages and disadvantages, in this section a brief description is provided in order to be able to choose the appropriate approach for this research.

Inductive research: this approach moves from specific to general, it starts with specific observations and ends with broader generalizations and theories. Sometimes it is informally called top -down" approach [137]. Figure 3.1 shows the inductive approach strategy. It starts with observations and measures begin to detect patterns and regularities, and then formulate some tentative hypothesis then ends with developing general conclusion and theory [137].

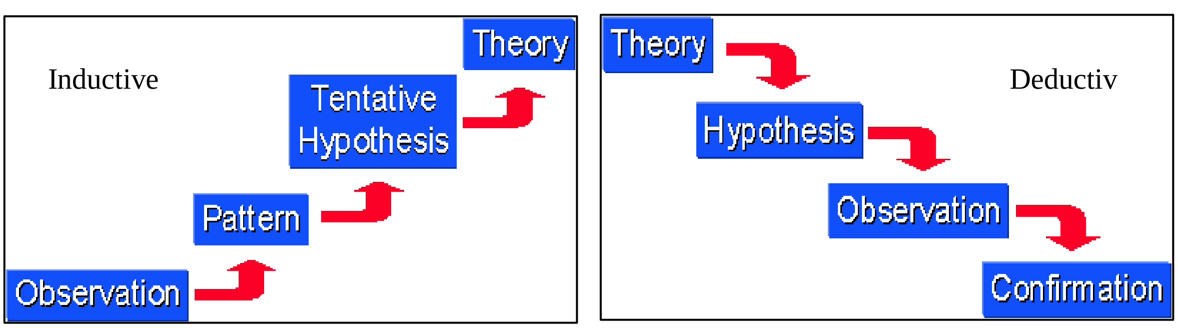


Figure 3.1: Inductive and deductive approaches [137].

Deductive research: this approach moves from general to specific, it starts with thinking up a theory related to the subject and then narrow it hypotheses which then tested to reach to confirmation or rejection [137]. Sometimes it is informally called top -down" approach see Figure 3.1.

The main difference between these two approaches is that inductive concerns with building new theory while deductive concerns with testing theory. In addition, the inductive research is appropriate for the small samples and the deductive approach is appropriate for large sample.

From the information above and the nature of this research, the appropriate approach for this study is the inductive approach as this research starts with observation and measures and ends with generalization.

3.2 Research Design

In the development of the system the User-Centered Design is used. According to [138] User-Center Design is a multidisciplinary design approach based on the active involvement of users to improve the understanding of user and task requirements, and the iteration of design and evaluation. In this approach it requires the focus on the users and their needs in each phase of the design process.

User-Centered Design approach consists of the following basic phases: specify the context of use, specify requirements, create design solutions and evaluate designs [139]. A description of the UCD process shown in Figure 3.2 firstly, identification of system or product user and the condition under which they will use the system. Then, the requirement should be identified in the second phase. In the third phase the design is done and lastly it is tested and evaluated.

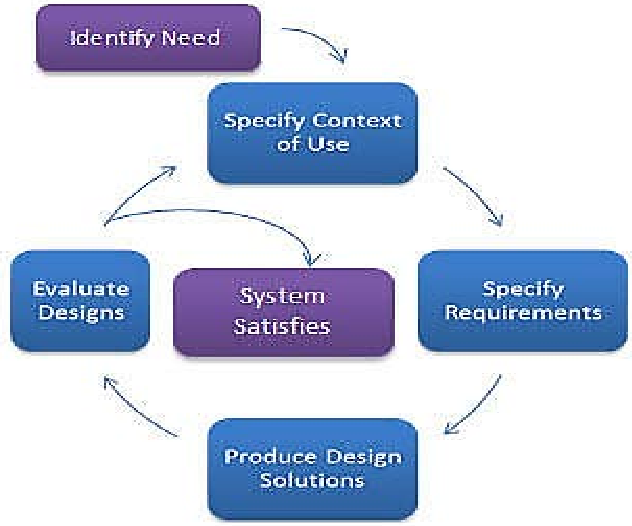


Figure 3.2: User-Centered Design process [139]

The UCD is adopted to be the researched design in this thesis, to answer the research questions I use three phases in this research design: needs assessment phase, design phase and evaluation phase.

Phase 1. Needs assessment:

To answer the first research question "What is the current situation of teaching deaf in Palestine?" an investigation and needs assessment is conducted to determine the needs of literacy development of deaf children from the point of view of teachers and experts and deaf students. The main aim of this phase is to collect data about the children, the problems they face, the current teaching strategies, the difficulties in literacy achievement and the special needs for them in learning to determine the type of contents and information to be included.

Phase 2. Design phase:

To answer the second research question: "How should AR-DLE app be designed so as to meet the needs of deaf?" an evaluation of some existent software and hardware is made, and some requirement is determined to be taken in consideration through the evaluation of these software and hardware to choose the appropriate tools for building the prototype. Web services is used to search for these tools and techniques and benefit from the experiences of former researchers, lastly the main appropriate tools are selected with guidance of my supervisor.

Phase 3. Evaluation phase:

To test the usability and usefulness of the prototype, to be able to answer the two evaluation questions, a study of the evaluation techniques is made to decide which of is the appropriate technique for the evaluation of this prototype.

3.3 Research method

In the research method a description and details of the ways used to collect data for the research design three phases: needs assessment phase, design phase and evaluation phase.

Phase 1: Needs Assessment.

At the beginning, a definition of the students' profiles is determined: elementary school and Kindergarten students of age 5-8 years (KG1 to grade2) who are learning Arabic literacy. To collect information about them, three schools in Palestine specifically in West Bank were visited about three times, semi-structured interviews with teacher and specialist were held, about 2-3 classes were attended in each school, and observation were conducted. Where official letters were sent from the university to schools for approval to conduct this study.

These three schools are: Total Communication Centre for Teaching and Rehabilitation of the Deaf in Ramallah, run by the Palestine Red Crescent Society, The Deaf School in Tulkarm, which is affiliated with the Qaqoun Charity Association and Deaf Secondary Mixed School in Nablus, run by the Palestine Red Crescent Society.

Phase 2: Design

In the development of this prototype some requirements have been regarded, such as: the used component will be free component, the ability to develop the prototype on both Android and iOS, quick development. Web services were used to search for the tools and techniques for achieving augmented reality with take in consideration these requirements and choose the appropriate tools. Other's work also was taken in consideration to facilitate the tools selection process. Table 3.1 shows summery of the selected tools and hardware.

<table>
<tr><th colspan="2">Selected tools and components</th></tr>
<tr><td rowspan="2">Software</td><td>• Vuforia
• UNITY3D
• 3D Computer Graphics Tools: in addition to UNITY3D, three tools were used for 3D designing and animation: 3D MAX, Make HumanTM and Blender.
• Online photoshop</td></tr>
<tr><td>The Windows operating system was selected as the programming environment ,it is compatible with the desired application Android/iOS and all the used tools mentioned above are available to be run in Windows OS.</td></tr>
<tr><td>Hardware</td><td>The used hardware to integrate and test the application are:
• android smartphone with minimum API level android 4.1 jelly bean (API level 16) and touch screen with appropriate size.
• iPad with minimum iOS version 9.0.</td></tr>
</table>

Table 3.1: Summery of the selected tools and hardware

Phase 3: Evaluation.

In order to choose the appropriate evaluation technique, brief explanations on the different evaluation methods are provided. Then the method that have been used and considered in this thesis is explained.

3.3.1 Evaluation techniques

A recent review of evaluation approaches in the Human-Computer Interaction (HCI) literature [131] divided these approaches into two dimensions: The nature of the study (empirical vs. analytical) regards to whether the study involves the user or not; and the methodological approach (quantitative vs. qualitative) regards to the approach of data collection.

Empirical approach: the usability empirical method depends on the implementation of the system - existing system or prototype - and the evaluation of it. This approach requires a group of potential users to participate in the evaluation, they may be end-users or/and experts. This approach can be experimental or Inquiry approach, the first like user testing and the other like questionnaire and interview [131].

Analytical approach: this approach simulates user's behavior according to theoretical models, rules or standards. And they are used basically in requirement analysis phase and usually doesn't require an existing product r prototype of a product. This approach can be inspection approach or theoretically based model, the first includes Heuristic Evaluation and Walkthroughs and the other used for performance predictions [131].

Quantitative approach: the aim of this approach is to gain data that can be statically analyzed with results numerically expressed in order to characterize a sample that reflects the usability needs of user group. The quantitative approach often conducting using questionnaires and experimental performance measures.

Qualitative approach: it provides insights and understanding of the problem setting. This approach to gathering data that focuses on describing a phenomenon in a deep manner, it gathers narrative data about the user behaviour, user experience while using the application or the system and also gather information about system design. This evaluation approach often is conducted using ethnographic methods [131].

Ethnographic methods

There are many ethnographic methods but here the concentration is on two of these methods which are used in this thesis, they are observation and interview.

- **Observation:** is a form of ethnographic research. It is considered as a systematic data collection where the focus is on the behavior of the people being tested, how they are affected by and how they affect their environment. Observations enable the researcher to describe existing situations using the five senses, providing a "written photograph" of the situation under study. [132]
- **Interviews:** A form of ethnographic research where a direct communication with participants is used to gather data. This approach usually combined with observation. This in order to get as broad a perspective on the subject as possible. There are three types of interviews: unstructured interviews, semi-structured interviews, highly structured interviews [140].

Usability test

A technique that is used in user-centered interaction design to evaluate a product by testing it on users since it gives direct input on how real users use the system [133]. It describes the degree to which a system can be used by specific users to achieve their goals in an effective, efficient and satisfactory way [134]. Usability tests are conducted with users of the system that needs to be evaluated. The objective of these tests is to identify problems that users face when dealing with the system. In this thesis, usability test is used in the testing sessions to evaluate advantages and disadvantages of the AR interfaces. The deaf children and their teacher have been presented with a prototype and allowed to use and interact with it. Then a feedback is accomplished in the form of observation, interviews and questionnaire.

In this thesis, empirical evaluation method is used. A mixed approach is used by implementing both qualitative and quantitative approaches, in each of these approaches the data is collected and analyzed separately then they are being converged in the interpretation stage. Qualitative results provide an explanation to the quantitative results, and quantitative results in turn provide a validation and confirmation to the qualitative results.

Qualitative Data was collected both through observation and interviews and quantitative data through questionnaires. The questionnaire and interview responses were described and analyzed. The observation was mainly concentrated on the general interaction with, and through the AR system in addition to the understanding of the content and the main aim. In the following subsections, explanation of these used collecting data approaches Table 3.2 shows details of interviews and observations.

Observation

The application targets elementary deaf school and kindergarten students aged 5-8 years (KG1 to grade 2) who are learning Arabic literacy. But after visiting the schools, it turns out that the grade includes clearly different age groups. For example, in the first grade, there are children aged 5 to 9 years for reasons such as the student joining the school at a late stage or a weak academic achievement that does not allow him/her to move on to the next stage. Moreover, the deaf student needs more time than the normal student to learn the same subject. For instance, according to one of the teachers, the deaf student needs two years at least to finish one academic year for the normal student. Thus, the dependence on the school stage (KG1 to second grade), regardless of age.

The participating children are from three schools:

- Total Communication School-Ramallah, second grade: 1 male and 2 females.
- Qaqoun Charity Association-Tulkarm, first grade: 1 male and 3 females.
- Deaf Secondary Mixed School-Nablus first grade: 9 students of varying age, 4 males and 5 females.

Observations were conducted in the three schools, group in Qaqoun, two groups in Total Communication School and Two groups in Deaf Secondary Mixed School. Each group rest from 50-90 minutes. A video was recorded in addition to taking images and notes, attitudes and effects were obtained. With mention that the parents' consent was obtained. The observation was held with the support of the teachers, the prototype was presented and explained for the teachers then for the students, after that the students try using it with follow-up and guidance from their teachers. Then the teacher starts asking them questions related to the content they see and the words and letters, they were asked to view a specific content, to pronounce a specific word, to match between the objects appears and the corresponding word etc. After finishing they were asked about their opinion about the system. Notes were taken, and videos were recorded for all groups.

Questionnaire

The data is collected from teachers of the observed children who are teaching Arabic or who taught it previously, in addition to a sign language expert. Seven teachers completed the questionnaire 2 from Qaqoun school, 2 from Deaf Secondary Mixed School and 3 from Total Communication school in addition to a sign language expert. six of them were interviewed and due to their circumstances, we were unable to meet two of them.

The usability evaluation is based on the USE (Usefulness, Satisfaction, and Ease of Use) questionnaire [135], USE questionnaire consists of four factors of usability: Usefulness, Ease Of Use, Ease of Learning and User Satisfaction. The participants rated each statement on a 5-point Likert scale from “Strongly agree” to “Strongly disagree”. The questionnaire consists of 28 questions (see Appendix C), it addresses three factors: usefulness, ease of use and ease of learning. The questionnaire starts with few multiple-choice questions to collect information about the participant. The questionnaire consists from four sections, the general section in addition to the three factors of USE questionnaire. Likert scale results were calculated by taking the average of all Likert items for each scale. Mean and standard deviation were used to summarize Likert data. SPSS software was utilized for the purpose of analyzing. To ascertain the reliability and usability of the questionnaires, Cronbach's coefficient alpha was utilized which considered as the most typical way of determining the reliability of the questionnaires, it is important to measure the consistency in the questionnaire items. The following table views the reliability statistics of each section and the total reliability. Kline mentioned in [136], that is generally, reliability coefficients around .90 are considered “excellent,” values around .80 are “very good,” and values around .70 are “adequate.” If r XX < .50, unacceptable.

