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# The effectiveness of using augmented reality in teaching science on developing basic scientific processes and perceived self-efficacy among 9th-grade female students

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**ABSTRACT**
Augmented reality has been applied in several fields. Its application in many fields has been researched. However, research on the application of AR in the educational sector is rare, especially in Gulf countries. The present study addresses this gap.
The aim of this study was to investigate the effectiveness of using augmented reality AR) in teaching science on basic scientific processes and perceived self-efficacy among 9th-grade female students. The sample consisted of 62 9th-grade female students in Arar, who were randomly divided into two equal groups: the control group, which received science education using traditional methods, and the experimental group, which received the same material using augmented reality.
To achieve the study objectives, two scales were used, one to measure basic scientific processes and the other to measure perceived self-efficacy. The validity and reliability of the two scales were confirmed. The results showed a significantly higher application of the basic scientific processes and self-efficacy by the experimental group (AR-using group) over the control group using traditional methods ($p<.001$). The findings support a large number of other related works.
These findings were used to recommend some steps to implement AR technology in the Saudi education sector and future research. Some limitations of this study have also been listed. They can be addressed by future research.

**Keywords:** augmented reality, teaching science, basic scientific processes, perceived self-efficacy.

## INTRODUCTION

Despite many reforms spending huge amounts of funds, the performance of Saudi children in international competitions on science, technology, engineering, and mathematics (STEM) subjects remains poor. One reason for this could be the difficulty in understanding and practising the lessons. The students seem to lack the scientific processes independently due to their perception of weak self-efficacies.
Different countries, including Saudi Arabia have tried many ways of improving the situation. Augmented reality (AR) is a fast-developing method in education for effective teaching. Many researchers have studied the advantages of using AR as a solution to the above problems.
In line with the directions of the Ministry of Education, which is keen to achieve educational goals in general and the goals of teaching science in secondary schools in specific, including developing scientific skills and perceived self-efficacy among students, it was necessary to choose teaching programs and strategies that are consistent with the scientific and technological development imposed by the current era and achieve the desired goals. As AR is an interactive and exciting way to design effective learning environments that present science education situations as real-life situations (Mertoglu & Kurt, 2017; Alsalamat et al., 2022), it is essential to use it in teaching science.
Augmented reality is defined as technology that seeks to enhance the materials and objects existing in the real world through several sensory methods (smell, sight, hearing, and touch) based on information and data (Reyes & Hernández, 2018). Learning with AR helps students process sensory information in a virtual environment and allows them to practice and repeat certain parts and situations according to their abilities and needs. The basic idea of AR is to integrate real-world learning environments effectively and attractively with virtual learning (Anderson & Liarokapis, 2014).
Several AR applications can effectively improve and develop educational activities and make them significantly better than what traditional books and curricula offer (Khan et al., 2019). This, in turn, contributes effectively to improving and developing the educational process's outcomes and enhances students' teaching and learning. Through the ability of augmented reality to display digital elements or integrate them into the real world, significant changes have been made in the learning process in classrooms (Perez-Lopez & Control, 2013).

**Study Questions**

The problem of the study is the weakness of 9th-grade female students in practising science processes and their perceived low self-efficacy levels during their study of science. The current study attempted to address this problem by answering the following main question:

1. What is the effectiveness of using augmented reality in teaching science on developing basic science processes and perceived self-efficacy among 9th-grade female students?
2. The main question is divided into the following two sub-questions:
   a. What is the effectiveness of using augmented reality in teaching science on developing some basic science processes among 9th-grade female students?
   b. What is the effectiveness of using augmented reality in teaching science on perceived self-efficacy among 9th-grade female students?

**Study Hypotheses**

Based on the previous study questions, the following two null hypotheses can be formed:

1. There are no statistically significant differences between the mean scores of the control group and the experimental group of female students on the post-application of the basic science processes scale due to the difference in teaching strategy (augmented reality, traditional).
2. There are no statistically significant differences between the mean scores of the control group and the experimental group of female students on the post-application of the perceived self-efficacy scale due to the difference in teaching strategy (augmented reality, traditional).

**Importance of the study**

The results of this study can benefit specialists at the Ministry of Education in redesigning, planning science curricula, and using teaching methods according to AR in response to global and local trends that call for the importance of scientific processes and perceived self-efficacy. The study may also benefit science teachers by providing them with a guide that clarifies the steps of teaching using augmented reality, focusing on the active and positive role of the student and making them the core of the learning process. AR is a rich field for research with the potential for several applications. For students, AR provides better and more effective learning methods. The Saudi government is benefitted by developing a highly skilled workforce who can match the global level job markets. It will be in line with the educational goals set for Vision 2030 of the country.

