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Efficacy of educational platforms in developing the skills of employing augmented reality in teaching mathematics

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Abstract

The aim of the current study is to reveal the effectiveness of a training program using an educational platform on developing the skills of employing augmented reality apps to enhance the teaching of mathematics among elementary school teachers. The experimental approach with a quasi-experimental design, a one-group pre-/post-test design, was used in this study. The study sample consisted of 36 elementary school mathematics teachers in Saudi Arabia, and an achievement test and an observation card were used as measurement tools. The study identified a statistically noteworthy distinction, with a significance level of 0.05, in the mean scores of the study group before and after the administration of the achievement test and the observation card, favoring the post-application results. The study suggested the importance of directing those in charge of developing training programs within the Ministry of Education to incorporate educational platforms as a key component of distance education methods.

Keywords: training program, educational platforms, augmented reality apps, teaching mathematics, elementary school teachers

INTRODUCTION

The ongoing advancement of information and communication technology has brought about substantial transformations in the educational landscape. Traditional face-to-face interactions in education are being supplanted by e-learning interactions. Conventional tools like whiteboards and printed materials are being substituted with a wide array of digital resources accessible through various electronic platforms. Consequently, educators in service are now expected not only to possess a comprehensive understanding of educational theories and their practical applications but also to possess the requisite technological skills for utilizing diverse e-learning tools and environments (Tschida et al., 2016). Ghavifekr and Rosdy (2015) underscore the considerable influence of teachers' technology usage on learners, as it liberates them from the constraints of limited curricula and resources. Electronic motivational activities serve to enhance their motivation to learn, engage their attention, and effectively integrate them into the educational process.

Augmented reality (AR) technology stands out as a technology that enables the integration of the real world with virtual elements, offering immediate assistance to learners and facilitating personalized learning experiences. One key benefit of AR technology is its capacity to deliver visual aids to learners, catering to various learning styles including kinesthetic and theoretical learning, ultimately enhancing authentic learning experiences (Matcha & Rambli, 2013). This technology is based on modifying reality by adding digital elements in order to improve the learner's perception. AR technology includes four main elements, which are:

(1) a camera to capture the target information,

(2) a marker of what is the target information,

(3) mobile phones to store and process information once the captured image is marked, and finally

(4) digital content, which will be displayed on the screen when the phone camera is able to track the

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Contribution to the literature

- It is important in this digital age for in-service teachers to have the skills to use AR in teaching mathematics.
- This study endeavors to make a meaningful contribution to the field of education by examining the effectiveness of a training program using an educational platform on developing the skills of employing AR apps to enhance the teaching of mathematics among elementary school teachers.
- This study provides evidence on the effectiveness of the educational platform in developing the skills of employing AR applications in teaching mathematics.

markers (Abd Majid et al., 2015; Abdullah et al., 2022; Cetin & Turkan, 2022).

Serio et al. (2013) explains that there are three main characteristics of AR technology:

(1) it combines real and virtual elements in the real environment,

(2) the alignment of virtual and real elements next to each other, and

(3) the interactive operation of real and virtual elements in real time.

AR technology offers various benefits, including its capacity to promote kinesthetic learning, facilitate the integration of diverse digital learning components to engage learners effectively, and enhance learner motivation (Anshori & Novianingsih, 2021; Diaz et al., 2015). Given the distinctive features, advantages, and educational efficacy associated with AR applications, it becomes crucial for in-service teachers to possess the requisite skills for utilizing these applications, especially in mathematics education, in light of their widespread adoption. Several studies (e.g., Angraini et al., 2023; Koparan et al., 2023; Korkmaz & Morali, 2022; Syafril et al., 2021) have confirmed that AR applications are effective tools in teaching and learning mathematics at various educational levels. Additionally, other studies (e.g., Ahmad & Junaini, 2020; Bulut & Ferri, 2023; Lai & Cheong, 2022; Pahmi et al., 2023) have underscored the importance of nurturing teachers' proficiency in the utilization of AR applications for teaching mathematics, considering them vital competencies that bolster the educational process.

