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Role of Augmented Reality Learning in Enhancing Palestinian University Students' Motivation and Reflective Thinking

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Abstract

This paper provides a new experiment based on augmented reality technology in the context of Palestinian higher education. The primary goal is to investigate the effectiveness of AR-based learning on motivation and reflective thinking as crucial indicators of student learning. The research is based on a combined quantitative-qualitative methodology using motivation and reflective thinking scales for the quantitative approach and semi-structured interviews for the qualitative approach. The experiment was implemented on students enrolled in microwave engineering courses in the telecommunication engineering department at An-Najah National University. Semi-structured interviews and surveys were conducted with the research sample, and the collected data were analyzed using thematic coding and statistical analysis with relevant tests on SPSS. Results indicate a positive effect of using AR technology for teaching and learning on all dimensions of motivation, such as attention, relevance, confidence, satisfaction, and volition. Similarly, AR has a positive effect on all dimensions of reflective thinking except reflection. In addition, the qualitative analysis and the thematic coding yield seven main themes, such as benefits, hope for the future, challenges, reflections, initial impressions, attitudes, and prior experience. However, the study has some limitations, including a small sample size, a one-semester experiment period, and the novelty of the AR technology.

Keywords: *Augmented Reality, Reflection, Motivation, Educational Technology.*

Introduction

Digital transformation influences all aspects of human life (Wilms et al., 2017); one of these aspects is education, especially when technology has been combined with appropriate pedagogical foundations. This combination offers exciting opportunities to design realistic and authentic ways to increase student engagement, understanding, and learning. Higher Education Institutions (HEIs) should ensure that effective use of technology for learning and teaching is integrated into curriculum design, including win-win methods that offer both improved outcomes and lower cost. Several studies indicated that augmented reality (AR) promotes enhanced learning performance, improves university students' laboratory skills, and helps them build positive attitudes relating to

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laboratory work. Since AR is an emerging technology that can be employed as a new strategy for enhancing teaching and learning (Karagozlu, 2021), this study addresses the different aspects of AR being integrated into education.

AR provides new teaching and learning methods at schools or universities to enhance effectiveness and attractiveness with an increasing ability to use ICT and related devices, such as computers, tablets, headsets, and smartphones that support AR applications. In this context, it is necessary to distinguish between virtual reality (VR), which refers to adding elements of reality to a virtual environment. VR includes more virtual information than real, while AR contains more real information than virtual. Both AR and VR conform to the cognitive theory of multimedia learning (CTML), which states that meaningful learning should merge text with graphical resources, such as pictures, videos, animation, and simulation, to maximize learning effectiveness.

Literature Review

In the Palestinian context, AR/VR-based education has appeared recently within the last four years at schools and universities as well. At universities, many external projects have been implemented to establish centers for AR/VR, aiming at training instructors and students to promote AR technology in education in various courses. Some of these projects targeted the tourism sector and utilized AR and VR to develop virtual tours to the archaeological sites (TechnoPark, 2023). For instance, An-Najah National University established the AR unit in 2022 through the Artificial Intelligence and VR research center. The unit intends to deliver cutting-edge technology and essential AR skills to interested instructors, students, workers, researchers, and developers within and beyond the university (An-Najah National University, 2023).

At the school level, teachers have taken individual initiatives through mobile applications for primary and secondary students. They focused on the transformation of static images and forms in the Palestinian curriculum into dynamic and animated material by directing the smartphone's camera to the textbook and programming the pages to show three-dimensional scenes to attract students. For example, they designed 3D models for human devices or any shape depending on the images (Aqel, 2017; Mashharawi, 2018). Moreover, teachers and students were provided with training to deal with AR and VR applications and to use them for education.

The Horizon Report 2020 highlighted six types of technologies that have a high impact on the future of learning and teaching in higher education. In addition to extended reality (XR), these technologies are adaptive learning, artificial intelligence, and machine learning in education; student-success analytics; instructional design; learning engineering; user-experience (UX) design; and open educational resources (OER) (Brown et al., 2020). The advancement in IT promotes innovative learning tools in education, among other fields. Several educational technologies are implemented to enhance teaching and learning methods. One such technology with vast potential is augmented reality (AR), which offers new pedagogies that serve education (Bistaman et al., 2018).

Several studies related to using AR in education were conducted in a systematic literature review. Papakostas reviewed 32 related studies on using AR in engineering education and students' spatial ability training that have been published since 2010. The author classified them into three categories: learning outcomes, pedagogical affordances, and technical perspectives. He revealed many advantages and some limitations of using AR, such as the need for more learning content and the lack of personalization in the developed applications (Papakostas et al., 2021). Nesenbergs et al. (2021) also systematically reviewed 30 articles from the Web of Science database that describe the use of VR and/or AR technologies in distance learning for higher education and their impact on learning outcomes. He investigated 24 articles with interventions related to their effect on the learners' performance, and the results revealed 11 positive, seven negative, and six interventions with no impact. The last six articles with interventions related to the effect on the learners' engagement showed a positive impact (Nesenbergs et al., 2021).

Another important systematic literature review conducted by Sommerauer and Müller (2018) focused on theoretical and empirical foundations for using AR in teaching and learning. He extracted the design elements that can be traced back to both abstract learning theories (the cognitive theory of multimedia learning, mobile learning, game-based learning and simulation, experiential learning, and situated learning) and concrete system features by analyzing the design elements, content preparation, and evaluation of the learning activities. ICT-based learning requires motivation along with other factors for developing thinking skills. In order to ensure student motivation in the learning environment, learners are required to be mentally present and to take active roles in the learning process (Ozdamli & Hursen, 2017). Keller (2016) defined motivation as "those things that explain the direction, magnitude, and persistence of behaviors". In 1984, an application-focused model was proposed with four categories: attention, relevance, confidence, and satisfaction (ARCS) (Keller, 2016). Over time, it was shown that these four categories did not adequately account for differences in persistence among learners, nor did they provide a basis for motivational support activities (Kuhl, 1987). Therefore, Keller (2008) added volition as a fifth category that is similar to self-regulation, yielding the ARCS-V model. This design will motivate learners to achieve the learning objectives (Keller, 2010).

