ABSTRACT

Early childhood learning is an important concern for the concept building of children. Students have been taught with traditional methods from the beginning. However, these methods lack kids’ attention. Application of Augmented Reality (AR) in a traditional way of teaching can help students in better engagement and better learning. In this research, an ABCD-AR mobile based application is designed to overcome the flaws in the traditional education system. While designing AR mobile applications, certain guidelines need to be considered that cause problems for kids in their learning. These may include but are not limited to small screen size and irregularity. Considering these problems, this study proposes 23 usability principles for AR based learning applications for kids. These identified usability principles are validated by human experts. Furthermore, experiments are carried out to evaluate the application in terms of efficiency, effectiveness, learn-ability, user satisfaction & engagement. The results implies that the developed game-based application is highly effective and efficient because the mean of marks obtained by students before using ABCD-AR application is lower (M=4.97, SD=1.650) than the marks obtained after using ABCD-AR application (M=7.97, SD=1.608). Similarly, results indicate that mean of time taken to perform tests without using ABCD-AR application (M=7.97, SD=1.650) is higher as compared to with using it (M=4.37, SD=1.608). Majority of the students were entertained by playing the game while learning, and felt motivated to continue based on the game’s scenario due to the variety of activities included. Teachers and parents involved in these experiments have shown satisfaction towards the use of ABCD-AR application in learning process of preschool kids.

INDEX TERMS

Augmented reality, usability principles, mobile application, kid’s learning.

I. INTRODUCTION

Application of augmented reality in education is majorly effective in enhancing the learning capabilities of early childhood kids. It keeps student attentive as it makes the overall learning process more interactive, interesting, and pleasant. Moreover, it plays a vital role in the future progression of kids. Child-care centres and pre schools can enhance the child’s learning, especially if the quality of education is high [1]. Research shows early learning has lasting effects on development of kids, but is rarely reversible. [2], [3] During early childhood, children have a remarkable ability to absorb information [4]. Currently various ways are being used for kids to learn and get trained regarding specific skills and information they need [2]. The conventional modes include computers, classroom lectures...
with books and other devices. [5]. In today’s rapid changing environment there is need to shift from traditional way of learning to IT equipped modes of learning [6]. Thus, Augmented Reality has grabbed the attention of educators and researchers because it allows virtual information to be shown in real time onto a real-world environment [7], [8]. As per research, usage of AR technology in educational applications would play an important part in improvement of kid’s understanding and perception of information [9], [10]. It also enhances interpret ability and problem-solving skills [11]. Adding AR to traditional learning can help get kids more interested in learning, which is important because students’ motivation and interest are dropping because traditional learning methods aren’t very interesting [12]. Even though AR has many advantages in academic sector, there are minimal studies that explore use of AR in learning alphabets and words recognition [12]. Developing an AR learning environment is challenging especially for kids so, when designing learning applications for children, age and interaction techniques are the main considerations. [8], [13]. Therefore, it is necessary to define and enumerate appropriate usability principles for developing augmented reality-based educational games for children. [14], [15]. The aim of this study is to propose and validate usability principles for AR based gaming application and then create the ABCD-AR application based on identified usability principles. Moreover, ABCD-AR game-based application is evaluated in terms of usability principles i.e., effectiveness, efficiency, learn-ability, user satisfaction, and engagement. Kids are interested in colors, images, gifts, surprises, and animations, and ABCD-AR application system provide all of these and captures the interest of kids which results in effective learning [16]. This application acts as a medium between teachers and parents for the better learning of kids. It is about alphabets learning and coloring with a lot of excitement and fun. Through ABCD AR game, kids can learn pronunciation of alphabets, writing styles of alphabets, and can learn much more about alphabets through informative and engaging activity sheets. Markers of our ABCD-AR application are according to kids alphabet book contents.

Following research questions are answered in this study:

RQ1: Can application of AR improve students’ learning performance i.e. effectiveness and efficiency as compared with traditional teaching materials?