**Study terms and procedural definitions**

**Augmented Reality**

A computer-based technology that integrates multiple media such as images, scenes, and videos from the real world with the virtual world in the form of three-dimensional technical drawings. The computer controls all these components (Itmezi, 2013; Chiang et al., 2014). Procedurally, in this study, Augmented Reality is defined as a technique through which virtual teaching and learning are used in educational situations to teach science to $9^{th}$-grade students, where the real world (learning environment) is enhanced with virtual three-dimensional forms and drawings that allow the student to practice learning in a way that resembles the real environment.

**Basic scientific processes**

Ali and Omeerah (2007) defined basic scientific processes as mental processes used in the learning process through which the learner acquires knowledge, skills, and attitudes. These processes consist of eight operations: observation, classification, measurement, communication, inference, prediction, use of time and place relationships, and the use of numbers. In this study, basic scientific processes are defined as simple mental processes used by the 9th-grade student during science learning and are measured by the total score obtained by the student in the basic scientific processes scale (observation, classification, measurement, communication) that was prepared for this purpose.

**Perceived self-efficacy**

Zimmerman (2000) defined perceived self-efficacy as an individual's perception of his/her ability to organise and execute tasks necessary to achieve a specific performance level and academic goals. It refers to the student’s belief about his/her capability to perform a task.

In this study, it is defined as thoughts and opinions of 9th-grade female students regarding their ability to achieve their tasks and goals, which was measured by the total score obtained by the 9th-grade female students on the perceived self-efficacy scale that was developed for this purpose.

**Study boundaries and limitations**

The study was limited to

Objective boundaries: Topics of unit five (motion and force) from the science textbook for 9th-grade students.

Human boundaries: A sample of $9^{th}$-grade female students.

Spatial boundaries: Second Secondary School in Arar.
Time boundaries: Second semester of the academic year 1442/1443 AH (2020-2021 AD).

**Theoretical Framework**
Augmented reality in an e-learning context is used as the theoretical framework in this study.

**Augmented Reality**
AR is conceived as a three-dimensional technology that supports students in understanding and perceiving the real world surrounded by objects created in a virtual environment (Leung & Blauw, 2020). It consists of three-dimensional graphics created by computers that create a bridge between virtual and real environments (Diegmann et al., 2015). Applications based on AR differ from those of virtual reality (VR). In VR, objects are created in artificial environments unrelated to the real world. On the other hand, applications based on AR allow for real-time interactions in a space where virtual and real worlds coexist (Carmigniani & Furht, 2011; Azuma et al., 2001).
Thomas Caudell and David Mizell first used the concept of AR in company presentations. With the development of technology, access to phones and computers has become much easier, making the use of AR easier in different environments and fields (Johnson et al., 2010). Applications based on AR have also quickly found their place among these technology-based applications and are being used in many fields (Çetin & Türkan, 2022). At present, technological tools and applications are used in many fields ranging from medicine to engineering and from scientific studies to literary activities (Kapur, 2019). According to Joan (2015), AR is a direct or indirect way of presenting a realistic educational environment in the real world, achieved by adding sensory elements designed and constructed using computers or mobile devices. Alharbi (2018) explains that AR is the integration of virtual information and subjects with real-world reality, with the aim of adding a range of information and data that enrich and enhance the student's visual perception. Alenezi (2019) sees AR as a system that allows the coexistence of the real and virtual worlds interacting in one place while providing students with rich and active learning environments and diverse scientific content through multimedia. According to Kinsara and Attar (2021), AR is the conversion of reality in the real world into digital data, designed, composed, and filmed using electronic display tools and methods that give an image of the reality of the real environment.