Many theories have been used in measuring the learners' motivation. Theall (1999) conducted a study about different factors of motivation using an author-by-factor matrix with thirteen studies. For example, Pintrich worked on self-regulation and used intrinsic motivation. One big challenge facing the learning process's success is the lack of motivation, so it is important to create and sustain motivation (Khan et al., 2019). Another study describing how motivation levels predict engagement across different types of technology-enhanced learning (TEL) showed that intrinsic motivation predicts engagement, while extrinsic motivation predicts usage (Dunn & Kennedy, 2019). The ARCS instrument has been validated and used in many motivation studies and technology strategies (Keller et al., 2020), such as Khan et al., who examined student learning motivation through an augmented reality mobile application for undergraduate health science learners at the University of Cape Town. The results showed that the attention, satisfaction, and confidence factors of motivation were increased, while the relevance factor was decreased (Khan et al., 2019).

In summary, attention in the ARCS-V model includes attention-seeking curiosity, excitement, interest, boredom, and other related areas such as sensation search. Relevance refers to learners' perceptions that instruction aligns their requirements with their goals, learning styles, and prior experiences. Confidence refers to the effects of positive expectations for success and attributes successes to one's abilities and efforts, not luck or the difficulty level of the task. Satisfaction refers to the combination of intrinsically rewarding and extrinsically rewarding results that maintain the desired learning and discourage unwanted behavior. Finally, volition, or self- regulation, refers to conscious efforts backed by determination or external requirements to transform intentions into actions (Keller, 2016).

Furthermore, reflective thinking plays an important role in technology-based learning (Yilmaz & Keser, 2016). It assists students in understanding course content deeply and provides an opportunity for comprehensive learning (Chang, 2019). In addition, reflective learning employs learners' prior knowledge to improve lifelong learning skills and enables them to gain better experience (Ozdamli & Hursen, 2017). Instructors can benefit from reflective thinking activities and strategies to develop positive attitudes and increase their teaching profession and performance. So, reflective thinking activities enhance learners' individual responsibility and awareness of their cognitive processes (Yilmaz & Keser, 2016).

Kember et al. (2000) derived from the Mezirow framework, and developed a reliable scale for reflective thinking that consists of four levels. These levels are described as follows:

1. Habitual action refers to activities that are learned through repeated use when the learner deals with the same action or problem many times as a routine. This behavior is similar to the "knowing-in-action" process described by Schön (1983) and Kember et al. (2000).

2. Understanding refers to the thoughtful activity of individuals, where the learners use their existing knowledge and comprehension of different subjects or phenomena (Ozdamli & Hursen, 2017). At this level, learners try to take notes, attempting to understand with or without personal reflection.

3. Reflecting refers to the critique and appraisal of assumptions about the content or a process of problem-solving (Mezirow, 1992). At this level, learners not only understand the concept but also make personal reflections.

4. Critical or premised reflection is a high level of reflective thinking. At this level, learners are aware of what they think, feel, and perceive and then require a critical review of assumptions from prior conscious and unconscious learning and results. So, learners here develop their reflective skills and recognize their belief phenomena (Ozdamli & Hursen, 2017).

The researchers used the EON-XR Platform to create 3D objects and animation, which is based on making immersive learning effortless, affordable, self-service, and interconnected (EASI). XR stands for extended reality, which refers to combined real and virtual environments, including augmented reality. The EON-XR application was used since it operates on both Windows and Mac operating systems, providing rapid development, deployment, and adoption of AR and VR. It also has such features as faster learning with real-time feedback and task-oriented contextual knowledge, safety through simulation, greater engagement, and performance-based assessment.

Figures 1and 2 illustrate sample lessons and related AR-based models as examples developed by one of the target students using the EON-XR application.

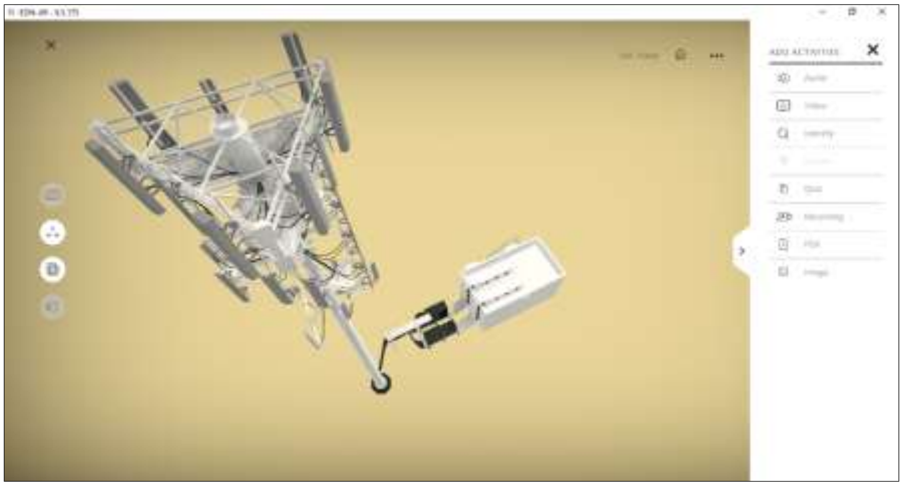

Figure 1. Developing a sample model using EON-XR platform.

Problem Statement

Many problems and challenges face universities, such as low levels of student interest, teaching methods and techniques, teacher characteristics, and a lack of tools and equipment. On the other hand, Karagozlu (2021) states that students have negative attitudes toward education because the delivered lessons do not support learning by doing or through experience, and there is a gap in the level of instructors' qualifications. Besides, the practical side of some activities in teaching practices is impossible because of their considerable cost, time, or health hazards (Darling-Hammond et al., 2020).

