Pictorial Cube: An Augmented Reality Application for 3D Visualization of Learning Objects

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Abstract:

Augmented Reality is a modern technology that can be applied to an educational environment to enhance learning and facilitate the transfer of information to children, making information easier to absorb. AR applications provide the children with exciting ways to view multiple pieces of information about varying objects. This thesis focuses on the development and designing of a mobile-based AR application called Pictorial Cube, to facilitate learning and teaching in early years of education.

Pictorial Cube is a black and silver cube focused on interacting with AR technology, the application activates the Cube, transforming it into a digital canvas. Once viewed through the application, the physical Cube presents visual images of objects in 3D. The application works by using the camera function in a phone or a tablet for detecting the pattern on the side of the Cube, making use of AR to present an image on the physical Cube, clarifying conceptual difficulties through a 3D portrayal of what is intended for the student to learn. The AR image is rotatable, and Pictorial Cube helps present the image in 3D for children at K-12 to experience smart learning of objects.

Design Science Research methodology is used to carry out the research, and initial testing has also been conducted to determine the learning effectiveness of the AR application on students. The frameworks used while developing the application include ARKit along with AR image tracking class. The research specifically focuses on the significance of AR technology and its implementation through a cube. The children that used the Pictorial Cube AR application found it easy to use and an effective means of understanding something otherwise complicated.

Keywords: Pictorial Cube. augmented reality, ARKit. AR image tracking class, object mapping, smart learning, K-12.

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List of abbreviations

VR Virtual Reality
3D 3-Dimensional
2D 2-Dimensional
AR Augmented Reality
ARKit Augmented Reality Kit
iOS iPhone Operating System
UEF University of Eastern Finland
DSR Design Science Research
KPK Khyber Pakhtunkhwa

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1 Introduction

The educational world is dynamic, ever-changing and diverse; from a black board to a white board, from a chalk to a marker, and from a traditional classroom to a modernized one. The way education is transmitted in today's world adapts various modes, which improvise with time. The best methodology of teaching has not yet been determined, numerous researches have been carried out to study the finest environment or a suitable teaching pattern that can be followed, in order to make the transfer of information as efficient as possible. However, it has been observed that the use of technology in a classroom aids the teaching process and makes learning not only easier, but also enjoyable. In this fast-paced world, where technology dominates every area, including the household, children are becoming more comfortable with technology and do not perceive it as something specific to a school environment. This having its benefits also paves way towards a habit of gadgets, which doesn't make their use fascinating any more. Therefore, it has become important to create innovations that are suitable to the classroom while being engaging and effective.

The use of Augmented Reality in a classroom is a revolutionizing idea that is different and also interesting. Learning through Augmented Reality (AR) is attractive to young learners (Chen, 2017) for it is a technology that incorporates reality with virtual 3D images. According to Oranç (2019), AR in early learning should be implemented because it provides students and teachers with related shapes that can be used in class. Augmented Reality acts as a connecting bridge between what is real and what is generated through a computer to appear real. This allows the student to experience the world perceptually through a technological lens, granting them an understanding which is unforgettable.

AR as a field opens doors to various forms of research, creating immersion, interaction, motivation, presence, and personalization (Chen, 2017; Agbo et al., 2020; Agbo et al., 2021). It is a fascinating yet extraordinary creation which can be applied to education, medical, gaming, and sports along with many other areas. It usually includes creating 3D models (3-dimensional models) that represent the prototype model. The computer algorithm focuses on using the sensor and

markers to spot the physical objects' current position and help control the replicated ones (Sural, 2019).

In this thesis, an application using AR and virtual objects is developed for interaction between students and the visually presented objects. This application is referred to as the Pictorial Cube. The Pictorial Cube is a futuristic technology that provides smart learning opportunities (Agbo et al., 2019a; Agbo et al., 2019b) and promotes a smart learning environment. A SLE has been researched to improve teaching and learning by providing a more personalized learning experience, instant feedback, motivation as well as learning support. (Agbo, 2019b) by establishing a direct interaction between a learner and the object presented in a virtual form via 3D images. The Pictorial Cube is both an iOS and android based application that can be activated once the camera option has been enabled in the smartphone or tablet. Through this application, the learner can interact with the real-world environment via virtual 3D images and Augmented Reality, hence acting as an innovative means for the learners to educate themselves about certain objects which they visualize. Students can explore animals, objects, or elements through a visual representation, encouraging them to learn about what is presented while engaging all their interests. Different 3D models can be fitted into the Cube; any object of choice can be transformed into a 3D model, making it inspect-able from every side. In this way, students are taught explicitly about animals or other inanimate objects using 3D technology (Lebaz, 2020). The interaction between the learner and AR through the Pictorial Cube is an example of learning made easy. This method of teaching enables the erasure of boundaries and limitations that exists between the teacher—whose intention is to convey the information in a comprehensible form, and the student that is exposed to new information every single day; the use of such a technological tool makes the transfer of information between the learner and the teacher as smooth as possible.

This research aims to incorporate AR technology with education, to improve teaching standards and equip children with the necessary tools for them to understand the basics of the world around them. This research is centered on teaching in a classroom and how modern technology can make it simple, while being accepted by the students and teachers. The Pictorial Cube operates on a certain pattern in which different photos of the object are taken, and the application helps to provide the accurate density mesh of the object. The mesh helps define the shape of the object,

create texture images that determine the object's color and inspect the 3D model from every aspect. The user can easily connect with the Cube and focus on studying the figures (Pochtoviuk, 2020). The framework used is based on AR technology that explicitly uses ARKit. This method was previously implemented and researched by Pochtoviuk (2020), who found it suitable for mobile learning. ARKit is a practical approach to providing educational applications (Pochtoviuk, 2020).

The Pictorial Cube in its physical form is a cube that has black and silver patterns on each side focused on interacting with the AR technology in order to convert the Cube into a digital canvas. This application operates by means of the users' phone or tablet's camera function, when the camera option is activated, the physical cube can be scanned on all sides, which is necessary in order to permit the coding to interact with the patterns. The AR technology allows the person to hold the Cube in their hands, making it easy to visualize the object.

Since learning is a process that involves listening, visualizing, hearing, and even writing; Pictorial Cube serves to visually educate the students while giving them a sample that they can observe in their hands, thus engaging their visual senses and building up curiosity, which contributes to learning. So, instead of dealing with the hassle of finding teaching materials in order to give an exact representation of certain elements, objects, or animals, the teacher can use the application as an instructional tool (Lytridis, 2018) and base his or her teaching on the 3D image produced by the Cube. The Pictorial Cube is an inexpensive AR technology that allows user-oriented experience, making it cost-effective and easily accessible for students' elementary learning (Philit, 2019). It is an application that can positively impact learning and provide the right kind of instrument to teach students (Howells, 2020). This research's main objective is to design and develop a visualized AR-based learning tool and test children’s opinions about the application's effectiveness and usability, and whether they would prefer its involvement in the classroom.

1.1 Motivation

Technology dominates every area in today's world, from the industrial sector to the hospitals, technology plays a massive role in making tasks easier and also of quality. Although the use of

projectors, computers, printers and tablets etc. are a part of most educational institutes in the world, it is important to develop handy tools that not only assist teaching but also make learning easier and memorable. Therefore, the use of a portable technology such as a Pictorial Cube in a classroom, is a smart method which promotes smart learning and enriches the experience of the students. The use of AR in a classroom is important because it adds a colorful flavor to the bland dish of daily classroom dictation. By the use of such a device, a child becomes in control of their learning process, which according to Carl Rogers Humanistic Theory of Education is essential. According to Carl Rogers theory, a child is the authority on how he or she chooses to learn, and so, it is important that the teacher grants this authority to the child so that they may learn quicker and better (McLeod, 2014). A tool like a Pictorial Cube will be an interesting sight to the students, they will view learning as an exciting activity rather than a burden, it will grant the students the ability to learn independently while connecting them visually with concepts, allowing them to envision conceptually difficult areas of study, giving them a more meaningful and clearly defined image that allows them to comprehend the teaching of the tutor better.

This being the driving force behind this research is also a vital part of a child's educational foundation. What makes up a successful society are children that grow into sensible adults, and what makes children fit into the right shoes are the many years of education. Education is not only important but also vital for the survival of a nation.

1.2 Research Problem Statement

Augmented Reality being a new concept to the field of education has not been widely implemented. Therefore, the motive of this research is to discuss the benefits of AR in the classroom or overall in the education sector. The use of Virtual Reality is limited to 3D videos, but AR being a new concept is not highly promoted because of either disbelief or less experimentation. The purpose of this research is to pose a solution to the educational challenges in early education, providing a technological solution to face teaching problems and introduce AR in education.

The research provides a detailed experimentation based on students in their early years of education, and how the use of AR technology in education can enhance its quality and make learning easier.

1.3 Research Objectives

The objective of this research is to create a framework which would promote the incorporation of Augmented Reality based learning in a classroom through the following ways,

- To explore the opinions of students regarding the incorporation of Augmented Reality in the classroom, that may be a new concept and dissimilar to conventional methods of teaching.

- To consider the perspective of teachers regarding the use of Augmented reality keeping in view the benefits and limitations, so that it may be considered relative to the traditional methods of teaching based on a designed framework.

1.4 Research Questions

To achieve the discussed objectives and explore the problem statements that have been mentioned earlier, the following research questions have been formulated,

- **RQ1.** How effective is the use of Pictorial Cube AR application as physical representation of learning objects?

  This research question will dive into the opinions and experiences of students and teachers regarding the use of AR technology in the classroom and the possible ways the Pictorial Cube can be used as a means to represent learning objects.