RQ2: Can AR satisfy parents and teachers in teaching process as compared to conventional teaching?

This study shows impact of AR based gaming application on effective and efficient learning process of preschool kid’s as compared to traditional learning methods of learning. This study involves the identification and verification of usability principles. It also includes development of an AR-based game using verified usability principles. Moreover, this study measures the effectiveness and efficiency of preschool students in their learning process. Furthermore, it also measures the response of teachers and parents towards the AR based ABCD game. This research paper is structured in five sections. Section 2 provides a brief overview of work that has already been implemented in the augmented reality and education sector and defines the problem statement. Section 3 elaborates on the methodology used to identify usability principles and develop the ABCD-AR application and its evaluation metrics. Section 4 discusses the impact of ABCD-AR application on kid’s knowledge and shows the results of measurement of effectiveness, efficiency, learn-ability, user satisfaction and engagement. Section 5 discusses the findings. Finally, the last section concludes this research.

II. LITERATURE REVIEW

A. USE OF MOBILE AR APPLICATIONS FOR EARLY CHILDHOOD LEARNING

Augmented Reality is latest trend in education sector as it makes the overall learning process more interactive, interesting, and pleasant [17]. For example, California is using an AR-based technology called ABC3D to improve print literacy knowledge for preschoolers. [18]. One more application of augmented reality (AR) was demonstrated using graphics, audio, and real-world scenarios. Students have the opportunity to become familiar with the general vocabulary of each letter and to discuss the influence that this has on their motivations for learning [19]. AR applications in general, like AR flashcards, can also help kids in kindergarten learn new words. The people who used the augmented reality flashcards were motivated to learn [20]. Magic book is earliest and well-known augmented reality-based AR application [21]. The purpose of this game is to generate 3D scenes of book. Glasses are used for the interaction with the virtual environment as well as with real environment [22], [23]. A mobile application named as “Educational Magic Toy (EMT)” uses flashcards, match cards and puzzles to give knowledge to early childhood kids about shapes, numbers, vehicles, vegetables, animals, fruits etc. [21]. Quiver Vision is another AR based mobile application that has capability of changing virtual object’s colors based on marker color that are drawn by users [24].

B. USABILITY OF AR APPLICATIONS

Spatial cognition, motor skills and attention are needed for the interaction with AR based applications [25]. As compared to conventional and traditional applications, AR applications requires more conceptualization skills to analyze virtual scenarios [26]. Usability principles for AR applications needs to be proposed [27]. Currently there is a need for evaluation of usability of AR applications as the findings indicate limitations of research in usability principles and interface designing [28], [29].

Furmanski proposed fifteen usability principles for AR applications including design for easy recovery. Design for limited and split attention, enable frequent users to use shortcuts, personalization, reversal of actions, error handling prevention, design for “top-down” interaction, multi-modal interfaces, offer informative feedback, enjoyment, design
for reduce memory load, consistency, dynamic and multiple contexts, and design dialogues to yield closure [30]. He also focused on some issues encountered using during development of AR applications.

H.J Kim et al proposed usability principles based off of usability related literature [28]. Here, he discussed 25 usability principles that includes consistency, prevention, arrangement, user satisfaction, simplicity, screen size, user control, direct manipulation, accuracy, attractiveness, learnability, control-ability, feedback, durability, tolerance, effectiveness, error mitigation, match between real world and the system, error indication, and efficiency.

According to J. Nelson, the application would have more user satisfaction if its design is based on user understanding and tasks [31]. The author has also proposed ten usability principles that includes error recovery, error realization, recognition rather than recall, efficiency, error prevention, help documentation, consistency, flexibility, similarity between real world and system, freedom, user control, system status visibility, minimalist design. J. D. Gould and C. Lewis proposed early test, early focus on interactive design, users, users iterative design as usability principles and mentioned that any application developed on mentioned usability principles would have more usability [32].