It is believed that AR is one of the most effective strategies that help learners study, think, and shift their learning into the real world. It introduces emerging technologies that can be employed to enhance teaching and learning methods, but unfortunately, it is still ambiguous due to the shortage of studies in the literature that strongly relate to AR learning theory or that describe how AR applications are designed and applied to improve learning outcomes and practices. AR provides better learning performance, learning motivation, improved perceived enjoyment, decreased cost of education, positive attitudes, and engagement (Alzahrani, 2020). Besides, using modern learning methods, such as AR, helps to keep pace with technological development and achieve satisfactory results (Lee et al., 2019). This invite making good use of technology in preparing learners, instructors, curriculum, and teaching methods in an attempt to develop the educational process and provide better teaching practices. The current study looks at the use of augmented reality (AR) in teaching and learning among university students in Palestine. Also, this study helps to determine the influence of AR-based learning on motivation and reflective thinking, as well as the students' perspectives on their experience in telecom engineering AR-based classes.

Research Questions

This study tries to answer the following main questions:

1. Are there differences in learners' motivation dimensions on pre- and direct tests?
2. Are there differences in learners' reflective thinking dimensions on pre- and direct tests?
3. What are the learners' viewpoints towards integrating AR technology into the learning environment?

Method

Research Design

The researchers used a mixed-methods research design, which includes data collection and analysis from multiple sources, to approach complex research issues in one single study (Creswell & Plano Clark, 2011). The quantitative experimental study aims to reveal the influence of using AR technology on learners' motivation and reflective thinking using the ARCS motivation scale (Keller, 2010), the validation for learning scale (VFLS) (Keller et al., 2020), and the reflective thinking scale (Kember et al., 2000). Moreover, semi-structured interviews were conducted with students, which helps in the deep understanding of special cases or when it is required to understand the meaning and preferences behind major patterns (Karagozlu, 2021).

The Sample

The sample consists of 13 students in the telecommunication engineering department who enrolled in a microwave engineering course during the second semester of the academic year 2021-2022 at An-Najah National University using the EON-XR platform for AR-based learning. Purposive sampling was used to choose this sample, which allowed the researchers to apply their specific knowledge or experience regarding the sample's competency with AR as a phenomenon of interest.

Data Collection Tools

The reflective thinking scale (RTS) by Kember et al (2000) was used in this research to measure the level of reflective thinking. It consists of four dimensions: habitual action, understanding, reflection, and critical reflection, with 16 items. In addition, the motivation scale (ARCS) by Keller (2010) was used to measure student learning motivation. It consists of four dimensions: attention;

nine items to measure relevance; nine items to measure confidence; and six items to measure satisfaction. Moreover, the volition for learning scale (VFLS) by Keller et al. 2020 that consists of 13 items was added to measure volition.

Data Collection

The researchers follow Denzin's (2012) triangulation approach, which includes multiple theoretical perspectives, multiple data collection procedures, and multiple analysis techniques. The use of multiple research design strategies and theories increases the depth of understanding and investigation. This research combines both quantitative experimental and qualitative descriptive research approaches.

Data Analysis

Appropriate SPSS tests were used for data analysis of the quantitative data. The Wilcoxon test was conducted to examine the differences between the pretest and the posttest, and the researchers used Mann-Whitney U to examine the pre-treatment measure of equivalence. Moreover, the semi-structured interview protocol was used that consists of 45–60-minutes interviews with participants who agreed to record their responses and signed a consent form. The interviewer asked questions to ensure the participants understood the meanings of the questions. The researcher designed a reflexive journal to obtain precise data and results. Content and thematic analysis techniques were used to analyze the qualitative data, where the transcribed documents were loaded into MAXQDA for coding the textual data and extracting the main themes.

Experiment Design

The researchers conducted the experiment in the microwave engineering course in the telecommunication engineering program. The experiment requires the students to have smartphones connected to the Internet, EON-XR accounts, and headsets (e.g., magic leaps or oculus quests). To get the best experience using the EON-XR app and to prepare the targeted students for the experiment, training was conducted for them on the EON-XR platform, and they were provided with some pedagogical knowledge. The researchers followed the five stages of the ADDIE model to conduct this experiment, as follows:

Analyze: This is the first phase that is essential to developing the next phases. It includes an analysis of the learning goals and the content of the course material. In addition, it identifies the targeted students' characteristics and the learning environment. Identify participants' characteristics: the students who enrolled in the experiment are third and fourth grades telecommunication engineering.

Design: This stage is essential to designing the scales and identifying the lesson objectives, the learning styles, and the teaching strategies.

Develop: In this stage, the educational resources are developed using the EON-XR platform through several assignments to the targeted students.

Implement: This stage is concerned with the integration of AR into learning, where the instructor assigned four learning activities to the target students with clear goals that cover the content to extend students' learning rather than testing their existing knowledge.

Evaluate: this stage was based on XR projects, midterms, and final exams. In the projects, each group should develop one 3D lesson satisfying at least one of the evaluation criteria.