- **RQ2.** Does the AR application motivate students to learn about animate and inanimate objects?

  This research question focuses on the student and what motivates them to learn about new objects, how one can engage the curiosities of young children and make them learn about animate and inanimate objects through Augmented Reality.

1.5 Research Method

This research has been carried out using the Design Science Method. It is conducted on five children between the ages of 8-12 and two school teachers. All the participants are from Pakistan and study in a private sector school in the Punjab province.

1.5.1 Data Collecting Technique

The data collected is through interviews. The interviews are then analyzed qualitatively, the data collected through the interviews is recorded for further analysis via a smart phone recorder option.

1.6 Thesis Structure

The thesis has been divided among seven chapters. Chapter 2 encompasses the literature in accordance with the area of research, highlighting the importance of AR in the educational area as well as students' interaction with AR. Chapter 3 outlines a comprehensive overview of the Design Science Method system as well the pattern upon which this research has been carried out. Chapter 4 discusses the implementation and initial testing of the Pictorial Cube. Chapter 5 narrates the methodology that has been opted for this thesis. Lastly chapter 6 and 7 discuss the researched information and sum up the research.

2 Literature Review

The use of projectors, virtual reality, tablets, and laptops have been incorporated into the classroom to make learning effective and easier. However, AR in the school is a rare concept and would resemble taking five steps ahead on the staircase. An AR application is not only practical but also easy to use, keeping all the factors into consideration that aid the process of learning via the Pictorial Cube it can be concluded that AR is an effective technology that must be considered. The ease of usability and access to easy learning are the major factors that promote the use of Pictorial Cube. Through the cube it has become possible to visualize and learn about an object from the palm of your hand. The algorithms involved in the creation of the Pictorial Cube focuses on sensors using markers by spotting physical objects' current positions and controlling them. This innovative device that is centered specifically on the promotion of quality education is a tool towards the future of AR, and smart learning in the classroom.

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2.1 Background of children education in Pakistan

A typical classroom comprises students with varying intellectual capacities and different capabilities, the goal, undoubtedly of every teacher, is that the information which they intend to convey becomes clear to each and every student. It is normally considered impossible for each and every student to grasp a newly presented concept in a single sitting, for it is generally believed that each student has their own learning ability and pace upon which they pick new concepts. Therefore, the use of AR in a classroom for teaching children is an effective means that is promising to the teacher. The Pictorial Cube is an interesting and easy tool to understand something that is verbally incomprehensible by the student. Therefore, the use of such a modern technology in the classroom is an innovative method to bring clarity in teaching and make information comprehensible to each student despite their diversification and abilities to catch up on fresh information. This research aims to provide a solution to such educational setbacks by making use of merging technologies, such as Augmented Reality and Virtual Reality to promote better learning.

Most educational systems around the world operate on a conventional teaching style that has remained unchanged. Schools in the government sector support a teaching methodology that has been unaltered for years. Although the conventional teaching methods are not entirely a failed route, but can be changed for the better. Many schools in Pakistan in the private sector do make use of technology in the classroom, making learning rather enjoyable than burdensome. With time the teaching methods have progressed and value has been attached with significant experience of the student. The modern form or methodology of teaching provides a more meaningful context to education and adds a realistic experience in relation to the teaching of the subject. In this research, we explore and aim to shift from a conventional method of teaching to a modernized transfer of information, that proves to be more effective, engaging and easy to use. By utilizing modern technology in the classroom, the learning experience of the students can be enhanced and therefore lead to a better understanding. In most Pakistani schools, the use of Virtual reality is non-existent, children are usually exposed to gadgets such as tablets, projectors or computers to aid learning, However, a device as peculiar as an AR cube is a brand new concept that should be implemented. The participants for this reason are handed the cube and tested to understand how children would react to such an innovation and whether or not it is suitable for a Pakistani based classroom. Education around the world follows the same pattern in the early years, children around the world are somewhat similar in how they choose to learn, however, the environment, the exposure to technology is an important factor that determines the extent to which a innovation will be accepted. Moreover, "the evolution of learning and teaching methods from the traditional classroom learning environment to a technology-enhanced learning environment positively impacts education" (Agbo, et al. 2021)

Waqar and Bokhari (2017) in their research provide a critical review of educational technology initiatives in Punjab, Pakistan. The research highlights the importance of meaningful learning with technology, evaluating the benefits of technology in education. It explores whether the implementation of technology to education will enhance its quality. The obtained results indicate that "that inexpensive technological interventions with the design of learning that can facilitate children to learn individually at their own pace are the most feasible solution to overcome the problems of quality teaching and can also be used to provide educational opportunities for out of

school children." Thus, the research concludes that a device that is easy to use, to carry, and to understand while being inexpensive is well-suited to a classroom and contributes to the quality of education. The Pictorial Cube in this regard, is an easy to use technology that can be applied to a classroom, because, such an innovation provides freedom to the user and allows them to learn better.

Suleman et al. (2012) conducted a study to investigate the role of educational technology in public and private institutes of Khyber Pukhtunkhwa, Pakistan. One of the main objectives of the study was to know the usefulness of educational technology in the public and private institutions of KPK. The findings of the research are as follows, "majority of the respondents responded that:

1. Educational technology increases students' attention.
2. It improves communication between teachers and students.
3. It makes complicated things easy and understandable.
4. It ensures the students' participation in the classroom.
5. Learning environment becomes effective by the application of educational technologies for instructional process.
6. Teaching is more systematic by the use of educational technologies and much time can be saved with the help of educational technologies."

The use and implementation of technology in Pakistan would be an innovative step leading towards betterment in the educational sector. It would aid in shifting to a more modernized classroom from a traditional one and help students learn better while being accompanied by technological tools. The adaptability of the technology is important in this regard, in the education sector, it is important for a technology to be accepted among its users for effective functionality (Agbo et al., 2019).

2.2 Educational application of Augmented reality

Technology has started to play a part by facilitating the learning process. Thus, with the change in how education is communicated, the role of the teacher has also changed over time. Teachers do not act as mere instructors, but are facilitators providing guidance and feedback. Therefore, shifts in how education is transmitted calls for alteration in the teaching techniques to accommodate such an innovative movement towards modernized teaching. "One of the techniques based on

interaction and visualization that increase motivation in education is augmented reality (AR), a technology that allows real-time visualization of computer-generated objects (graphics, images, videos, 3D objects sound) superimposed in the real world of the user." (Boboc et al. 2021)

Wei et al. (2016) performed an experimental research in order to investigate the effect of AR applications as a learning and teaching tool to aid the learning of the English alphabet for the children of kindergarten, in the Kuwait state. Safar et al. (2016) performed an experimental study to investigate an AR educational application's learning outcome in two groups. The first group was taught using the AR application, and the second (control group) was taught through traditional face-to-face methods. A total of 42 people conducted and enrolled in the educational system participated in this study. According to Safar et al. (2016), a significant difference was observed among the control group and the experimental group, the one that studied using AR and the one that was taught in a traditional way, the results observed a degree of interaction through English alphabets favoring the experimental group. The result showed a strong relationship which is a linear correlation between the children with the interaction of English words and the scores of English alphabet tests in the experimental group. It means that many differences exist between the groups, and it is essential to understand these differences to get on the right track. After all these studies were carried out, it was concluded that AR technology is beneficial in education (Safar, 2016).

Emerging teaching methodologies now incorporate the use of mobile devices, Augmented Reality as well as game-based learning in education. The combination of these elements in an educational setting is considered highly innovative, for it allows learning to exist beyond a classroom environment and challenges the boundaries of traditional teaching (Pombo et al., 2020).

Pombo et al. (2020) carried out a research to determine the potential educational value of mobile Augmented Reality games and empirically revealed that mobile based Augmented Reality games have educational value and could be a beneficial option for those that intend to integrate AR based games in the education system. Oyelere. (2017) also carried out a research based on a mobile based game application called MobileEdu concluding that its implementation helped students to learn from their learning activities. The mobile learning application provided learners with a positive pedagogical experience and improved their learning. (Oyelere 2017).

Therefore, it is to be noted that Augmented Reality is of great significance in education, the use of Augmented Reality applications promotes learning.

2.3 The use of augmented and virtual realities in education and the experiences of K-3 teachers

Research has proven how AR and virtual reality have advanced teaching and learning nowadays. Virtual reality (VR) has recently gained momentum in various areas of work and study such as entertainment, military, and education. Incorporating VR and AR in education can improve its quality. (Ati et al., 2018; Syahidi et al., 2019; Oyelere, et al., 2020; Agbo, et al., 2021). To confirm this statement, we refer to Arnhem et al. (2018) research on the 'Merge Goggles' and 'Merge Cube', the purpose solely was to determine the usage and consumption of virtual and augmented reality as an educational tool. According to the study the Merge Cube is a wise piece of circulation and an educational tool for the classroom, media, laboratories, or libraries, obtained at a low cost. In comparison to the Pictorial Cube, which is dedicated towards enhancing classroom learning for children, the Merge Cube is a multi-purpose technology, not specific to the education sector. The Merge Cube is used by different users' categories without any special equipment but instead it operates through an app or a smartphone that supports them.

Duarte et al. (2020) presented a study on virtual reality and Augmented Reality through a scoping review. Durate et al. (2020) stated that there are no significant teaching changes in universities for expositive lectures and other anatomy laboratory activities. However, with new emerging technology such as augmented reality, simulators, and virtual reality, many doors have been opened to new possibilities within teaching methods. The study evaluates a comparison among the traditional techniques of virtual reality and augmented reality, by performing research on Cochrane library, EMBASE, LILACS and also use some terms of mesh anatomy with virtual reality and augmented reality. They concluded in their study that virtual reality and augmented reality promise value for teaching anatomy with a positive economic impact on schools and universities.

