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Augmented Reality in Higher Education: Perspectives of Telecommunication Engineering Students

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ABSTRACT

Objectives: The paper presents a novel experiment in Palestinian higher education that uses augmented reality technology. The study employs qualitative methods. **Methods:** The experiment was carried out on 15 students enrolled in microwave engineering course at An-Najah National University's telecommunication engineering department. With the research sample, semi-structured interviews and surveys were conducted, and the obtained data was analysed using theme coding. **Findings:** The qualitative analysis and thematic coding produce seven major topics, including benefits, future hope, challenges, reflections, initial impression, attitudes, and prior experience. The highest frequency was for benefits with 34.6% and the lowest frequency was for prior experience with 6.3%.

Keywords: Augmented Reality, Educational Technology, Telecommunication Engineering.

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الواقع المعزز في التعليم العالي: وجهات نظر طلبة هندسة الاتصالات

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ملخص

الأهداف: يعرض البحث تجربة جديدة في التعليم العالي الفلسطيني تستخدم تقنية الواقع المعزز. تستخدم الدراسة الأساليب النوعية، حيث أجريت تجربة على 15 طالباً مسجلين في مساق هندسة الميكروويف في قسم هندسة الاتصالات في جامعة النجاح الوطنية. **الأدوات:** تم إجراء مقابلات شبه منظمة مع عينة البحث، وتم تحليل البيانات التي تم الحصول عليها باستخدام التحليل النوعي وترميز المواضيع. **النتائج:** أظهرت نتائج التحليل النوعي وترميز المواضيع سبعة مواضيع رئيسية، تضمنت الفوائد، وآمال المستقبل، والتحديات، والتأملات، والانطباع الأولي، والاتجاهات، والخبرات السابقة. أظهرت النتائج أن أعلى تكرار كان للفوائد بنسبة 34.6%، وكان أقل تكرار للخبرة السابقة بنسبة 6.3%.

الكلمات المفتاحية: الواقع المعزز، تكنولوجيا التعليم، هندسة الاتصالات.

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Introduction

AR can be integrated into educational instruction in various ways(Wilms et al., 2017). For example, interactive teaching systems are used to present virtual objects that can be manipulated to observe and analyze them from different perspectives. Furthermore, augmented reality can be used to guide students in their learning process, by providing additional information such as hints, tips, and explanations. Moreover, AR-assisted laboratories can be used to provide students with realistic virtual environments and simulations of experiments. This can help them to understand the concepts better. AR can also be used in the classroom to support individualized instruction, by giving students the opportunity to explore and manipulate objects in their own way, thus increasing the level of engagement and level of understanding.

AR provides new teaching and learning methods at schools or universities to enhance their effectiveness and attractiveness with an increasing ability to use ICT and related devices, such as computers, tablets, headsets and smart phones that support AR applications (Safar et al., 2017). In this context, it is necessary to distinguish Virtual Reality (VR), which refers to adding elements of reality to a virtual environment and includes more virtual information compared with AR that contains more real than virtual information (Wu et al., 2013). Both AR and VR conform to the Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2009), which states that a meaningful learning should merge text with graphical resources, such as pictures, videos, animation and simulation, to maximize learning effectiveness.

Many studies have been conducted related to higher education environment, such as (Sáez-López et al., 2020), which investigated the impact of AR training on instructors' attitudes and practices using qualitative and quantitative methods. Results showed significant benefits to the participants in different domains, such as creativity, innovation, participation, and motivation. Similarly, Iatsyshyn & Kovach (2020) applied AR technologies to educate students on Ukraine universities, which revealed a positive impact on learning outcomes, increased learners'

interest for subjects and learners' motivation for independent educational activities (Iatsyshyn & Kovach, 2020).

Finally, AR can be used to motivate students and foster collaboration, by providing students with the opportunity to work together to solve problems and explore new ideas. This can lead to increased knowledge and skills, as well as increased motivation to learn. In conclusion, the integration of augmented reality into education offers exciting possibilities for improving teaching and learning. AR can be used to create engaging, interactive learning experiences.