Educational digital platforms (EDPs) are one of the latest and most popular educational technology products. These platforms have brought about a major change in how teachers and their students communicate and engage, and in the relationship between learners in terms of exchanging information. It has also become available to everyone to learn through it at any time, without any restriction or condition (Ismail, 2016). In addition, EDPs are one of the applications of interactive learning environments, which combine viewing and practicing accompanying educational activities related to formative assessment methods. This linkage aims to enhance the understanding of the content being watched, as it provides many opportunities for interaction with the content (Stonebraker et al., 2016).

EDPs do not need classrooms, arenas, transportation, or costly educational tools when used as a distance learning or training tool. They accommodate a large number of learners without age and geographic restrictions, and it is characterized by high speed in follow-up and continuous response. It also emphasizes that the education process is no longer confined to a specific time or place, or controlled in a strict schedule, but rather the possibility of education anywhere and at any time without restrictions (Ahmed, 2016; Alausaimi, 2018).

The characteristics of EDPs include:

(1) **productivity:** the teacher can produce materials, lessons, or any learning content and present it to learners through the platform,

(2) **ease of organization:** this is done through the tools used in the platform and arranged to serve the educational process,

(3) **ease of access and availability:** this is done by publishing content and making it available to learners,

(4) **collaboration and sharing:** occurs through teamwork between learners in the implementation of tasks, projects, and assignments, and also between learners and trainers,

(5) **evaluation:** allows the occurrence of various forms of evaluation, such as: diagnostic, initial, formative and summative, and (6) providing appropriate feedback (Al-Buhairi, 2019; Al-Jraiwi, 2017, Shalaby & Murad, 2017).

Several studies (e.g., Mustafa, 2019; Shalaby & Murad, 2017; Shaltout, 2017) confirmed the effectiveness of using EDPs in training and education. Mustafa (2019) pointed out the effectiveness of interactive learning platforms based on electronic projects on developing the skills of producing electronic children's magazines. Shaltout (2017) found the effectiveness of a proposed training program using open source courses "MOOCS" to develop skills for employing social networks as educational platforms. The study of Shalaby and Murad (2017) also concluded the effectiveness of educational platforms in developing the skills of electronic content production and academic integration among graduate students.

Microsoft Teams is an EDP. It is defined as a cloud-application digital platform that enables conversations, meetings, and file sharing in a single learning management system (Microsoft, n. d.). Tsai (2018) explained that EDPs, such as Microsoft Teams, provide functions that email cannot do. These functions include chat rooms, video conferencing, as well as other features offered by social media.

Study Objectives

The current study aimed to identify each of:

1. The effectiveness of educational platforms in developing the cognitive aspect of the skills of employing AR applications in teaching of mathematics.
2. The efficacy of educational platforms in enhancing the practical aspect of utilizing AR applications for teaching mathematics.

Study Problem

One consequence of the COVID-19 pandemic was the shutdown of numerous schools, necessitating the adoption of e-learning as the primary and unavoidable method for instruction. This discovery has presented substantial difficulties for educators in adjusting to e-learning tools and platforms, maintaining limited face-to-face interaction with students, and facilitating student learning (König et al., 2020). Among the various e-learning tools in education, AR applications are recognized as an effective solution. Abdalhameed (2019) found the effectiveness of AR in developing self-regulation and achievement skills. Similarly, Hussien. (2019) explored the effectiveness of AR in developing digital image processing skills and achievement motivation. In addition, Reda (2018) confirmed the effectiveness of AR in correcting learners' wrong scientific concepts. Alzahrani (2018) also emphasized the effectiveness of AR in developing higher-order thinking skills.

Based on the foregoing and after reviewing previous studies, many studies have underscored the importance of enhancing teachers' abilities to produce AR applications at different educational levels (Angraini et al., 2023; Kellems et al., 2020; Koparan et al., 2023; Korkmaz & Morali, 2022; Syafril et al., 2021). Furthermore, the researchers of this study have observed that mathematics teachers in elementary schools do not use AR technology to enhance the teaching of mathematics. The researchers conducted a set of unstructured interviews with 25 primary school mathematics teachers (not the study sample). The interviews concluded the following results: that 22 teachers (88%) could not define AR, 23 teachers (92%) did not have the ability to use AR technology, and 24 teachers (96%) stressed their need for training in the skills of using AR technology in teaching mathematics. In addition, the Ministry of Education in Saudi Arabia has approved the use of Microsoft Teams as a strategic option to complete distance learning for learners. Microsoft Teams is a unique interactive learning platform with its capabilities and features that allow for interaction and collaboration. Elsaadany's (2018) study emphasized the need to employ EDPs in training and education, and thus the capabilities and features of the interactive Microsoft Teams can be used in training.