Semi-structured Interviews

The semi-structured interviews were conducted individually in each school. Interviews spanned two days where it was held in 3 Governorates. Each interview lasted approximately 45 minutes to an hour. As mentioned previously, six participants were interviewed after filling the questionnaire to discuss its aspects, some of them are currently teaching children at the elementary level and some of them taught previously at the elementary level. Those who are currently teaching, before the interview the observation was held in their presence. The interviews were audio recorded and conducted in Arabic, the interviews consist of group of prepared questions (Appendix D), as well as questions generated by participants' answers, also the participants were allowed to talk freely about details. Table 3.2 shows details of research methods

<table>
<tr><th></th><th>Observation</th><th>Questionnaire</th><th>Interviews</th></tr>
<tr><td>Participants</td><td>Students at (KGI to second grade)
• Total Communication School, second grade: I male and 2 females.
• Qaqoun Charity Association, first grade: 1 male and 3 females.
• Deaf Secondary Mixed School, first grade: 9 students of varying age, 4 males and 5 females</td><td colspan="2">Teachers at the three schools:
Seven teachers completed the questionnaire 2 from Qaqoun school, 2 from Deaf Secondary Mixed School and
3 from Total Communication school in addition to a sign language expert. 6 of them were interviewed</td></tr>
<tr><td>Collecting data</td><td>• A group in Qaqoun, two groups in Total Communication School and Two groups in Deaf Secondary Mixed School.
• Each group 50-90 minute.
• A video was recorded in addition to taking images and notes, attitudes and effects were Obtained.</td><td>• The usability evaluation is based on the USE (Usefulness, Satisfaction, and Ease of Use) questionnaire.
• Using 5, point Likert scale from "Strongly agree" to "Strongly disagree"
• SPSS software was utilized for the purpose of analyzing</td><td>• Semi-structured interviews were conducted individually in each school each about 45 minutes.
• The interviews were audio recorded and conducted in Arabic</td></tr>
</table>

Table 3.2: Details of research methods

Chapter Four

The Proposed System

In this chapter, the technical implementation and the development of the Augmented Reality based Deaf Literacy Enhancement prototype (AR-DLE) and the approach taken are described and discussed.

This chapter starts with the needs assessment analysis in section 4.1. Section 4.2 describes the overview of the system. In section 4.3 the system implementation is explained.

4.1 Needs assessment analysis

Analysis of the interviews (see Appendix B) was done and obtained the result to extract the important information for developing the prototype. In the following paragraphs interviews results were presented.

Regarding the information that says: the level of reading for the deaf student doesn't exceed fourth grade reading level, teachers attributed the reason to the lack of repetition of the words before them, specifically that they are hearing impaired and need to repeat more, making them forget easily, this reduces the linguistic wealth and therefore difficult to express and difficulty reading or more accurately, the difficulty of understanding what they read.

Two of the interviewees did not support this information in general and argued that the reason is not the abilities of the deaf child, but the parents and the community who do not believe in their abilities and consider them limited capacity and do not provide them the appropriate method or tools that is suit their needs and make them able to perform better.

All of the interviewees confirmed that deaf face difficulties in learning Arabic literacy where the Arabic language and its alphabets is not easy, especially the letters which their articulation points are close to each other, lack of linguistic wealth since their early childhood, Lack of exposure to voices, words and concepts, which the parents bear the greatest responsibility in it, all of these problems lead to make it difficult to the deaf to learn literacy.

They said that the most reliance in education is on sign language, one of them explained sadly that the greater emphasis on sign language and make it the basis, and slightly neglected the concept and the visual guidance, as they mastered the sign language but unfortunately as information and concepts quickly forgotten.

The means used in all schools are pictures, videos, paintings and cards, in terms of technology they use the projector and the smart board, but they are only available in one or two classrooms in the school, not in each class. In terms of applications of special techniques in education, they have not been used in any of the schools.

All of them supported the use of technology in education in general and for the deaf in particular. One of the teachers said: “This is the era of technology; deaf and special needs have priority in employing technology in their education." They said it provides a wealth of information in a wonderful, attractive and easier way than the traditional way of delivering information. One of the teachers said: "I strongly support, where the technology which has provided social media and has been used by many deaf people successfully, helped them break the barrier between them and the community and facilitated their communication, this technology is able to contribute in giving wonderful results if used in their education ".

The findings of this assessment show that the most problem faces those students is the difficulty in learning letters due to their deafness, the problem of achieving new vocabulary. They are suffering from a lack of linguistic wealth and the problem of difficult to remember and the need of a lot of repetition to consolidate the information they receive because they can't hear so they can't easily remember it. And all these difficulties lead to weak literacy which also affected the ability to learn in other subjects

From the interviews and observations, there was an emphasis on that the deaf students are visually learner and they depend on visually aid media like pictures, videos etc. In these schools, they use pictures, cards, educational cartoon boards with paints and sometimes real objects. Due to the loss of hearing, they rely very heavily on vision and connect the information they learn with visual things. They also have good ability in visual communication using sign language and it is the main communication method for them, it is their mother language and they use finger spelling to spell words.

The finding indicates that there is a lack of applications for deaf education and learning support.

There is some similarity in teaching in deaf schools, but unfortunately there is no unified curriculum in schools, and some of them uses the same syllabus and curriculum used in normal primary school for normal children which severely restrict the speed of learning literacy.

As a result of these investigations, deaf students depend on visually, interactive, attractive media. So, in the development of 3D objects, videos, attractive pictures in addition to sound will be used to add interesting and enhancing their learning.

System Requirements Specification

Based on the needs assessment for deaf learning in the previous section and the research presented in the previous chapters in augmented reality and its role in education, functional requirements of augmented reality application for developing deaf literacy are established and described as follows:

- Provides a viewing of the digital contents in real time.
- Provides combination between physical and digital components.
- Interface should be designed as simple as possible with minimal details.
- Implemented for iOS and android devices.
- Provide different types of multimedia concentrating on 3D animation due to its attractiveness and interactivity.
- The augmented reality prototype should be based on an "image-based tracking". It recognizes flashcards and then augments the appropriate digital content.
- Prototype provides the ability for the user to move easily between different contents with button click.
- The digital content either 3D animation or video should play in infinite loop.
- Choose the right paper type for flash cards to avoid tracking problems, use a non-glossy cardboard papers for the flashcards and with A5 format.
- Provides the ability of individual and collaborative work.
- Depends on the main strategy of learning letters and words in the schools.

The system will provide flash cards which contains different contents. These contents were determined according to the strategy the schools use. It may contain letter, parts of word, word or image. According to the content the system augments the appropriate digital objects, including: 3D animating signing avatar, 3D animation that explains the concept of the word, a video that provide finger spelling of the letter, part of word or word. In addition, the system also contains audio to help those with hearing residue.

4.2 Design phase results

A description and detailed information of the structure of the prototype in terms of software (tools) and hardware that were selected to implement the prototype are presented.

Software:

There are different components used in the implementation of the system, a simple overview of these components described below:

- Vuforia: is an AR-SDK for mobile devices other similar mobile device that capable to run Augmented Reality applications into a real time. The Vuforia platform uses top-notch, superior, stable, consistent and efficient computer vision-based image recognition technique and it also have several rich features, enabling capability of building mobile apps utilizing these features freely of technical limitations. It seamlessly integrated with unity3D which the industry-leading 3D game engine and this provide a low complexity, effort and time of the development; it also supports virtual buttons and provides cloud services. Another characteristic feature of Vuforia that it was created by Qualcomm company which is world leader in the production and design of processors of mobile devices, this make it most optimal choice for them. [129,130]. Vuforia SDK comprised of the following core components [130]:

    1. Camera which capture frame and pass contents to the tracker.

2. Image Convertor simply converts image taken by camera to a format suitable for OpenGL ES rendering and for internal tracking.
3. Tracker which can load and activate multiple dataset at same time which basically contains the computer vision algorithms that detect and track real-world objects in camera video frames.
4. Video background renderer to render camera image stored in the state object.
5. Application code which for newly detected targets query the state object which results in updating of application logic with new input data and rendering the augmented graphics overlay.
6. Device database to store marker targets in device itself and lastly cloud database which stores the target in the cloud.

Figure 4.1 shows the Vuforia SDK architecture [129].

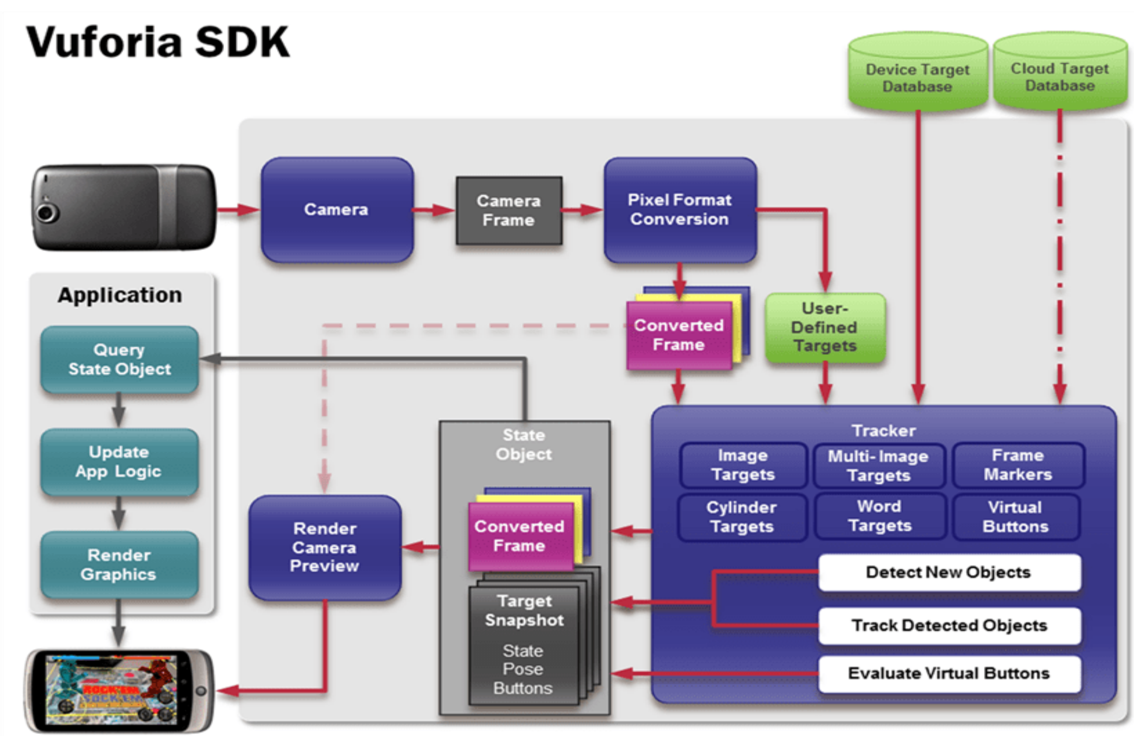


Figure 4.1: Vuforia SDK architecture [129]

- UNITY3D (Development Environment): it is the industry-leading game engine with a built-in IDE. It is used here as the main core of the implementation as it contains the most important aspects in the implementation rendering, scene-graph, transformation and building and other aspects, it also provides scripting, it provides programming using C# making it easy to extend the application and easy to deploy it to various operating system like android and iOS. It also has the ability to import 3D models and real-time animations from other sources as Blender and the capability of integrate it with Vuforia.
- 3D Computer Graphics Tools: in addition to UNITY3D, three tools were used for 3D designing and animation:
    1. 3D MAX: a 3D modeling, animation, and rendering software, it was used to build models and animation in the system.
    2. Make Human™: a free, Open-Source and high-quality toolkit for making 3D rigged characters, this toolkit provide the ability to easily build different types of human avatars without much human efforts. These characters can be used in other application, it also can be exported to Blender to be animated.
    3. Blender: free and open source 3D creation tool. It provides all abilities needed to deal with 3D object: modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation. It is used in the system to animate the avatars designed in the previous tool to handle sign language. It provides the ability to export the animated objects to UNITY3D.
- Photoshop: a powerful tool helps to edit, manipulate and make effects to images. It was used for designing the flashcards. The online version was used.

The Windows operating system was selected as the programming environment for this implementation as it is compatible with the desired application Android/iOS and all the used tools mentioned above are available to be run in Windows OS.

Hardware:

The used hardware to integrate and test the application are android smartphone with minimum API level android 4.1 jelly bean (API level 16) and touch screen with appropriate size. In addition to iPad with minimum iOS version 9.0.

4.3 Overview of the system

The main objective is to develop a prototype of an augmented reality application, including the necessary flashcards, and to test it at the mentioned deaf schools in the West Bank in Palestine.

Empirical evaluation methods were used to investigate if augmented reality has the potential to positively affect the deaf children literacy learning process.

In the development of this prototype, there are several important things that have been adopted in developing the system: use free components in developing the system. It is a demo tool to be used in experiment and the system based on the strategy used in the mentioned schools and the letters and words of their planes.

Figure 4.2 shows the block diagram of the system. The Vuforia engine consist of the SDK which will be explained in the following paragraph, provides the image recognition ability, tracking to decide the position and direction of the virtual object, it is connected to the target database. The application also contains the assets related to the system and the virtual objects and codes. After recognizing the target and deciding which content to display, the captured video is overlaid with the content and displayed at the device screen.

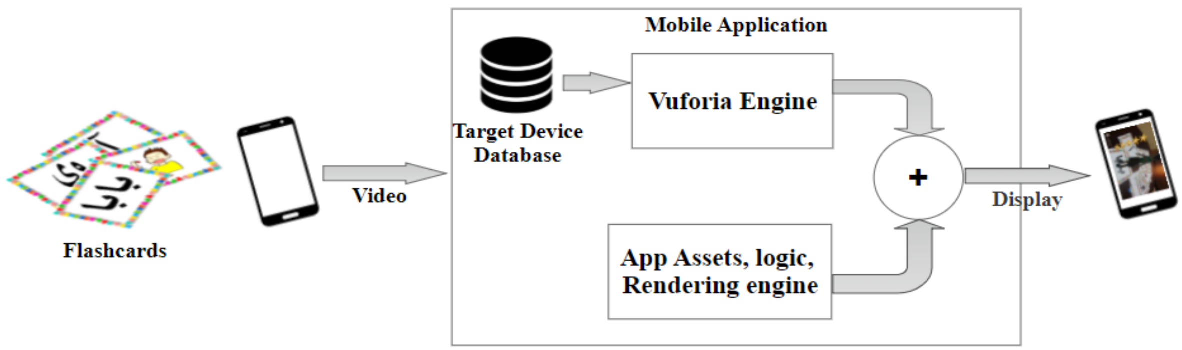


Figure 4.2 The block diagram of the system

The prototype consists of flashcards and augmented reality application, the flashcards is implemented according to teaching plan used in the visited deaf schools, where they start with letters then parts of words consist with the learned letters, then they learned a word consists of just learned letters and learned word parts. In addition, there are flashcards contains a 2D graphics corresponding to the learned word. The flashcard content forms the target of the application, when the camera of the device detects the target the application augments it with the suitable digital content. The application provides various contents and gives the user the ability to switch between these contents. For letters the system provides a signing video for that letter with audio of its pronunciation. For the part of the words, the system provides a finger spelling video of the word part and audio of its pronunciation. For the word flashcard the system provides 3D signing avatar, 3D animation to clarify the meaning, and a fingerspelling video with audio of pronunciation of the word and for the image provides the opposite process, this to ensure the link between the linguistic term and the concept for the development of linguistic wealth.

