Marwan M.A. Abualrob
Palestine

The New Educational Review

The Affordances of Augmented Reality in Delivering the Science Curriculum to Elementary Grades

DOI: 10.15804/tner.2019.58.4.03

Abstract

The current science books for Palestinian elementary schools essentially consist of picture-based activities. Each lesson features images which students are asked to reflect on, and provide oral and written answers to questions linked to each image. This rich curriculum is being delivered in traditional methods, and few teachers have to date ventured into utilizing modern technologies that can be easily accessible. The present research effort measures the affordances of augmented reality in delivering the science curriculum to elementary grades in the West Bank. An interaction analysis study was used, in which activities from the third grade science textbook were demonstrated using AR technologies to identify their role in enhancing learners' interaction with pictures in the science school books. A sample of 50 third grade female students, from a West Bank basic school for girls, was drawn from the study population (all third grade students in the West Bank). The 50 students were divided evenly into homogeneous control and intervention groups. Seven activities were delivered conventionally for the former and with augmented reality technologies for the latter. The findings suggest that students taught with augmented reality-enhanced procedures were particularly engaged and effectively responsive, both orally and in written tasks.

Key words: *Augmented Reality, Science Curriculum, Videotaping*

Introduction

Textbooks have for centuries remained the bedrock of the teaching-learning process in all educational systems around the world. Yet the structure and content of these schoolbooks have revolutionarily evolved in the past few decades, such that the experiences students are now exposed to are very different. The purpose is very clear: the way information is presented to students is integral to how much interaction with a textbook's material learners show. And thanks to today's technological advances– with more digital content being infused into curriculum materials, more learner–textbook interaction has characterized much of what is happening inside classrooms.

With national educational systems looking ahead for aligning learning materials with today's academic standards, policymakers have started to question the relevance of the rigid traditional paper-and-ink textbooks. The assumption is that the learners' performance that was assessed by exams at the end of each unit/chapter/module in the textbook should now be measured by how well learners have acquired the preset learning objectives, be it through exams, by means of in-classroom interaction or in any other possible method of assessment (Abualrob & Al-Saadi, 2019). This has given rise to educational digital content, including augmented reality technologies.

At the Local Level

The first Palestinian curriculum saw the light only in 2001(before which Palestinian school students would study the Jordanian curriculum). It then became apparent that the new curriculum fell short of preparing the learners to acquire 21st century skills. In an effort to address the gaps, the Ministry of Education formed in 2015 a team of academics, supervisors and educators to analyze the curriculum and identify its shortcomings. The team reached the conclusion that a new curriculum was needed, a recommendation that the Ministry responded to positively (Ministry of Education and Higher Education, 2017).

Keeping up with global trends with respect to technological advances that many countries have introduced into their school systems was made a priority by the Ministry of Education. Accordingly, a plan was drafted to build curricula that allow teachers, whenever possible, to integrate technological sources that can support student learning. Right away, the Ministry commissioned its Curriculum Development Center to build a new curriculum. Soon the Center picked up steam and by July 2016 it had built the new curriculum and delivered it to schools. In designing the new textbooks, the planners acknowledged the imperative of allowing the infusion of technology into each individual unit. The planners might have envisioned a curriculum with portions offered by digitized aids, including augmented reality technologies, which would make it possible to supplement the traditional curriculum with virtual world applications.

The premise behind the initiative was that the best form of learning is that which generates a sense of knowledge, making the process a more enjoyable experience – with little traditional content and much more practice. The current science books for Palestinian elementary schools essentially consist of picture – based activities. Each lesson features images which students are asked to reflect on, and provide oral and written answers to questions linked to each image. The curriculum also incorporates components designed in a way which ensures that students are learning what they are supposed to know at each grade level. Those who drafted the schoolbooks have, it appears, assumed that schools are supposed to tap all the possibly-implemented education-related modern technologies to augment the print books. The new textbooks created wide room for integrating technology into the curriculum, which was envisioned as a tool to hone critical analysis – one of the most important targets of educational activities in the Palestinian third grade science curriculum (Abualrob & Abu-Alrub, 2018).