Boboc et al. (2021) implemented and developed an AR application for android devices and later conducted an experiment consisting of 116 students as participants. The study revolves around the technology acceptance model and student’s perceptions regarding the use of AR in the classroom. The students' responses were assessed using structural equation modeling. The results obtained showed positive feedback from the students, which highlighted the potential of such a technology. The student’s positive response indicates that AR must be incorporated during study in not just one but other disciplines as well.

The classroom is an interactive environment that a teacher governs. A teacher's only intention is to provide clarity of information and the easiest way it can be presented to the learners. Ntuli et al. (2019), in their research, introduced the teachers to the Merge Cube. Teachers of K-3 were trained specifically in a STEM workshop to learn and focus on AR and Merge Cubes in a classroom. Children in their K-3 are challenging and have a short attention span, it is quite difficult to keep them attentive, for they get distracted easily. Therefore, such a technology is tested and the main focus of the study is to support the teachers with innovative tools and consider their perception regarding the use of AR as a teaching tool. The teacher's feedback is collected and recorded to be optimistic with regard to the use of Merge Cube in the classroom. The positive response from the teachers indicates that the Merge Cube is a useful tool that can be incorporated in classroom study. The teachers believed that the teaching approach using the cube increased the children's attention and aroused interest in the subject. Ntuli et al. (2019) concluded that a teacher and a student's barriers could be minimized through such technology. The Pictorial Cube, on the other hand, is dedicated to understanding children's experiences with the Cube rather than the teachers. It is focused on how they perceive an AR application as a means of education. Their experience and opinion is given priority, and the Cube is designed to be used by the children.

Different methods have been tested over time to engage the students; the use of technology in the classroom is a tested method that makes learning exciting and memorable (Yadav, & Oyelere, 2021). Zahara M. et al. (2021) carried out research to analyze teacher and students' perceptions about AR assisted worksheets alongside the STEM approach in physics learning. The study concluded that there is a need for interactive teaching materials integrated with STEM (Zahara et al. 2021) and the use of AR is a good means of assistance.

2.5 Augmented Reality applied in various areas of education

Augmented Reality has been experimented in various areas of study including, physics, mathematics, chemistry, geometry, language and much more. The researches that focused specifically on certain subjects made use of AR in that specific domain and considered its efficiency in relation to the subject of focus. Hendracipta et al. (2021) carried out a research that

explored how Augmented Reality can improve mathematical conceptual understanding of pre-service elementary education teachers. The purpose of the study was to determine the understanding of pre-service teachers in mathematics through the use of Augmented Reality media. Hendracipta et al. (2021) from their findings concluded that augmented reality is an efficient tool and can be used as a learning medium in mathematics. Thus, AR is not only suitable for children, but also can be put to great use in the teaching service. The suggestion in this research is that further development of augmented reality media is needed at all levels of education and it needs to be tested on a larger scale in order to know its effectiveness to be used in all levels of education (Hendracipta et al., 2021). AR promotes a smart learning environment, a smart learning environment makes learning accessible to everyone and that is the true purpose of education itself (Oyelere, 2019)

The implementation of AR has not been limited to mathematics, Macariua et al. (2020) in their research "Learn Chemistry with Augmented Reality" states that AR is an interactive experience of a real-world environment. Before recent releases of cheap and affordable smart devices, AR large-scale applications in education were almost impossible. After a brief analysis of current trends in the use of AR, a new system was proposed, named AR Chemistry Learning, to support the Romanian educational system. In this research AR is used as a means to teach chemistry to children and it is concluded that AR helps to develop logic, to explore the world and understand the subject better. The research intends to convey the importance of these emerging technologies, suggesting they must be used in the classroom.

Children as they begin formal education do not enter the school premises without prior knowledge of the world, this knowledge that has become a part of their information is due to the experiences they undergo with respect to the world around them. This prior knowledge is the product of their activities, interaction, experiences, games etc. through this prior knowledge they can exceed in school. Traditional teaching methods do not allow adapting to the learning that students need, therefore the use of technological tools in education is essential, for it provides different learning opportunities for both students and teachers (Sotelo et al., 2020). Usually, schools are provided with a set curriculum by the Ministry of Education, even specifying the textbooks that are to be taught. So, it then lies upon the school and most importantly the teacher to make a certain subject simpler and interesting rather than boring and hard. The teachers' creativity comes into play on

how he or she chooses to present the study materials, making them engaging and memorable. However, depending solely on learning materials is not enough, for children have a limited attention span and they lose interest easily. Thus, the use of technology in a classroom not only makes studying interesting but also unforgettable (Jalaluddin et al., 2020). Motivated and engaged instruction is an essential part of every teaching and learning environment; lectures are given with an intention to explain abstract ideas, sometimes making use of activities to help the students understand better. However, teaching environments could be made more engaging and interesting if technology is put to play (Oyelere, et al, 2017). Jalaluddin I. et al. (2020) carried out a research on students that were learning vocabulary in English. The experiment involved 45 students and the motive of the experiment was to explore the effectiveness of using MAR, that is, Mobile Augmented Reality in vocabulary learning. The findings of this research showed improvement after the implementation of MAR.

3 Overview of Design Science Research framework

The most critical yet essential step in determining the efficiency and quality of a research is the methodology that has been opted to be acted upon. In case of this research the Design Science Methodology has been chosen to represent the collected information and analysis. DSR is a latest approach to research (Reubens, 2016) that aims to solve problems instead of explaining a current problem or reality in order to make sense of it (Iivari and Venable, 2009). The purpose of DSR is to develop valuable and reliable knowledge for designing a specific solution to a posed problem. (van Aken, 2004)

Horváth (2007) and Baskerville et al. (2015) stated the motive of DSR is (1) to utilize the gained knowledge, to solve existing problems, or to improve existing solutions; and (2) to produce new knowledge, understandings and academic explanations.

The outcome of DSR “can be a product or a process; it can be a technology, a tool, a methodology, a technique, a procedure, a combination of any of these, or any other means for achieving some purpose” (Venable and Baskerville, 2012, p. 142).

The DSR process generally includes six steps or activities (Peffers et al., 2007; Lapão et al., 2017; Teixeira et al., 2017) which are:

1) **Identification** of the problem, the step towards defining the research problem and justifying a solution.

2) **Definition** of the objectives for a certain solution.

3) **Design and development** of artifacts i.e. models.

4) **Demonstration** by using the artifact to resolve the problem.

5) **Evaluation** of the solution, comparing the objectives and the observed results via the use of the artifact; and finally

6) **Communication** of the problem, the artefact and its effectiveness to other researches.

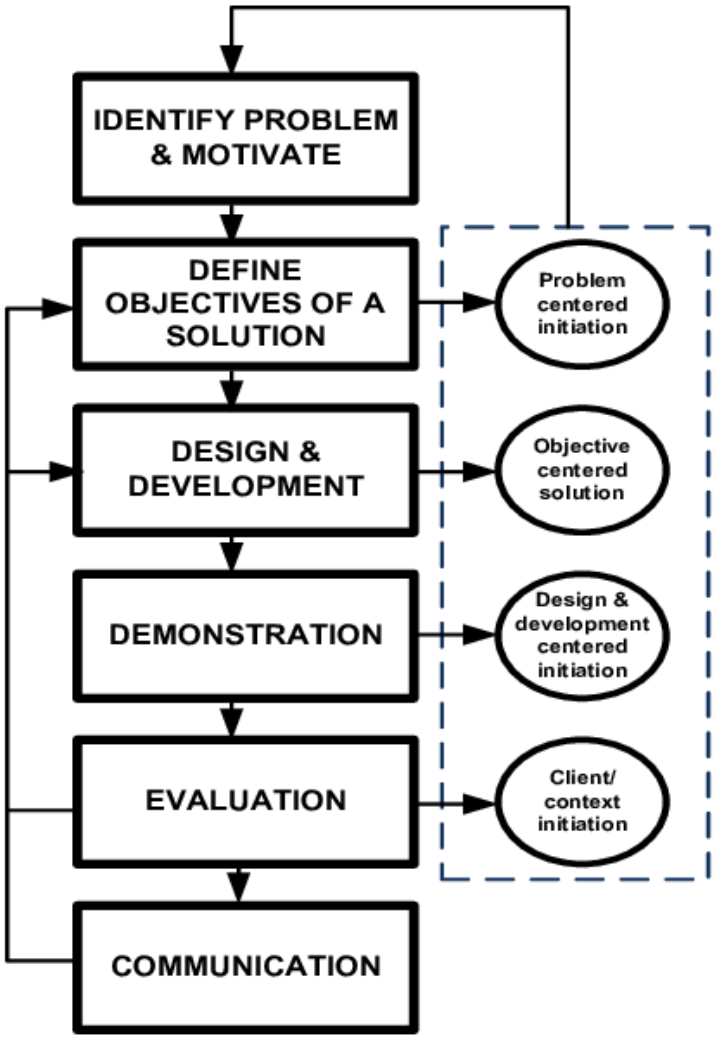

Fig.1 Steps of DSR (adapted from Azasoo and Boateng, 2015)

3.2 Activities in design science research Model

The Design Science Research as mentioned earlier operates on six steps, including the identification of problems, artefact creation and few others in order to come to a logical conclusion. The activities of the DSR require a considerable amount of time, effort and attention to detail. The key element of DSR is to add new information thus making it different from other design models. The activities are discussed below.