System functionality

In this subsection the software analysis of the prototype is explained. The guidelines of the development are described.

1 Use Case Diagram.

The use-case diagram in Figure 4.3 shows the various activities that the user can perform in the system. These use cases are described as follows:

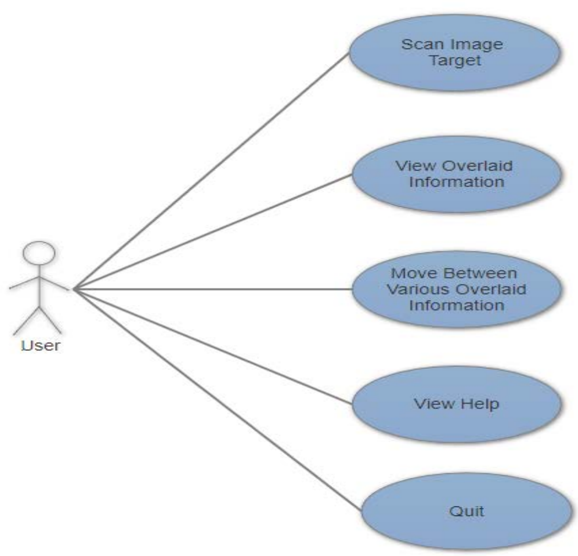


Figure 4.3: Use-Case diagram of the system

Scan Image Target: This interaction is called when the user wants to scan the targets in the flashcards. View Overlaid Information: This interaction is called when the user wants to view information overlaid after successfully recognize the target. Move Between Overlaid Information: this interaction when user wants to view other types of overlaid information such as video, animation etc. View Help: This interaction is called when the user wants to view help information. Quit: This interaction to terminate the application.

2 Activity Diagram

The flow of activities that user can perform are described in Figure 4.4. The user can scan the image target if detected then the appropriate information is overlaid, and the user can choose other types of information or scan new target.

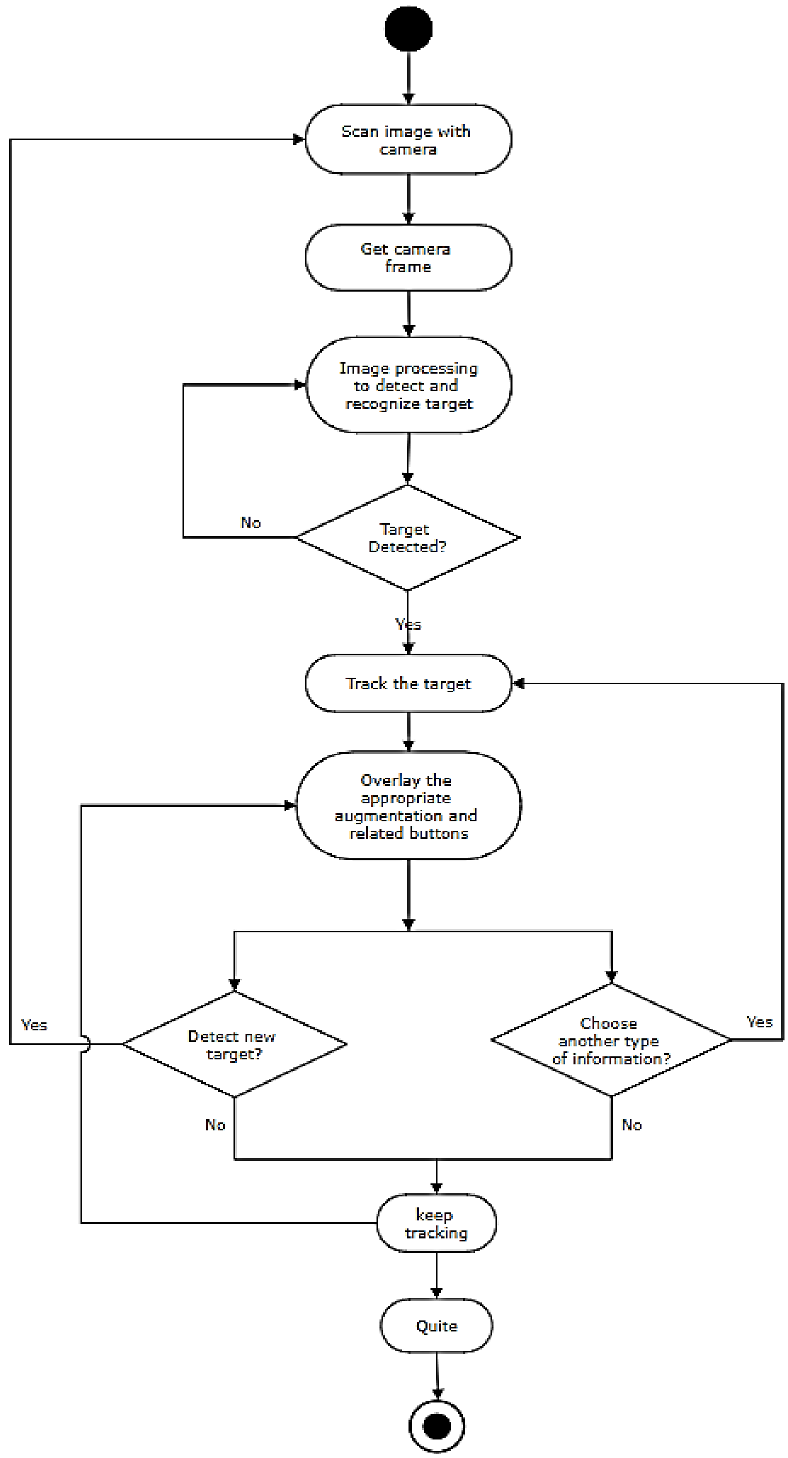


Figure 4.4: Activity Diagram of the system

4.4 System implementation

For the system development objective of this thesis, a prototype was built so as to test the principles defined, and to take observations on the deaf students, their behaviors and attitudes and get their teachers viewpoint, opinions and notes. In this section the system development stages are described in detail. The implementation can be divided into two parts: flashcard implementation and the android application implementation. The following flowchart Figure 4.5 summarizes and explains the development process of the system.

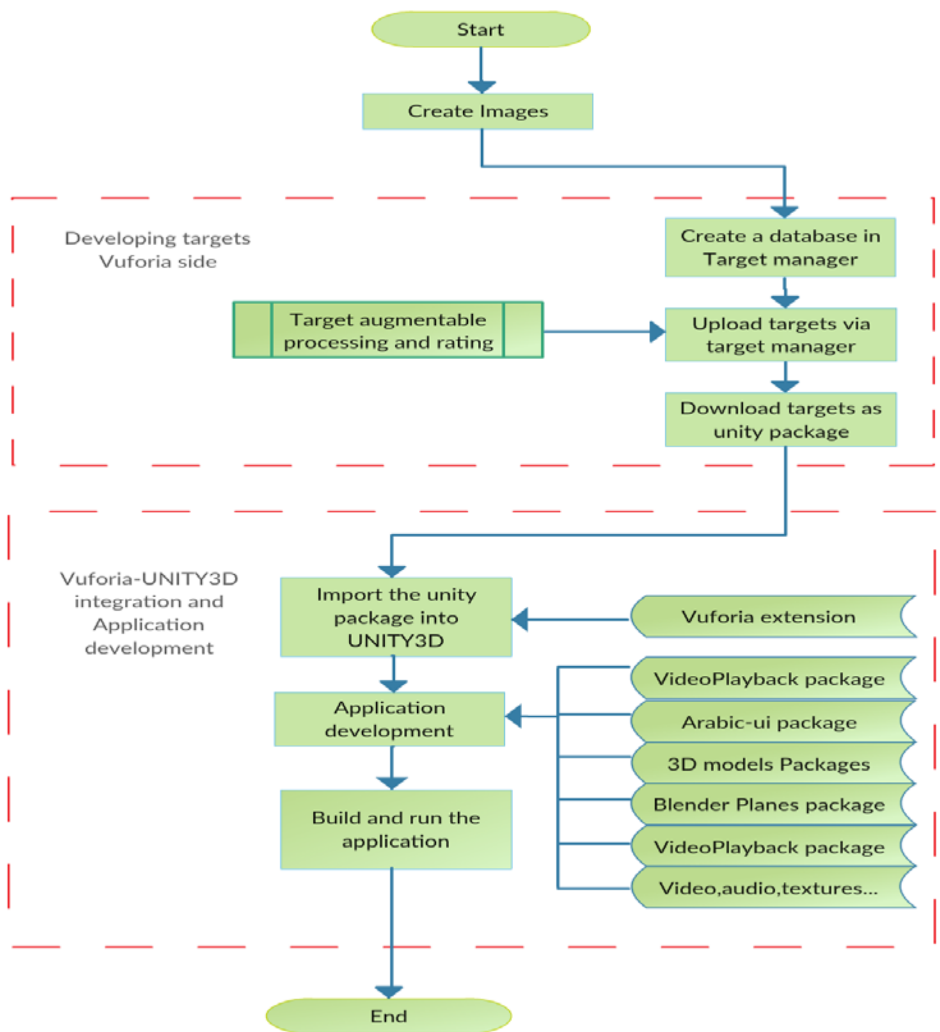


Figure 4.5: Workflow chart of the prototype development process

4.4.1 Flashcard Implementation

The flashcard was designed using online Photoshop. The information in the flash card obtained from the schools and depends on the plan the follow in the Arabic language learning process. The content of the cards is one of four types: a letter, a part of word (section), a word or 2D image represents a specific word.

The first letters are the vowels (ا، و، ي), followed by the part of words consists of these vowels (وا، وي). Then a word of these word sections and 2D image related to this word. The same strategic for other letters, the letter, the letter combined to the vowels like (با، بو، بي) and words of these section or any previous ones. Figure 4.6 shows some of these cards. The cards were printed on A5 non-glossy cardboard papers.

Figure 4.6: Sample of the designed flashcard

4.4.2 Application Implementation

The application uses the UNITY3D engine as the core of the implementation. The system provides: image for the spelling with sign language, 3D avatars for representing sign language, 3D animation to explain the meaning, two videos one to view the fingerspelling and the other for the pronunciation of the word (lip reading), and these are enhanced with audio recorded or downloaded for those with hearing residue.

Videos

The videos of the fingerspelling and pronunciation were captured for two hearing childes with age of 5 years old in cooperation with Al Furqan Educational Establishment.

Image for spelling

Designed using online Photoshop and edited in Blender to be suitable to use in UNITY3D as augmentation.

Creating 3D animated avatars and 3D interactive animation

The software used in creating, rigging and animating 3D objects are MakeHuman, Blender, 3D max and all of these are capable of integrated with unity. Figure 4.7 shows the used avatars in the prototype.

Figure 4.7: The 3D avatars used in the prototype.

MakeHuman provides the ability to create a 3D human avatar with high quality features; it also provides the ability to 3D avatar to be rigged. The model is designed and modeled easily by choosing the desired characteristics for gender, age and other characteristics like face, hands, legs etc. after the model was designed, it was rigged by adding the skeleton (bones and joints) to be ready for animating. After the avatar was finished it was exported as mhk2 file to be imported and animated in Blender to represents the sign language. Figure 4.8 a and b show example of the design, rigging respectively.

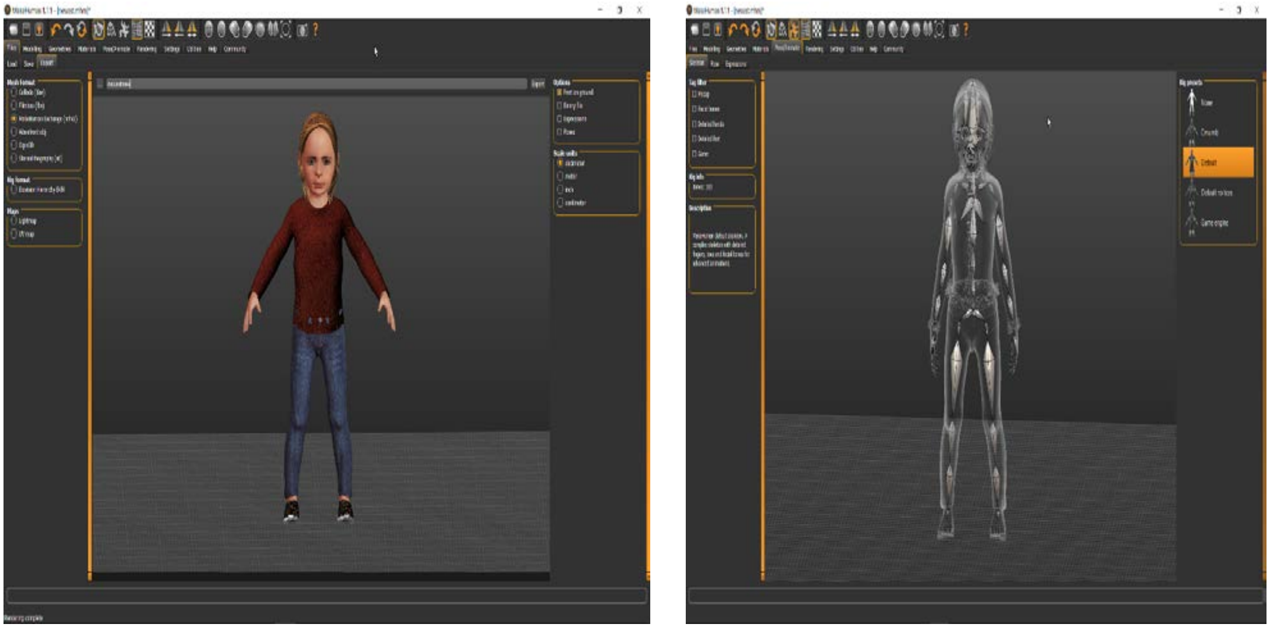


Figure 4.8: a) Avatar Designing in MakeHuman. b) Avatar rigging in MakeHuman

After it has been exported as mhk2, it was imported in blender see Figure 4.9.