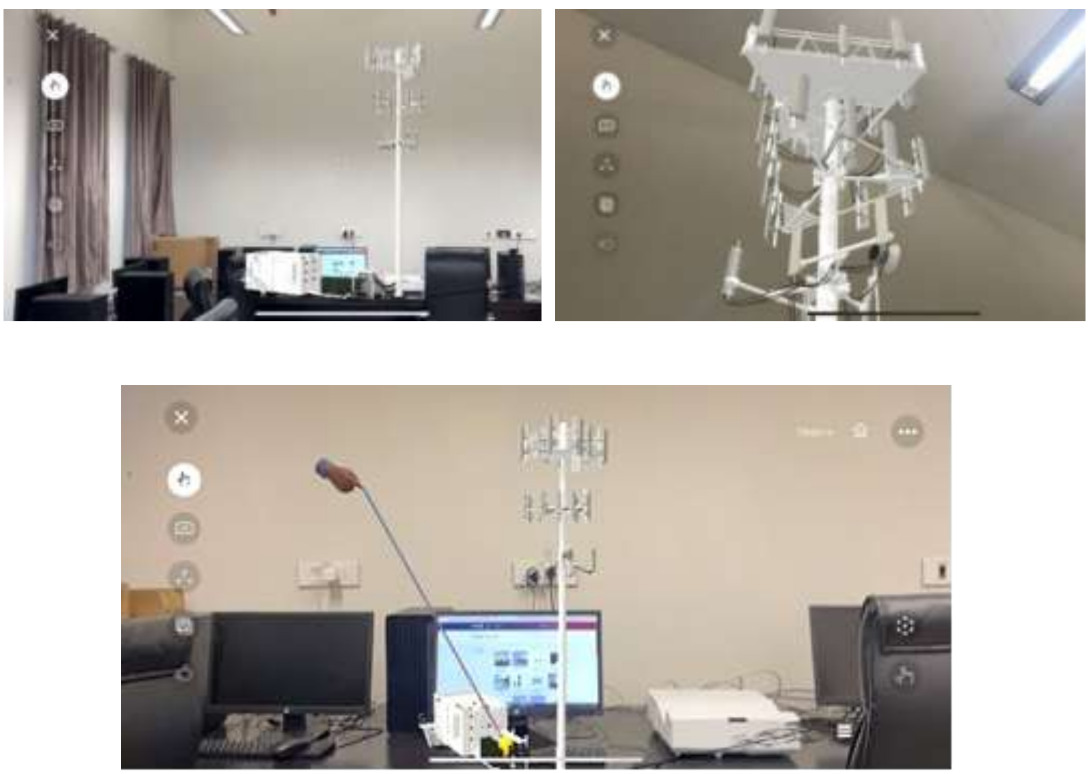

Figure 2. Students' experiments using EON-XR platform in learning.

Findings

This section highlights the main results of both quantitative and qualitative research instruments. Starting with the quantitative approach based on motivation and reflective thinking scales. The Shapiro-Wilk test was used to investigate the normality assumption because it is more appropriate for small sample sizes (< 50 participants) (Laerd, 2018). The normality assumption was not satisfied as the significance was less than 0.05 for the motivation scale, with (p= 0.019) for the pretest and (p = 0.02) for posttest. Similarly, significance was less than 0.05 for the reflective thinking scale, with (p = 0.029) for the pretest and (p = 0.026) for the posttest. Therefore, the researchers used non-parametric tests. The results are presented by answering three research questions. The first two questions present the quantitative results, and the third presents the qualitative results.

Research Question 1: Are there significant differences in learners' motivation dimensions between pretest and posttest for the microwave engineering course experimental group?

To answer this question, the researchers followed three steps; At the first step, the means, standard deviations, and medians for the experimental group on pretest and posttest were calculated for the motivation scale, as shown in Table 1.

Table 1

Means, standard deviations and Median for the experimental groups on pre and post tests for motivation scale.

Dimensions	Pretest			Post test		
	M	S. D	Median	M	S. D	Median
Attention	3.2564	.70091	3.3333	3.8718	.68179	3.5000
Relevance	3.6752	.65336	3.5556	4.0513	.56586	4.0000
Confidence	3.3504	.65396	3.2222	3.9316	.60780	3.8889
Satisfaction	3.6410	.55213	3.6667	4.0897	.57581	3.8333
Volition	3.3205	.55886	3.2500	3.8590	.53401	3.6667
Total	3.4167	.57181	3.3333	3.9407	.56249	3.6458

Table 1 compares the means and medians of the pretest and posttest for the experiment group on all dimensions of the motivation scale. The results show apparent differences between means and medians on the total score of the motivation scale and all its dimensions in favor of the posttest. At the second step, the researchers used Mann-Whitney to examine the statistical differences in the students' responses to the motivation scale pretest and posttest for males and females (pre-treatment measure of equivalence). Results show no significant differences in motivation pretest mean ranks due to gender (U=5.00, P=0.235), implying that the groups have comparable characteristics and are therefore suitable for the study. Moreover, results show no significant differences in motivation posttest mean ranks due to gender (U=10.00, P=0.843), i.e., after using AR technology in teaching the microwave engineering course. At the third step, a Wilcoxon test was conducted to examine the differences in the motivation scale and all of its dimensions between the pretest and the posttest for the experimental group, as shown in Table 2. Finally, the results indicate that AR-based teaching has an impact on all dimensions of the motivation scale.

Table 2

Wilcoxon's signed ranks test for the pre-test and post-test for the motivation scale.

Test	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
Post-Pre-Total	Negative Ranks	3	4.00	12.00	-2.343	.019
	Positive Ranks	10	7.90	79.00		
	Ties	0				
Post-Pre-Attention	Negative Ranks	3	3.17	9.50	-2.090	.037
	Positive Ranks	8	7.06	56.50		
	Ties	2				
Post-Pre-Relevance	Negative Ranks	2	2.50	5.00	-2.077	.038
	Positive Ranks	7	5.71	40.00		
	Ties	4				
Post-Pre-Confidence	Negative Ranks	3	4.50	13.50	-2.238	.025
	Positive Ranks	10	7.75	77.50		
		0				
Post-Pre-Satisfaction	Negative Ranks	4	3.00	12.00	-2.357	.018
	Positive Ranks	9	8.78	79.00		
	Ties	0				
Post-Pre-Volition	Negative Ranks	4	4.38	17.50	-1.959	.050
	Positive Ranks	9	8.17	73.50		
	Ties	0				

Research Question 2: Are there significant differences in reflective thinking dimensions between pretest and posttest for the microwave engineering course experimental group?

To answer this research question for reflective thinking, the researchers followed the same steps above, where the means, standard deviations, and medians were calculated for the experimental group on pretest and posttest for the reflective thinking scale, as shown in Table 3.