3.2.1 Problem Identification

The first essential step towards a well-defined research is the identification of the problem that is to be looked upon. The foundation upon which DSR is carried out is the understanding of the problem that is to be dealt with. In the case of this study, the problem which the Pictorial Cube is created to solve is the interest and effectiveness of education on children in their early years of learning. The application with the help AR aims to make education interesting and effective, while keeping it simple and easy to understand. The Cube aims to attract all the attention of the users so that they may grasp a concept better and understand it without hindrance. The problem here lies in the limited attention span of children, disinterest in studying, and the inability to comprehend what has been taught. Keeping all these factors in mind, the Cube is created so that children may be interested in studying and would pay attention to what is being taught. The purpose of such a creation is to make both learning and teaching easier, so that education can become of quality.

3.2.2 Define Requirement

This step determines the required methods that are to be followed in order to solve a problem. It includes understanding the problem and illustrating a solution to the problem(s) outlined. With reference to this study, the requirements include ease of functionality as well as the designing and environment of the artifact. The Pictorial Cube is used primarily in a classroom and is built keeping in view the limitations as well as the environment it will be placed into. The Pictorial Cube functions on a basic principle and that is the use of AR to make education easier for children. The required methods that are to be kept in mind is the ease of use by the students, the ability to clearly showcase what is intended to be informed, and to arouse an interest in the subject.

3.2.3 Design and the development of the process

In this stage an artifact is created as a solution to the research problem. The artifact fulfills all the necessary requirements that are needed to solve the research problem. There are various forms of artifacts ranging from concepts to design theories, models or even installations. Any object developed to assist research and aid in giving a satisfactory output is a DSR artifact. In case of this research, the Pictorial Cube has been developed and designed and also exists in physical as well as in digital form. The creation of such an innovation helps solve the research problem.

3.2.4 Demonstration

The demonstration of the artifact to resolve a problem falls under this category. The artifact is used as a means to solve a certain problem. It is created with an intention to address a specific issue, to act as a tool that would help fix a certain problem. When an artifact is developed, it has to to be applied to get results, in this case, the Pictorial Cube is applied and tested on children from the age of 8 to 12. The application and the initial testing procedure is discussed in the upcoming chapters.

3.2.5 Evaluation

After the artifact is applied, the next step includes the evaluation of the solution by comparing the objectives and the results. The solution is then evaluated to reach a logical conclusion. In this research, the objectives are attained and successfully tested through the Pictorial Cube, providing a satisfactory answer.

4 Implementation of Pictorial Cube

4.1 Design and Implementation of Pictorial Cube, an AR-based application

The Pictorial Cube is an iOS application that operates on Augmented Reality and is activated once the physical cube is scanned through the camera of either a phone or a tablet. The application makes use of AR technology and virtually presents the selected or pre-determined objects on the physical cube in a 3D form. The 3D image appears on the cube once viewed through the application. AR enables educators to improve learning outcomes by increasing engagement and interactivity. This application helps to build interest and provide outstanding visualization, which isn't usually observed in the traditional classroom, hence increasing the quality of education.

Pictorial Cube aims to break the barriers between a child and the knowledge that is presented to them through AR technology, featuring aspects that enhance learning through problem-solving, collaboration, and creative thinking to better prepare children for the future and make information understandable to them.

The design and development of Pictorial Cube followed the software development process methodology. The Use case diagram in Fig. 1 depicts the learner's interaction with the application's features and components.

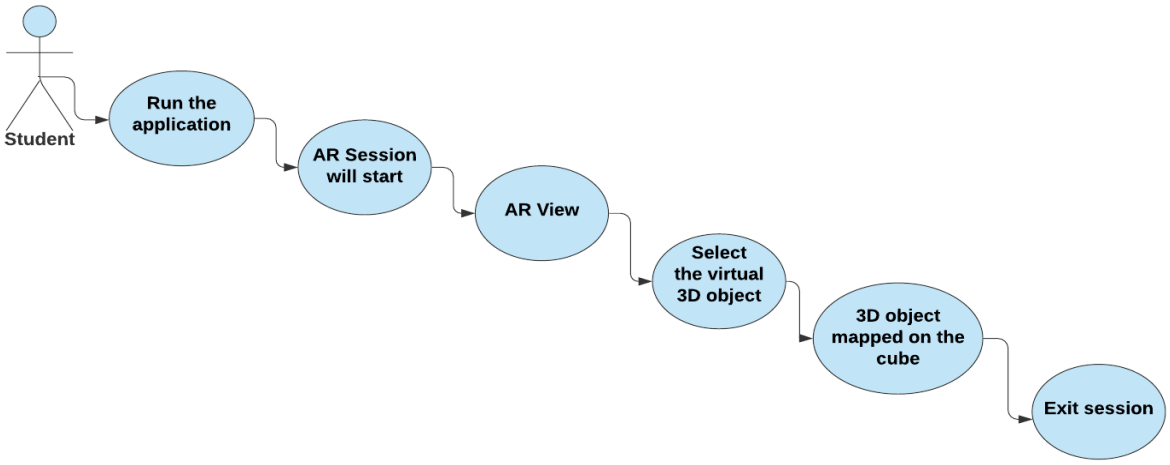

Fig.2 Use case diagram of the Pictorial Cube AR application

4.2 ARKit and Pictorial Cube Development

Pictorial Cube was created with Apple's Xcode version 12.0. It's an iOS app in which the application components are developed independently to keep the code clean. Pictorial Cube being an iOS application has been run and tested on an iPhone. To enable AR in the iOS app, an ARKit was employed. Augmented Reality is a technique that incorporates digital material into the real world, which includes high-precision augmented reality overlays. The image tracking class is in charge of implementing the AR images. This program operates by activating the camera and seeing the image through the application onto the Cube. The pictures may be recognized using an image tracking class to establish the frame of reference for the AR scene.

The ARKit is a remarkable feature that enables the program to recognize 2D photographs and transform them to 3D by enabling digitally augmented material to be shown in 360-degree photographs. The 3D animations are utilized in class for observation. The photographs have been seen and stored in the shape of the Cube on the application. The program can load the exact

embodiment after it has been selected. An ARKit then employs a method known as visual-inertial odometry, which combines data from the iOS device's motion-sensing hardware with a computer vision analysis of the scene visible to the mobile phone. The ARKit combines device motion tracking, powerful scene processing, and display conveniences to make designing AR experiences easier. Figure 2 displays the system's high-level architecture and interactions between the actual and virtual worlds. Several AR experiences may be used by concentrating on the back camera and using the front camera of an iOS iPhone. The cube has six sides, and all of them have been successfully scanned. Whenever the application shows the material in conjunction with a camera picture, the application shows the content with a camera picture. It is the point at which the person recognizes the picture as a part of reality.

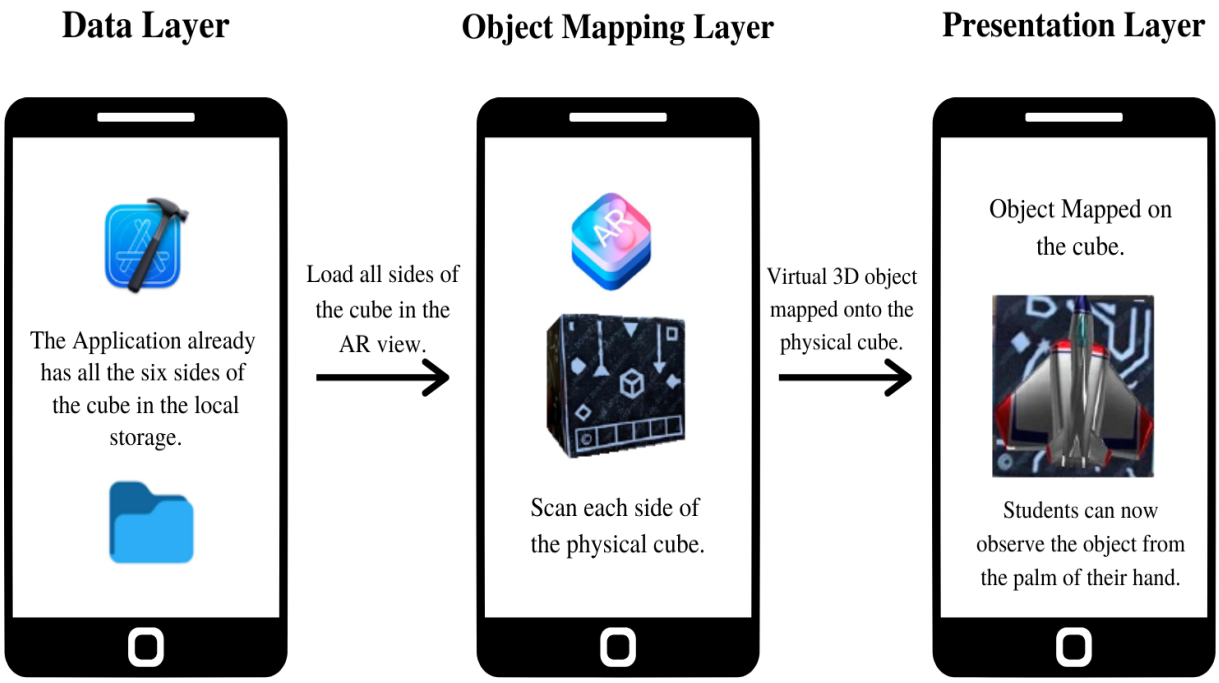

Fig. 3 High-level diagram of the system architecture

In the ARKit, a right-handed paradigm has been employed, with the y-axis pointing upward, the z-axis pointing towards the viewer, and the x-axis pointing to the viewer's right. Similarly, a

session setting might modify the origin and orientation of the coordinate system concerning the real world. The goal of utilizing this class is to scan the image from every angle and ensure that the face characteristics are captured as a cube. To construct the correlation between the actual and virtual environments, ARKit employs a technique known as visual-inertial odometry. It is the type of procedure that integrates information from the device and displays it through the device's camera. ARKit also focuses on combining hardware information with computer vision analysis. It is an important method for tracking the location of these features and comparing the information to motion-sensing data.