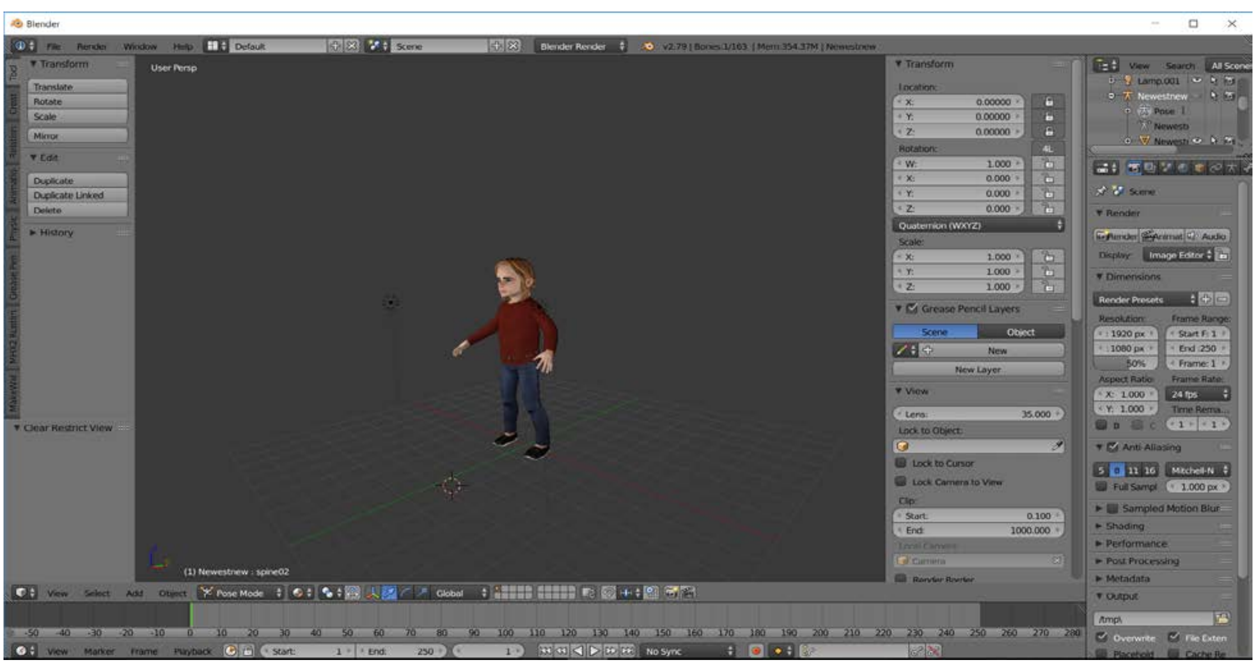


Figure 4.9: Import mhk2 into Blender

Then the camera and the lights are set and positioned, and the skeleton viewed to start animation see Figure 4.10.

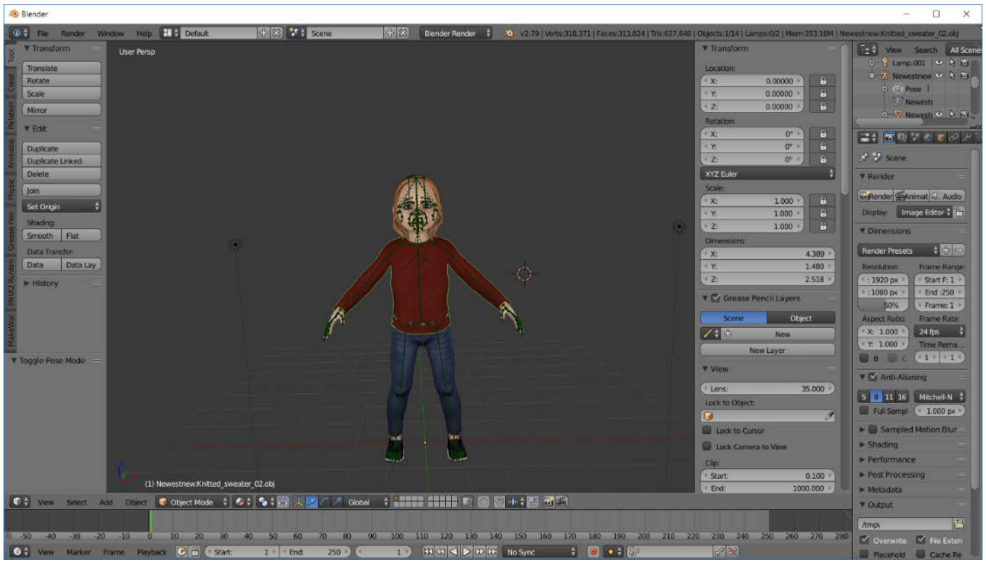


Figure 4.10: Positioning the lights and the camera.

Then the platform is prepared to start the animation by choosing the pose mode and the animation screen layout and start moving, rotating, animating the bones and recording the animation see Figure 4.11. After finishing the animating, the file is exported as fbx to be easily used in unity.

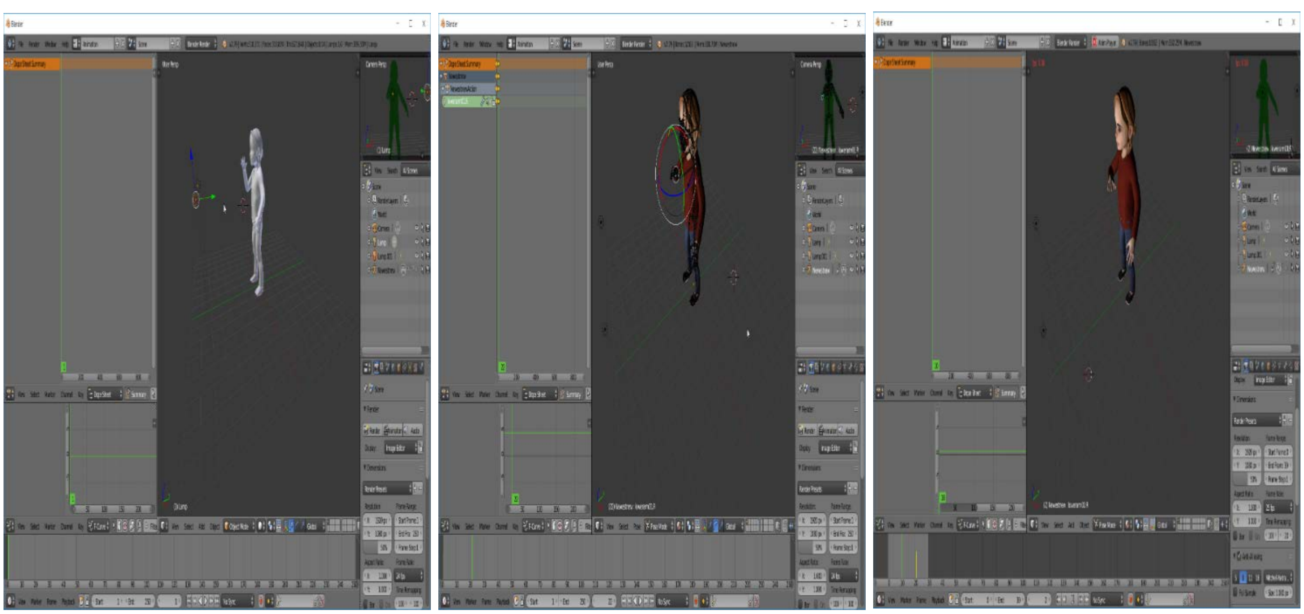


Figure 4.11: Animating the model in Blender.

In addition to 3D avatar, 3D objects were designed to provide a meaning or representation of a word. For example, to represent the word ambulance, a 3D animation of ambulance - Figure 4.12- is designed and later enhanced with ambulance siren sound. Blender and 3D max are the software used to design and animate these 3D objects, and some were downloaded from UNITY3D assets.

Figure 4.12: 3D animation example to represent the word ambulance.

Developing the application

In this part, the development of the program using UNITY3D and Vuforia is illustrated. First, Vuforia is used to build the targets database, then this database is integrated in UNITY3D which is the core of the system. Before starting development, the development environment was set up where the JDK, Android SDK, were downloaded and installed, Vuforia extension was downloaded, needed unity package were downloaded.

Vuforia part:

Vuforia SDK was used as the augmented reality framework for this application. It is a well-developed framework by the company Qualcomm, the structure of Vuforia SDK is displayed in chapter 3. The components of Vuforia platform: Target Management System available on the developer portal (Target Manager), Cloud and Device Target Database and Vuforia engine.

Registration or correct alignment of the virtual content with the real world is a key issue of any augmented reality application. This guarantees that real and virtual object are always aligned inside the user's perspective. As discussed earlier in chapter two, there are two common registration techniques depend on vision, they are: marker-less, and marker-based. In this research, the marker-less registration technique especially feature-based technique was used. In which recognizes the object by track features such as distinguishable points, lines, edges, corners and blobs. In this technique, the feature of the scanned image is compared with the features of earlier stored image. Image target which we will us in this system is an application of this tracking technique.

Vuforia uses the Target Manager component to generate markers as this component support creating the cloud and device database which enable the user to add targets to generate markers. This target manager makes it easy to identify the tracking points. At Vuforia portal, image targets database has been created, the image targets have been uploaded and processed. Then the database was downloaded as a unity package in order to be able to use it in UNITY platform. Appendix A shows the steps in more details.

Design in unity

UNITY3D engine was used due to its ease of use and independency, by this engine the application can be easily deploy to different devices and platforms without the need to change the source code. It also has the ability to be integrated with all other software used. In the following paragraphs a discussion of building the app using UNITY3D.

1) AR-Scene design.

A new unity project is created, after finishing the previous step, building the targets database; it was downloaded as a unity package, this package imported to the unity project in addition to the Vuforia-unity plugin. This plugin contains prefabs and allows to create user prefabs, every entity in the hierarchy is a game object, the two main prefabs in Vuforia unity SDK are: ARCamera that streams live content on the display of the mobile and ImageTarget which also known as a marker, it is recognized and tracked by the ARCamera and the augment content is allocated relating to its feature points.

The main camera was deleted, and these two prefabs were dragged to the scene. And the ARCamera is positioned and configured by adding the App license key get from Vuforia portal, and the dataset is set to the database created in Vuforia and activated Figure 4.13 a)

Every marker in the database should be connected to a specific ImageTarget prefab, the ImageTarget is dragged to the scene, positioned and configured, the Image Target Behavior script of this marker set database to our database and image target to the related marker, figure 4.13 b). And this is repeated to all targets.

ImageTargetBehaviour.cs and TrackableEventHandler.cs scripts, which are predefined scripts in Vuforia unity, were used to obtain the tracking and handle tracking states.

At this level the targets are ready to be recognized, now the level of adding the augment content. The 3D objects designed in 3d MAX and Blender are imported in unity. In addition to the images for fingerspelling created in Blender and videos are added to unity and using 3d cubes to be held. To add any augment content is dragged to be child of the target related. Some of these targets have 2 or more types of augmentative contents. Each one is added as a child to this target, the animation to 3D objects is added and configured.

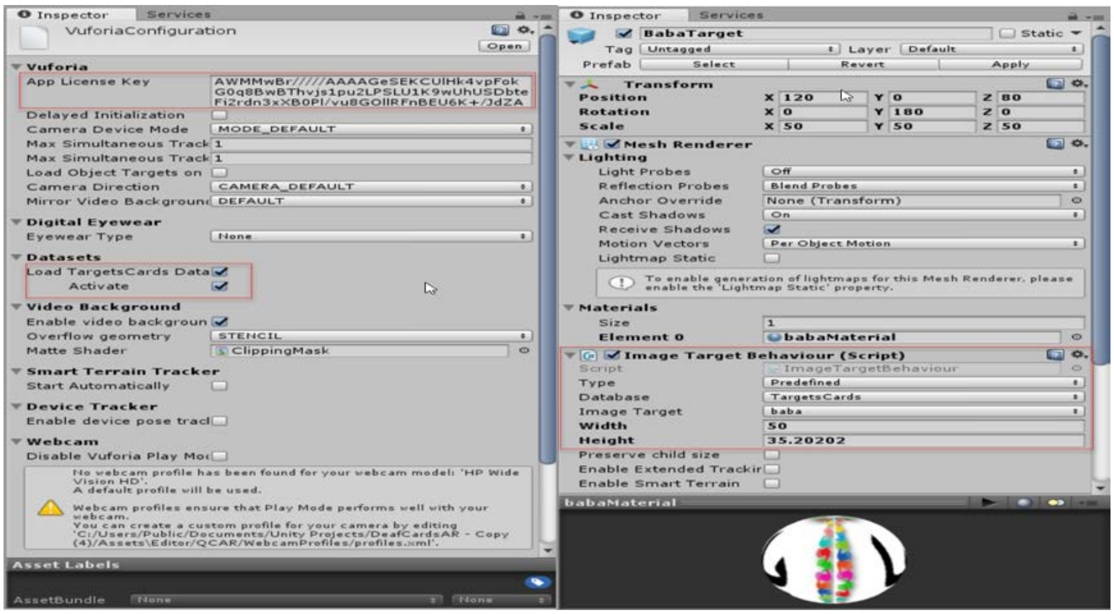


Figure 4.13: a) ARCamera configuration. b) ImageTarget configuration

To provide the ability to switch between these contents, a simple UI is build, a canvas used as it is the root component for rendering UI object an example showed in Figure 4.14, these buttons are inserted in the canvas and the canvas was added as a child to the target related. The C# programming language was used as it was set by default, but one can also use JavaScript and Boo, a C# code is implemented to control the hide and show of contents according to the pressed button. Another C# code is implemented to give the initial state of the content hidden/shown and connected to a Game Object, then every content is configured according to it. Then OnClick() method is implemented for each button, for each related Game Object the state of being active is determined by giving a Boolean value true/false. Sample code shown in Figure 4.15

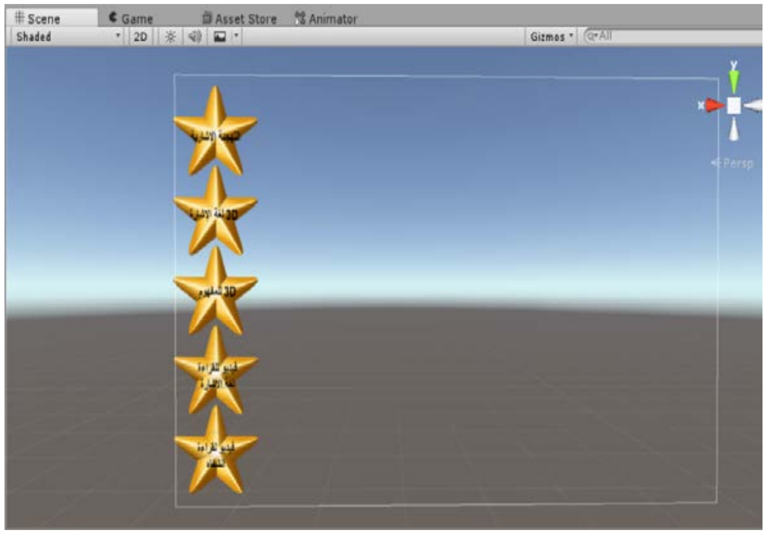


Figure 4.14: Example of canvas used to render UI component.