**E-learning**
Bashir and Bassiouni (2018) indicated that e-learning is characterised by the ability of those in charge to modify and update its scientific content easily and conveniently. E-learning also allows and encourages interaction between the student, the teacher, and among students themselves using the internet and several media, whether synchronously or asynchronously. E-learning is also flexible, allowing students to learn at a time, place, and speed that suits their abilities, needs, and interests. In addition, this type of learning is managed electronically based on the computer and the internet. One of the most important applications of e-learning in the educational field is AR, which expands the real world by adding layers of information produced by computers to create a real learning environment. The data and information that are added can be in the form of graphics, text, video, audio, etc. (Anderson & Liarokapis, 2014).
AR, as a modern technique in teaching science based on e-learning, contributes significantly to the enrichment and activation of learning environments through the provision of information, data, and multimedia content of sound, image, and videos in an advanced and sophisticated way. Thus, it makes these environments effective and active and rich in information sources that suit all students with their different learning styles, abilities, and attitudes. It helps to provide a suitable environment for achieving self-learning and focuses on adding virtual information, data, situations, pictures, and videos to reality synchronously, which motivates students and attracts them to practice. Thus, it enhances their academic achievement and attainment of various educational goals (Qashta, 2018; Alharbi, 2018; Alabbasi & Alghamdi, 2020; Dünser et al., 2012; Castro & Virata, 2016; Yildirim & Kapucu, 2021). Donnelly (2020) also indicated that AR helps to develop various digital skills of students by integrating digital objects with physical objects to overcome the gap between cognitive and practical aspects in physical learning environments. It stimulates students' motivation and interest and contributes to improving their ability to memorise and retrieve information, in addition to encouraging them to collaborate and communicate to develop various social skills.
By simulating reality, AR helps to create and design a stimulating learning environment. AR enhances the attractiveness of e-learning and makes it more exciting. It focuses on practical scientific methods in the teaching and learning process instead of theoretical approaches. Thus, it contributes to self-learning and skills development. Additionally, it contributes to cost savings and reduces the effort required for learning (Alzahrani, 2019).
The current era requires a generation of students capable of facing challenges by possessing 21st-century skills acquired through scientific processes and technological skills that enable them to access, utilise, manage, and evaluate information. AR helps to consider the individual differences among students, making it easier even for weak students to understand scientific information and achieve the desired objectives.

**Science Processes**
Science processes are defined as a set of mental abilities that represent the behaviours of scientists and are transferable

from one situation to another, and are learnable (Atallah, 2010). They are also defined as thinking skills that students acquire and use to acquire the desired scientific knowledge and skills (Karamustafaoğlu, 2011). Ozgelen (2012) defines them as a set of mental abilities and skills that appear in the form of student behaviour and scientific thinking.
Science is both a subject and a method. Hence, both forms are important. The educators focus on equipping students with the processes of science in both these forms (Zaytoun, 2013). Science is considered an applied subject that heavily relies on practical lessons in school laboratories. It allows students to practice all the scientific skills and processes to acquire new knowledge and effectively tackle problems (Opara, 2011).
One of the most important objectives of teaching science is to develop science processes to help students become scientifically literate individuals capable of interacting with various scientific events and phenomena in a scientific manner (Bati et al., 2009). Hence, there is an increasing interest in acquiring science processes among students in which they are given the opportunity to train and acquire the knowledge they need to solve the problems they face (Foley & McPhee, 2008). Educators use these processes to develop thinking skills among students in science curricula (Aydogdu et al., 2013; Mutlu & Temiz, 2013). Zaitoun (2013) explained that science processes include mental skills that students use to understand the world and its phenomena. They also determine the behaviours the scientists can acquire and practise to apply in situations in various aspects of life.
Scientific processes are divided into basic scientific processes and integrative scientific processes (Al-Hawidi, 2012; Zaytoun, 2013; Sheeba, 2013). The basic scientific processes are simple cognitive processes that can be easily acquired. It forms the foundation on which other processes and skills are built. These processes include observation, classification, measurement, communication, inference, prediction, using time and place relationships, and using numbers (Chabalengula et al., 2012; Zaytoun, 2013).
Basic scientific processes play an important role in teaching and learning science. They enable knowing and understanding science and its nature, make students the centre of the learning process, help students expand their learning, and encourage learning through research and inquiry. They develop students' self-learning abilities, make them responsible and independent learners, and enhance their scientific, critical, and creative thinking (Al-Hawidi, 2012).