C. GAME BASED LEARNING

Game based learning is gaining increasingly importance in education and knowledge building especially for kids [33], [34], [35]. Game based learning focuses on application of various game attributes in non-game based environment [36]. Kids are more attracted towards games as it keeps them engaged as compared to traditional learning methods [37]. According to a research, students are more attracted towards game-based learning approach [38].

Several research articles have proved the advantages of game-based learning [39], [40], [41], [42], [43], [44]. Gamification plays an important role to increase the motivation, involvement, and interest of students [45], [46], [47]. Since, gaming is involved, students use more time on it and thus learning outcome increases. This study shows that game-based learning models have many attributes that uphold interest in gaming activities. These attributes include scoring, visual aesthetics, achievement, motivation, collaboration (teamwork), story telling, rules, competition, problem solving, commitment, emotion, outcome (score), imagination, challenge, interaction, and includes purpose. [48], [49].

Game attributes also contribute towards the development of soft skills like collaboration, communication, creative thinking, etc. Game based learning effectively enhances the process of learning new things and memorizing new concepts [50].

Similarly, learning with educational games is even more impending in learning computer programming. For this purpose, a MMORPG based game named as CMX is being developed that helps the players to learn C programming while playing the game. The game involves hackers and crackers as two teams. Hackers protects the servers and crackers must pass different levels like seneis, iron seneis and gold seneis to reach the server. The seneis is the basic level in which player only learns the programming basic concepts. Iron seneis is more advanced as compared to seneis and it involves learning of syntax of programming language and flow of program through drag and drop features. Finally in gold seneis players write proper line of code to reach the server. The evaluation framework used for the evaluation of game includes pre tests and post tests conducted by 76 university students and then the results are compared. This application works effectively for university students. [52]

What distinguishes Augmented Reality applications from other apps based on interconnectivity, e-learning content, device handling, and so on? Do users (particularly younger kids) encounter screen size, loss of concentration, lack of consistency, functionality, and so forth when have interaction with mobile based augmented reality applications? Is there any specific design guideline that needs to be follow when creating a handheld Application? Are there enough quantitative and qualitative studies with a larger sample size that analyzes the usability of a handheld AR mobile application for kids’ future? This research aims to address the issues raised above such as ABCD game for kids to identify usability principles to create an ABCD game for kids based on usability principles that are identified and based on performance, reliability, and satisfaction, evaluate the ABCD game’s usability.

III. METHODOLOGY

This section presents the 03 phases involved in obtaining the desired research goal. It discusses procedure for selection of usability principles, development procedure of ABCD-AR application and discusses the strategy for the evaluation of ABCD AR game. Figure 1 shows the modules involved in this research work.

FIGURE 1. Research methodology to develop an ABCD-AR application.
TABLE 1. Selected experts for usability principles validation.

| Expert ID | Qualification | Area of Specialization | Meeting Date | Duration |
|-----------|---------------|-------------------------|--------------|----------|
| Expert-A  | PhD           | Usability metrics       | 05/Nov/2021  | 30 min   |
| Expert-B  | PhD           | Augmented reality       | 15/Oct/2021  | 25 min   |
| Expert-C  | PhD           | Human computer interaction | 18/Nov/2021 | 40 min   |
| Expert-D  | PhD           | School management       | 22/Oct/2021  | 25 min   |
| Expert-E  | PhD           | Usability and pre-school learning | 05/Nov/2021 | 25 min   |

A. MODULE-1: IDENTIFICATION

The aim of this research is to gather usability principles to develop an AR game that enhances the learn-ability of kindergarten students. From literature survey, a list of usability principles was collected [14], [28], [29], [51]. The validation of obtained usability principles was carried out through expert reviews, as it is one of the most important methods for the identification of drawbacks and shortcomings. Meetings with experts and reviews obtained from experts helped in removal of duplicate principles and helped in categorization of usability principles into different categories.