In order to be able to write in Arabic in Vuforia, Arabic-ui unity package was downloaded and imported in unity, in addition to C# codes to provide support of rtl writing.

For videos, another unity package was downloaded and imported also, the package is VideoPlayback-6-2-10 unity package, in addition to C# codes to control the video playing, it was imported, and the videos were configured. These steps are repeated to all targets, figure 4.16 shows example of target with its related contents.

```
// Use this for initialization
void Start () {
        // this code to decide the initial state for each game object
        gameObject.SetActive (false);
}

// Update is called once per frame


void OnClick () {

        // this code to decide which game object to show when a specific button is
        // pressed this make the other game objects hide

        gameObject1.SetActive (false);
        gameObject2.SetActive (false);
        .
        .
        gameObjectn.SetActive (true);


}
```

Figure 4.15: Sample code for hiding/showing objects

To enhance the interactivity of the application, interaction with objects was added, the user is able to scale, rotate and translate any object they want by two fingers touching. This was handled using the Lean touch assets, it was downloaded and imbedded into the system. These steps repeated to all targets as needed, after finishing all the targets, the scene was named and saved.

Figure 4.16: Example of target and its structure in the platform.

2) Main menu User Interface (UI) design and implementation.

A new scene was created, and a resolution for the UI screen was decided and the orientation was chosen.

A canvas was created to contain the UI buttons of the GUI, images used as icon and background were designed using Photoshop.

The user interface contains three buttons: the first to start the ARCamera and start the application, the second contains explanation about the application, the last is exit button.

This scene was saved as main, a C# script implemented to handle these three buttons, the code for each of the first two buttons have to call the loading of the related scene. For example, the first button implementation calls the loading of the scene saved in the previous point, the second button aims to call the scene about, the last button calls the Quit() method to close the program. Each scene contains a return back button that returns back to the main screen when pressed, the code is connected to image target in order to be able to use it easily with buttons by calling its methods inside the Onclick() method exists in each button.

After finishing these steps, the project is build and run on different Android devices, before building process a needed configuration is done, the scenes were added firstly to the building window, a player setting then determined and the identification were determined then the project is built and run on the device.

At this point, about 30 flashcards were designed to be used in the learning process. These flashcards integrated in the project as targets, various types of augmentative contents were added to these objects with a simple GUI to move between these contents. These objects were supported with interaction properties using touch screen, such as scaling, rotating and translating. These contents contain images, recorded audio and video, 3D avatars and 3D animation. In order to understand the application and its functions in a better way, Scenes of two of the flashcards in the prototypes with explanation of the system provided abilities are shown.

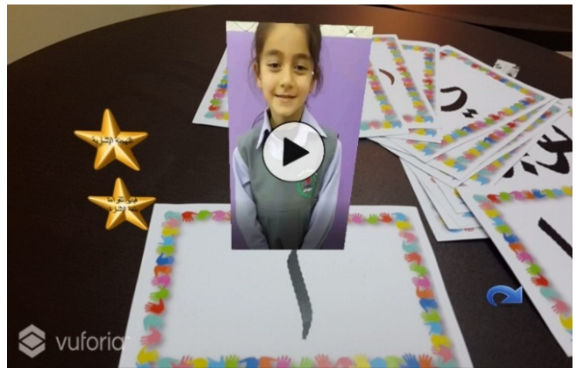
The first sample is for the letter (ا), and its augmentation: sign language and video for pronunciation see Figure 4.17. When running the application, the main menu appears as shown in scene 1. By pressing the start button the AR camera starts and waiting for flashcard to recognize see scene 2, when the system recognizes the letter (ا) the sign language of this letter appears, and two buttons also appear in the left of the screen see scene 3. Pressing on the second button, a video of the pronunciation of the letter appears, scene 4. Pressing at the middle of the video- play icon- in the previous scene, the video will play as seen in scene 5. The button with blue arrow on the right returns back to the main menu, scene 6. And when pressing the help button, the help screen appears as shown in scene 7.

The second sample in Figures 4.18 and 4.19, scenes of the augmentation of word (بابا) is declared. When the image scanned by the camera, sign language spelling image appears as shown in scene 1. Pressing the second button, a 3D avatar of sign language of word (بابا) appears as shown in the second scene. Scene 3 and scene 4 show this avatar and the ability to interact with it by rotating and scaling respectively, the avatar is animated, and the animation goes in infinite loop. Scenes 5 and show animation to represent the concept when pressing the third button, here (بابا) word which means father, represented by animation of a father hugging his child, the animation is played in infinite loop. Scenes 7-10 show video of reading the word by finger spelling, with the ability to move, scale and rotate the video to be vertical or horizontal respectively, this achieved by pressing the fourth button. While the last button provides a video of the pronunciation of the word with audio, this to provide a lip-reading ability to deaf and to provide the voice for those with hearing residue, the video also has the properties of the previous video as scaling rotating etc. see scenes 11-12

Scene 1

Scene 2

Scene 3



Scene 4

Scene 5

Scene 6

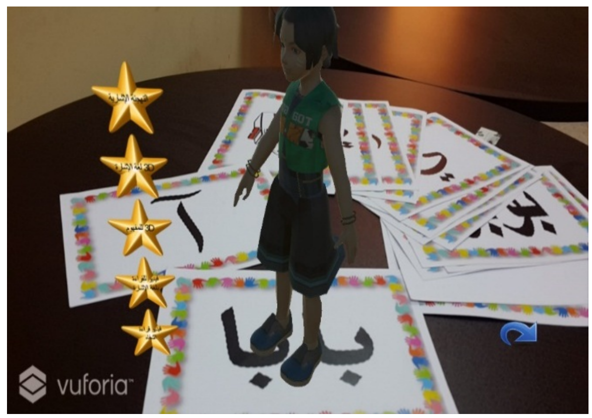
Scene 7

Figure 4.17: Scenes of sample of flashcards of a letter

Scene 1

Scene 2

Scene 3

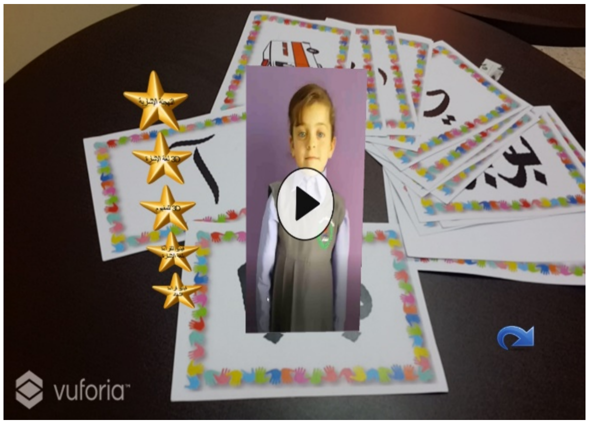


Scene 4

Scene 5

Scene 6

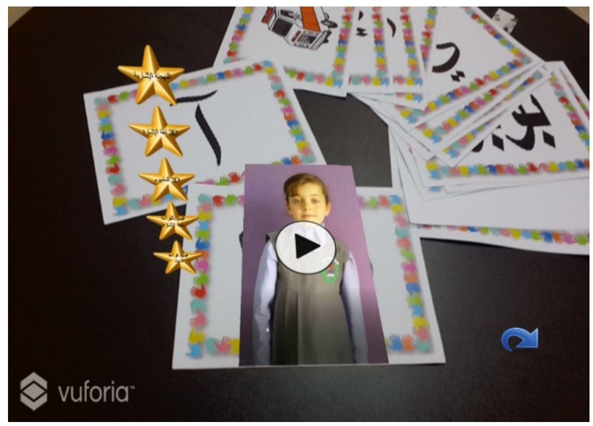
Figure 4.18: Scenes of sample of flashcards of a word part1



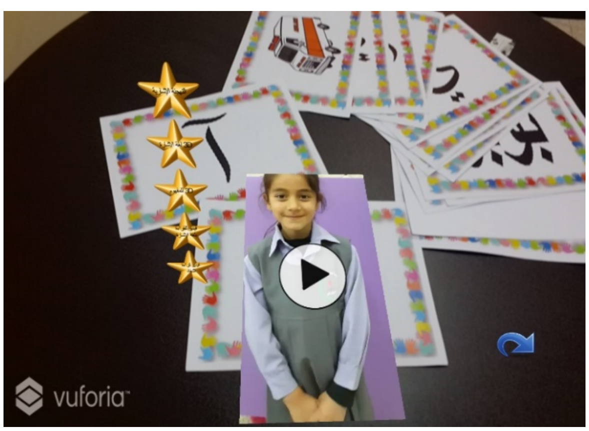
Scene 7

Scene 8

Scene 9



Scene 10



Scene 7

Scene 8

Figure 4.19: Scenes of sample of flashcards of a word part 2

Chapter Five

Experiments and Result

According to the literature review, many applications on different technologies are founded for deaf students including augmented reality, but not for supporting their literacy especially in Arabic language. There is just preliminary investigation that was conducted by one research [128].

In this chapter, the collected data is analyzed, and the results are obtained, then the results of the two approaches are combined to obtain the conclusion and answer the research questions and also to get the overall result of the evaluation.

5.1 Quantitative Analysis

A USE questionnaire with 5-point Likert scale was used in the usability evaluation, the SPSS software was used to analyze these data. The questionnaire starts with main question to get information about participants in terms of age, experience and educational background, Table 5.1 indicates theses information about the participants. The rest evaluation is divided into four parts. First part is general questions about deaf and smart devices in learning, and the second part is for the measurement of perceived usefulness, while the third part for the measurement of perceived ease of use, followed by the last part for the measurement of ease of learning. Figure 5.1 illustrates that most of the participants with experience exceeding ten years.

#	School	Age range	Year of experience	Educational background	Info.
1	Total communication school	37-45 years	> 10 years	Bachelor of History	Courses in sign language and methods of teaching deaf people belonging to the Palestinian Red Crescent, the League of Arab States and the Arab Federation of the Deaf
2		> 45	> 10 years	Expert in Sign Language - Diploma	Training and development courses
3		22-28 years	5-10 years	Bachelor of Arabic Language	Courses in sign language, methods of teaching deaf people
4		29-36 years	5-10 years	Bachelor of Arabic Language	Courses in sign language, methods of teaching deaf people
5	Deaf Secondary Mixed School	> 45	> 10 years	Sociology and Psychology	Courses in sign language, methods of teaching deaf people and courses on curricula through the Ministry of Education
6		37-45 years	> 10 years	Bachelor Social Service	Courses in sign language, methods of teaching deaf people
7	Qaqoun Charity Association School	37-45 year	> 10 years	Bachelor of Islamic Education	Courses in sign language, methods of teaching deaf people
8		>45	> 10 years	Bachelor of Arabic Language	Language courses and educational qualification through the Palestinian Red Crescent

Table 5.1: Summary of participants information

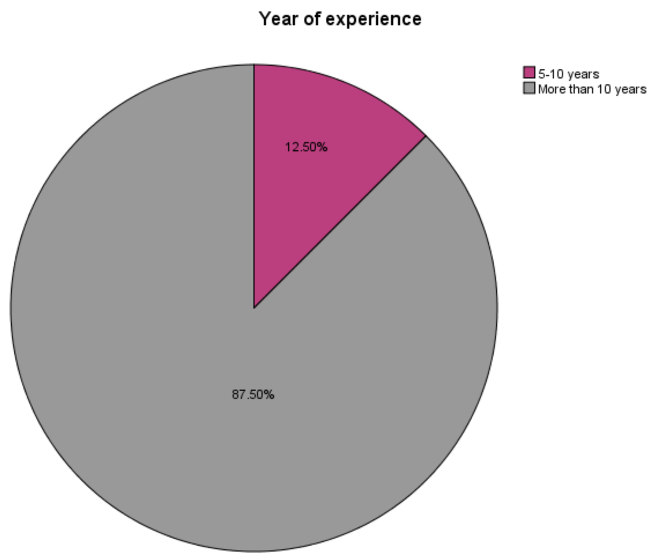


Figure 5.1: a chart illustrates the year of experience of the participants

The first three questions which were categorized under general title, were to obtain how much the participants agree with theses information, smart devices in learning, deaf as a visual learner and activity learning for deaf. Figure 5.2 shows the statistics about these questions. From the figure about 75% agree with the fact that deaf considered as visual learner and interactive learning increases achievement, while opinions differed as to the possibility of dispersion if the smartphone is used to learn in class but the most agreed with that it doesn’t lead to distracting. Just about 12.5% agree that it cause to distracting, 25% on neutrality, while 37% agree with question and 25% strongly agree.