**Perceived Self-efficacy**

According to Pintrich and Schunk (1995), there are three dimensions of self-efficacy: magnitude, strength, and generality. Recent research on motivation and its processes has shown that the cognitive functions that drive behaviour and contribute to its continuity and direction are the result of growth and experience. This is in addition to the importance given to changes in cognitive functions such as goal setting, emotions, and expectations. Self-efficacy is an important process that enhances motivation and affects students' behaviour while learning science. As Hamdi and Dawood (2000) have indicated, self-efficacy is a concept of cognitive, social theory and an important foundation for the individual and their personality. It significantly affects individuals' practices, behaviour, and attitudes. It develops and changes over time to become a characteristic of an individual's personality, regulating their learning mechanisms.
Studies by Zimmerman (2000), Bacchini and Magliulo (2003) and Mohammed (2010) revealed the existence of different forms of self-efficacy among individuals based on the type of tasks performed or the goals and objectives to be achieved, whether social, professional, or academic. These types include academic self-efficacy, ideal self-efficacy, physical self-efficacy, and perceived self-efficacy.
Bandura (2006) showed that self-efficacy is an effective indicator of students' learning proficiency and motivation and can detect minor changes in their academic performance, as well as coordinate their learning process. It was also found that students' self-efficacy plays an important role in achieving and motivating their academic proficiency. Yusuf (2011) also found that self-efficacy can directly impact students' academic achievement. Dinther et al. (2011) found that positively directed learning experiences that provide students with practical experience can lead to a stronger sense of self-efficacy. Liu (2015) chose the path of least movement and designed an innovative marine learning program integrated with AR to enhance students' confidence in learning and affect their self-efficacy for learning science. Both Al-Rafu and Al-Qaisi (2009) and Al-Salamat (2018) have shown that when students realise their self-efficacy by assessing their ability to accomplish at the expected level that is consistent with their expectations, it contributes to achieving their desired goals matching the effort they put in. Social cognitive theory shows that students' knowledge and beliefs about their self-efficacy will change their behaviour. Competence will determine their choice of activity and participation with the reduced effort they put into achieving goals, even as they face obstacles. Therefore, Zimmerman (2000) believed that if a student's self-efficacy is developed, it will significantly contribute to the development and improvement of their academic achievement through their acquisition of various academic and life skills. They prefer to engage in activities and experiences that they believe they could succeed in and avoid activities they believe they cannot succeed in. A student's behavioural variables affect his/her personal variables. When a student engages in a learning task and performs it, he/she will notice their progress. This will show them how their abilities enable them to learn by contributing to the development of their self-efficacy.

Studies by Abu Labdeh (2011) and Al-Salamat (2018) showed that perceived self-efficacy is developed through educational situations and teaching strategies that are appropriate for science subjects. Students who have high self-efficacy show harmony and a desire to learn, and achieve desired goals, exhibit confidence in their ability to achieve goals and interact actively with educational situations and activities. Students with low perceived self-efficacy, on the other hand, show a desire to withdraw from educational situations and lack confidence in their ability to complete educational tasks before starting to practice them, leading to academic failure.

## REVIEW OF LITERATURE

### AR to increase learning effectiveness

Shing et al. (2014) observed that a proposed mobile AR learning system was able to improve science learning and achieve high academic performance through higher motivation in the dimensions of attention, confidence and importance compared to those who used traditional mobile learning systems. Ahmed (2016) observed the high effectiveness of an AR-based program in developing visual thinking skills in science among ninth-grade students in Gaza, using the pre-post experimental method with a sample of 43 ninth-grade students. Using a sample of 58 7th-grade female students in an experimental study in Gaza, Qishatah (2018) showed a positive effect of AR on the development of scientific concepts and a scientific sense among these students. Two tests were applied to measure scientific concepts and cognitive aspects of the scientific sense. The experimental group was taught using the layer AR reality and Element D application. Alenezi (2019) obtained increased student motivation and achievement using AR as an interactive and engaging tool in teaching biology. The AR mobile application was tested on a random sample of 60 secondary school students (30 male and 30 female) from the Northern Borders Region of Saudi Arabia.

From the results of a quasi-experimental study of 100 Turkish 7$^{th}$-grade students, Sahin and Yilmaz's study (2020) observed higher levels of scientific achievement and more positive attitudes towards science among students who used AR applications than those in the control group. In addition, the results showed that students were happy and wanted to continue using AR applications in the future. They also did not show any signs of concern when using AR applications.

Results obtained by Khalaf (2021) also showed that the use of AR for teaching science is effective in developing logical thinking skills among 7$^{th}$-grade Egyptian students in the intermediate stage.

The sample consisted of 80 students who were divided into two groups: control and experimental. The study tool was a logical thinking test, and the experimental group was taught through a virtual learning environment based on augmented reality.

In the studies of Husamiya (2021), AR improved visual thinking and academic achievement among 4$^{th}$-grade female students in Jordan. A quasi-experimental approach was used, and the sample consisted of 57 female students who were divided into control and experimental groups. Two tests were applied to measure academic achievement and visual thinking.

AR was effective in developing cognitive and performance aspects of experimental science skills in the studies of Al-Ajmi (2021). In the quasi-experimental studies, 60 sixth-grade students in the Al-Jahra Educational Area in Kuwait were used. Study tools included a test of cognitive aspects related to science experiment skills and a performance observation card related to science experiment skills.

Using a quasi-experimental approach on 50 6$^{th}$-grade students from a secondary school in the Odunpazarı region of Eskisehir, Yildirim and Kapucu (2021) observed a positive effect of AR in enhancing students' scientific achievement, retention of acquired knowledge and recall abilities. A quasi-experimental approach was used in teaching the Solar System and Eclipse unit and the systems in our bodies unit in the science curriculum. An achievement test and a semi-organised interview were used as research tools.