Literature Review

AR is a technology that allows for student-centered exploration and data collection and observation when fieldwork is impractical. It also allows for contact with students or instructors and enables online access to research material instantly. Studies have been conducted related to higher education environments, such as Sáez-López et al and Iatsyshyn (Iatsyshyn, 2020; Sáez-López et al., 2020). The most significant advantage of AR is the integration of the virtual environment's contribution with the reality of the classroom. Games were implemented to enhance learners' self-confidence in an elementary school for learners with different disabilities(Medina Herrera et al., 2019; Omar et al., 2019).

Augmented Reality (AR) technology overlays virtual objects into the real world (Akçayır & Akçayır, 2017). It is defined as "a situation in which a real world context is dynamically overlaid with coherent location or context-sensitive virtual information" (Diegmann et al ., 2015). AR is recognized as a technology with a higher impact on university education (Sáez-López et al., 2020). Karagozlu (2021) indicated that AR promotes improved learning performance, enhances university students' practices, and aids in the development of good attitudes about laboratory work (ALharahsheh & Al-Dhiabat,2021). Moreover, AR was reported as an emerging technology that can be employed as a new strategy for enhancing teaching and learning.

Another study underlined that AR can build today's learners' required abilities, such as varied evaluation, collaborative learning, problem-

solving, and comprehending hard concepts(Leal Filho et al., 2020). Moreover, AR can support the student-centered learning process by increasing classroom interaction, cooperation, retention of knowledge, and design of learning tasks. Additionally, AR can improve the academic achievement of learners with and without special educational needs and is effective in deeper student engagement, perceived enjoyment, and positive attitudes(Sabbah et al., 2023). Papakostas, Nesenbergs, Ajit et al., Sommerrauer & Müller, and Diegmann et al. have all conducted systematic reviews on the use of AR in engineering education and students' spatial ability training. Papakostas reviewed 32 related studies and classified them into three categories: learning outcomes, pedagogical affordances, and technical perspectives (Sommerauer & Müller, 2018).

Nesenbergs conducted a systematic review of 30 articles from the Web of Science database, which revealed 11 positive, seven negative, and six interventions with no impact. Ajit (2021) conducted a review related to the advantages and difficulties faced by using AR in teaching STEM(Ajit et al., 2021). Sommerrauer & Müller (2018) focused on theoretical and empirical foundations for using AR in teaching and learning.

Problem Statement

Universities face many challenges, such as low student interest, teaching methods and techniques, teacher characteristics, and lack of tools and equipment(Omar et al., 2019). AR is believed to be an effective strategy to help learners to study, think, and shift their learning into the real world (monaem, 2020). AR provides better learning performance, motivation, perceived enjoyment, the decreased cost of education, positive attitudes and engagement, and helps to keep pace with technological development(Medina Herrera et al., 2019).

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, help to keep pace with technological development and to achieve satisfactory results (Lee et al., 2019). This encourages the use of technology to better prepare learners, instructors,

teaching techniques, and curriculum in an effort to improve the educational process and deliver better teaching practices. Students, on the other hand, have unfavourable views about education, according to Karagozlu (2021), because the delivered lectures do not encourage learning by doing or via experience, and there is a gap in the degree of instructors' qualifications. Furthermore, the practical aspect of some activities in teaching practices is impossible due to their high cost, time commitment, or health risks (Darling-Hammond et al., 2020).

This study (Sabbah et al., 2023)looks at the use of Augmented Reality (AR) in teaching and learning among university students in Palestine. It aims to explore the viewpoints of Telecommunication Engineering students on AR-based learning. AR is thought to be one of the most effective tools for assisting learners in studying, thinking, and applying their information in the actual world. It introduces new technology that can be used to improve teaching. The research question is: What are the learners' perspectives on using AR technology in the classroom?