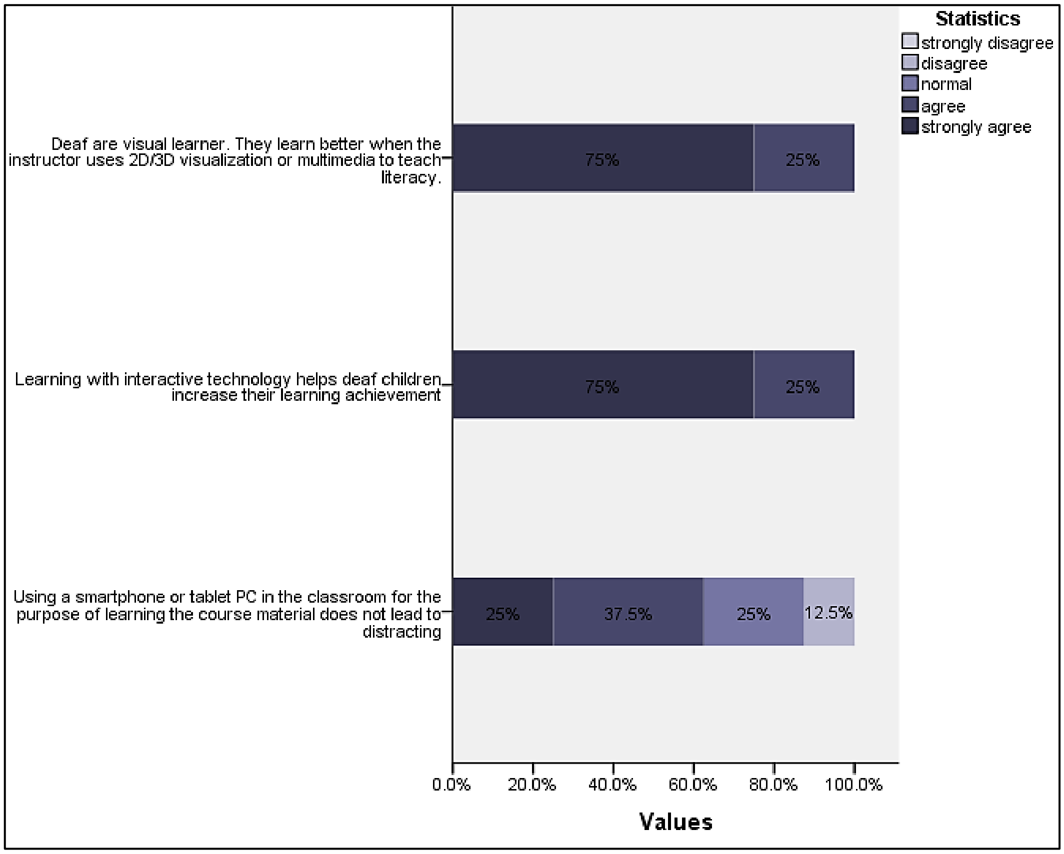


Figure 5.2: Statistics related to general information in the questionnaire

Usefulness

The second part of the questionnaire is about how much participants perceived the system as being useful. Tables 5.2 provides descriptive statistics for the usefulness factor, the utilized are statistics standard deviation and mean. The table shows the usefulness section 12 questions, the mean of the values answers and the standard deviation. The results appear that all questions had a high Mean that is bigger than four. For Usefulness the system scored higher on Q9 (“The literacy learning for deaf is more useful and interesting with AR.”) with mean=5 and SD=0, then Q10 and Q12 with mean=4.75 and SD=0.46. Where these questions play the main role in the first research question.

The total degree of mean of the Usefulness is about 4.45 which consider a high degree of usefulness with SD=0.311.

Statistics of Usefulness part			
#	**Question**	**Mean**	**SD**
Q1	Using the application in my job increase my productivity	4.38	.518
Q2	Using the application improve my job performance	4.25	.463
Q3	Using the application in my job increase my effectiveness	4.25	.463
Q4	It does everything I would expect it to do.	4.00	.926
Q5	It makes the things I want to accomplish easier to get done.	4.63	.518
Q6	It saves me time when I use it.	4.13	.835
Q7	It is useful	4.50	.535
Q8	The application helps deaf children to remember information and improve memorization skills.	4.13	.354
Q9	The literacy learning for deaf is more useful and interesting with AR.	5.00	.000
Q10	I think that AR application can be a valid form of vocabulary learning?	4.75	.463
Q11	Using the AR application motivate them to learn	4.63	.518
Q12	I would like to use this application in classroom.	4.75	.463
Usefulness		**4.45**	**.311**

Table 5.2: Statistics of Usefulness Dimension

Figure 5.3 shows that the deviation is low for most of the questions Usefulness, the most deviated scores were given for Q4.

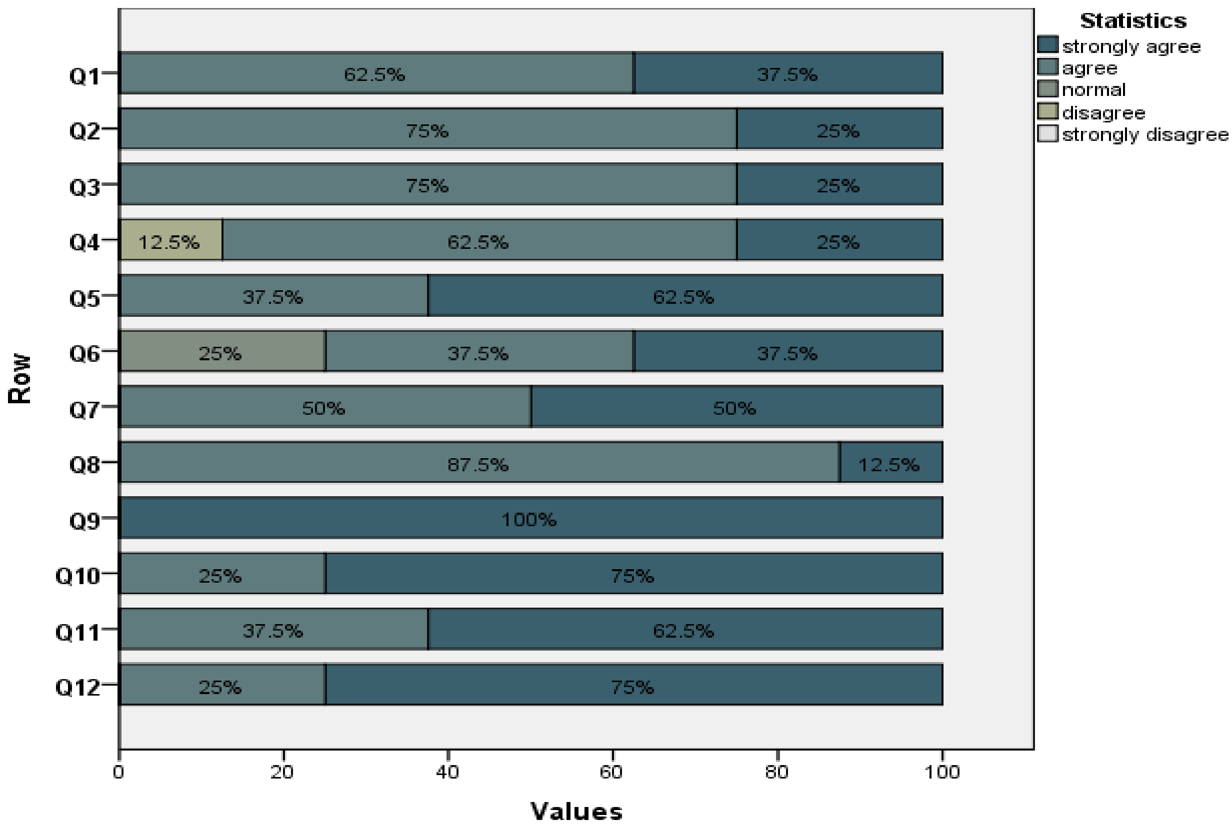


Figure 5.3: Stacked percent deviations for Usefulness scores.

Ease of Use

The third part of the questionnaire is about how much participants perceived the system as being easy to use. Table 5.3 provides descriptive statistics for the Ease of Use factor; the utilized statistics are Standard Deviation and Mean. The results appear that all questions had a high Mean that is bigger than four. Overall the result for this section and its questions was high. For Ease of Use the system scored higher on Q1 ("It is easy to use.") with mean=4.63 and SD=0.518.

The total degree of mean of the Ease of Use is about 4.29 which consider a high degree of usefulness with SD=0.444. Figure 5.4 shows that the deviation is low for most of the questions Ease of Use, the most deviated scores were given for Q8

Statistics of Ease of Use part			
#	Question	Mean	SD
Q1	It is easy to use.	4.63	.518
Q2	It is simple to use.	4.38	.744
Q3	It is user friendly.	4.00	.756
Q4	It requires the fewest steps possible to accomplish what I want to do with it.	4.38	.744
Q5	I would imagine that most people could learn to use this system very quickly	4.00	.756
Q6	It is flexible.	4.25	.707
Q7	Using it is effortless.	4.50	.926
Q8	I can use it without written instructions.	4.13	.991
Q9	I can use it successfully every time.	4.38	.744
Ease of Use		4.29	.444

Table 5.3: Statistics of Ease of Use Dimension

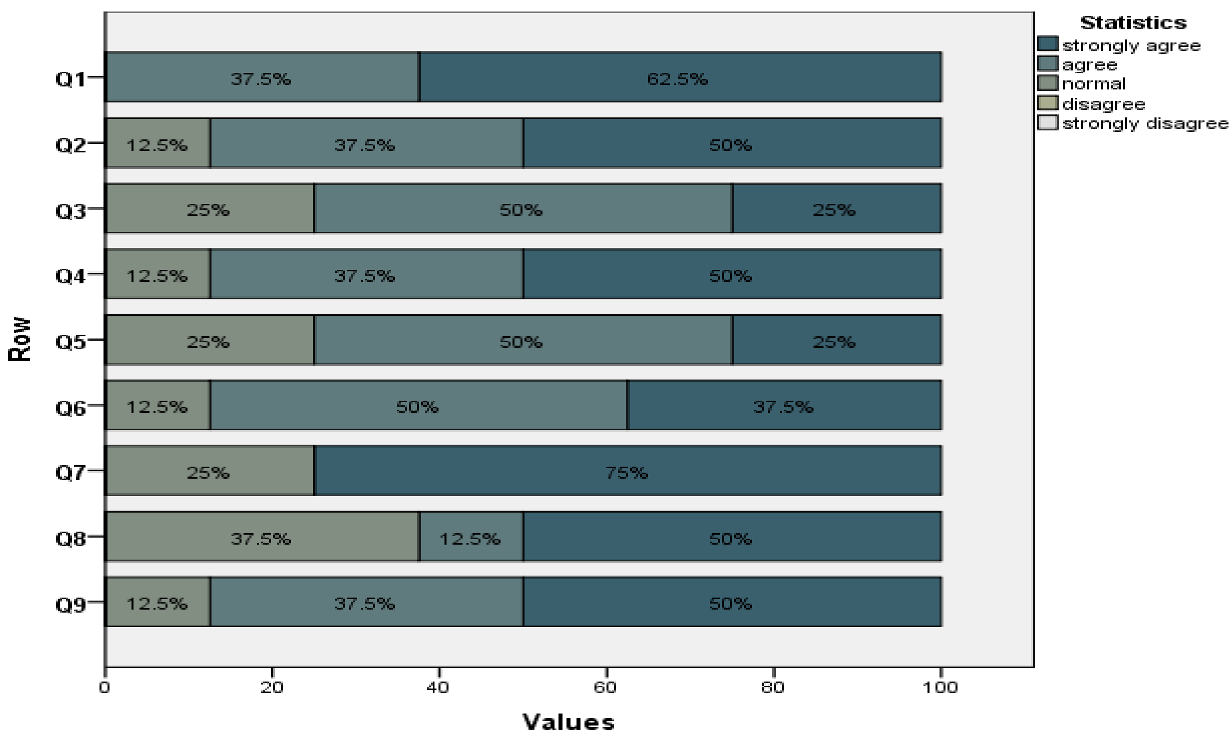


Figure 5.4: Stacked percent deviations for Ease of Use scores.

Ease of Learning

The fourth part of the questionnaire is about how much participants perceived the system as being easy to learn. Tables 5.4 provides descriptive statistics for the Ease of Learn factor; the utilized statistics are Standard Deviation and Mean. The table consists of three columns, a column contains the usefulness section 7 questions. A column refers to the Mean of the values answers and column for the Standard Deviation. The results appear that all questions had a high Mean that is bigger than four. Overall the result for this section and its questions was high. For Ease of Learn the system scored higher on Q5 ("The information provided by the application was easy to understand") with mean=4.63 and SD=0.518. and as seen in the table Q6 which indicates the helpful of the system in the teaching process which is a very important point, its mean is high, it equals 4.38 with SD=0.518. The total degree of mean of the Ease of Learning is about 4.43 which consider a high degree of usefulness with SD=0.458.

part			
#	**Questions**	**Mean**	**SD**
Q1	I learned to use it quickly	4.38	1.061
Q2	I easily remember how to use it	4.38	1.061
Q3	It is easy to learn to use it	4.50	.535
Q4	I quickly became skillful with it	4.25	.707
Q5	The information provided by the application was easy to understand	4.63	.518
Q6	The information provided by the application help me in teaching process	4.38	.518
Q7	The ordering of information is logical	4.50	.535
Ease of Learning		4.43	.458

Table 5.4: Statistics of Ease of Learning Dimension

Figure 5.5 shows that the deviation is low for most of the questions Ease of Learning, the most deviated scores were given for Q1 and Q2.

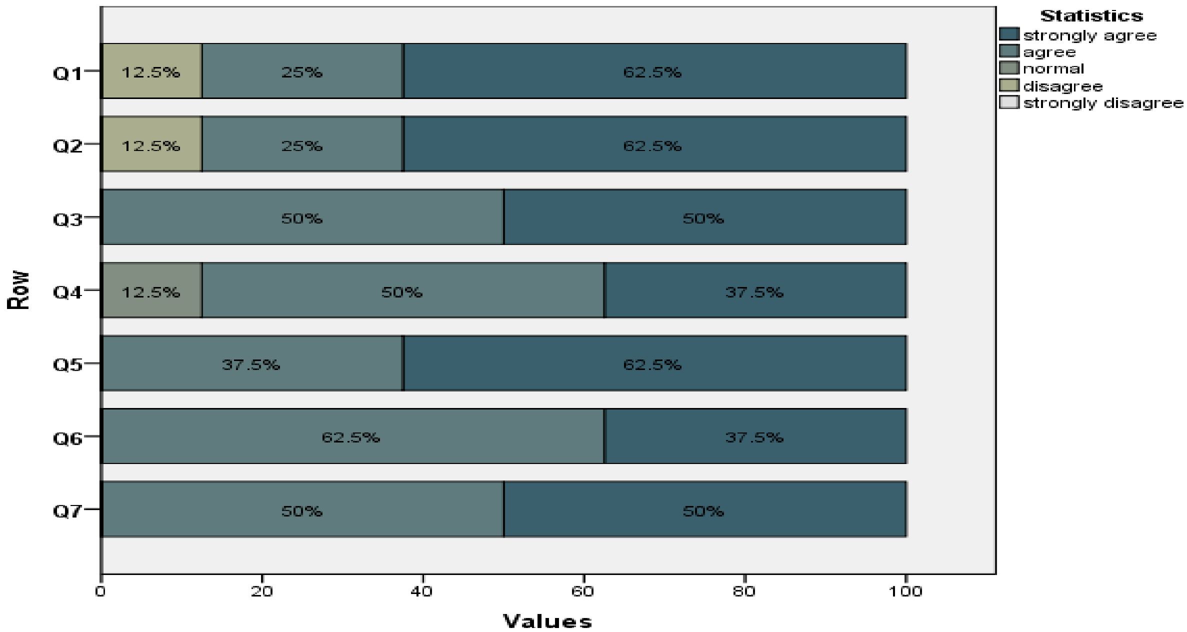


Figure 5.5: Stacked percent deviations for Ease of Learning scores.