From the previous information, it is possible to clearly determine the necessity of the current study of the low level of skills in employing AR applications to enhance the teaching of mathematics among elementary school teachers in Saudi Arabia. This study attempts to take advantage of the interactive electronic learning platforms, Microsoft Teams, and the many features it contains in developing those skills. The main question can be defined as follows: What is the effectiveness of educational platforms in developing the skills of employing AR applications in the teaching of mathematics?

Branching from this main question are the following sub-questions:

1. How effective are educational platforms in enhancing the acquisition of cognitive elements associated with the utilization of AR applications for teaching mathematics?
2. To what extent do educational platforms enhance the practical proficiency in employing AR applications for teaching mathematics?

Hypotheses

1. A statistically significant distinction, at the 0.05 significance level, exists between the mean scores of elementary school mathematics teachers who underwent education via educational platforms in the pre- and post-administration of the cognitive aspect achievement test, regarding their competence in utilizing AR applications in mathematics teaching, in favor of the post-application.
2. A statistically significant distinction, at the 0.05 significance level, exists between the mean scores of elementary school mathematics teachers who received instruction through educational platforms in the pre- and post-application of the performance aspect observation card, pertaining to their proficiency in using AR applications in mathematics teaching, in favor of the post-application.

Study Delimitations

1. **Population:** Mathematics teachers in elementary school.
2. **Objective:** Focused on using the EyeJack app for AR. AR technology was chosen because the nature of mathematics includes abstract concepts that need clarification and simplification to bring the concept closer to students, and to motivate students to continue learning mathematics, which is what AR provides.
3. **Temporal:** The initial semester of the 2020-2021 academic year.
4. **Spatial:** Confined to elementary schools within the Education office in Western Dammam, Saudi Arabia.

Study Definitions

The researchers in this study operationalized the terms, as follows:

1. ***Educational digital platform:*** It is an integrated interactive learning environment with multiple resources, which includes electronic content to present courses, educational programs, educational activities, and electronic learning resources for learners (Alausaimi, 2018). It is operationally defined in this study as an interactive environment that provides interactive tools and materials for content presentation, allows sharing of resources, allows audio and video communication, and enables interaction between elementary school mathematics teachers to achieve various training and educational goals.
2. ***Augmented reality:*** It is an application made through mobile devices and based on user interaction from the mobile phone screen through the sense of touch (Diaza et al., 2015; Elsayed & Al-Najrani, 2021). It is defined operationally in this study as a cellphone application based on integrating reality with digital elements (video, pictures, graphics, etc.) in order to achieve the targeted educational goals.
3. ***Skills of employing augmented reality applications to enhance mathematics teaching:*** In this study, it is procedurally defined as the elementary school mathematics teachers' capability to employ the EyeJack app for AR in teaching mathematics with ease and convenience.

Study Importance

The current study may benefit the following parties:

1. **Mathematics teachers in the elementary schools:** encourage them to move towards sustainable professional development to raise their efficiency at work and their ability to deal with technological innovations.
2. **Elementary school students:** provide teaching and learning applications that benefit primary students in enhancing their learning of mathematics through AR applications at anytime and anywhere according to their own abilities, with the possibility of providing immediate feedback to them.
3. **The Ministry of Education:** make use of EDPs to train teachers in the performance skills related to their field of work.
4. **Researchers:** may open the way for other studies aimed at developing the different performance skills of teachers using training programs based on EDPs.

THEORETICAL FRAMEWORK AND REVIEW OF RELEVANT LITERATURE

Training Using Educational Digital Platforms

There were many definitions that dealt with EDPs. Shaltout (2017) indicated that EDPs are websites based on communication and participation between teachers and their students in terms of exchanging information, educational activities, and assignments using modern web tools. Homanova and Prextova (2017) defined EDPs as an integrated set of interactive online services that provide teachers, learners, parents, and others involved in education with information, tools, and resources to support and enhance education. Abu Al-Nasr (2017) defined it as an interactive electronic learning environment that takes place over the Internet and employs web applications to facilitate the teaching and learning processes. It enables teachers and students to communicate, interact, and share content, information, and opinions. It also enables parents of students to view the results and assessments of their children, and follow up on their learning, which leads to the achievement of the desired educational goals.