Semi-structured interviews with nine students who participated in a study on 4D AR applications related to the "systems in our bodies" led Sontay and Karamustafaoğlu (2021) to conclude that the AR application helped to a better understanding of learning the subject and increased the motivation of the students to enjoy learning science lessons.

The achievement and attitudes of 3$^{rd}$-grade students towards the science course Electric Vehicles increased when AR was used to enrich the course. In this study, Çetin and Türkan (2022) used a sample consisting of 15 students in the third grade of Sırat Turkish School during the academic year 2020-2021. AR-enriched lessons were presented to students through the Zoom program. A pre-and post-test was performed.

AR technology improved the understanding of electrical concepts among 11$^{th}$-grade Malaysian students in an experimental study by Ropawandi et al.'s (2022). Pre- and post-tests were done in the control group of the traditional method and the AR experimental group.

### Self-efficacy

Cai et al. (2019) designed and developed a series of statistics and probability lessons using AR on tablet devices to examine the impact of AR on concept development and learning strategies for secondary school students of varying levels of self-efficacy. A sample of 101 students was divided into two groups based on their self-efficacy for learning mathematics. The results showed that AR applications in mathematical lessons could increase self-efficacy so that students pay more attention to higher-level concepts. It can also help high self-efficacy students apply more advanced strategies to learn mathematics.

Cai et al. (2020) developed a dual AR-based educational application to explore the impact of augmented reality technology on high school students' self-efficacy. The results of this study on a sample of 98 high school students in an experimental study showed that integrating AR into the learning systems, along with practice and communication, improved the level of understanding of the concepts and cognitive skills. Also, the students were motivated to engage in deeper learning.

The above review of previous studies shows that most of the studies were like the current study in their adoption of using AR in teaching science, but they varied and differed with it in the dependent variables.

**The current study**

The study, based on the researcher's field of expertise, focused on studying the effectiveness of AR on the processes of science and the self-perceived efficacy of female students in Saudi Arabia. The above review helped effectively contributed to providing a theoretical background for the current study on the use of AR in teaching science, to identify the problem of the current study, adopt the appropriate methodology, design the teacher's guide, extracting, discussing, and interpreting the results, and benefiting from them and linking them to the results of the current study.

Methodology

**Study population and sample**

The study population consisted of all 9$^{th}$-grade female students at secondary schools in Arar during the second semester of the academic year 1442/1443 AH (2020-2021 AD). Sixty-two female students were selected from the 9$^{th}$ grade at the Second Secondary School and randomly distributed into two groups, a control group consisting of 31 students and an experimental group consisting of 31 students.

**Study materials and tools**

**Teacher's guide for implementing the motion and force unit using augmented reality:**

To build this guide, the motion and force unit was reviewed and adopted as a suitable unit to be implemented using AR due to its high scope of suitability for AR augmentation. Then, several Arab and foreign studies that used augmented reality in teaching science were reviewed. The papers reviewed were Chiang, Yang & Hwang (2014), Ahmad (2016), Qashtah (2018), Khalaf (2021), Al-Husamia, (2021), and Yildirim and Kapucu (2021). Based on the review results, the ADDIE model was chosen to prepare the teacher's guide for implementing the unit using AR. This model consists of five stages Analyse, Design, Develop, Implement and Evaluate. The first stage represents analysis by identifying the goal of AR. It led to the development of the basic scientific processes and scientific attitudes of the 9th-grade female students. Then, analysed the content of the unit, the characteristics of the students, and the learning environment.

The second stage in the design process involves building and formulating educational objectives, daily plans, writing scenarios, collecting educational materials, software, applications, and appropriate videos, application of practical measures of basic scientific processes and pre-scientific directions, use of continuous and final evaluation through the post-application of practical measures of basic scientific processes and scientific directions.

The third stage is development, which includes preparing and building educational media that can be implemented through AR. The fourth stage is represented by implementation or conducting the experiment on a sample of 20 female students to ensure the suitability of augmented reality for teaching the selected unit topics to 9th-grade students.

Finally, the fifth stage is represented by evaluation, which involves presenting the augmented reality teacher guide to a group of specialists in educational technology and science curricula.

**Basic scientific processes scale**

To measure the basic scientific processes (observation, classification, measurement, and communication) among 9th-grade secondary school students, a number of references and previous studies were consulted (Abu Juhjouh, 2008; Zaitoun, 2009; Al-Qasimiya, 2010; Chebii et al., 2012; Aydogdu et al., 2013; Saleh, 2014; Al-Rawdan, 2015; Al-Otaibi, 2019; Al-Ma'lawi, 2019).