Table 3

Means, standard deviations, and medians for the experimental group on the pre-test and post-test of the reflective thinking scale.

Dimension	Pretest			Posttest		
	M	S. D	Median	M	S. D	Median
Habitual Action	3.0962	.69626	3.0000	3.6346	.67404	3.7500
Understanding	4.0769	.44936	4.0000	4.6731	.37339	4.7500
Reflection	4.0192	.60778	4.0000	4.3077	.46942	4.2500
Critical Reflection	3.3462	1.14354	3.7500	4.2115	.88886	4.5000
Total	3.6346	.55718	3.5000	4.2067	.45742	4.1875

Table 3 shows apparent differences between means and medians on the total score of the reflective thinking scale and all its dimensions in favor of the posttest.

Table 4

Wilcoxon's signed ranks test for pre and posttests of reflective thinking scale for the Microwave Engineering course.

Test	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
Post-Pre-Habitual Action	Negative Ranks	2	6.75	13.50	-2.254	.024
	Positive Ranks	11	7.05	77.50		
	Ties	0				
Post-Pre-Understanding	Negative Ranks	2	2.00	4.00	-2.590	.010
	Positive Ranks	9	6.89	62.00		
	Ties	2				
Post-Pre-Reflection	Negative Ranks	5	4.40	22.00	-.985	.324
	Positive Ranks	6	7.33	44.00		
	Ties	2				
Post-Pre-Critical Reflection	Negative Ranks	1	7.00	7.00	-2.520	.012
	Positive Ranks	11	6.45	71.00		
	Ties	1				
Post-Pre-Total	Negative Ranks	1	8.00	8.00	-2.623	.009
	Positive Ranks	12	6.92	83.00		
	Ties	0				

At the second step, the researchers used the Mann-whitney U test to examine the statistical differences in the reflective thinking scale pretest and posttest for males and females (the pre-treatment measure of equivalence). Results show no significant differences in the reflective thinking scale pretest mean ranks due to gender ($U=7.00$, $P=0.430$), implying that the groups had comparable characteristics, and therefore are suitable for the study. In addition, results show no significant differences in the reflective thinking scale posttest mean ranks due to gender ($U=6.5$, $P=0.373$), i.e., after using AR technology in teaching the microwave engineering course.

At the third step, Wilcoxon test was conducted to examine the statistical differences in the reflective thinking scale between pretest and posttest for the experimental group and all its dimensions, as shown in Table 4. This indicates that AR-based teaching has an impact on all dimensions of reflective thinking except the reflection dimension.

Research Question 3: What are the learners' viewpoints towards integrating AR technology in the learning environment?

The researchers used the inductive analysis process of the interviews using MAXQDA20 to introduce the results. A codebook was generated that constitutes seven main themes: reflection, prior experience, initial impression, benefits, challenges, attitudes, and hope for the future. Figure 3 illustrates MAXMaps of the generated codes and subcodes using MXQDA20.

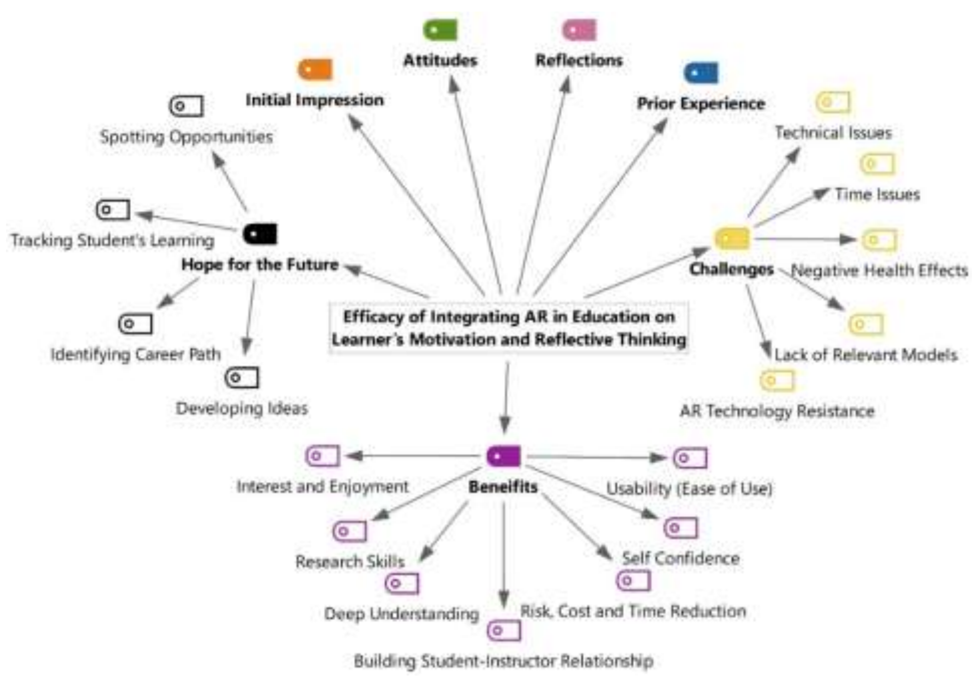

Figure 3. Code-subcode-segments model in MAXMaps.

According to the thematic coding and the qualitative data analysis, the researchers classified the generated themes into seven codes; three of them have their own subcodes. Figure 4 illustrates the code segments' frequency distribution, where the highest frequency was for benefits with 34.6% and the lowest frequency was for prior experience with 6.3%.