4.3 How Pictorial Cube functions

Pictorial Cube employs a virtual picture that appears on the physical cube once the application is launched; the virtual picture is predefined and appears on the cube via the application. The object in virtual representation may be examined from all sides.

To begin, image detection must be enabled. AR Reference Image resources are loaded from the application for this purpose. AR image tracking was employed in this application to help with the device's camera functionality. It scans and stores the photos as cube patterns while using the core data to save those photos into the database with a specific name so that AR can track those photos precisely. Pictorial Cube next monitors the photographs and retrieves the photographs in 3D cube form from the database where they were previously saved. The Pictorial Cube gives a wonderful chance for educational institutions to choose a cost-effective method of educating young children. AR not only creates a duplicate environment, but it also manipulates the current world and overlays its characteristics. It provides a practical alternative for functioning in a globalized environment, allowing kids to learn about new forms, objects, or animals while still in their classroom. As seen in Fig. 3, the Pictorial Cube allows 3D items and simulations to interact, touch, and hold the form in hand. It is intended for use in the classroom or at home for hands-on learning. Students only need to install this software on their iOS devices and use it with a single tap. This program serves as a digital learning platform for students to self-educate.

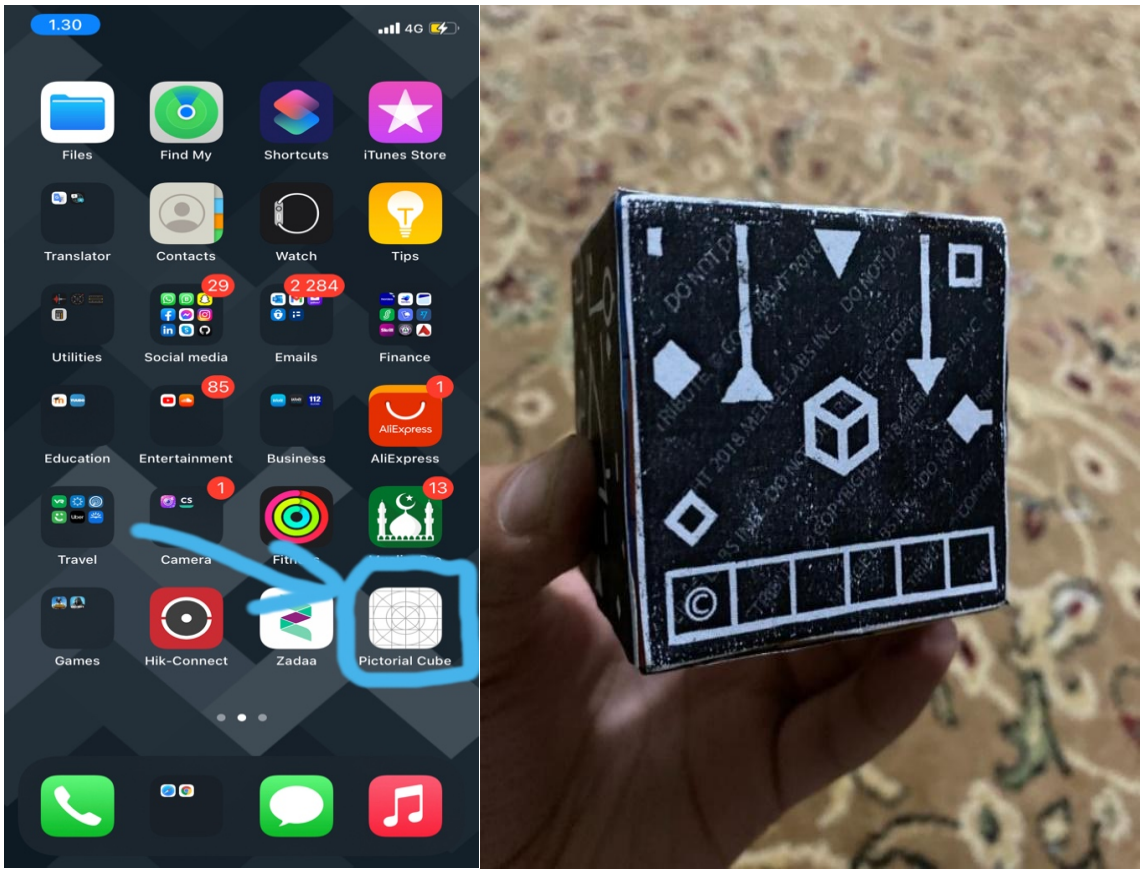

Fig. 4. The Pictorial Cube Application (left) and in Physical Form (Right)

The major goal of the project is to investigate novel methods of teaching children, one of which is the use of augmented reality (AR). Teachers may present students with creative methods to study by using the Pictorial Cube. This program helps to expand learning beyond the boundaries of traditional teaching by allowing pupils to interact with virtual things. This boosts their involvement, intellectual curiosity, and academic accomplishment in the classroom.

4.4 The system implementation strategies and procedure

The application operates on scanning the patterns and producing a virtual image, for this purpose AR comes into play and aids the process of scanning and converting the images into 3D objects. The problem that arises which must be dealt with is that the cube is moveable, and all sides of the cube must be detected in order to produce an image that is 3 Dimensional, because, the constant movement of the cube causes hindrance in production of an accurate image, for it is expected that on the rotation of the cube, the image must rotate efficiently as well. To resolve such an issue, the class of AR world tracking has been used. AR world tracking is a library from an ARKit used to

scan the real world and place virtual objects. Here, the first-class used is the AR image, and the second one is to use the AR tracking that helps track the cube patterns, create the world-tracking configuration and pass these reference images to the detection images properly. In addition, we have used the run (_: options:) method to run the session with the configuration. This process highlights how the AR world tracking libraries convert the 2D images into 3D images.

In addition to the following setup, the objects need to be placed into a rotational form so that it may become easy to rotate and observe the image from every side. This process helps shift the application to the right direction and makes sure that the application can scan the objects of the real world and save them into the core database. After saving them, whenever the object is required to be presented this application helps to show the image in the form of an AR 3D image, that is rotatable. This study's approach could be very beneficial to children's learning because the AR images are rotatable, and the students can learn about them from each side in an engaging way as shown in Fig 4.

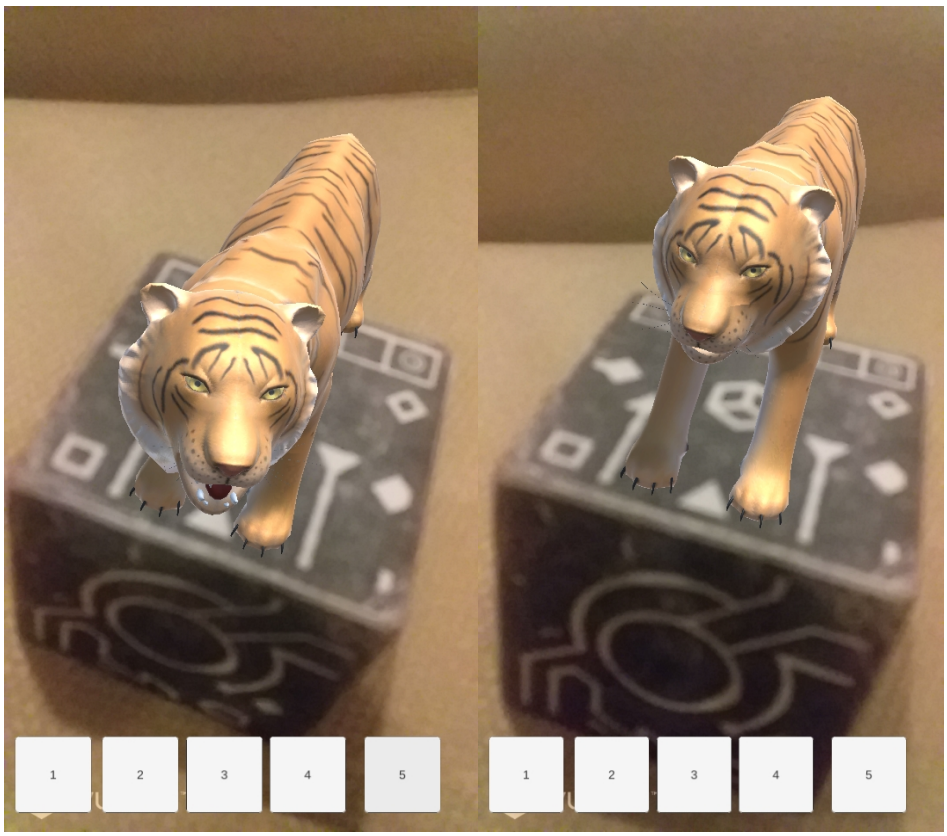

Fig. 5. The 3D view of a chosen object is visualized through the Pictorial Cube application.

While implementing the desired objective of the application, several new concepts arise that need to be produced. Alongside the above mentioned requirement, it has also been found that there is a

need to create a virtual cube over the real cube. This concept includes placing the 3D object in the virtual object, bringing forward an observation that when the real cube has been moved the virtual cube also moves, because it mirrors the image present on the database, therefore, the 3D object inside the cube also moves automatically. The first step that is to be taken involves making the cube and specifying each side with a different color in order to address it. The sides that are determined include left, right, up, down, front and back. After the cube has been made, the next step to be followed is to place the image texture on each side. The real object is then added in the front area of the cube scan, the problem that arises here is that the virtual object is not added in the same area and whenever the mobile phone moves in a backward direction it becomes easy to view the virtual object. Which indicates that each side of the cube has been provided with the same side of the object, for giving a better view of the application.