1) SELECTING EXPERTS FOR REVIEW OF USABILITY PRINCIPLES

Verification of usability metrics was conducted through experts’ opinions and feedback, for this purpose five experts from academia field were contacted through email and telephone call. Selected experts belong to core areas of this research i.e., Augmented Reality, Usability Metrics, and Human Computer Interaction. All experts are PhD holders in their respective fields and having experience of 4 years, 6 years, 7 years, 5 years, and 8 years respectively. After thorough discussion with experts regarding this research, they showed their interest in verification of usability principles through feedback and reviews. Among five experts four of them agreed on face-to-face meeting while one expert agreed on online session. Moreover, comments and suggestions were provided by experts related to proposed usability principles along with provided forms. Table 1 summarizes the expert’s qualification, area of specialization, meeting date with individuals and meeting duration.

The purpose of this paper is to propose and evaluate new usability principles for Game-based Learning Applications. The proposed usability principles can assess applications based on the functionalities and features functionalities and features it provides. As a result, this study was simplified to assess the Game-based Learning Application’s knowledge for kids.

2) SELECTION OF THE MOST APPROPRIATE USABILITY PRINCIPLES

Initially more than 50 usability principles were selected from literature, however based on experts review and suggestions 23 usability principles most related to ABCD-AR application are shortlisted. Experts advised to combine related metrics in one group and categorize them accordingly. Based on experts’ feedback and exploratory factor analysis as discussed by Tuli and Mantri in their study [28], usability principles related to ABCD-AR application are classified into four categories i.e. effectiveness, efficiency, learn-ability, and user satisfaction & engagement. Duplicated usability principles were removed and only the most relevant were selected. Figure 2 shows the final categorized usability principles.

FIGURE 2. Proposed usability principles.

B. MODULE-2: DEVELOPMENT

For the validation of proposed usability principles, an AR based learning application named “ABCD-AR application” is developed. Using this ABCD-AR application, kids may learn and visualize to learn in and understand in an effective way.

1) GAME AND MARKER DESIGN

Unity and Vuforia were used in the development of the ABCD-AR app. The education of the children is the central focus. The following are the educational benefits that can be gained from using the ABCD-AR app. 1) To help children learn more effectively, it associates the alphabet and phonics with a variety of topics, including foods, animals, and non-living things. 2) It can be used as a teaching tool for activities such as colouring, writing, and reading. 3) By utilising its many different modules, it enables teachers and parents to effectively supervise their students or kids. The ABCD-AR application provides a visual representation of audio and interactive augmented reality content in three dimensions. Children can interact with virtual content in six different degrees of freedom while they view virtual content, listen to different audio pronunciations, and interact with virtual content as they scan the markers. The creation of these entirely virtual contents takes place in accordance with the markers that have been specified. For instance, if a child scans a marker depicting an apple, a three-dimensional apple
will appear on the mobile screen, and an audio clip titled “A for Apple” will start playing. Ten points will be given out to each maker after they have successfully visualised their creation for a few seconds. Children can earn points by scanning all of the markers from A to Z, seeing and listening to their virtual content, and following the instructions shown in figure 3.

The ABCD-AR application includes a reading section, a speaking section, a writing section, a colouring section, and a quiz section. Each of these categories also has a corresponding set of subcategories. While the first level of each of the five categories is initially unlocked, the other levels are locked. When children have earned the maximum number of points in a level, they are able to unlock the subsequent sub-levels. It is also possible for a parent to submit a request to a teacher for a specific category level in order to unlock it. It is up to the teachers to decide whether to cooperate with the requests made by the parents. The “Quiz” category of markers follows the format of the corresponding worksheet in their design. Kids are able to visualise the information that they have written with the help of the mobile augmented reality application, and then they can take a screenshot of their worksheets. This screenshot is then sent to their instructor, who is able to evaluate the work that they have done. Children are awarded points based on the evaluations completed by their teachers. When the point total of a level reaches its maximum, the level that comes after it becomes available to play. Parents are able to access their child’s progress depending on the points awarded in various levels of any category, and teachers are able to view their students’ activity sheets as well as their progress. As a result, this ABCD-AR application makes it easier for parents and teachers to communicate with one another, which eventually helps the education of kids.