EDPs are founded on the principles of motivational theory, suggesting that the system that maximizes a learner's personal enjoyment is the most efficient in cultivating motivation for accomplishment. E-learning platforms greatly assist the learner in the self-development processes necessary to achieve the targeted learning goals (Al-Halfaway et al, 2017). Several studies (e.g., Ch & Popuri, 2013; Oproiu, 2015; Sandybayev, 2020) have shown that EDPs are among the applications of interactive e-learning environments, where they have many similar characteristics, such as:

a. **Interactive:** EDPs provide an interactive learning environment between teachers and learners, between learners and their colleagues, between learners and the educational institution, and between learners and educational content.

b. **Flexible:** Learners on EDPs are provided flexible learning according to their circumstances and time, so that learners can access their lessons anytime and anywhere.

c. **Equity:** EDPs help achieve the principle of equal educational opportunities among learners without discrimination. Communication tools allow each learner the opportunity to express his opinion at any time without embarrassment or fear.

d. **Self-learning:** EDPs consider the principle of individual differences among learners. They allow the learner the freedom to control the course and time spent in the learning process.

e. **Diversity:** Diversity in the presentation of educational content helps to raise the mental abilities of learners through a variety of stimuli that address the different senses such as moving and static images, written and audio texts, audio and graphics files, and others.

f. **Communication:** EDPs allow learners to easily communicate through different types of communication networks with their teacher, as well as to communicate with their colleagues from different places and in different languages.

g. **Low cost:** These platforms allow for the ingestion of large numbers of learners at one time and at a lower cost compared to traditional learning.

h. **Easy development:** In general, it can be said that an EDP is an always renewable system that can be developed easily, and thus increases its effectiveness.

i. **Multi-evaluation:** The real-time assessment tools offered by EDPs give the teacher a variety of ways to build, distribute, and categorize information in a quick and easy way to assess learners' development and achievement of educational content objectives.

EDPs are distinguished by the fact that they do not need a programming specialist in order to deal with them as a user, but their use requires a set of competencies that can be easily developed in their users. They are also characterized by the ease of development and modernization at the lowest cost and effort (Abdul-Kader & Khalifa, 2021). The advantages of EDPs can be listed as: motivating learners to continue learning by offering them interactive and participatory activities between learners, combining social networks to help users exchange opinions and ideas, enabling the teacher to create virtual classes to conduct dialogues between users, providing a digital library containing learning resources, easing the evaluation of the learners' work by the teacher, and encouraging of communication between teachers and students from all over the world (Adzobu, 2014; Ahmed, 2016; Amandu et al., 2013; Nyagorme et al., 2017). In addition, numerous studies (e.g., Giordano & Marongiu, 2021; Liu et al., 2020; Soy-Muner, 2020; Yang et al., 2021) have emphasized the significance of EDPs in meeting the training needs of teachers and attaining training objectives.

Augmented Reality

AR technology is one of the technologies that allows the merging of real and virtual reality. One of the benefits of this technology is its capability to offer visual reinforcement to learners, catering to kinesthetic and theoretical learning styles, facilitating authentic learning experiences, and enabling personalized learning. There are many definitions of AR in the literature. Diaz et al. (2015) defined it as an application through mobile devices and based on the interaction of the user from the mobile phone screen through the sense of touch. According to Chen and Tsai (2012), it involves an environment that encompasses elements of both virtual reality and the actual physical world. Within this environment, users can perceive the real world while virtual objects seamlessly integrate with it. Salmi et al. (2012) defined AR as a mobile-based learning environment that combines real-world phenomena, and uses images, graphics, and sounds to enhance the learning process, improve the understanding process, and increase the learner's motivation towards the learning process.