Challenges are confronted while dealing with the 3D object on the real cube patterns due to the cube having many patterns, in such a situation understanding all the patterns is not entirely possible. This minor setback occurs because of AR image tracking and AR World tracking simultaneously, so that it becomes possible to resolve any kind of problem related to scanning and saving the Cube pattern. Still, instead of making the problem go away, it increases it. Hence, AR image tracking is only involved. Furthermore, all of the cube patterns are used and scanned for testing purposes to ensure that the right direction can save the cube patterns. However, the major problem is that the Cube is in 2D, showing only one side. The need is to use the 3D objects because the problem will only be resolved if the Cube is placed in 3D form and perceived in that manner. To resolve this problem, the 3D object is placed on the Cube, yet the problem persists; the problem exists not inside the Cube, rather it is on the Cube placement, which suggests that the Cube's scanning is the point at which the problem keeps recurring. There are different places and sides from which the object can be placed or moved in the exact size. This approach could be explored or considered to improve the implementation of the AR application better.

5 Research Methodology

5.1 Initial evaluation of the Pictorial Cube AR application

This section presents the methods followed in conducting initial testing of the Pictorial Cube, an AR application on children. The children are handed the cube and briefly explained about its use, they are brought together to observe the Cube and are also handed the Cube individually to experience it on a personal level. Keeping in view the DSR method of research, an objective was well-defined before experimentation and well-crafted questions were created so that the predetermined objective could be understood. A total of five children participated in the Pictorial Cube testing, ranging from the age of 8 to 12. The children all study in a private sector school and are not unfamiliar with the use of technology in the classroom. However, their exposure to AR is for the first time. Initial responses of the children were recorded and their opinions were later assessed during the interview.

Fig. 6 Children interacting with the Pictorial Cube

5.2 Research design and ethical consideration

The initial testing procedure was focused on children, and their perception regarding the Pictorial Cube was recorded and later analyzed. The study focuses primarily on children's experiences and how one can incorporate an AR technology in class in order to improvise the educational standard. Students were interrogated about their experience with the cube, they were asked to narrate their opinion regarding the innovative learning methods and the use of a peculiar technological tool during their teaching session. Five children, between the ages of 8-12 were randomly selected and handed the Pictorial Cube to explore. When the children went through the application they were later questioned in order to understand their perception better. The interviews were recorded using a smartphone recorder function for further analysis. The interview involves the participation of children and highlights their personal experiences, therefore the research is qualitative in nature. Qualitative interview questions have been used to collect the data to evaluate educational intervention (Mursic, 2020).

Fig. 7. Children making use of the Pictorial Cube in real-life context.

The qualitative interview method makes room for an answer that is based more on experience rather than numerical figures, it gives space to a better understanding of human experience and allows the research to obtain answers to specific research questions. In this study, the main research questions are focused on investigating how to develop an educational tool which would facilitate children's learning of certain objects while motivating them to learn. For adding more value to the research and increasing its credibility to some extent, two teachers have been involved in the research who are directly related to early childhood education. The purpose of such an involvement arises from the need of having an intellectual contribution so that the teachers may provide their take on the use of AR in the class and share their ideas as well as valued experiences.

The use of a qualitative method was put into practice in order to obtain the participant's opinions and thoughts regarding applying an AR tool to facilitate learning different objects in 3D form. The focus group's purpose was to present an augmented reality application to understand teacher's thoughts regarding the application and explore their views in a social context (Johnstone¸ 2017).

Fig. 8. Children making use of the Pictorial Cube in real-life context.

Before participation, a consent form was handed to the children's parents and the teachers to obtain permission on behalf of the children. In accordance with the ethical standards of research, the

participants were given full authority on how they chose to be a part of the research, which involved voluntary contribution that could be taken back at any point during the research.

5.3 Participants

The research was carried out with five children between the ages of 8-12 and 2 teachers. The children include three girls and two boys, meanwhile both the teachers are female. All of the children study in a Pakistani school, and despite different origins speak Urdu at school and study under the same general curriculum.

Although learning from private schools, the traditional form of teaching is prevalent in Pakistan, the use of technology in the classroom is an entirely new concept and AR as a device for better understanding is not a part of any school system in Pakistan. Therefore, the results obtained will pave a way towards a better understanding of technology and promote its use in the classrooms to aid teaching and learning. Very few schools make use of tablets and projectors to facilitate the learning process. Thus, the use of AR during teaching is an innovative and economical concept that could be applied.

5.4 Data collection and analysis

The interview session involved five participants. The opening questions were of a general nature, simply consisting of questions to learn more about participant background and their motivation towards augmented reality. The questions that followed were more centered on the research and its objectives. Finally, the closing questions gave priority to the participants' opinions and further information like suggestions, activities, or materials to improve the tool's design and implementation. Furthermore, the future of Augmented Reality implementation for educational purposes in the classrooms was explored. The responses were recorded via a smart phone recorder. Every participant downloaded the Pictorial Cube application and used it to learn about specific animate and inanimate objects. With the provision of several animal pictures, the participants were asked to share their thoughts on how the application can be used in the classroom. They were asked to list several animals that could be integrated with augmented reality applications.

The results were later recorded for observation and at the moment record of information was also written down. This helped in further assessing and analyzing the information that was collected.

6 Results and Discussion

6.1 Interview Results

In this section, we present the results obtained from the participants through qualitative interviews. The findings obtained from the interview relate to the research questions discussed in this section. The discussion aims to elaborate the research so that it may become simpler to comprehend.

Purposeful questions were asked from the participants, the children shared their experiences regarding the Pictorial Cube and answered the questions that were formulated; the questions were as follows:

1. Did the Cube help to clarify concepts that were normally difficult to grasp?
2. Should the Cube be incorporated into classroom teaching and learning?
3. Augmented reality being a new concept is exciting to you or a challenge?
4. Was the application easy for you to use, and will you want to use it again?
5. Is there a need for this kind of application during teaching?
6. Did you have a different learning experience than you usually have?
7. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?
8. Can you recall all the objects that were presented to you through the cube?

It is to be noted that all the participants are Pakistani and are learning in a Pakistani-based school system, which means that the Cube is a rare encounter they had with technology in the classroom. Pakistani classrooms operate on a traditional teaching methodology; the use of technology such as laptops, tablets, or projectors in a classroom is significantly less, especially in early education. Therefore, the children's exposure to AR through a cube is an entirely new concept they have not encountered before.

Three major themes were identified that revolved around the main objective of the research: (1) Participants experience with the cube (2) Incorporation of the Cube in classroom teaching, and (3) The effect of the cube on children's learning. The interview questions are centered on these themes.

6.1.1 *Theme 1: Participants experience with the cube*

The participants' found the Cube to be an efficient tool that helped clarify their concepts by providing real-life representation. The participants showed excitement towards the portrayal of different animals and inanimate objects on the Cube. When questioned about whether they would prefer the use of the Cube in the classroom, they showed a liking for the Cube rather than the traditional drawing method on the board. The Cubes usability was tested by asking the children of their experience, was it a challenge or an effortless activity. Participant 5, age 8, found the Cube to be a little confusing for it was his first experience with virtual reality images. He had difficulty adjusting to the concept of AR and the Cube. The remaining participants found the Cube easy to use and were too excited to turn each side. The perceived ease of use of an application is important in supporting the acceptance of an application or system within the user's community or age group (Oyelere, S. S, 2019).Therefore, it can be deduced that the Cube and its application are user-friendly, although further evaluation is required to concretize these findings. Two questions were formulated to address this theme. They are,

1. Augmented reality being a new concept is exciting to you or a challenge?
2. Was the application easy for you to use, and will you want to use it again?

The responses are as follows,

Participant 1

1. Augmented reality being a new concept is exciting to you or a challenge?

"I find this to be very interesting, cool, and it made me really happy to see the animals on the cube making movements."

2. Was the application easy for you to use, and will you want to use it again?

"At first I didn't understand what is AR, but I know Virtual Reality and so I understood. Once I was guided, the rest was easy."

Participant 2

1. Augmented reality being a new concept is exciting to you or a challenge?

"I never knew what AR was until today. But I love the cube and the idea of seeing objects as if they're in my hand, it was very extraordinary."

2. Was the application easy for you to use, and will you want to use it again?

"I would definitely want to try it again."

Participant 3

1. Augmented reality being a new concept is exciting to you or a challenge?

"There was no challenge. I am familiar with Virtual Reality games and so I understood how to use it. I saw this as a kid of game as well."

2. Was the application easy for you to use, and will you want to use it again?

"It was easy and I want to try it again."

Participant 4

1. Augmented reality being a new concept is exciting to you or a challenge?

"I was very excited when I found out I can see animals and things on the palm of my hand. There was also movements, like, the tiger was roaring and the elephant was dancing."

2. Was the application easy for you to use, and will you want to use it again?

"I found it to be very simple, all I had to do was see through the app and select options of what I want to see."

Participant 5

1. Augmented reality being a new concept is exciting to you or a challenge?

"I didn't understand what it was at first, then slowly I got it. After that I liked it."

2. Was the application easy for you to use, and will you want to use it again?

"I want to use it again."