Then, 24 paragraphs were written to measure those processes using a multiple-choice format. Thus, the scale was initially prepared, consisting of 24 paragraphs that measure the four basic scientific processes, with six paragraphs for each basic process.

To ensure the validity of the measure, it was presented to a group of specialists in science teaching methods from faculties of education and science supervisors and teachers, who provided some feedback for modifying some paragraphs.

The preliminary measure was applied to a sample of 21 female students from outside the study sample, and the Pearson correlation coefficient was calculated between the score of each paragraph and the total score of the process to which it belongs, as well as between the total score of each process and the total score of the basic scientific processes. The correlation coefficients ranged from 0.551 to 0.821, all of which were statistically significant at the 0.01 level. This indicates that there is a correlation between the processes and the total score of the scale.

The scale's reliability was calculated by determining Cronbach's alpha for the entire scale and operations. The values of the coefficient for the four basic science operations ranged between 0.77 - 0.89, while the coefficient for the entire scale

was 0.91, indicating high reliability and stability of the scale (Ouda, 2010).
Thus, a scale was adopted for measuring the four basic science processes among 9th-grade female students. The scale consists of 24 multiple-choice paragraphs, with one point for each correct answer and zero for each incorrect answer. The highest possible score is 24, and the lowest score is zero.

**Perceived Self-Efficacy Scale**

To detect the perceived self-efficacy among 9th-grade female students, a scale was constructed after reviewing several related studies, including Bacchini & Magliulo (2003), Devonport & Lane (2006), Al-Sharaideh (2006), Ghanem (2007), Kazem & Suhail (2008), and Salamat (2018). Initially, 28 paragraphs that suited 9$^{th}$-grade female students were written, which were then transformed into a scale according to the Likert three-point scale.
To ensure the validity of the scale, it was presented to a group of specialists consisting of professors of science teaching methods in education colleges and educational psychology faculties. They provided some feedback that involved modifying the formulation of some items and deleting others. As a result, the scale consisted of 25 paragraphs in its final form.
The scale was applied in its initial form to a sample outside the study sample, consisting of 21 9th-grade female students, and the Pearson correlation coefficient was calculated between each paragraph score and the total scale score, which ranged between 0.502-0.790, all of which were statistically significant at the 0.01 level, indicating a correlation between the items and the total scale score. The reliability of the scale was calculated by Cronbach's alpha coefficient, which was found to be 0.84, indicating high reliability (Ouda, 2010).
Thus, the Perceived Self-Efficacy Scale for 9th-grade female students, consisting of 25 paragraphs according to the Likert three-point scale, was adopted, where the highest possible score was 75 and the lowest possible score was 25.

**Ensuring the Equivalence of the Two Study Groups**

To ensure the equivalence of the two study groups before teaching, the Science Processes Scale and the Perceived Self-Efficacy Scale were applied in advance, and the mean and standard deviation of the results were calculated. The t-test was used to detect differences between the means, and the results are shown in Table 1.

**Table 1. Pre-application results of the t-test to detect significant differences between the mean scores of the experimental and control groups on the Basic Science Operations Scale and the Perceived Self-Efficacy Scale.**

| Scale | Group | Number | Mean | Standard Deviation | t- value | Degree of Freedom | Significance level |
|---|---|---|---|---|---|---|---|
| Basic Science Processes | Experimental | 31 | 13.45 | 2.68 | 0.466 | 60 | 0.643 |
| | Control | 31 | 13.10 | 3.28 | | | |
| Perceived Self-Efficacy | Experimental | 31 | 52.35 | 9.80 | 0.628 | 60 | 0.532 |
| | Control | 31 | 50.84 | 9.18 | | | |

Table 1 shows that the calculated t-values (0.466) and (0.628) are not statistically significant at the ($p=0.05$) level, indicating that the two groups were equivalent before the start of the teaching process.

## RESULTS

**First: Presenting the results related to the first study question, discussing, and interpreting them**

The first research question was about the effectiveness of using AR in teaching science on developing some basic scientific processes for 9th-grade female students. To answer this question, the mean and standard deviation were calculated for the responses of the two study groups on the post-application of the basic science processes scale. The results are shown in Table 2.