Some studies (e.g., Anggraini et al., 2020; Elhlafawy, 2011; Wu et al., 2013) indicated the most important characteristics of AR, which are providing three-dimensional content that contributes to enhancing the learning process, ease of movement within smart device applications that integrate real and virtual reality, ease access to augmented virtual versions of real objects anywhere and at any time, ease of interaction of learners with their teachers and with each other, flexibility in obtaining services for students and teachers, ease of use of AR technology, where it does not require high computer skills, and the possibility of cooperation between learners, which develops their social interaction skills.

According to Ahmad (2021), Akcayir et al. (2016), Radu (2014), and Yuen et al., (2011), AR technology has the advantage that it helps students engage in real-world exploration, improves learners' laboratory skills and increases understanding of scientific content; helps learners learn subjects that are not easily perceptible or touchable, such as astronomy and geography; helps retain information in memory for a longer period; motivates learners to discover information from different angles; helps learners to control the way they learn according to their preferred method, and increases learners' enthusiasm for learning and a sense of satisfaction.

Table 1. Study design of one-group pre-/post-test design

Pre-test	Treatment	Post-test
O_1	X	O_2

Dunleavy (2014) indicated that the patterns of AR are divided into two forms, which are

(1) **location-based:** it relies on GPS technology, which enables the availability of various digital media to learners during their movement through different real physical media,

(2) **vision-based:** it is linked to directing the learners' camera of the mobile device to a specific physical reality that is displayed on the mobile in a variety of digital media.

Moreover, numerous studies (e.g., Avila-Garzon et al., 2021; Buchner & Kerres, 2023; Gudoniene & Rutkauskiene, 2019; López-Belmonte et al., 2020; Sharma et al., 2022) have emphasized the importance of using AR applications at various educational levels to achieve the targeted learning outcomes for different academic subjects.

METHODOLOGY

A quasi-experimental design is used in this study to measure the impact of the independent variable (use of EDPs) on the dependent variables (the cognitive aspect of the skills of using AR applications, and the performance aspect of the skills of using AR applications). Thus, this study employs the quasi-experimental design that is known as the one-group pre-/post-test design, wherein the experimental control conditions of the independent variable are met. This type of design was chosen because the current study falls within the scope of developmental research aimed at determining the effectiveness of EDPs as a new technology in developing the skills of employing AR in teaching mathematics. Therefore, this study does not need a control group. **Table 1** shows the design of the current study.

Study Population and Sample

The study population consists of all elementary school mathematics teachers in the Dammam West Education Office, Saudi Arabia. Using simple random sampling, thirty-six mathematics teachers voluntarily accepted to participate in this study.

Study Procedures

The current study relied on the ADDIE model when designing the educational program based on EDPs because it provides simplicity of design, ease of use, and suitability for beginners. The general model of instructional design is a systematic approach to the instructional design process that provides the designer with a procedural framework to ensure that educational products are effective and efficient in achieving objectives. The following is an explanation of the stages of building a training program based on EDPs.

First phase: Analysis

It is the basic phase in the instructional design process, and its steps can be explained, as follows:

1. **Identifying the study problem:** The study identified the primary problem as the low level of skills in employing AR applications in enhancing mathematics teaching among elementary school mathematics teachers. The current study attempts to design a training program using EDPs to overcome this problem.
2. **Analysis of the participants' characteristics:** The study sample is characterized as 36 elementary school mathematics teachers in Dammam, their ages ranged between (31-46) years old, all of them are males, they have smart devices, and they have the ability to use EDP.
3. **Analysis of the learning environment:** The use of EDP requires only the availability of a smartphone or computer, which is available to all members of the study sample.

Second phase: Design

The design phase went through the following steps:

1. **Determine educational goals:** The overarching aim was to enhance the competency in utilizing AR applications to improve the teaching of mathematics.
2. **Identifying the learning strategy:** The discovery learning strategy was used in EDPs, where the training objectives were defined at the beginning of the training. A question or problem that fits the training content has been added. Video footage was shown or a live video presentation with comments and hints were added to guide teachers during training. Finally, some tasks and activities were added at the end of the training session.
3. **Selection of resources:** The Internet was searched for appropriate educational resources. The researchers of this study were able to obtain some suitable sources (photos and videos) that could be used; however, those sources were needed to be modified. Images were edited with Adobe Photoshop Cs, and videos were modified with Camtasia Studio program.
4. **Multimedia selection:** At this step, the multimedia that would be used in EDPs has been determined.