Literature Review

AR technology in education is a form of e-learning which is grounded in a number of theories, the most important of which is constructivism. Literature in the field shows that demonstrating the learning material using multimedia-enhanced activities supports the process of building learners' skills and competences in interactive environments, which in turn leads to better learning. According to Kukla (2000), reality is constructed by human activities.

The term "Augmented Reality" was first introduced by Thomas Caudell and David Mizell in the early 1990s (Caudell and Mizell, 1992). The notion applies when people use the 3D virtual world to simulate the real-time world. Given its potential to provide dynamic learning experiences and discovery-based learning, AR has easily found its way into education. Through practice, discovery-based learning, according to Jerome Bruner (1961), allows learners to acquire information by themselves "in a way that makes that information more readily viable in problem solving" (p. 26). By means of AR, the real environment is enhanced by digitally-generated material tied to specific activities (Yuen, 2011).

For learners, perhaps there is nothing as conductive as combining classical print books with virtual reality technologies, such as moving images displayed on a computer screen via an overhead projector. This newly-created world can construct more productive experiences that are hard to forge with classical methods of teaching. In some accounts, AR empowers learners by providing interactive methods, thus allowing learners to live a "unique discovery path with rich content from computer-generated three dimensional environments and models" (Lee, 2012: 18).

Literature in the field signals many positive outcomes of AR. It helps students engage in first-hand, authentic discovery of the real world (Dunleavy et al, 2009); it facilitates understanding of printed materials (Wu et al, 2013); it fosters learners' engagements (Sotiriou & Bogner, 2008); it assists in designing immersive hybrid learning environments that combine digital objects and conventional material (Dunleavy et al, 2009); and it builds learners' positive attitudes toward school (Akçayır & Akçayır, 2017).

Existing literature also shows that learners are happy using AR applications in the classroom (Cai et al, 2013). Not only do learners acquire realistic knowledge, they also find such an enhanced atmosphere capable of helping them overcome common misconceptions about the real world (Shelton & Hedley, 2004). Learners are enabled to construct mental patterns that guide their learning, making it easy for them to understand the world around. With such patterns, it is possible for learners to handle virtual input, which will then be projected onto real life environments, thus giving learners more skills and greater knowledge. This way, AR technologies translate rigid materials into a practical process of constructing reality – a strategy that has proved functional and motivating (Liu & Chu, 2010).

In Palestine, a small number of studies on AR application have so far been carried out. Three months into introducing the new Palestinian curriculum, Ahmed (2016) conducted a study to examine the relationship between the use of AR technologies and the development of visual thinking strategies for ninth grade science students in Gaza. Ahmed used a field method with 43 students. The material was presented to the students in a classical way. A test was then conducted and the results were recorded. The same lesson was then presented to the students using AR technologies. The students then did a post-test, and the difference in performance was significant.

A later study by Aqel and Azzam (2017) targeted seventh grade chemistry pupils in Gaza. The authors drew a sample of 93 students in two separate homogeneous sections: the first was taken as a control group, and the second as an intervention group. A lesson in chemistry was then demonstrated to both sections: one with traditional instruction, and the other with AR audiovisual materials. The two groups then did the same exam. The researchers found very significant differences in performance. Qeshta (2018) followed suit (targeting seventh graders), adopting the same methodology and reaching similar results.

Rationale

Palestinian pupils start learning science in the third grade. For the purpose of this study, I have chosen the third grade because the textbook features many picture-based activities that encourage pupils to contemplate and link what they see to their knowledge of the real world around them. Nevertheless, the rich curriculum is currently being delivered in traditional methods, and few teachers have ventured into utilizing modern technologies that can be easily accessible (Abualrob, 2019). This is attributed to a wide array of factors, including a relative failure of delivering education through AR. In many of the schools, the teachers' attitudes toward using digital content remain as barriers to proper implementation of augmented reality technologies.