6.1.2 *Theme 2: Incorporation of the Cube in classroom teaching*

The participants were questioned regarding the Cube's necessity in the classroom, to which they gave a positive feedback and showed interest in the Cube. The participants found the use of the Cube to be an exciting experience that they look forward to having in their school, and not only did the cube help provide real-life images, it also made learning enjoyable. The following questions were formulated to address this theme,

1. Did the Cube help to clarify concepts that were normally difficult to grasp?
2. Should the Cube be incorporated into classroom teaching and learning?
3. Is there a need for this kind of application during teaching?

Participant 1

1. Did the Cube help to clarify concepts that were normally difficult to grasp?

"The Cube was fun to use, I feel as if I can still see the images in my head. It helped me to learn about new objects, seeing the virtual images actually felt like they were real."

2. Should the Cube be incorporated into classroom teaching and learning?

"I think that would be a very good experience."

3. Is there a need for this kind of application during teaching?

"Yes… I would love being taught through the cube."

Participant 2

1. Did the Cube help to clarify concepts that were normally difficult to grasp?

"Yes, it felt like a new experience, something out of the box… and I like the idea of how it taught me through visual images, I learned a lot and want to learn more through the cube."

2. Should the Cube be incorporated into classroom teaching and learning?

"I think that would be great, I would love to study with the cube alongside my friends."

3. Is there a need for this kind of application during teaching?

"Yes, it would be better if it's used."

Participant 3

1. Did the Cube help to clarify concepts that were normally difficult to grasp?

"The difficulty usually occurred in imagining a certain object, the cube gave a direct reference and that has made it easier to learn."

2. Should the Cube be incorporated into classroom teaching and learning?

"Yes, that would be cool … imagine using it with your friends."

3. Is there a need for this kind of application during teaching?

"After what I've learned, I believe that yes, it should be used to teach."

Participant 4

1. Did the Cube help to clarify concepts that were normally difficult to grasp?

"In one way, it has provided more clarity and made it easier to understand. So, I agree that it made difficult concepts easier."

2. Should the Cube be incorporated into classroom teaching and learning?

"Yes, it's different."

3. Is there a need for this kind of application during teaching?

"Yes, it should be included."

Participant 5

1. Did the Cube help to clarify concepts that were normally difficult to grasp?

"I saw different animals that I haven't seen in real life, I also saw a boat from up-close, I haven't seen a real boat yet and the cube showed it to me."

2. Should the Cube be incorporated into classroom teaching and learning?

"Yes, I would also like for my friends to see those animals."

3. Is there a need for this kind of application during teaching?

"Yes… because it makes me want to see more animals."

6.1.3 *Theme 3: Effect of Cube on learning*

At such a young age the ability to retain information is short lived of children, therefore, the question "Can you recall all the objects that were presented to you through the cube?" was asked to gain an insight into the influence of the Pictorial Cube on the retention of information. The children were asked whether they can recall all the objects that were presented on the Cube, four of the children remembered all the objects and the remaining child, 8 years of age, recalled three out of five. Therefore, it can be concluded that the children found the Cube to be helpful while teaching, for it, gave them a visual image that they could refer to and remember even if they never saw the animal in real life. The use of the Pictorial Cube helped the children to remember all the objects they came across, for it presented these objects in an interesting manner, this also implies that the cube managed to attract all the attention of the children, increasing their focus and hence adding to their learning. Thus, based on the learners' responses, it suggests that the Cube should

be incorporated in classroom teaching. The following questions were formulated to address this theme,

1. Did you have a different learning experience than you usually have?
2. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?
3. Can you recall all the objects that were presented to you through the cube?

Participant 1

1. Did you have a different learning experience than you usually have?

"Usually, no such device that is ever used in the classroom, infact no technology is used at all. The cube is an interesting device that made me visualize concepts and see what is being taught before my eyes."

2. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?

"The cube is better."

3. Can you recall all the objects that were presented to you through the cube?

"Airplane, elephant, boat, tiger, helicopter."

Participant 2

1. Did you have a different learning experience than you usually have?

"Usually, I lose interest by the end of the day, some subjects that I don't like I do not pay attention to them. By using the cube, I have become interested to know more about the options I have."

2. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?

"Hundred percent the cube."

3. Can you recall all the objects that were presented to you through the cube?

"Um ... Elephant, tiger, boat, airplane, helicopter."

Participant 3

1. Did you have a different learning experience than you usually have?

"Normally the teacher just explains and leaves, the cube makes studying more engaging and makes it easier to remember what is taught. So, it is a better experience."

2. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?

"The cube."

3. Can you recall all the objects that were presented to you through the cube?

"Elephant, airplane, helicopter, tiger, boat."

Participant 4

1. Did you have a different learning experience than you usually have?

"I found learning through the cube to be interesting, the cube was a new experience, a more engaging experience, a more memorable experience."

2. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?

"The cube is easier."

3. Can you recall all the objects that were presented to you through the cube?

"Elephant, tiger, boat, airplane, helicopter."

Participant 5

1. Did you have a different learning experience than you usually have?

"Usually, the teacher asks us to draw a tiger, or shows a picture … the cube showed me a real looking tiger."

2. Is it easier to understand through the Cube or through hand drawn images and teacher's explanation?

"The cube is better, it shows things in a more real way."

3. Can you recall all the objects that were presented to you through the cube?

"Helicopter, tiger, elephant."

The themes that reflect upon the objectives of the research justify through the interview that the Pictorial Cube is a fascinating technology that should be incorporated in teaching. These qualitative interviews do not entirely stamp a final label upon the necessity of AR in the classroom, a larger sample size would add even more credibility to the outcome of the interview.

6.2 Research Questions and Results

RQ1. How effective is the use of Pictorial Cube AR application as physical representation of learning objects?

The participants' responses indicate the effectiveness of the Cube for educating students; their inclination towards the Cube suggests that the use of augmented reality is an effective method for the portrayal of learning objects. Both the participants involved, and the teachers believe that learning can become quick and innovative through the physical representation of objects. Through physical representation, participants were more interested, interactive, and excited about the subject. According to the participants, whenever a concept is visually presented before them in class, it allows them to understand better. This study is a reflection of how exposure to technology in class enhances the learning process. The findings of this study state that technology engages children bringing into play their creative and intellectual abilities. Developing personal characteristics, intellectual characteristics, creativity, and socialism, facilitating students to be active and have critical participation (Ibáñez¸2018). The collusion of the findings suggest that the children found the experience with AR to be enjoyable, they claimed to have understood better and also showed an increased ability of remembrance of the stated information. Hence, It is concluded that Augmented Reality applications are the best way to showcase the physical representation of objects.

RQ2. Does the AR application **motivate students to learn about animate and inanimate objects?**

Augmented reality is an innovative technology that captured the interest as well as the attention of the participants' and invoked in them a peculiar curiosity towards technology itself. Generally, a student detests the very process of learning something difficult, they usually avoid it or pay no heed. These are usual problems that pose a threat to learning, retaining limited information and a

short attention span can act as a hurdle for teachers while teaching. Therefore, the use of such equipment, which makes learning easy and the students find interesting, is essential. For instance, showing interest in the Cube implies that the student is showing interest in learning itself. Thus, the Pictorial Cube helps to attract the students towards a particular object, which eventually aids in clarifying a specific concept. The research explores the possibilities that can be achieved by the implication of the Pictorial Cube, the findings suggest that students' motivation is increased through the use of the Cube, hence providing the students with the real-life representations of animals and objects as though they are in front of them. Participants also confirmed that keeping up with the digital world is more interesting than an image drawn before them. Children in today's world have grown up among technology. The use of 3D images is not an alien concept to them. Engaging the students should be the top priority of an institution, and the only way that can happen is to understand how the students prefer to be taught. Augmented reality helps support the learning process and motivates the students by improving their learning and understanding. Through the features of Augmented Reality, they understand more clearly than usual.

7 Conclusion

This research focused on implementing the Pictorial Cube, an AR-based application to facilitate learning among children in the classroom. The study also conducted initial testing of the application to gain feedback about children's experiences that used the Cube as a tool for observing different objects such as animals. The interviews are qualitative, and the research is based on the DSR method. A qualitative method is chosen in the interview so that the participants can express themselves freely and be assessed in the right direction. The answers received from the participants helped to conclude the study in a satisfying manner, the results indicated that the Pictorial Cube improves learning and is a user-friendly application that contributes to education in the K-levels. Positive responses from the participants suggest that the Pictorial Cube is a practical and an important tool that could be used to improve the quality of education.

The independent qualitative analysis and interview among the students regarding the Pictorial Cube supports the idea that the Pictorial Cube is an interesting technology piece. The attitude towards its interference in the classroom is encouraging. However, due to certain external factors such as the COVID-19 pandemic, including more participants for the application's initial testing

was difficult, the closure of educational institutes is another factor that contributed to the small number of participants. Consequently, this study may require an in-depth analysis with more sample participants to gain further insights.

In general, this study has shown that through the Pictorial Cube educators can improve their students' learning outcomes, by using a tool that would increase their engagement and interactivity. Augmented Reality in education promotes learning ability, including problem-solving, collaboration, and creative learning, enabling the students to equip themselves with the necessary skills required for a better future. AR image and ARKit have been used for offering unique affordances and virtual worlds. Such ways have been used to provide a new direction to the image visualization by making an application that helps the students set upon new learning paths.

7.1 Limitations and Future work

Certain limitations exist in every research in one way or the other. In the case of this study, keeping in view the ongoing global situation, the sample size was kept small, the participants were not more in number. The limited sample size occurred due to the pandemic, which affected many students' participation. Nonetheless, future research should be carried out on a large scale to attain a more valid conclusion. Moreover, other than the sample size, the children's age group was limited, the experimentation did not take into account children older than 12 years of age. The Pictorial Cubes use was limited to that of a classroom and the educational sector, it only served one purpose, however, if certain features are added to the Cube, it would prove to be very useful in various diverse user groups and fields. It can become helpful in medicine, history, space, and education. Thus, future research shall explore the many ways Pictorial Cube can be used in different areas of study and different fields of work.