The three sections: usefulness, ease of use and ease of learning were combined in the following table to obtain the total usability value. The total Mean equals **4.39** and the Standard Deviation equals **.359**, this Mean indicates a high value of the usability of the system, Table 5.5.

Statistics of usability		
Field	**Mean**	**SD**
Usefulness	4.45	.311
Ease of Use	4.29	.444
Ease of Learning	4.43	.458
Total	**4.39**	**.359**

Table 5.5: Statistics of usability

To ascertain the reliability and usability of the questionnaires, Cronbach's coefficient alpha is calculated. Form the table 5.6, it has been shown that the 2 items Usefulness coefficient is 0.808 which is very good, and 9 items Ease of Use with reliability coefficient 0.744 and 7 items Ease of Learning with reliability coefficient 0.729 which consider adequate. And for the total questionnaire he reliability is 0.9 which is considered an excellent value.

Reliability Statistics		
Field	**No. of Items**	**Cronbach's Alpha**
Usefulness	12	.808
Ease of Use	9	.744
Ease of Learning	7	.729
Total	28	.900

Table 5.6: Statistics of Relibility

5.2 Qualitative Analysis

5.2.1 Observation analysis

As mentioned in data collection section, observations were conducted in the three schools, in addition of writing down the observation notes, videos were recorded to capture the interaction between users and the application and then these videos were analyzed. With the help of the teacher, the basic steps were explained for the students and an experiment was conducted to illustrate how to use. The observation indicates that all children in the three schools were enjoyed using the application and were engaged in with using and interacting with it. Images for the children while using and interacting with the system shows their emotions in Figures 5.6 and 5.7.

Figure 5.6: Images captured in one of observation

Figure 5.7: Images captured in one of observation sessions for the children and their teacher.

In particular, when the AR contents suddenly appeared on the screen, they were surprised especially with 3D animation, they began interacting with it and start imitating the signing avatar or saying the corresponding word. The AR objects attracted their attention, they try to explore how it appears and try to catch it and see what happened. They ask their teacher what is happening and how. After exploring the system, the teachers start asking them questions related to the used words and flashcard, they also require them to perform tasks as require them to switch between the contents to view a specific one. they also require them to connect between the word and its meaning or to spell it, pronounce it. Student performance was great in all age groups and in all schools. They quickly learn how to use, how to move between contents, how to view a specific content depending on a letter, word etc.

In one group to test how quickly they learn to use and understand the idea, the application was explained to one child, then he uses it in front of the rest and he learns his peer how to use it. They caught on quickly and understand the concepts and how to use, and the child were very happy in explaining to his peers how to use it. In one of the schools, just one participant’s interactive was low and understanding is slower than the other, this participant is not only a deaf child but also -according to the teacher-suffers from other problems.

When they finished all the cards they asked for more. The majority of them expressed their admiration for the application and they would like to use it in education. When they were asked about repetition about 90% expressed willingness to repeat the activity. In terms of difficulties, most answered that it was easy. Through the observation, some of them were found to have some difficulties especially the small age group, such as standing very close to the flashcards and thus the camera could not recognize the whole picture and difficulty of adjusting the screen, help was provided in this situation and they easily continue. The most excited and favorite part for the majority was the 3D animation, it was attractive part for them.

These observations show that this mobile Augmented Reality application with flash card is easy to use and easy to learn especially for deaf.

5.2.2 Semi-structured interviews analysis

Semi-structured Interviews with the teachers were held in order to obtain valuable additional information related with the usability of the augmented reality prototype and the flashcards in addition to personal impressions, opinions, comments, from the point of view of teachers, to add valuable information and more explanation to the questionnaire. The questions touched the overall experience, the usability of the system, UI, advantage and disadvantages, their observation of the students and other question, the main prepared question in appendix D.

Interviews were analyzed in order to obtain the valuable information and connect its result with research questions. To achieve this, the results from interviews must be combined and interpreted the voice recorded interviews were transcribed verbatim in Arabic then translated to English in order to analyzing.

The interviews were held in the three schools. In total, five teachers and one sign language expert were interviewed. The interviewees were exposure to the application, and some of them use it with their students, then after filling the questionnaire the interview was held.

From the interviews, all responses given by the teachers are very positive and agreed that AR technology is useful, suitable and effective to be used in learning Arabic literacy for deaf.

The interviewees were asked about the Augmented Reality technology whether they knew it before, they all answered that it was the first time they heard about it.

About their feeling about this app, they found that the application is very impressive and useful in teaching literacy, and they strongly support its use and application in the classroom.

Most of them indicated that the application is appropriate in group education and would be very useful and their results clearer in individual education sessions. They also stressed that Parents can access it as an educational resource that enables them to learn with their children their sign language in the early stages, which will increase their linguistic wealth and enhance what they have learned in schools. they support that the application encourages the children in their independent learning as they can use it at home.

When they were asked about the application and the traditional method of education, they explained that the application has linked the word or the letter with its pronunciation, spelling, and concept and so on in one application and in a way that makes it easier to link between them and memorize them. In the traditional method, there may be some kind of dispersion. In addition, it required an effort in the preparation of the means and it may impossible to bring some things to the classroom to clarify the concepts. But in the application, everything will be pre-prepared, in addition to the things that cannot be brought in reality, it will be easy to provide them in an attractive and interactive way, especially since the visual education for the deaf stabilize information more. One of the teachers also indicated that the application will reduce the required effort of the parameter to prepare and thus increase the productivity and will facilitate the delivery of information, for example will reduce the use of the board, as well as for example the video of the pronunciation will help of repetition several times without effort. It may not be easy to completely dispense with the traditional method, but this application will be a great supporter of the process of education

After observing their children, regarding to the question about their opinion to the children reaction for the system, they say that the children were very happy and very interacting, they merged so much that they asked for more, they fully understood what the application was doing and were able to perform what they were asked to do, they were very impressed and attracted to the 3D animation. One of the teachers pointed out that this application and this technique will also be very useful in learning to read even for hearing children in kindergartens.

Regarding to the question about the ability of the application to reduce the time required learning a new word and mastering it in all respects, they said that the issue is relative, it depends on the letters and words. Some letters are difficult, they may take two weeks in normal mode and some are easier and take less. As well, depends on the child's abilities, as individual differences affect the time required. But on average in the current situation takes almost a week. They said that in order to answer this question a realistic answer, the program should be tested for a reasonable period of time, but based on our experience, we expect that the program will reduce the time needed to learn a new letter or new word significantly. Two teachers from two different schools said that based on their experience and the application's potential, they believed that it could reduce the time period from a week to two days, especially if there is a parent support. one teacher said: "The application is wonderful and will have many positive aspects, especially as it is also a means of clarification, fun and attractive to the child, and thus will have clear and concrete results, but must be tested in practice in order to give accurate results"

They have shown their desire to use the application in their classes and publish it in all schools, emphasizing the need to apply on iPad devices where the screen is larger and clearer, provided that a device is available for each student to apply the app in an effective way. When they were asked about the difficulties they might face, they denied that if the devices were available, there would be any difficulties. On the negative side, only the child addiction to the mobile which is a negative for using the device, not for the application itself.

Beside the positive responses, a meeting was held with a teacher at one of these deaf schools who works in the individual education, her response was somewhat negative. After the presentation of the application, she changed her mind a bit and then returned to rejecting the idea. When she clarified the matter, she confirmed that she not only rejected this idea but rejected any other application, she insisted on her traditional way and stressed that she could not replace or even use the application in addition to the traditional way and felt that no application could offer anything new to her method and apologized for the interview.

A summary of the collected results of the interviews of the teachers indicates that the augmented reality application has a positive influence on the success of literacy learning of deaf children. In order to be able to get accurate result about the goal, the system should be tested for a reasonable period of time and on larger samples

Chapter Six

Discussion

The main objective of this research has been to develop a mobile augmented reality prototype combined with flashcards for deaf children and to assess its potential to enhance their Arabic literacy skills.

The design of the Mobile Augmented Reality-Based Literacy Enhancement for Deaf Children (AR-DLE) is based on holistic views drawn from the perspectives of deaf teachers obtained from the semi-structured interviews as described in Chapter 4. The prototype was then tested by three methods: the observation, a questionnaire and interviews answering the two evaluation questions:

> Q1. How does the use of AR application combined with flashcards improve the deaf children literacy learning and enhance it? How useful is this technology in this domain?
>
> Q2. Can this technology play an active role in increasing the linguistic wealth of the deaf which help them develop their literacy abilities?

The results of the questionnaires show that the system usability degree is very high with a Mean value of 4.39. The field of Usefulness which is the most important aspect that examines the benefit of this application, which answers the first question, obtained the highest average and its Mean value is 4.45, which is very high. This result is greatly cross checked as those interviewees confirmed that the application was able to support Deaf Arabic literacy significantly. It also supports the process of education and makes it more enjoyable, which raises the level of educational achievement for them. The observation also enhanced this result according to the observation of the performance of tasks were required from them.

In addition, all of the interviewees confirmed that according to the possibilities provided by the application, it will decrease the required efforts in the literacy learning process and can reduces the period of time required to acquisition new letter or vocabulary. But they also confirmed that the system should be tested with higher number of users in order to get accurate answers.

6.1 System Usefulness

The findings show that there are several advantages of AR-DLE such as independent and self-learning, personalization, repetition, visual learning, motivation, entertainment and interactivity.

The system supports the independent and self-learning as it is easy to use without need of help. From the observation most of the students were able to use and interact with the system independently without following specific teacher guidelines. In addition, the teachers support that the application encourages the children in their independent learning as they can use it at home not only at the school without need of help. This finding is similar to the result of the research [124] which aimed to provide an independent learning facility of Indian alphabet and the result of result achieved by Nikolaraizi & Easterbrooks [86] that shows that using visual resources of multimedia software supports independent learning.

Repetition is very important for deaf, according to their teacher they need a lot of repetition to consolidate the information they receive because they can’t hear so they can’t easily remember it. AR-DLE system provides this ability as videos and animation in the application repeated in infinite loop so one can repeats as needed and according to his/her abilities of learning, and this enhances the previous finding that the system enables the children to learn by their own each according to his need as it supports the individual learning. In addition, the teachers like this property in the system as it will help of repetition several times without effort.

Another usefulness of AR-DLE is the personalization as the system took care of the individual differences of the deaf children. The system provides audio of the pronunciation for those who have hearing residue. In addition to the infinite replication ability that give the chance for each child to repeat according to their need and capability to learn. This finding matches with the information in [59] that the provided services for deaf must take into account their needs.

Visual learning is another advantage of AR-DLE system as it takes care of that deaf students depend on visually, interactive, attractive media. The system provides 3D objects, videos, attractive pictures to enhance their learning and according to teacher this visual content stabilize information more as they are extremely visual learner and about 75% of the teachers emphasizing on this fact. This advantage of AR-DLE will enhance and affect positively the deaf children literacy and linguistic wealth as it agrees with the information that visually enriched environment to deaf enhances vocabulary acquisition and similar to the result achieved by [86] which provides a visual resources of multimedia software and the assessment shows increasing in their comprehension.

Another usefulness of the AR-DLE system is that it is effective, interesting and motivating. All students were enjoyed using the application and were engaged in with using and interacting with it and asks for new cards, as well the ability to use it anywhere and without the need of help as it is mobile application and it is easy to hold and use. In addition, all teachers agree with that this application motivates them to learn as it consists of promoting and attractive contents. This finding is similar to the study in [37] which mentions that AR has the potential to engage, motivate and stimulate students. As well with the study about mobile learning [49] which explained that mobile learning increase motivation as the owner ship of the handheld devices seems to increase commitment to using and learning from it. In addition, it is similar to the result of the findings of Streibl [120] that shows that the developed AR application improved learning reading skills and increased motivation.

Entertainment and interactivity also are another two important advantages of AR-DLE. Where it provides interactive and attractive rich contents through providing different types of multimedia concentrating on 3D animation due to its attractiveness and interactivity to the children, so it combines between fun and learn which supports the process of education and makes it more enjoyable, which in turn raises the level of educational achievement for the children. The teachers confirm this and pointed out that the system provides a wealth of information in a wonderful, attractive and the children were very enjoyed and attracted through the experiment. This achievement agrees with the study [2] that pointed out that with AR features it can absolutely transform learning process into a more lively, productive, pleasurable and interactive experience for students. In addition to the research [47] which confirms that MAR is an approach in which students use mobile devices in teaching and learning process to accomplish a good interactive learning and this allows students to easily interact with content and teacher any time, any place. As well as with the research [33] which said that AR turns the learning process into a more attractive, pleasant and fascinating activity.

From the evaluation we can answer the research questions. The second question e is answered first as it leads to answer the first question which forms the main point in the thesis.

For the second question, the result of this question in the questionnaire equals 4.75, which is the second highest score in the usefulness field. The interviews also reinforced this result, the interviewees indicated that the application contains the necessary information for learning the new word and provides it in a logical sequence; it also provides everything related to the word in one application. In addition to the observation result, the students' quick understanding of the application and the content they use, and the ability to easily navigate between its contents, have enhanced the student's ability to learn a new word, as the children were exposed to the AR-DLE system about just 5- 7 minutes then they were skillful of using it, so the time to learn how to use the tool in addition to the time to learn a word according to the teachers is obviously less than the time to learn a word in the usual way. The application offers the ability to replicate content in a way that enhances information; it also supports independence learning for deaf people. So, the system can increase the linguistic wealth of deaf students.

To answer the first question, we return back to the fact mentioned in the introduction that to gain good literacy one should have two capabilities: language familiarity and decoding. The AR-DLE supports the two capabilities. The first capability can be achieved as it is obvious from the answer of the second question above, the system supports to learn new words quickly which increase their linguistic wealth. Furthermore, the system supports the second capability as it provides the ability to match between the letter or word with its related information as comprehension, meaning etc. and this improve their ability to decoding. In addition, the teachers' answers in the interviews and questionnaires reinforce this achievement. So, the AR-DLE system can significantly enhance Arabic deaf literacy, but still want to be tested for a reasonable period of time and on larger samples. Teachers also drew attention to the fact that this application can be used not only by the children but also by their parents as a reference for learning sign language.