**Table 2:The mean and standard deviation of the scores of the control and experimental groups on the post-application of basic science processes scale**

| Process | Group | Number | Mean | Standard Deviation |
|---|---|---|---|---|
| Observation | Control | 31 | 3.52 | 0.57 |
| | Experimental | 31 | 5.48 | 0.57 |
| Classification | Control | 31 | 3.48 | 0.68 |
| | Experimental | 31 | 5.13 | 0.67 |
| Measurement | Control | 31 | 3.52 | 0.63 |
| | Experimental | 31 | 5.19 | 0.60 |
| Communication | Control | 31 | 3.32 | 0.60 |
| | Experimental | 31 | 5.00 | 0.68 |
| Basic science processes | Control | 31 | 13.84 | 2.16 |
| | Experimental | 31 | 20.81 | 1.93 |

Table 2 shows higher mean values for the experimental group compared to the control group for all four stages of the basic science processes. To test the statistical significance of these differences, a multivariate analysis of variance (MANOVA) was used, and the Wilks' Lambda value was (0.210), which is associated with a probability of (<.001), meaning that the differences between the mean scores are statistically significant. As a result, a one-way analysis of variance was conducted, and the results can be presented in Table 3.

**Table 3:Results of one-way ANOVA comparing the mean scores of female students in the control and experimental groups on the post-application of basic science processes scale.**

| Process | Source of Variation | Sum of Squares | Degrees of Freedom | Mean Square | F value | Significance level | Eta Squared η |
|---|---|---|---|---|---|---|---|
| Observation | Processing | 60.02 | 1 | 60.02 | 184.82 | <.001 | 0.755 |
| | Error | 19.48 | 60 | 0.325 | | | |
| | Mean score | 79.50 | 61 | | | | |
| Classification | Processing | 41.95 | 1 | 41.95 | 92.45 | <.001 | 0.606 |
| Process | Source of Variation | Sum of Squares | Freedom Value | Mean Square | F value | Significance level | Eta Squared η |
| | Error | 27.23 | 60 | 0.454 | | | |
| | Mean score | 69.18 | 61 | | | | |
| Measurement | Processing | 43.61 | 1 | 43.61 | 115.89 | <.001 | 0.659 |
| | Error | 22.58 | 60 | 0.376 | | | |
| | Mean score | 66.19 | 61 | | | | |
| Communication | Processing | 43.61 | 1 | 43.61 | 105.63 | <.001 | 0.638 |
| | Error | 24.77 | 60 | 24.77 | | | |
| | Mean score | 68.39 | 61 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Basic Science Processes | Processing | 752.52 | 1 | 752.52 | 178.44 | <.001 | 0.748 |
| | Error | 253.03 | 60 | 4.23 | | | |
| | Mean score | 1005.55 | 61 | | | | |

Table 3 shows statistically significant differences at the p<.001 level between the mean scores of female students in the control and experimental groups on the post-application of basic science processes as a whole and on each of its processes. This difference was in favour of the experimental group who studied using augmented reality.

Based on the results, the null hypothesis "There are no statistically significant differences at the p=0.05 level between the mean scores of female students in the control and experimental groups on the post-application of basic science processes due to teaching strategy (augmented reality, traditional)" was rejected, and the alternative hypothesis "There are statistically significant differences at the α=0.05 level between the mean scores of female students in the control and experimental groups on the post-application of basic science processes due to teaching strategy (augmented reality, traditional)" was accepted, and this difference is in favour of the female students in the experimental group.

As shown in Table 3, the effect of AR on the development of basic science processes among the experimental group students ranged from 0.606 to 0.755 in terms of eta squared (η^2), which indicates that there is development in basic science processes ranging from 60.6% to 75.5% due to using AR in teaching science.

The results indicate that AR provided an active and effective e-learning environment. This environment encouraged students to be active and observant regarding the learning topics. A study by Chiang et al. (2014) showed that AR contributes to providing a learning environment that increases students' motivation to learn and enables them to directly use different learning processes available in this environment, such as videos and situations that simulate real-life phenomena.

Using AR allowed students to practice scientific processes by observing and interacting with the topics they were studying. In addition to the visual techniques that AR provides, enabling students to see objects from all directions and is accompanied by sounds, videos, pictures, and augmented shapes arranged with information in a way that is closer to reality. This attracted students' attention and increased their positive interaction, individually or in groups, and motivated them to engage effectively in classification, measurement, and communication processes.

Furthermore, using AR outside the classroom allowed students to revisit and repeat the learning topics in a way that suited their learning ability and freedom to choose the appropriate time and place, which directly contributed to the development of their basic learning processes.

This result is consistent with those obtained by Ahmed (2016) and Alhusamia (2021) that using AR develops visual thinking skills among science students. It is also consistent with Alajmi's (2021) observation that using AR contributes to developing science experiment skills, including basic learning processes.