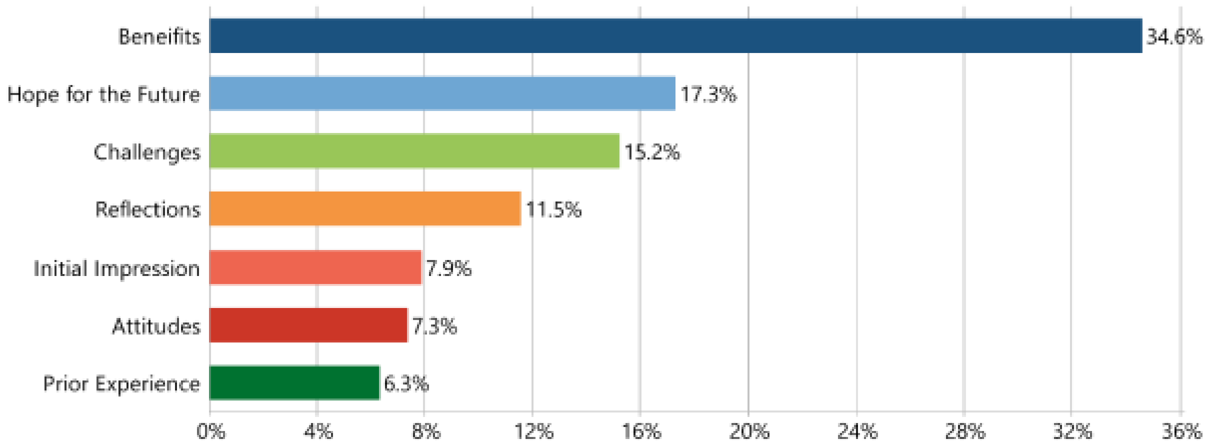

Figure 4. Frequency distribution of the code segments.

Prior Experience

Prior experience refers to students' previous knowledge about some topic or skills related to some technology (Rakap, 2010). Teaching and learning in a new learning environment are influenced by previous knowledge, which could be a set of misconceptions significantly interfering with the new concepts (Naah & Osei-Himah, 2021). Results show that all students had no background or prior experience related to AR or VR in education. Moreover, their experience in other fields is divided between either no prior experience in their life or some experience in 3D virtual games, cinema, watching 3D film using TV classes, scientific experiments using VR, or VR books using mobile applications.

For instance, AA said, *"I have some knowledge related to VR-based games that are not in education or learning. For example, I used to play VR-based games such as zombies and racing. It was a good experience, and since that day I have had a passion for virtual games"*.

Initial Impression

Initial impression can be defined as an initial opinion and perception formed regarding people, phenomena, technologies, events, or concepts facing a human being or he is experiencing for the first time (Haselton & Funder, 2006). Results show that the students were divided into two groups; the first struggled with using AR to study at the beginning and was afraid of dealing with this new technology. Also, some female students had technostress when they wore the Oculus and immersed themselves in the virtual world.

For instance, SN said, "*It was hard to learn based on AR technology right now since I am overloaded in the last year of my studies, even though it was an enthusiastic experience.*"

On the other hand, the second group felt excited to use AR technology to understand the difficult concepts since engineering topics are described as imaginative. They were satisfied with their assignments, homework, and achievements using AR or VR.

AGh said, *"I am satisfied with my achievement while working on this course using AR technology. It was a wonderful and perfect course, and I am proud of my instructor who gave me this opportunity"*.

Benefits

This section summarizes the students' perceptions of the main benefits gained during their experiment in the AR-based courses. Some subcodes are similar to those introduced in the previous studies. For instance, advantages of AR in learning physics by Fidan & Tuncel (2019) introduced codes such as better understanding and analyzing the problem scenarios; retention of concepts; facilitation and concretization in learning; autonomous learning; and an interesting, realistic, enjoyable, and interactive learning environment. In this study, the AR benefits were classified into five subthemes, as discussed below.

1. **Building Student-Instructor Relationships**

Student-instructor relationships affect learning outcomes, and students with strong connection with teachers reported better learning outcomes and academic achievement Further, they were more confident and self-directed (Creasey et al., 2009).

In this research, the students expressed that their relationship with the instructor was changed. As a result, they became cooperative team members. Moreover, the students expressed their satisfaction in dealing with the instructor as a result of continuous communication inside and outside the classroom.

ES said, "*I have certainly strengthened my relationship with the instructor. I used to see him during the lecture only. I began to see him and communicate more often in the center to help us understand things*".

In short, the relationship between the students and their instructor has turned into a friendship.

2. Usability (Ease of Use)

The students described the AR-EON platform as an easy one. It supports the Arabic language as well. Any student with basic IT skills can use it without the need for advanced skills.

TS said, *"It was not difficult and didn't need much experience. Today, it's all on mobiles, and everyone knows how to use Google and YouTube*."

Even though, students might require some initial training to get acquainted with the platform and use the available ready-made AR and VR models. Moreover, it is suitable for all ages and disciplines.

3. Deep Understanding

The students described the courses in telecommunication engineering as applied courses that require imagination skills. They include concepts that can be forgotten quickly, but after using AR in practice, such concepts became easy to memorize and understand.

AGh said, *"We started to understand the concepts more because our major is all about imagination. Even the term 'imagine' has been mentioned in almost every single lecture.*

AA added, "W*e became more familiar with the new concepts and understood them in a physical sense based on AR and 3D visualization."*

Moreover, ES added, "*I used to enroll in such university courses, but after a while, I forget most of the concepts, especially in complicated topics. With the new approach, such concepts started to grave into our memories and catch our attention."*

The interviewees mentioned that the new concepts became easier to understand when they designed the lessons themselves in a practical way and that it was their responsibility and challenge to accomplish their assignments.

TS confirmed, "*It will be better consolidated in my mind when I design a system and develop it with its components. In the traditional approach, after we finish a course, we might miss what we learned, but with AR and deep understanding, we never forget it. The instructor assigned us tasks, and we accepted the challenge"*.

This experience has affected students' understanding of the different system components, including installation and uninstallation, especially since the microwave engineering course covers a wide range of concepts and systems containing a lot of components.