Third phase: Production

The production phase went through the following steps:

1. **Identification of multimedia programs:** The researchers of the current study relied on a number of computer programs to produce the multimedia, which are Adobe Photoshop Cs5, MS Word 2013, and Singate 9 to record video clips.
2. **Multimedia production:** The researchers designed the multimedia needed for EDPs, which were texts with compatibility between font and screen size, still images as needed with some annotation, and video clips of high quality.
3. **Determining how training content would be delivered:** The Microsoft Teams educational platform was used to deliver training content. This platform is characterized by ease of use, a variety of tools, the ability to share photos and videos, live broadcasts, and the ability to share the trainer's screen.

Fourth phase: Implementation

The implementation phase went through the following steps:

1. **Preparing the Microsoft Teams user guide:** The Microsoft Teams user guide is built to help teachers use it efficiently in training, and to achieve targeted training goals.
2. **Conducting the pilot study on some teachers:** Microsoft Teams was applied to an experimental sample of 20 elementary school mathematics teachers (not the study sample) to ensure the integrity of the training content, and to make the necessary adjustments. This step took a week.

Fifth phase: Evaluation

At this stage, the training content was presented to seven experts in the educational technology field to provide their comments and suggestions. All the experts' recommendations and suggestions were followed, and some modifications were made to the training content regarding the linguistic aspect and clarity of information.

Instruments

The instruments of this study consisted of an achievement test and an observation card. Therefore, the researchers followed the following stages.

Achievement test

The test aimed to measure the cognitive aspect (remember, understand, apply) of the skills of employing AR in enhancing the teaching of mathematics among elementary school teachers. Multiple choice and true and false questions were used to prepare the test items. Furthermore, the researchers prepared a table of specifications for the achievement test in order to link the educational goals with content and determine the number of items needed for each goal specific to the levels (remember, understand, apply). The number of test items in its final form was 38 items. The grading was such that the teacher gets one point for each correct answer, and zero for each one wrong or left blank. Thus, the maximum total score for the achievement test is 38 points.

Test validity: To assess the test's validity, face validity was employed, involving the presentation of the initial test form to a panel of educational technology experts to solicit their opinions and feedback. The researchers made the modifications suggested by the experts, which consisted of reformulating some of the test items, and replacing or deleting some words to ensure clarity.

Pilot study: Following the validation of the initial version of the achievement test and its vocabulary through expert evaluations, the researchers carried out a pilot study of the test with a randomly selected group of 20 teachers. The ease and difficulty index were calculated for each item of the test. The ease index (0.38-0.67) was acceptable, and the difficulty index (0.33-0.62) was acceptable too. Moreover, the discrimination index was calculated, which expresses the ability of each test item to distinguish between high performance and low performance of the sample members. The discrimination index ranged between (0.57-0.80), which are acceptable as an index because each item that gets a discrimination index less than (0.2) is considered to have a weak discriminatory ability. In addition, the average time taken by each teacher to answer the test was calculated based on the following formula: The appropriate time for the test=700 minutes÷20 teachers=35 minutes.

Reliability: The test's reliability was assessed utilizing Cronbach's alpha coefficient, yielding a satisfactory value of 0.89. Thus, the test results can be trusted when applied to the study sample.

Observation card

An observation card aimed at determining the level of teachers in the skills of using AR applications was developed. The statements on the observation card were crafted with consideration of the competencies related to the utilization of AR applications. Additionally, the quantification of the observation card was used as follows (performed, performed after assist, not performed). Therefore, the final score on the observation card for proficiency in utilizing AR applications for teaching mathematics was set at 120 points.

Validity: The observation card's validity was determined through a face validity process. Five experts were given the observation card to evaluate the precision

Table 2. Results of paired-sample t-test before & after administration of achievement test

Group	Count	*M*	*SD*	df	*t*	Eta squared	*p*
Pre	36	13.50	1.765	35	47.490	0.985	0.000
Post		35.31	1.969				

of the instructions, the effectiveness of the structure and wording of the card's statements, and to suggest any necessary revisions. All feedback provided by the experts was carefully considered and incorporated.