In some personal interviews I conducted with elementary science teachers in the West Bank, teachers reported difficulties students have in dealing with the activities in the print textbooks, particularly analyzing pictures, which teachers said are rigid and of little use if taught in a traditional way without the help of digital supplementary material. Teachers also said it is important to use teaching aids, definitely the talk here is about AR technologies, that motivate learners and develop their thinking patterns as well as their self-reliance. These observations came to support reports by the Ministry of Education which voiced concerns about the below-expectation performance of science students in standardized tests, as well as the reluctance of college students to pursue a degree in science education (Ministry of Education and Higher Education, 2017).

This paper is an interaction analysis study of the affordances of applying AR technology in delivering science education to third graders in West Bank schools. The assumption is that the textbook environment can be enhanced by adding additional layers of information through supporting digitized materials– in our case AR technologies. The textbook would thus provide written material that can be further enhanced by such technologies, creating an environment where the student becomes an active learner who helps serve the objectives of the learning process. This way, the material is presented through dynamic, interactive simulations, making the process easy and interactive– features that print books alone cannot provide.

Methodology

This is an interaction analysis study in which activities from the third grade science textbook were demonstrated using AR technologies to identify their role in enhancing learners' interaction with pictures in the science school books. A sample of 50 third grade female students from a Khadija Khuwailed Basic School for Girls, was drawn from the study population (all third grade students in the West Bank). The 50 students were divided evenly into homogeneous control and intervention groups. The division was based on the marks record from the school.

All the activities in the third grade science book were digitized, whereby the still pictures were turned into 3D animations using AR platforms (specifically Vuforia AR application development platform and Aurasma platform). Pupils of the intervention group were asked to bring their or their parents' smart phones, to which the AR content was transferred and saved in a file on the home screen to allow for easy access by the pupils (pupils who brought smart phones shared their devices with those who could not). The teacher of the two groups was then trained on using those technologies. For some activities, the teacher's smart phone was used for demonstration via an overhead projector: questions and instructions in the book would be projected together with animated images corresponding to those in the textbook. For example, together with the question "How do snakes in the desert hide from hot temperature?", a moving image appeared in which a snake burrows in dens to hide from hot temperatures. Or, to the question "How do chameleons protect themselves from predators or other enemies?", a moving image is displayed on the screen showing a chameleon changing its color to mimic its background. See Figure 1.

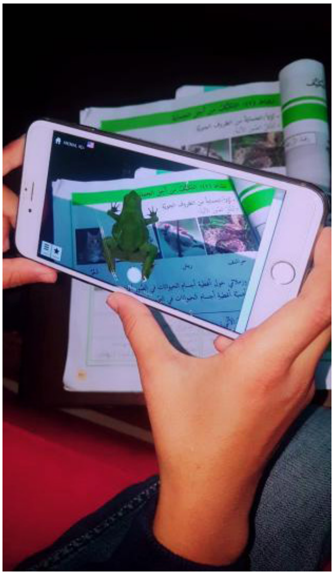


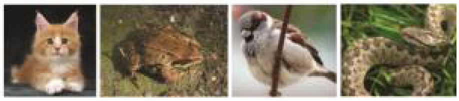
Figure 1. A sample of Textbook Activities

The AR-enhanced curriculum was delivered by the same teacher over the Spring Semester in parallel with traditional teaching methods for the control group. For the purpose of the study, seven activities were chosen for both groups and demonstrated in the regular time of the period. See Figure 2 below. The seven activities were delivered in fourteen sporadic days (seven sessions for each group), the dates of which were coordinated by the teacher and the researcher.

A picture on the cover page of a unit in the third-grade science book
Reflect on the pictures below.
What do we call the places where these creatures live?
How can these creatures live in such places?