References

Agbo, F. J., Sanusi, I. T., Oyelere, S. S., & Suhonen, J. (2021). Application of Virtual Reality in Computer Science Education: A Systemic Review Based on Bibliometric and Content Analysis Methods. *Education Sciences*, *11*(3), 142.

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Adewumi, S. (2019, November). A systematic review of computational thinking approach for programming education in higher education institutions. In *Proceedings of the 19th Koli Calling International Conference on Computing Education Research* (pp. 1-10).

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2019). Identifying potential design features of a smart learning environment for programming education in Nigeria. *International Journal of Learning Technology*, *14*(4), 331-354.

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2021). Scientific production and thematic breakthroughs in smart learning environments: a bibliometric analysis. *Smart Learning Environments*, *8*(1), 1-25.

Agbo, F. J., & Oyelere, S. S. (2019, July). Smart mobile learning environment for programming education in Nigeria: adaptivity and context-aware features. In *Intelligent Computing-Proceedings of the Computing Conference* (pp. 1061-1077). Springer, Cham.

Arnhem, J. P. J. V. (2018). Mobile Apps and Gear for Libraries: Merge Cube's Handiness with Holograms Makes it a Good Place to Start with Augmented Reality. *The Charleston Advisor*, *20*(1), 56-58.

Ati, M., Kabir, K., Abdullahi, H., & Ahmed, M. (2018, April). Augmented reality enhanced computer aided learning for young children. In *2018 IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE)* (pp. 129-133). IEEE.

Azasoo, J. Q., & Boateng, K. O. (2015, June). A retrofit design science methodology for smart metering design in developing countries. In *2015 15th International Conference on Computational Science and Its Applications* (pp. 1-7). IEEE.

Baskerville, R. L., Kaul, M., & Storey, V. C. (2015). Genres of Inquiry in Design-Science Research. *Mis Quarterly*, *39*(3), 541-564.

Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using Augmented Reality in Education from 2011 to 2016. *Innovations in smart learning*, 13-18.

Duarte, M. L., Santos, L. R., Júnior, J. G., & Peccin, M. S. (2020). Learning anatomy by virtual reality and augmented reality. A scope review. *Morphologie*.

Boboc, R. G., Chiriac, R. L., & Antonya, C. (2021). How Augmented Reality Could Improve the Student's Attraction to Learn Mechanisms. *Electronics*, *10*(2), 175.

Hendracipta, N., Rafianti, I., Pujiastuti, H., & Haryadi, R. (2021, February). The use of augmented reality to improve mathematics conceptual understanding of pre-service elementary education teachers. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012018). IOP Publishing.

Horváth, I. (2007). Comparison of three methodological approaches of design research. In *DS 42: Proceedings of ICED 2007, the 16th International Conference on Engineering Design, Paris, France, 28.-31.07. 2007* (pp. 361-362).

Howells, K. (2020). Continuing to provide the education in physical education-experiences of the Physical Education Teacher Education Network. *Physical Education Matters*, 89-93.

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, *123*, 109-123.

Iivari, J., & Venable, J. R. (2009). Action research and design science research-Seemingly similar but decisively dissimilar.

Jalaluddin, I., Ismail, L., & Darmi, R. (2020). Developing Vocabulary Knowledge among Low Achievers: Mobile Augmented Reality (MAR) Practicality. *International Journal of Information and Education Technology*, *10*(11).

Johnstone, M. L. (2017). Depth interviews and focus groups. In *Formative research in social marketing* (pp. 67-87). Springer, Singapore.

Joseph, A. F., Sunday, O. S., Jarkko, S., & Markku, T. (2019, June). Smart learning environment for computing education: readiness for implementation in Nigeria. In *EdMedia+ Innovate Learning* (pp. 1382-1391). Association for the Advancement of Computing in Education (AACE).

Lebaz, S., Sorin, A. L., Rovira, K., & Picard, D. (2020). Widgets: A new set of parametrically defined 3D objects for use in haptic and visual categorization tasks. *European Review of Applied Psychology*, *70*(3), 100552.

Macariu, C., Iftene, A., & Gîfu, D. (2020). Learn Chemistry with Augmented Reality. *Procedia Computer Science*, *176*, 2133-2142.

McLeod, Saul. “Carl Rogers Humanistic Theory.” (2014). *Simply Psychology*. https://www.simplypsychology.org/carl-rogers.html

Miller, M. R., Jun, H., Herrera, F., Yu Villa, J., Welch, G., & Bailenson, J. N. (2019). Social interaction in augmented reality. *PloS one*, *14*(5), e0216290.

Mursic, S. (2020, June). " It’s all fun and games until…": The exploration of barriers to engagement in individual and collaborative learning with mobile augmented reality materials. In *EdMedia+ Innovate Learning* (pp. 530-539). Association for the Advancement of Computing in Education (AACE).

Ntuli, E. (2019, November). Augmented Reality in Early Learning: Experiences of K-3 Teachers with Merge Cubes. In *E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* (pp. 557-560). Association for the Advancement of Computing in Education (AACE).

Oranç, C., & Küntay, A. C. (2019). Learning from the real and the virtual worlds: Educational use of augmented reality in early childhood. *International Journal of Child-Computer Interaction*, *21*, 104-111.

Oyelere, S. S., Bouali, N., Kaliisa, R., Obaido, G., Yunusa, A. A., & Jimoh, E. R. (2020). Exploring the trends of educational virtual reality games: a systematic review of empirical studies. *Smart Learning Environments*, *7*(1), 1-22.

Oyelere, S. S., Agbo, F. J., Yunusa, A. A., Sanusi, I. T., & Sunday, K. (2019). Impact of puzzlebased learning in computer science education: the case of MobileEdu. In *18th IEEE International Conference on Advanced Learning Technology (ICALT), Maceio-AL, Brazil*.

Oyelere, S. S., Suhonen, J., Wajiga, G. M., & Sutinen, E. (2018). Design, development, and evaluation of a mobile learning application for computing education. *Education and Information Technologies*, *23*(1), 467-495.

Oyelere, S. S., Suhonen, J., & Laine, T. H. (2017, November). Integrating parson's programming puzzles into a game-based mobile learning application. In *Proceedings of the 17th Koli Calling International Conference on Computing Education Research* (pp. 158-162).

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems*, *24*(3), 45-77.

Philit, S., Lacaze, S., & Pauget, F. (2019). Innovative automatic fault detection using a volume 3D scanning method. In *SEG Technical Program Expanded Abstracts 2019* (pp. 1923-1927). Society of Exploration Geophysicists.

Pochtoviuk, S., Vakaliuk, T., & Pikilnyak, A. (2020). Possibilities of application of augmented reality in different branches of education. *Available at SSRN 3719845*.

Pombo, L., & Marques, M. M. (2020). The potential educational value of mobile augmented reality games: The case of EduPARK app. *Education Sciences*, *10*(10), 287.

Reubens, R. R. R. (2016). To Craft, By Design, for Sustainability: Towards holistic sustainability design for developing-country enterprises.

Safar, A. H., Al-Jafar, A. A., & Al-Yousefi, Z. H. (2016). The effectiveness of using augmented reality apps in teaching the English alphabet to kindergarten children: A case study in the State of Kuwait. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(2), 417-440.

Sotelo-Castro, B., & Becerra, D. I. (2020, September). Human Body AR: A Mobile Application for Teaching Anatomy for Elementary Students Using Augmented Reality. In *Iberoamerican Workshop on Human-Computer Interaction* (pp. 146-154). Springer, Cham.

Suleman, Q., Hussain, I., & Akhtar, Z. (2012). Role of Educational Technology in Public and Private Institutes at Secondary School Level in District Karak (Khyber Pukhtunkhwa) Pakistan. *International Journal of Learning and Development*, *2*(5), 39-56.

Sural, I. (2018). Augmented Reality Experience: Initial Perceptions of Higher Education Students. *International Journal of Instruction*, *11*(4), 565-576.

Syahidi, A. A., Tolle, H., Supianto, A. A., & Arai, K. (2019, April). AR-Child: Analysis, Evaluation, and Effect of Using Augmented Reality as a Learning Media for Preschool Children. In *2019 5th International Conference on Computing Engineering and Design (ICCED)* (pp. 1-6). IEEE.

Van Aken, J. E. 2004. Management Research Based on the Paradigm of the Design Sciences: The Quest for Field-Tested and Grounded Technological Rules: Paradigm of the Design Sciences. *Journal of Management Studies*, 41 (2), pp. 219–246.

Venable, J., & Baskerville, R. (2012). Eating our own cooking: Toward a more rigorous design science of research methods. *Electronic Journal of Business Research Methods*, *10*(2).

Waqar, Y., & Bokhari, T. B. (2017). Technology Enters the Classroom: An Evaluation of Educational Technology Initiatives in Punjab. *Pakistan Journal of History and Culture*, *38*(1).

Wei, X., Weng, D., Liu, Y., & Wang, Y. (2015). Teaching based on augmented reality for a technical creative design course. *Computers & Education*, *81*, 221-234.

Yadav, A. K., & Oyelere, S. S. (2021). Contextualized mobile game-based learning application for computing education. *Education and Information Technologies*, *26*(3), 2539-2562.

Zahara, M., Abdurrahman, A., Herlina, K., Widyanti, R., & Agustiana, L. (2021, February). Teachers' perceptions of 3D technology-integrated student worksheet on magnetic field material: A preliminary research on augmented reality in STEM learning. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012083). IOP Publishing.