Methodology

The researchers used a qualitative research design to investigate the influence of using AR technology on learners. The sample consisted of 15 students from An-Najah National University using the EON-XR platform for AR-based learning. The students who enrolled in the experiment are third and fourth years, and their age is between 20-21 years old. A semi-structured interview approach was employed, involving 45–60-minute interviews with individuals who agreed to have their comments recorded and signed a consent form. The interviewer asked questions to ensure that the participants understood what the questions meant. To acquire precise data and results, the researcher created a reflective notebook. The qualitative data was analyzed using content and thematic analysis methodologies, with the transcribed documents put into MAXQDA for categorizing the textual data and extracting the key themes.

Data Collection

In this section we used inductive analysis process of the interviews using MAXQDA20 to introduce the results. The interviews were analyzed

following thematic coding and content analysis methodology (Parker, 2005) to identify the codebook that consists of the main themes emerging from the written material based on bottom-up data driven text analysis to extract codes. After reading the responses of each participant carefully, the concepts and statements containing similar words were identified, and the analysis process continued as follows: (a) open coding from the participants' narratives to generate the main themes; (b) the codes and subcodes were organized into structured text; and (c) the codes and subcodes were discussed and elaborated with evidences of the extracted segments (Mahamid, 2020).

Experiment Design

The researchers conducted an experiment on Microwave Engineering course in a telecommunication engineering program. They followed the five stages of the ADDIE model, which included analysis, design, develop, implement, and evaluate. The experiment required the students to have smartphones connected to the Internet, EON-XR accounts, and headsets. A training was conducted on the EON-XR platform and some pedagogical knowledge was provided.

The researchers followed the five stages of ADDIE model as shown in table 1, to conduct this experiment, as follows:

Analyze: this is the first phase that is essential to develop the next phases. It includes 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 the experiment are fourth year in the telecommunication engineering program.

Design: this stage is essential to design the scales and identify the lesson objectives, the learning styles and the teaching strategies.

Develop: in this stage, the educational resources are developed using 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 covered the content to extend students' learning rather than testing their existing knowledge.

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

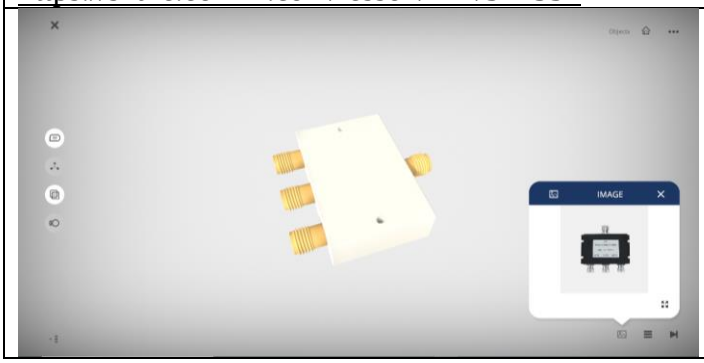
Figure 1 illustrate a documentary photo of the lessons and experiments using the EON-XR platform in learning.

Figure (1): A documentary photo of a lesson.

Table (1): A sample lesson for microwave engineering course based on ADDIE model.

LESSON TITLE: Power Divider.
LESSON INTRODUCTION
Power dividers and directional couplers are passive devices used mostly in the field of radio technology. They couple a defined amount of electromagnetic power in a transmission line to a port enabling the signal to be used in another circuit.
INTENDED LESSON LEARNING OUTCOMES/OBJECTIVES
(*What do you expect users to know and be able to do by the end of the lesson?)* The aims of this project are:

<table>
<tr><td colspan="2">1. Describe the shape of the main components of the power divider.
2. List the types of power dividers.</td></tr>
<tr><td>DESCRIPTION
(What will users see, what happens in this lesson?) Digital Asset/Model Name: The model added from the grab cad site, which have one input port and three output ports.</td><td>USER ACTIONS
(e.g. explore model, ray, exploded view)
Xray</td></tr>
<tr><td colspan="2">SCRIPT INFORMATION:
Text to Speech: Yes
Audio uploaded file: Yes</td></tr>
<tr><td>SUPPLEMENTARY MATERIALS
Video Used: Yes Copyrights: Yes</td><td>VIDEO DESCRIPTION
The video talk about the described model.</td></tr>
<tr><td>LESSON OPTIONS
The lesson can be presented using VR with Oculus and using AR with a smartphone. Both require an EON-XR account and the App.</td><td>AR APPROACH
(How will learners use AR?)
Download EON-XR mobile App, then open the App and start the lesson, and click the option that operates AR.</td></tr>
<tr><td colspan="2">SCREEN RECORDING
1. Components of power divider
2. Type of power divider
3. Applications of power divider
4. Uses of power divider
5. How the power divider works.
6. The other names of the power divider.</td></tr>
<tr><td colspan="2">IDENTIFY
The main aim of this project is to show the power divider using virtual reality, and the basic concept of strip line in practical examples, not in the theoretical equation.</td></tr>
</table>

<table>
<tr><td colspan="2">QUIZZES: (How many quizzes are there, and where will they be located?)</td></tr>
<tr><td>Four questions are designed:
Q1. This model is called:
a) Power splitter
b) Power compiler
c) Power divider
d) All
Q3: What are the uses of a power divider:
a) To divide a power source equally between the output signals
b) A&D
c) Not mention
d) Test system to measure two different characteristic signals.</td><td>Q2. What is the type of power divider?
a) reactive
b) resistive
c) A&B
d) No type
Q4: The model is:
a) 2 ports
b) 4 ports
c) 5 ports
d) 8 ports</td></tr>
<tr><td colspan="2">THE LESSON’S LINK
https://share.eon-xr.com/lesson/424/312534</td></tr>
<tr><td colspan="2"> 
</td></tr>
</table>

RESULT

The researchers used MAXQDA20 to generate a codebook of seven main themes. A codebook was generated that constitutes seven main themes: Reflection, Prior Experience, Initial Impression, Benefits, Challenges, Attitudes, and Hope for the Future. Figure 2 illustrates MAXMaps of the generated codes and subcodes using MXQDA20.

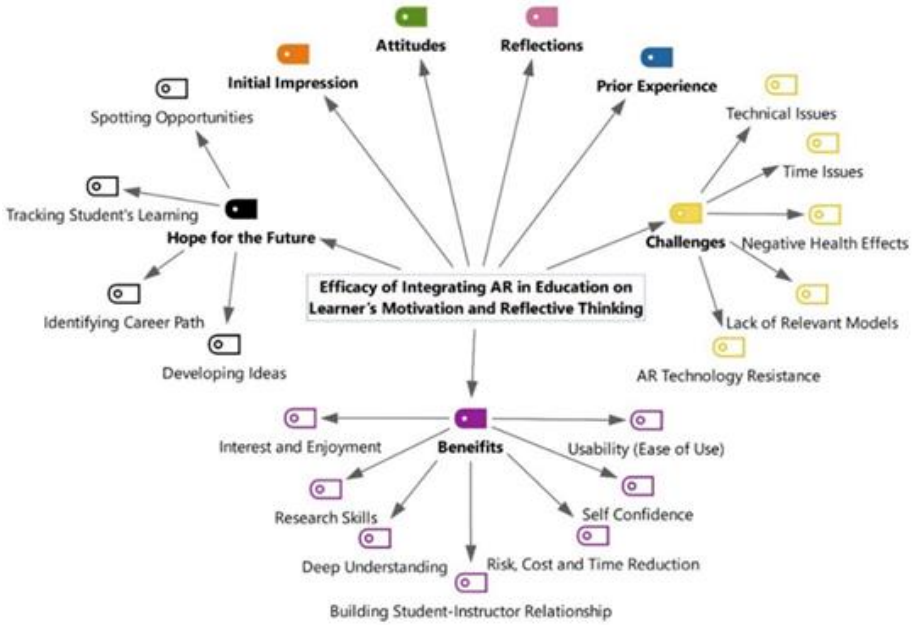


Figure (2): Code-subcode-segments model in MAXMaps.