ZH said, "*We benefited a lot, when we became able to look inside the components, identify, separate, and insert them into a system, as well as adding audio or video to the lessons to explain and learn them easily. It became easy for the teacher to communicate the idea to us. Instead of an image, we deal with a 3D model, move, rotate and identify it and its operation principle".*

4. Interest and Enjoyment

The students expressed their interest in using AR in teaching and learning as a unique and new experience that they enjoyed while doing their assignments, as EON provides different models that could be used as the most appropriate ones in a motivating way. Moreover, students disseminated their experience to their families and colleagues and expressed their interest and passion. Some of them suggested designing models and presenting their graduation projects using AR or VR technology.

5. Risk, Cost, and Time Reduction

One of the most important benefits of AR in education is time and cost reduction while practicing the practical part of a course.

SH *reported "AR based learning saves our time and money when we design a virtual model instead of using real hardware".*

Finally, AR-based learning offers more benefits, such as enhancing students' self-confidence and research skills. It positively changed their personalities and the way they dealt with their colleagues through teamwork and the desire to learn emerging technologies.

Challenges

As with any other emerging technology, AR has several advantages and provides users with a lot of benefits. At the same time, it has some disadvantages, and users might face some challenges. Fidan & Tuncel (2019) referred to the limitations of using AR, which include effects on physical health and technical difficulties in the learning activities. This study generated five subcodes, as will be discussed in the following subsections.

1. AR Technology Resistance

The main challenge that faced the students in this experiment was AR technology resistance, which is related to rejection or nonacceptance of emerging technologies.

TS said, *"Some team members did not prefer to work with AR technology. I think they will feel sorry since we are approaching a lifetime that is full of AR and other emerging technologies"*.

2. Lack of Relevant Models

The students need AR models that are relevant to their specialization, and it was difficult to find appropriate models.

AA said, "*Many models are not designed for our specialization or, sometimes, do not exist"*.

For the above reasons, students had to buy the required models or design them using appropriate applications.

3. Technical Issues

The students encountered some technical obstacles in file patching or in the design process itself, such as identifying the model's parts. This prompted them to contact technical support, which takes three working days to respond.

RQ said, *"For example, in a microwave project, we could not disassemble the 3D model into its components and could not label them. We also struggled during the microwave project with the 3D model recording and saving"*.

4. Time Issues

Another obstacle that students faced was the short time allocated to perform their assignments, as they needed a lot of time to search for an appropriate model and prepare its educational resources.

AA said, *"The problem was the short time required to conduct activities"*. MGh disagreed by saying, *"The time for each project was convenient, but I was overloaded with other courses. In general, I was able to submit all projects on time"*.

5. Negative Health Effects

Some of the other obstacles were related to negative health effects, which included stress and bad effects on the eyes, vision fatigue, and body imbalance when wearing the oculus and immersed within the AR/VR environment.

SH said, *"I should be able to balance because I was dizzy and felt body imbalance when I immersed myself within the VR environment"*.

Hope for the Future

This theme is related to students' future expectations and desires after the new experience using AR and VR in education. Hope for the future can play a major role in improving resilience and social well-being. Hope is described as a cornerstone of coping, overcoming distress, and living under unusual and painful life experiences (Mahamid, 2020). The thematic coding yielded four subthemes, developing ideas, identifying career path, spotting opportunities, and tracking learning.

1. **Developing Ideas**

AR technologies can be employed in marketing and developing business ideas or project proposals.

AA said, *"AR can be used to present ideas effectively, I can develop a 3D model for an idea that illustrates the main concept. This helps to market your ideas and yourself in the field of work".*

2. **Identifying Career Path**

AR technology has opened new career paths and job opportunities, and students can add this experience to their CVs. It will be the future profession, and the students should be encouraged with some kind of incentive for training others.

AA said, *"AR technology and metaverse experience can enrich students' CVs".*

3. **Spotting Opportunities**

It can be described as using imagination and abilities to identify opportunities for creating a value (Bacigalupo et al., 2016). In the near future, modern technologies, such as XR, will spot new business or investment opportunities.

4. **Tracking Students' Learning**

The use of AR/VR in education can positively affect students' learning methods, as it transforms learning into a vibrant, motivating, and enjoyable process, especially for school students trying to understand difficult topics.

RKh said, *"Some lectures are usually boring, but with EON you can zoom in and zoom out 3D models and explain complicated topics in a couple of words in a nice and understandable way".*

Reflections

Reflection can be defined as giving the students an opportunity to do self-evaluation and debriefing at the end of a lesson or evaluation of a technology. At this point, students should set some of their own goals, monitor their progress, show evidence of what they have learned, and share it with others (Cavilla, 2017). Results show that the students' experience with AR-based learning reflected positively on their learning progress. Their imagination skills improved when they manipulated the 3D models for new concepts. This enabled them to employ visualization, drawing, and design of new models to view them clearly in detail, which led to effective acquisition of new concepts and improved their knowledge.

AA said, "*Engineering requires some imagination skills. The instructor used to show us some systems in the surrounding environment, such as the communication towers on the mountains, that we could not see very well. With AR, we can see these towers closely in detail and the instructor can explain better, so we generated some new ideas that have been in our minds before."*

Furthermore, students should have some necessary skills; such as design, presentation, research, persuasion, and imagination skills. This facilitates how the students present their ideas and can be easily acquired throughout the training sessions.

AGh said, *"Of course, imagination, recitation, and idea delivery are the most important skills, i.e., how the student arranges his speech and presentation, since not all of us have the same design skills. I took on the role of a teacher who wants to present a lesson efficiently"*.

Attitudes

Attitudes towards a behavior refer to the individual's positive or negative evaluation of a behavior. It can be seen as environmental education, cultural awareness, curiosity, seeking learning opportunities, working with technology experts, and trying new technologies (Sahin & Yilmaz, 2020). The AR intervention was attractive and made it easier to learn and memorize, as the instructor used to show students a set of videos and simulations, making it for him to explain the lessons. It also led to an increase in students' desire to design 3D models that are not available on the Internet for free

AGh said: *"When we develop a lesson in details and answer its questions, the instructor will not make big efforts to explain it, and we will understand it easily"*.