In Augmented Reality, markers are visual cues that show the virtual information. Markers can have different patterns such as black and white patterns or colorful designs. For ABCD-AR application, we focused on keeping markers simple yet colorful, so that kids can easily attract towards them. While designing markers both lower-case and upper-case alphabets are written and also the spelling of each word is written at the bottom.

To use Adobe Photoshop CC 2019, we created the AR markers. Figure 4 displays all known ABCD-AR application indicators. Content of markers is based on kid’s alphabet books used in schools for kindergarten students to learn the phonics. Different augmented reality markers are used across the game’s five modes (read, speak, write, colour, and quiz). The Speak category must have 26 alphabet AR markers, the Write section has three, as well as the colour, read, and quiz groups each have two.

2) IMPLEMENTATION OF ABCD-AR APPLICATION
In order to develop an ABCD-AR application, we relied on the following software and hardware: Unity Engine 2018.4.12f1, Vuforia SDK 8.5.8 (for augmented reality technology), Visual Studio 2017 (for back-end scripting), Microsoft SQL Server 2014 (for storing user information such as user type (parent or teacher), points, and screenshots), Adobe Photoshop CC 2019 (for marker development), Google Blocks, and Sketckfab for 3d modelling. After integrating the SQL server database with the WebAPI that was created in Visual Studio, we then integrate the WebAPI with the scripts that are used in Unity. As can be seen in Figure 5, these are then imported into the Unity engine, which is used to create the FINAL application. After finalising the coding and the creation of the scene, we will then save, build, and export the application before having to install the .apk file (which stands for “android application package”) on the mobile device. When a mobile application tends to focus the camera on augmented reality, the smartphone’s camera is activated, the pose is calculated, and a 3D model is augmented on the screen. Figure 5 explains the implementation of different apps for the design of ABCD-AR application.

C. MODULE-3: EVALUATION
This study focuses on the usability acceptance of an ABCD-AR application whether users accept it and what’s their attitude in terms of effectiveness, efficiency, learnability, user satisfaction and engagement? For this purpose, different experiments were conducted between pre-school children, their parents, and teachers of pre-schools located at Rawalpindi, Pakistan.
1) EXPERIMENTAL DESIGN FOR MEASURING THE EFFICIENCY, EFFECTIVENESS, AND LEARNABILITY OF ABCD-AR APPLICATION

Effectiveness is the accuracy and completeness with which user achieve their objectives. Similarly, efficiency is the minimum resources required to complete a task. To measure the efficiency and effectiveness same experimental process is followed. The experimental design is shown in (figure 6). Initially, before the deployment and training of ABCD-AR application, an initial test was conducted by students. The reason of initial test was to measure the time taken by students to solve a test before using ABCD-AR application. Furthermore, the current knowledge of students is also assessed using initial test.

2) EXPERIMENTAL DESIGN MEASURING USER SATISFACTION AND USER ENGAGEMENT OF ABCD-AR APPLICATION

A group of 30 children along with their parents and 10 teachers were involved in experiment. All participants were asked to freely play this game. Teachers and parents created their accounts. Parents downloaded markers and gave their mobile phones and markers to their children to play and learn alphabets, enjoy coloring, and have some fun. Each child interacts with markers, visualizes virtual content, and learns alphabets in an innovative way of learning. Teachers & parents checked the progress of their children. They observed that how much their children were attentive, engaged, and motivated throughout the activity.