Reliability: The reliability of the observation card was determined through a multi-observer approach, focusing on the performance of a single teacher. Subsequently, the agreement coefficient among the observers' assessments was calculated using Cooper's formula. Five teachers (not the study sample) were selected to perform the skills of using AR applications. The researchers jointly with two additional members evaluated the performance of these five teachers. The observers exhibited a high level of agreement, with an average consensus rate of 93.33%. This signifies a strong reliability coefficient for the observation card, confirming its suitability for use in the study sample.

Pre- & Post-Application of Study Instruments

The pre-application of the two instruments (achievement test - observation card) was carried out on the participants and took almost a month. After completing the pre-application of the two study instruments, an introductory meeting was held with the sample members. They were familiarized with the objectives of the training, the nature of its content, its activities, and how to accomplish those activities. In that meeting, an attempt was made to motivate teachers for training through EDPs. Participants were trained to employ AR in their teaching mathematics, where teachers were trained to prepare detailed explanations of mathematical problems and provide more than one way to solve these problems. Then, the trainees save those solutions and explanations in AR application library. The goal of saving this information in the application is when students pass their cellphone on a problem in the textbook, the application will present these explanations and show them to the students. This method helps students understand the problem, interact with it, and motivate them to provide creative solutions to the problem.

After that, Microsoft Teams training sessions were run daily for three weeks. Interaction tools between trainer and teachers were provided during the training period to provide feedback. Each teacher studied the training content according to their own progress and abilities by providing videos of the training session so that teachers could review and train in light of them. Individual and group training activities were provided to keep teachers active during training. Finally, the post application of the two study instruments were applied to the participants.

RESULTS

First Hypothesis

A statistically significant distinction, at the 0.05 significance level, exists between the mean scores of elementary school mathematics teachers who underwent education via educational platforms in the pre- and post-administration of the cognitive aspect achievement test, regarding their competence in utilizing AR applications in mathematics teaching, in favor of the post-application.

To test the first hypothesis, a paired sample t-test was used to compare two correlated samples. **Table 2** shows that there is a statistically significant difference (p= 0.000) between the average scores of the pre and post application of the achievement test in favor of the post application (M=35.31). The results indicated that the first null hypothesis was rejected at the 0.05 level of significance. Thus, the training program made a difference on the test of cognitive aspects associated with the competence in using AR applications. Furthermore, the actual effect size of the training program was calculated using the Eta squared coefficient. The results of **Table 2** indicate that the training program has a high effect size (0.985), which proves its practical effectiveness in developing the achievement of the cognitive aspects associated with the competence in using AR applications to enhance the mathematics teaching among elementary school teachers.

Second Hypothesis

A statistically significant distinction, at the 0.05 significance level, exists between the mean scores of elementary school mathematics teachers who received instruction through educational platforms in the pre- and post-application of the performance aspect observation card, pertaining to their proficiency in using AR applications in mathematics teaching, in favor of the post-application.

To test the second hypothesis, a paired sample t-test was used to compare two correlated samples. **Table 3** indicates highly significant distinctions (p=0.000) between the average scores of the pre and post application of the observation card in favor of the post application (M=113.28). The results indicated that the second null hypothesis was rejected at the 0.05 level of significance. Therefore, the training program made a difference in terms of the test of the performance

Table 3. Results of paired-sample t-test before & after utilization of observation card

Group	Count	*M*	*SD*	df	*t*	Eta squared	*p*
Pre	36	37.22	5.210	35	76.119	0.994	0.000
Post		113.28	5.108				

associated with the competence of employing AR applications. Furthermore, the actual effect size of the training program was calculated using the Eta squared coefficient. The findings of **Table 3** indicate that the training program has a high effect size (0.994), which proves its practical efficacy in enhancing the performance aspects associated with the utilization of AR applications for improving teaching mathematics among elementary school teachers.