I Adapt
Identify the creatures that can adapt to all environments: Cooperate with your classmates in interpretation

Adaptation
Think about the pictures below: snake, bird, frog, cat You and your classmates discuss the animal body coverings in the picture above
Write about the importance of these animal body coverings



Protection from enemies
Think about the pictures below. Answer the questions in collaboration with classmates:
Is it easy for an eagle in the sky to see this snake? Why? What is the purpose of adaptation camouflage? In your opinion, can humans use this camouflage strategy? How?

A picture of a kitchen
Think about the picture above:
What similarities/differences do the items in the picture have?

Aquatic environment
What are the elements of the environment pictured?

Solid? Liquid?
Describe the picture in two statements.

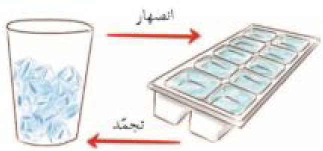


Figure 2. A sample of Textbook Activities Demonstrated by AR Technology

An interactive assessment module– with ready-made drills– was designed to allow students to simultaneously respond to questions. After each session, a worksheet (with the same questions) was given to both groups. Answers were collected and analyzed. In parallel, videotaped responses were also sorted out. This way allowed for drawing realistic comparisons between answers from the AR-intervention group and those from the control group. The demonstrations of the target activities (given to both groups) were videotaped by the researcher for the purpose of the study. Videotaping is essential when human behavior cannot be adequately described using only live observation. In analyzing the content of the videos, a Framework proposed by Creswell (2019) was used. First, all the videotaped data were extracted and transcribed on paper. Second, the transcribed data were coded for their relevance to six themes: oral and written responses; idea generation; time of interacting with images; making inquiries; concentration and participation. For validity of the procedure, two experts in education were given a sample of the transcription and asked to assess the relevance of the themes. For reliability purposes, the researcher asked a second rater to make codings for 33 percent of the videotaped material as well as for the written responses. To measure interrater agreement, the Kappa statistic was used, and results showed an acceptable level (0.6–0.75).

Discussion

While analyzing written answers was a straightforward, easy process, sorting out videotaped material took a lot of time and effort. However, videotaped data were found to be relevant and quite helpful, since I had the opportunity to play the recorded materials several times and compare them to the transcriptions, thus gaining more insights that informed the analysis. According to Garcez et al, "the proper use of the moving image, coupled with the audio, allows capturing aspects that may go unnoticed when other resources are used"(2011: 250). The analysis of the collected data focused on six aspects:

Oral and written responses

In analyzing the videotaped material, it has been found that the students of the intervention group were more capable than those in the control group in responding orally to the questions. This comes as no surprise, since students are familiar with technology: they use their smart phones at home and wherever they go (Table 1 and Table 2).

Table 1. Oral Expression: Animals Adaptation to Their Habitat

	Intervention Group				Control Group			
Activity 2: Animals Adaptation to Their Habitat	**No. of Students**	**No. of students with correct answers**	**Duration of responses**	**Duration average**	**No. of Students**	**No. of students with correct answers**	**Duration of responses**	**Duration average**
Description of snakes' skin scales	7	3	S1=20 sec S2=17 sec S6=21 sec	**16 sec**	7	2	S1=7 sec S5=10 sec	**8.5 sec**
Description of snakes' adaptation	5	4	S7=12 sec S3=8 sec S9=12 sec S10=10 sec	**10.5 sec**	5	3	S9=5 sec S11=8 sec S12=6 sec	**6.33 sec**
Explaining the purpose of adaptation	5	3	S13=10 sec S14=11 sec S15=14 sec	**11.66 sec**	5	2	S14=10 sec S16=4 sec	**7 sec**
Explaining how humans can use snake strategies of adaptation	8	4	S19=12 sec S20=11 sec S21=10 sec S22=11 sec	**11 sec**	8	2	S1=9 sec S22=6 sec	**7.5 sec**
Average response	25	14			25	9		