In this research, the students designed their lessons based on the models available in the EON-XR platform. Table 1 shows a sample lesson developed by the students using a template designed by the researchers for this purpose.

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 3 illustrates the code segments' frequency distribution, the MXQDA program calculates the frequency of each theme by counting the number of instances or segments of data that are assigned to each theme. This provides an indication of how frequently certain themes appear in the data. where the highest frequency was for benefits at 34.6% and the lowest frequency was for prior experience at 6.3%.

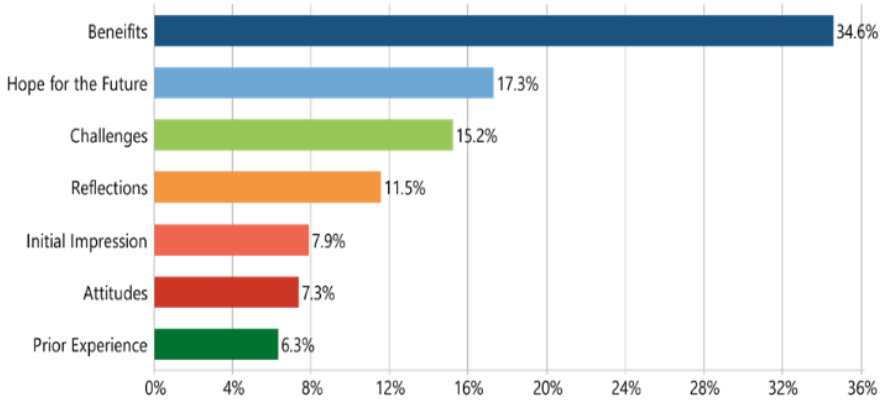


Figure (3): Frequency distribution of the code segments.

Prior experience

Prior experience is a set of misconceptions that can interfere with teaching and learning in a new learning environment (Rakap, 2010).Results show that all students have no prior experience related to AR or VR in education, but some experience in 3D virtual games, cinema, watching 3D films, scientific experiments, or VR books.

For instance, AA said, "*I have some knowledge related to VR-based games, 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

An initial impression is an initial opinion and perception formed regarding people, phenomena, technologies, events, or concepts(Ajit et al., 2021). Results show that students were divided into two groups: the first group struggled with AR technology and had technostress, while the second group felt excited to use AR technology and were satisfied with their assignments and homework.

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 study. Even though it was an enthusiastic experience"*.

Benefits

This text summarizes the main benefits gained during an experiment in AR-based courses. These benefits were classified into seven sub-themes: Building Student-Instructor Relationships, Usability (Ease of Use), Deep Understanding, Interest and Enjoyment, Risk, Cost and Time Reduction, and Self-confidence and Research Skills. The students described the AR-EON platform as an easy one, suitable for all ages and disciplines. The students expressed their satisfaction in dealing with the instructor as a result of continuous communication inside and outside the classroom. The students described the courses in Telecommunication engineering as applied courses that require imagination skills (Karagozlu, 2021).

The students expressed their interest and passion for using AR in teaching and learning as a unique and new experience. The most important benefits of AR in education are related to time and cost reduction while practicing the practical part of a course. Finally, AR-based learning offers more benefits such as enhancing students' self-confidence and research skills.