**Second: The study results related to the second question are presented, discussed, and explained**

The second question was about the effectiveness of using AR in teaching science on perceived self-efficacy among 9th-grade female students. To answer this question, the mean scores and standard deviations of the responses of the study groups were examined using the perceived self-efficacy scale, and a t-test was conducted to compare the means of the experimental and control groups. Table 4 shows the results.

**Table 4:Results of the T-test to examine the significance of differences between the mean scores of female students in two study groups on the perceived self-efficacy scale**

| Group | Number | Mean | Standard Deviation | t-value | Degrees of Freedom | Significance level | Eta squared η2 |
|---|---|---|---|---|---|---|---|
| Control | 31 | 54.81 | 8.83 | 6.589 | 60 | <.001 | 0.42 |
| Experimental | 31 | 66.84 | 5.03 | | | | |

Table 4 shows a statistically significant difference at level p<.001 between the mean scores of female students in the two study groups, in favour of the experimental group who studied the scientific material using AR. The calculated t-value was 6.589 with p<.001. It also indicates that there is a large effect of using AR, where the value of Eta squared (η2) was (0.42), which means that 42% of the variation in the scores of the perceived self-efficacy scale was due to using AR in teaching science.

Based on the result, the null hypothesis "there are no statistically significant differences at level α≤ 0.05 between the mean scores of female students in the control and experimental groups on the dimensional application of the perceived self-efficacy scale due to the difference in teaching strategies (augmented reality, traditional)" is rejected, and the alternative hypothesis which states "there are statistically significant differences at level $\alpha \leq 0.05$ between the mean scores of female students in the control and experimental groups on the dimensional application of the perceived self-efficacy scale due to the difference in teaching strategies (augmented reality, traditional)" is accepted, and this difference is in favour of the experimental group.

These results show that teaching using AR has clearly contributed to the development of perceived self-efficacy among female students in the $9^{th}$-grade students. AR has provided an electronic learning environment that has stimulated the student's motivation to learn, as well as encouraged them to be active learners by providing opportunities for them to study, investigate, and analyse scientific material. The students feel that they are an important part of the educational situation and a key player in it.

AR also respects individual differences among students by providing each student with the opportunity to learn and acquire scientific knowledge and skills according to his/her unique abilities. This allows students to monitor their own learning, continuously adjust and evaluate their performance, which, in turn, significantly increases their self-confidence and perceived self-efficacy.

The role of the science teacher in implementing and monitoring the use of AR has a clear impact on the development of students' perceived self-efficacy. The teacher encourages students to utilise the videos and images presented through AR software, express their opinions, and propose new ideas and suggestions related to educational situations and materials. Additionally, the teacher should use different assessment methods and tools. While using augmented reality, the teacher transitions from traditional assessment methods based on tests to electronic assessment methods such as achievement files, immediate feedback, and other modern approaches that enhance student learning and self-evaluation and ultimately contribute to the development of their perceived self-efficacy.

This result is consistent with those obtained by Cai et al. (2020), showing that integrating AR in physics classrooms significantly enhanced students' self-efficacy. Similarly, Cai et al. (2019) found that AR improved students' learning outcomes across different levels of self-efficacy.

**Recommendations and suggestions**

Based on the above results, the following recommendations and suggestions can be presented:

1. The curriculum development and supervision committee should consider AR technology through specialised training workshops and attempt to include this method in science textbooks and curricula.
2. Science materials for secondary school should be reproduced to align with educational technology in general and AR in particular.
3. Science teachers should be encouraged and trained to consider using AR while teaching their subjects.
4. AR-based educational programs should be activated in the science teacher preparation programs offered in education colleges.
5. Science teachers should be trained to choose appropriate methods for developing their students' basic scientific processes and perceived self-efficacy.
6. More extensive studies should be conducted in other grades and subjects with both male and female students to examine the impact of AR on other dependent variables that were not included in this study.

## CONCLUSIONS

Results of the empirical studies reported in this paper clearly show the effectiveness of AR in developing scientific processes and improving self-efficacy among $9^{th}$-grade female students of Saudi Arabia. If more extensive studies on more schools, both male and female students and grade levels, uphold this trend, it will show a pathway to enhance the scientific skills of the Saudi population to the global level and thus achieve some of its Vision 2030 goals.

## LIMITATIONS

1. The representativeness of the sample to the population of $9^{th}$-grade female students in the country was not tested.
2. The samples were selected from a particular school in a particular area.
3. Only the effectiveness of scientific processes in learning and self-efficacy were evaluated.

The above three limitations can be addressed by the final recommendation given above.

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