Unlike traditional methods, students felt that they were actually living the experience, and the training increased their challenge and willingness to study.

MGh said, *"Unlike other courses, I started to learn more and to gain more knowledge"*.

Discussion

The findings of this research revealed a contribution of instructional design using AR-based learning to improve all dimensions of students' motivation, i.e., attention, relevance, confidence, satisfaction, and volition (ARCS-V), which matches the findings of previous studies (Badilla-Quintana et al., 2020; Khan et al., 2019b). The researchers justify this result by saying that motivation develops when students' learning is meaningful, satisfactory, and related to their goals, and when they have confidence to succeed in their tasks. So, the learners raise their motivation towards the learning material, activities, animation and videos, voice-recorded lessons, model design, illustrations and examples, simplified concepts, practical exercises, and final projects. AR-based learning improves learners' motivation through teamwork, feedback, achievement, exchange of experience, and time and place flexibility. This agrees with Moreno-Guerrero et al.'s (2020) findings that AR was effective in teaching students, especially for the acquisition of spatial-oriented content.

Regarding the experimental groups' reflective thinking supplemented with AR applications, our findings show that habitual action, understanding, and critical reflection are significantly higher in the microwave engineering course. The researchers explained this result by saying that students begin to design AR models many times and to solve the related activities without difficulty (i.e., a habitual-action activity). This lets them understand the concepts better (i.e., an understanding activity), think about their work (i.e., a reflection activity), and then try to make their work better in a different way (i.e., a critical-thinking activity). This conforms with Chang (2019), Ozdamli and Hursen (2017) who point to positive views toward AR applications in education. However, the reflection dimension was not significant since reflection appears in exploring action reasons or assumptions that usually occur but are rarely observed (Kember et al., 2000). The researchers suggest providing students with training on writing reflections as well as implementing reflection in a structured and intentional manner to improve their reflection (Cavilla, 2017).

Related to qualitative data from the interview transcripts, thematic coding revealed seven themes in the codebook: prior experience, initial impression, benefits, challenges, attitudes, hope for the future, and reflection. Some of these codes have two or more subthemes.

The above themes agree with either themes or subthemes of the previous studies. For instance, Ozdamli & Hursen (2017) revealed an advantages theme that includes subthemes like enhanced enjoyment, increased interest, and help to understand. Moreover, Karagozlu (2021) proposed codes such as easing understanding, getting excited, being happy, making the lesson fun, and permanence of what is learned. Our codes and evidence segments quoted from the sample students in the microwave engineering course revealed that the AR videos through the EON-XR platform assisted in explaining the complex concepts being taught. The AR features increased students' motivation to memorize these concepts as well. Furthermore, the design of AR models enabled students to align the lessons learned with their life skills, and the related activities were useful in engaging students and getting them to ask more questions. These activities were more student-driven and less teacher-directed, which enhanced their learning and, therefore, helped them perform better on their assignments and exams. On the other hand, this research explored the challenges of using AR technology in education, such as technical issues, time issues, negative health effects, and the long time allocated for students to perform their assignments.

However, this research has some limitations that should be addressed later in future research. The sample size was relatively small, and the experiment focused on one course only. In addition, practicing AR-based learning was based on one short semester, which is insufficient to provide training for students and instructors and to generalize results. Furthermore, the ARCS-V motivation and reflective thinking scales need to be tested more frequently on AR-based courses in the Palestinian education context. In addition, the novelty of the AR and VR center at An-Najah National University, where AR is employed in teaching and learning for the first time, Accordingly, the participants expressed that the implementation of AR needs more experience and evaluation.

Conclusion

The main contribution of this study is the investigation of two important factors affecting students' learning and instructors' teaching, i.e., motivation and reflective thinking, while introducing augmented reality (AR) in education, which shapes the future of the metaverse. This comprehensive study employs the ARCS-V scale, which includes attention, relevance, confidence, satisfaction, and volition. After an intensive work with students and instructors, this section summarizes our main conclusions from the experiments on the sample practicing AR with the EON-XR platform in the learning and teaching of a telecommunication engineering course at An-Najah National University.

It has been approved that AR-based learning contributes to improving students' motivation, since it allows effective learners' communication that enables them to develop their motivation through suitable feedback. Additionally, AR-based instructional approaches take into account student adaptive learning, allowing each student to study fearlessly in accordance with his or her aptitude, desire, and learning speed. Moreover, AR-based videos help teachers communicate and help students memorize difficult concepts. As a result of the design of AR models and related student-driven activities, students' motivation and, hence, their performance on assignments and tests improves. They develop new abilities that help them connect what they have learned to practical life experiences.

Since AR is a new technology, the Palestinian educational system might take advantage of its benefits by incorporating it into the teaching and learning processes in Palestinian schools and universities. In light of the fact that science, technology, and engineering courses are replete with difficult concepts that call for creative thinking, the researchers advise that the curricula in the Palestinian HEIs be supported with AR. This experience can be gradually applied to other courses in various fields later.

The success of this experiment requires HEIs to provide training programs for instructors who will be designing courses and lessons based on AR and VR applications. In order to improve student learning, it is also advised that teachers optimize the current features in accordance with the available ICT infrastructure. Additionally, collaborative initiatives and networking with peer institutions worldwide are required to prepare the tools and requirements to adopt AR technology, such as software, technical equipment, tutorials, training, and the exchange of experience and best practices. Leading this endeavor should be the development of educational policies and plans for incorporating augmented reality into the classroom. This will increase the likelihood that learners will be extremely motivated and equipped with reflective thinking skills in their lifelong learning. According to certain earlier research, the learning content becomes meaningful and relevant for both genders when motivation is increased in a digital setting. So, future studies will be done to evaluate the impact of integrating AR into learning different subjects among both genders of students.

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