In the end, all participants (parents, teachers, and children) were asked to fill up questionnaires. Questions are just in a 5-point likertscale with the options of strongly disagreeing, disagreeing, being neutral, agreeing, and strongly agreeing. Every participant must choose one option for each question. For children, the instructor read the question explain it to the children, and the participant answers according to which instructor selects the appropriate option. The questions included in questionnaire for students are mentioned below.

1) Like the game.
2) You learn Alphabets.
3) You want to play it again.
4) Game is not boring like books.
5) You are comfortable playing this game.

Ten questions were designed for both parents and teachers. These include:
1) Playing game (using this application) is a productive use of time.
2) Playing game helps kids to learn as compared to traditional learning.
3) Games encourage kids’ interaction as compares to traditional learning.
TABLE 2. Kids satisfaction questionnaire for abcd-ar application system.

| Questions                                                                 | Mean ± SD    |
|----------------------------------------------------------------------------|--------------|
| Q1. Like the game.                                                         | 4.93 ± 0.25  |
| Q2. You learn alphabets.                                                   | 4.6 ± 0.88   |
| Q3. You want to play it again.                                             | 4.93 ± 0.25  |
| Q4. Game is not boring like books.                                         | 4.83 ± 0.73  |
| Q5. You are comfortable playing this game.                                 | 4.77 ± 0.56  |
| 4) You recommend this application to other kids.                           |              |
| 5) The application helps you to teach kids.                                |              |
| 6) Marker size and marker content are appropriate for kids.                |              |
| 7) Playing game helps kids to memorize alphabets easily.                   |              |
| 8) Virtual Objects use in augmented reality play mode are appropriate for kids. |              |
| 9) Playing game improves kids’ grades.                                     |              |
| 10) Kids enjoy augmented reality game-based learning as compared to traditional book learning. | |

Finally, Mann Whitney test was conducted to evaluate the satisfaction level of parents and teachers for using the ABCD AR application in kids learning process.

IV. RESULTS

A. USER SATISFACTION AND USER ENGAGEMENT

This section presents the evaluation results that are derived from the questionnaire-based evaluation. As 30 children were involved in the activity, so we have 30 filled questionnaires from children, 30 questionnaires from parents, and 10 from teachers. (Below Table) shows kid’s satisfaction and engagement results. We analyzed these questionnaires and calculated mean and standard deviation according to a rating of each question. The results of mean shown in table 2 indicates that students are satisfied with game and ranks the game as highly engaging.

With the help of descriptive analysis table 3 shows the attitude evaluation of both parents and teachers. We analyse these questionnaires and calculate the standard deviation and mean for each question. We examined and compared the responses of parents and teachers who completed the same sort of questionnaires in order to determine which user type had a higher (more highly agreed answers) positive attitude ratio. There was no discernible difference between parents’ and instructors’ attitudes according to the Mann Whitney test except for questions four and five (p < 0.05). Even though it has been a significant difference for question four and five, the height means value (greater than 4.00) indicated both teachers & parents are satisfied with the ABCD AR game.

B. EFFECTIVENESS AND LEARN-ABILITY

Paired sample t test is implemented to check the effectiveness and learn-ability of ABCD-AR application. The mean of marks obtained by students in both initial test and sub-test were calculated and results were examined. Results shows significant difference in marks obtained by students as shown in table 4. The students’ marks after using the ABCD-AR application in addition to traditional learning (M = 7.97, SD = 1.650) were noticeably higher than their grades after using the traditional approach alone (M = 4.37, SD = 1.650). Results show that after the usage of ABCD AR application performance score was increased. The results of paired sample t test are shown in table 5. The null hypothesis of the paired-samples t-test assumes that the mean difference of both initial test samples and post test samples is equal to ‘0’. The initial and post test sample means differ by 3.6. The p value for the t-statistics is demonstrated to be less than the 5 percent level of significance. Therefore, it is possible to reject the null hypothesis that states the mean difference is zero. Since the average test scores after using ABCD-AR application is higher than average test scores before usage of the ABCD AR game, it can be determined that the ABCD-AR application very effective in improving children’s performance and learning ability.