DISCUSSION

The results of this study identified a statistically significant disparity at the 0.05 level between the average scores of the participants in the pre and post administration of the achievement test assessing the cognitive aspects associated with the competence in using AR applications for teaching mathematics in favor of the post application, as well as in the observation card for the performance aspects of those skills. The researchers attribute these results to the effectiveness of the training program using EDPs, which provided educational activities based on a combination of individual tasks, participatory tasks, and self-evaluation. Participation in accomplishing some tasks within the same group and sharing their work with the rest of the groups helped to improve the knowledge and skills of the participants. This result is based on the principles of social constructivism theory, which stresses the importance of social interaction and co-working in building the cognitive process and acquiring skills (Teague, 2000). In addition, the diversity of media (words, visual, and auditory) in the training program captured the teachers' attention and helped them develop positive attitudes towards the use of technology. This outcome aligns with the cues summation theory, suggesting that as the quantity of cues or stimuli accessible increases, the learning process becomes more effective (Maniar, 2012). Furthermore, the training program using EDPs allowed participants to interact with what they were seeing, and thus allowed them a space of freedom. Participants have the ability to regulate the pace at which the training material's content is presented, a feature that contributed to the enhancement of both cognitive and performance aspects related to the utilization of AR applications. This result is consistent with the cognitive flexibility theory, which emphasizes the importance of enabling learners to access educational content at different times, for different purposes, and in different contexts as well (Sprio et al., 1991).

The researchers attribute the results of the current study to the extent to which the study benefited from the characteristics of EDPs. These characteristics expedited access to information, enabled discussions among trainees and between them and the trainer, and allowed trainees to document their ideas about the training topic. Furthermore, EDPs helped conserve the trainer's time and effort by making the training content readily available to trainees, facilitating discussions among them, and facilitating the implementation of training activities through them. EDPs also supported both direct (online) and indirect (offline) training by providing access to various training resources, facilitating multidirectional communication between trainees and the trainer, and supporting collaborative training among trainees.

Additionally, the results of the current study agree with the results of several studies (e.g., Giordano & Marongiu, 2021; Ismail, 2016; Liu et al., 2020; Moreno-López et al., 2022; Mustafa, 2019; Ramzy, 2019; Shalaby & Murad, 2017; Soy-Muner, 2020; Yang et al., 2021) that indicate the effectiveness of EDPs in developing cognitive and skill aspects. Mustafa's (2019) study confirmed the effectiveness of EDPs in developing children's e-magazine production skills. Ramzy (2019) showed the effectiveness of EDPs in improving Internet use skills and reducing the cognitive burden. Shalaby and Murad (2017) pointed out the effectiveness of EDPs in developing the skills of electronic content production, self-identification, and academic integration among graduate students. Ismail (2016) illustrated the effectiveness of EDPs on developing visual thinking skills and geographical curiosity.

CONCLUSIONS

AR applications have many characteristics, advantages, and educational effectiveness. Therefore, it is important in this digital age for in-service teachers to have the skills to use AR in teaching, in general, and in teaching mathematics in particular. EDPs are an application of interactive learning environments that combine viewing of content and practice of educational activities to enhance understanding of what has been seen. Thus, the current study sought to reveal the efficacy of an educational program conducted through EDP in enhancing the competency of elementary school teachers in utilizing AR applications for teaching mathematics. The findings substantiate the program's effectiveness in cultivating these skills. This study underscores the significance of bringing to the attention of those responsible for curriculum development at the Ministry of Education the advantages of incorporating EDPs as a method for training mathematics teachers. This study also suggests conducting other studies that examine the effectiveness of some structural variables related to the educational design of EDPs in developing the skills of employing AR applications in enhancing mathematics teaching.

Recommendations

The current study recommends:

1. The importance of harnessing web-based technological advancements, particularly EDPs, to offer advanced and practical solutions for addressing training and distance education challenges.
2. Advising the individuals in charge of crafting training programs within the Ministry of Education to incorporate EDPs as a training method. This is justified by these platforms' capability to cater to the individual variances among trainees and their effectiveness in cultivating technology utilization skills for mathematics instruction.
3. Providing education schools with a high-speed internet to help mathematics teachers employ AR applications in teaching mathematics.

Suggestions for Future Research

The current study suggests studying:

1. The effect of the interaction between the timing of feedback in e-learning platforms and the cognitive style in developing e-book production skills for elementary school teachers.
2. The pattern of feedback based on educational analyses in EDPs to enhance of elementary school teachers' ability to create electronic tests.
3. The effectiveness of a training program using virtual reality in developing personal knowledge management skills for elementary school teachers.

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