This system, AR-DLE, is the first in this field, no real work on the augmented reality for Arabic deaf literacy has been done, only a preliminary study [128] without actual implementation so it was impossible to compare results. On the other hand, there are two researches on the literacy for other languages, the first is Chinese [114] which is still in its initial stages, and the second is German [120], The results of the study coincided with the results of [120] and the expectation of the Chinese application [114] and preliminary study [128] in that the augmented reality can enhance and improve deaf literacy. The Chinese system mentions that the system can help the deaf children learn fast but the system itself has not been tested. The preliminary study in [128] was conducted to determine the visual needs of deaf children from their personal perspectives, the perspective of their teachers and parents, it expected to improve their literacy.

Streibl's system [120] was tested and interviews were conducted, the results show that the students can use the word more quickly in the correct context, it also emphasizes that the hearing impaired can build vocabulary in the earlier age with the use of this system and the system enhances their literacy which coincided with the result of this work. But there are no numerical results to be compared and the measuring tools are different, and the content is not the same.

Comparing the system with the Streibl's system [120], it is only providing a sign language video. However, AR-DLE presents everything related to the word as spelling, comprehension, meaning etc. The same thing as in [114], they are similar in viewing a 3D model to explain the word or character and sign language, but AR-DLE also provides the spelling of the word, its comprehension, audio etc.

Other AR researches targeted deaf have a different aim than this thesis, as it concerns of learning other subjects like math and science, or it concerns with only communication as converting speech to text or translating it to sign language. Also, ELRA [125], MagicCamera [126] and MuCy [127] are concerning with just learning sign language with different languages, Brazilian an ASL, these systems show a 3D avatar correspond to a specific letter.

In addition, a similar Indonesian system [118], it shows a 3D animated hand. So, the comparison of these systems is impossible.

6.2 Challenges and Requirement

As for the challenges facing the implementation of this system, there were many challenges that include: financial challenges, infrastructure challenges, training challenges and technical problems.

For the financial challenges, in the normal situation, these schools suffer from a lack of financial support and to apply this system in the schools it requires a good finance to get the app in addition for offering a device for each child and the cost of the required periodic maintenance. As for the challenges of infrastructure it is required to have a device for each child and teacher and make sure it is always charged. As well as having robust internet as the system will be expand so the material will be reached from cloud and this requires achieving security. In term of training challenges, it is required to have training for teacher especially when the system expanded to include the advanced levels as well as for parents. In term of technical problems, the system applying may face device malfunction and required maintenance; it may also face the security problem as it will be connected to the internet.

The requirements to meet these challenges: it is important to have mandatory decisions for schools to apply this system and providing the required finance to apply it. In addition to offer a device for each child to achieve effective use. Another requirement is to follow up the development of the application and ensure its compatibility with the study plan and follow up its scalability to include all next levels. It is also important to offering robust internet connection as here in Palestine 3G is Recently applied and its costs are high, so it is necessary to find a robust alternative with high quality. One of the most critical requirement is achieving security as the devices will be connected to the internet especially because they are small aged and should be protected against illegal and child inappropriate content and other internet risks, this may be achieved by for example mandating pre-installed filtering services in addition to provide parent control on the devices. It is also required of presence of IT specialist in each school to provide them with technical support, solve technical problem they may face in addition provides them with recent technology and provides support to use these technologies as not everyone is familiar with technology. It is required to offer training for teachers and parents to be up to date with the system updates as it will be a bit harder in the next stages and need support and training to be proficient in using it optimally.

Chapter Seven

Conclusion and Further work

7.1 Summery and conclusion

The objective of this thesis was to investigate and explore how augmented reality can improve the deaf literacy and its role to support and develop their linguistic wealth, promote and motivate them to learn and improve their memorization skills. This thesis encompasses a description of the Augmented Reality technology, its concepts, technologies, applications and other related issues. As, a literature review on previous attempts had been accomplished to create similar research and projects, technologies for the deaf were reviewed and then Augmented Reality deaf systems were reviewed too. In order to obtain the thesis objectives, a prototype, AR-DLE, was built and evaluated using qualitative and quantitative methods.

First, a preliminary study on the reality of the Deaf people in Palestine, the difficulties they face, the literacy learning challenges they face, and the methods of their teaching were conducted through field visits to three schools in the West Bank. Interviews with teachers and sign language experts were held in these schools to gather information.

A mobile augmented Reality-based system prototype has been developed in conjunction with flashcards that cover sample of learning letters and words at the primary level. AR-DLE system has been developed utilizing on Vuforia and UNITY3D software., the system provides the user with rich augmentative content covers all the aspects of the learning word as attractive 3D animation to describe the concept, a 3D avatar to for sign language, videos for finger spelling and lipreading in addition to audio for the pronunciation for those with hearing residue. AR-DLE is an interactive system, the child can interact with it through the touch screen as rotating, scaling and choosing the content.

The evaluation study assessed the usability of the system using quantitative and qualitative methods. First, observations were held schools and usability and error were observed and written. Eight teachers and sign language experts were given time to explore the prototype system and fill a questionnaire followed by a semi-structured interview. This allowed both quantitative Likert scale data from the questionnaire and qualitative data to from interviews to be obtained. The three types of data were analyzed, this make it able to confirm and explain the quantitative results by the qualitative results.

In particular, the development and enhancement of the deaf literacy and the increasing of linguistic wealth would be positively influenced and promoted significantly by the Augmented Reality application and the flashcards. The fact of reducing the time required to learn a specific word is not easy to determine accurately because of the children different abilities, the system should be tested in a reasonable period of time to accomplish this result, but all the teachers agree that it would reduce learning time significantly, while two of them explained that according to their experience and the presented prototype, in average the required time to learn new word will be reduced to two days instead of a week in the usual case, which considered an excellent effect.

Another achievement was obtained from the teachers, that the application enhances the role of the parents and their cooperation with the school. It will provide them with a source of learning the sign language as well as its availability at home, which will help them to follow up and teach their children. It also improves the level of the individual education and supports it greatly, especially because of individual differences and abilities.

In conclusion, the employment of AR to enhance the deaf learning capabilities is very promising and can greatly enhance the learning processes as well as greatly reduce leaning time. As the system features concentrate on supporting the two literacy capabilities mentioned in the introduction chapter: language familiarity and decoding.

7.2 Limitations and Constraints

There are many restrictions and limitations related to the study in general, especially in the assessment, where there were lack of sources and the small sample size.

In terms of sources, the available information is few, and research in this area, especially with regard to the Arabic language is scarce. In addition, the information related to the deaf and the plans in their teaching, where it was not easy to get a plan or method teachers usually follow, but follow the information recorded from the interviews.

In terms of sample size, as mentioned in the introduction, the total number of deaf students is about 2000 students from all grades and distributed in all public and private schools in Palestine. So, the primary level has a few numbers of children and in each school the number of teachers of this level doesn't exceed three teachers, and this affects the study.

In terms of the evaluation, the similar studies were few and the comparison with other systems was superficial, because of the numerical results were not available for the other studies.

7.3 Future Work

In future, this application can be extended and modify the following:

- Evaluate the system with quite a large sample size.
- Expansion of the project to include all letters and other words in the primary stage, as well as the addition of exercises that enable the examination of student performance

- Adding content explaining how to write letters and basic principles in Arabic.
- Expanding the project to include the next stages.
- Develop the nature of the content in terms of three-dimensional designs and make them more attractive and increase the degree of interactivity.
- As well as give the teacher the ability of control of the system as: determining of the content displayed, the control of the animation speed adjust the repetition, sound and others.

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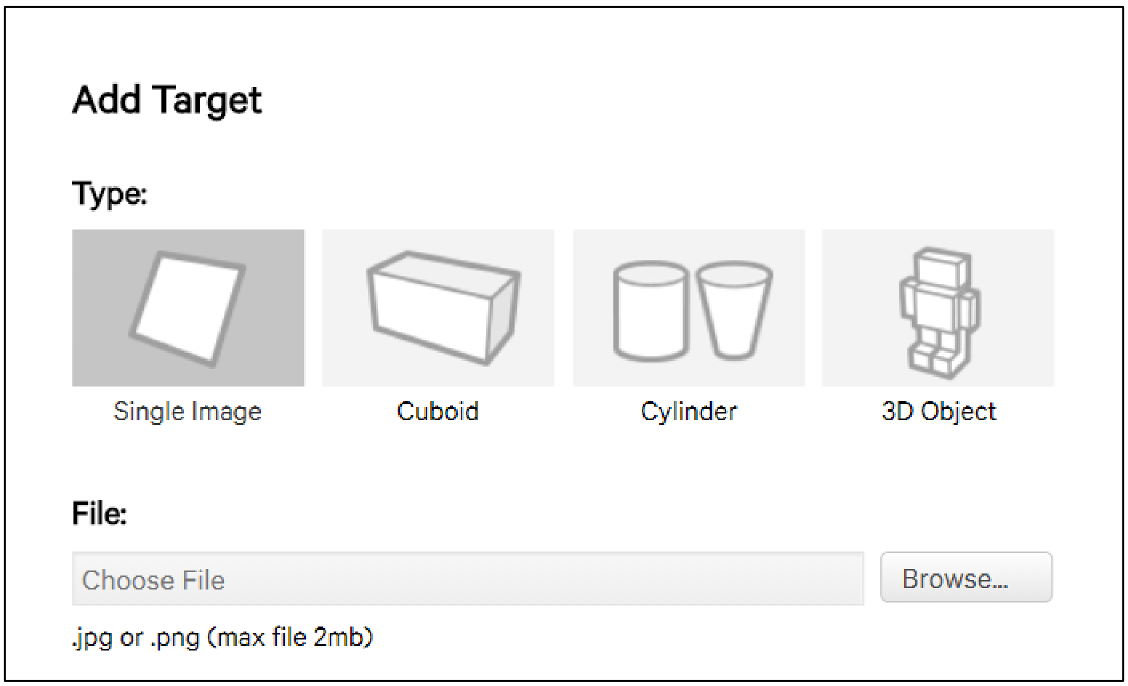
Appendix

Appendix A:

Here is a discussion of using Vuforia in the system to make the targets. Vuforia requires the creation of a target database, which is created using the Vuforia portal which is named Target Manager, the types of targets that contained in the database are various such as: cylinders, cuboids, image targets, 3D objects, see the following figure In this project just image target is used, about 30 image targets database accepts several types of targets: image targets, cuboids, cylinders



Firstly, an account in Vuforia portal was created, then from develop tab, using the Target manager a device database is created and targets are uploaded, each uploaded target should determine the target type- in our case all of them are image target- determine the width where the height is then calculated automatically, and be sure the target is active. After providing these information, the target manager used its algorithms to find the features and the points of interest of the image and provides a rating form 1-5 to indicate how the image is good to be tracked see the following figure. According to the developer, the strategy used for evaluation this rating depends on number of features, local contrast and distribution of features, and the best detection and tracking requires the target to be with rich details, good contrast and with no repetitive patterns. After uploading these targets, the database is given with development key which needed when the integration with UNITY happens. After this step, the database is ready to be downloaded to be used in AR unity application by choosing in a form the development platform unity editor.

Appendix B:

Pre-interview semi-structured interview

1. Research shows that most deaf student reading level is at about a fourth-grade. Why do you think this might be?
2. What is the difficulties the deaf student face in learning Arabic literacy especially in primary level?
3. What is the current strategies and methods to teach your students Arabic letters and vocabulary?
4. Do you use videos, pictures or three-dimensional objects in your teaching?
5. Do you use new technologies in your teaching, mobile devices, digital whiteboard, simulations, multimedia resources...etc.?
6. Are you in favor of using new technologies available to educate and entertain?
7. How can technology help children in early literacy development in primary school?

Appendix C:

The used Questionnaire:

Research questionnaire

NOTE: Please answer all questions.

1. Please indicate your age group

☐ 22-28 ☐ 29-36 ☐ 37-45 ☐ Above

2. Year of experience of learning Arabic to deaf children

☐ Less than 2 years ☐ 5-10 years
☐ 2-5 years ☐ More than 10 years

3. How long have you been in this school?

☐ Less than 2 years ☐ 5-10 years
☐ 2-5 years ☐ More than 10 years

4. What is the range age of children attending your class?

☐ 3-5 years ☐ 6-8 years

5. What is your educational background?

6. Are you currently teaching Arabic? If so, what sections?

N	Question	Evaluation				
General		Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1	Deaf are visual learner. They learn better when the instructor uses 2D/3D visualization or multimedia to teach literacy.					
2	Learning with interactive technology helps deaf children increase their learning achievement.					
3	Using a smartphone or tablet PC in the classroom for the purpose of learning the course material may be distracting.					
Usefulness						
1	Using the application in my job increase my productivity					
2	Using the application improve my job performance					
3	Using the application in my job increase my effectiveness					
4	It does everything I would expect it to do.					
5	It makes the things I want to accomplish easier to get done.					
6	It saves me time when I use it.					
7	It is useful					
8	The application helps deaf children to remember information and improve memorization skills.					
9	The literacy learning for deaf is more useful and interesting with AR.					
10	I think that AR application can be a valid form of vocabulary learning?					

11	Using the AR application motivate them to learn					
12	I would like to use this application in classroom.					
Ease of use						
13	It is easy to use.					
14	It is simple to use.					
15	It is user friendly.					
16	It requires the fewest steps possible to accomplish what I want to do with it.					
17	I would imagine that most people could learn to use this system very quickly					
18	It is flexible.					
19	Using it is effortless.					
20	I can use it without written instructions.					
21	I can use it successfully every time.					
Ease of Learning						
22	I learned to use it quickly					
23	I easily remember how to use it					
24	It is easy to learn to use it					
25	I quickly became skillful with it					
26	The information provided by the application was easy to understand					
27	The information provided by the application helped me in teaching process					
28	The ordering of information is logical					

Appendix D:

The semi-structures interview for evaluation, here the main pre-prepared questions

1. Have you heard of Augmented Reality? If yes do you know what AR is?
2. How do you feel about this app?
3. According to your observations, how much the children enjoyed and reacted using the system?
4. What is the most thing impressed the students video, images, 3D objects? What would make student more excited to use the app?
5. How does this application help to improve and support language learning and literacy development for deaf children?
6. Do you think it would be beneficial to use the system in the classroom?
7. In your point of view, how this app affect learning outcome?
8. What are the benefits of using AR for language learning when compared with traditional methods.
9. What were the positive aspects of this experience? What were the negative aspects of this experience?
10. Would you share this application with other teachers? Why?
11. What additional features would you add to the app? How would you improve the app?