C. EFFICIENCY

Efficiency of ABCD-AR application is also measured using the paired sample t test. Similar procedure that is followed to measure effectiveness is followed to measure the efficiency of ABCD-AR application. The average time required for
V. DISCUSSION AND CONCLUSION

Research Question 1: Can application of AR improve students’ learning performance i.e. effectiveness and efficiency as compared with traditional teaching?

To identify the impact of AR based game learning on kids the application is evaluated to determine the efficiency, effectiveness, user engagement and learn-ability of kids. The results have made it evident that application of technology or game-based applications in learning process of preschool kids is highly efficient when compared with traditional mode of learning. Through the use of AR based ABCD application preschool students remained motivated and attentive throughout the learning process. Paired Sample T test which is used to conduct the comparison of means of two measurements taken from same individual or related unit indicated that ABCD AR application is more efficient because the time required by youngsters to solve the test after using ABCD AR application alongside conventional learning was significantly less as already mentioned in results section. This indicates that ABCD AR application boosted the learning capabilities of students as the game provides the visual content in 3-dimensional way along with audios. Preschoolers can interact with virtual content with 6 degrees of freedom. Thus, playing the game while learning keeps them engaged. Similarly, as anticipated the performance of kids also increased that makes the application more effective to use in learning process of preschool kids. Kids who were involved in learning through ABCD AR application showed significant improvement in their marks it is because of the fact that the students were able to learn alphabets and their phonics related to fruits, animals and non-living objects. The game was divided into levels and each level contains the sub-level. It provides a competitive environment for students to learn and unlock all other levels of game by earning maximum marks in previous level. Also, the game includes practicing activities for kids related to reading, writing and colouring that contributed to the significant improvement in kids learning and their test’s scores.

Research Question 2: Can application of AR satisfy parents and teachers in teaching process as compared to conventional teaching? To answer this question the researchers had involved parents of 30 children including 10 teachers and performed Mann Whitney Test which ensures that parents and teachers are fully satisfied with the application of Augmented Reality in learning process. Because the height means value (more than 4.00) indicate that parents and teachers are highly satisfied with the AR based game. ABCD AR application provides the shared medium to both parents and teachers for monitoring the learning skills and academic progress of kids. Both parents and teachers can check the marks obtained by students in various tests. Thus, ABCD AR application provides better interaction between parents and teachers for learning of kids. This is the reason for parents and teachers being highly satisfied for using ABCD AR application.

Safar et al. [53] have performed man Whitney test in order to measure achievement level of kids using AR in learning alphabets. They included both a control group (conventional) and an experimental group (AR). Both groups showed a significant difference in their results between the control group (traditional) and the experimental group (AR) at the 0.05 level. Similarly, they have also performed Man Whitney test to calculate the interaction of kids with the lesson. Their results are also showed the advantage for the experimental group which is using AR in alphabet learning as compared to controlled group that is using traditional method. The experimental group had a mean of 27.57 and the control group had a mean of 15.43.

In conclusion, this research proposed and validated 23 usability principles for an AR game-based learning application for pre-school kids. Academic experts from the core field of our research were selected to validate the usability principles. Centered on identified usability principles, an ABCD-AR application was developed for learning purpose specifically for childhood learning. This application provides alphabets and their phonics about fruits, animals, and non-living objects. Furthermore, the ABCD-AR application is integrated with traditional mode of teaching to check its impact on learning of early age students. Reading,
writing, and colouring are all made easier to practise with the help of this application, which demonstrates itself to be the superior choice in this regard. Even though, traditional learning techniques in educational institutes cannot be removed by technologies, however, by combining an adequate traditional method with technology can empower children learning and can also help them to be more creative and sharper. Further research should be conducted to determine impact of psychological learning activities on academic performance of teachers and students using AR based applications as to whether it improves understanding of content, assessment performance.

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121394

VOLUME 10, 2022

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