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TS said, *"I used to search for certain 3D objects and models, which enhanced my research abilities. I was trying to design a model and upload it to the portal, but the upload process failed. I contacted the company to solve this technical error, and I'm still waiting for their response".*

Challenges

AR technology has several advantages, but it also has some disadvantages. This study generated five subcodes, including AR technology resistance, lack of relevant models, technical issues, time issues, and negative health effects. AR technology resistance was related to the rejection or nonacceptance of emerging technologies, while a lack of relevant models was difficult to find. Technical issues included file patching, time issues, and negative health effects. MGh was able to submit all projects on time. Negative health effects included stress and bad effects on the eyes, vision fatigue, and body imbalance.

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

Hope for the Future

Hope for the Future is a theme related to students' future expectations and desires after using AR/VR in education (Darling-Hammond et al., 2019). It includes four subthemes: developing ideas, identifying career paths, spotting opportunities, and tracking learning. Developing ideas can be used to market ideas, identify career paths, spot opportunities, and track learning. Career paths can be added to CVs while spotting opportunities can be used to create value. Tracking learning can transform learning into a vibrant, motivating, and enjoyable process.

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 nicely and understandably".*

Reflection

Reflection is the process of self-evaluation and debriefing at the end of a lesson or evaluation of technology(Rakap, 2010). Results show that AR-based learning improved students' imagination skills, which enabled them to visualize, draw and design 3D models to view them clearly in detail. Additionally, students should have necessary skills such as design, presentation, research, persuasion, and imagination skills to facilitate how they present their ideas.

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 behave or can be seen as environmental education, cultural awareness, curiosity, seeking learning opportunities, working with technology experts, and trying new technologies. AR intervention made it easier to learn and memorize, increasing students' desire to design 3D models. Training increased the challenge and willingness to study.

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

Discussion

Thematic coding revealed seven themes in the codebook: Prior Experience, Initial Impression, Benefits, Challenges, Attitudes, Hope for the Future, and Reflection. These themes agree with themes of the previous studies. For instance, Ozdamli & Hursen (2017) revealed 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 learnt. More similar themes include feeling interested and motivated, wasting time (Medina Herrera et al., 2019), ease learning process, increase interest, interactive, assist visualization task, increase concept (Omar et al., 2019). In addition, motivation and engagement and teacher acceptance themes were suggested (Delello, 2014), as well as opportunity for collaborative communication and problem-solving among students (Kamarainen et al., 2013). These themes match with themes of our codebook such as benefits, hope for the future and challenges.

Our codes and evidence segments from the microwave engineering course sample suggested that the AR films via the EON-XR platform aided

in explaining the complicated concepts being taught. Furthermore, design of AR models enabled students to align the lessons learnt with their life skills, and the related activities were useful in engaging students and asking more questions. These activities were more student-driven and less teacher-directed, which enhanced their learning, and therefore, performed better on their assignments and exams.

In addition, results revealed that students' motivation develops when their learning becomes meaningful, satisfactory, and related to their goals, and when they have the confidence to succeed in their tasks. AR-based learning improves learners' motivation through teamwork, feedback, achievement, exchange of experience, and time/place flexibility. Finally, AR videos through the EON-XR platform assisted to explain the complex concepts being taught, and the related activities were useful in engaging students by asking more questions.

Conclusion

Thematic coding identified seven topics in the codebook related to qualitative data from interview transcripts: prior experience, initial impression, benefits, obstacles, attitudes, optimism for the future, and reflection. This research adds a new contribution to the field of teaching and learning. It investigates two important factors that affect students' learning and instructors' teaching methods, AR-based teaching approaches taking into account individual differences among students, allowing each student to learn without fear according to his aptitude, motivation, and speed.

Furthermore, AR helps educators clarify complex concepts and allows students to memorize them. The design of AR models and accompanying student-driven activities improves students' learning and engagement, resulting in higher performance on their assignments and exams. They develop new talents that allow them to apply what they've learned in real life. However, the experiment was limited to a single course in telecommunication engineering and it is recommended to be expanded to include additional subjects. Furthermore, the practice of AR-based

learning was limited to a single 16-week semester, which is insufficient to generalize outcomes.

Conflict of Interest

The authors declare no conflict of interest.

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