When asked to reflect on the images orally, the group with the digitized content was much more responsive than the other group. For example, one of the instructions asks learners to say whether humans can use the strategies of camouflage that chameleons use to hide from predators. Students in the AR group described orally how soldiers use clothes that mimic the physical environment background for lurking. At the body language level, the same group students used hand movements, gestures and face expressions to show their surprise the moment they saw the snake burrowing in dens to hide in the sand. In this last encounter, the students in the control group showed no particular reaction looking at a static picture in the textbook. Out of 25 students within the AR group, 14 students provided correct answers, and the average duration of their responses to all questions within the activity had a range of 10.5–16 seconds (against 6.33–8.5 for the control group).

Table 2. Written Responses: Animals Adaptation to Their Habitat

Activity 2: Animals Adaptation to Their Habitat	Intervention Group No. of students with correct answers	Control Group No. of students with correct answers
Writing the type of adaptation	14	10
Explaining the purpose of adaptation	15	10
Writing description of the snake's environment	18	12
Explaining how humans can use snake strategies of adaptation	15	7
Organizing ideas	16	7
Clarity of language	14	15
Average No. of students with correct answers	**13**	**9**

Worksheets were designed to test the written performance of the target students. For example, one activity involved 6 items- those same activities that were used for oral expression. The average number of students who provided correct answers to the items within the activity was 13, compared with 9 students from the control group, as shown in Table 2.

Idea Generation

The interaction with the moving images that AR platforms provide can help learners connect with the lesson and engage on a deeper level. The AR-supported images allow learners to look at the pictures (which come alive right in front of them) and think about many things at a time, while generating ideas from different angles. For example, with the help of digital technologies, the student can zoom through the face of a lion, thinking about how it captures its prey; or the limbs of a deer to show how fast it can run and hide from big cats. Animated, vibrant and life-like images can also generate ideas regarding the habitat of an animal, as well as its relationship with other species in the same environment. By contrast, the pictures in the textbook are lifeless images that allow for little reasoning and minimal interaction.

Helped by AR-enhanced learning, the students in the intervention group outperformed their counterparts within the control group. For example, when asked to describe the cover picture of Unit Three in the science textbook (which features animals in different environments with different adaptation strategies), the description of the control group students was brief, general and minimal: "Different animals in different places." By comparison, responses from the intervention groups were more detailed, yet more specific: "Fish have streamlined body shape which allows them to move easily in water. Horses eat grass thanks to their strong teeth."

More time interacting with images

The use of AR technology increased the time of interaction with the images featured in the activities. This is natural because students are familiar with–and they prefer– using virtual world technologies such as smart phones and tablets. With such identification (which, it appears, echoed well with students' attitudes), students were found to be happy spending more time on an activity compared with students in the traditional classroom setting. For each activity, students in the intervention group spent 7 minutes on average more than the time spent on the same activities in the control group– which meant more interaction and more effective communication. For example, students with AR-enhanced demonstrations spent 15 minutes discussing the unit's cover picture, compared to only 4 minutes by the students in the control group (See Table 4 below).

Table 3. Time spent on describing pictures

Activity	Time spent (in minutes): Control group	Time spent (in minutes): Intervention group
Unit 3 cover picture: Animals' strategies of adapting to different environments	4	15
Activity 1 pictures: I adapt	6	13
Activity 2 pictures: Protection from harsh weather conditions	3	10

Activity	Time spent (in minutes): Control group	Time spent (in minutes): Intervention group
Activity 3 pictures: Protection from enemies	2	8
A picture of an aquatic environment	2	7
Unit 4 cover picture: Matter and temperature	4	11
Activity 2 pictures: solid, liquid	2	6

Making Inquiries

The AR aids provided the learners with links to their real world, making the experience appealing and urging learners to ask questions proactively. The questions focused on exploring things right in front of them. Hearing answers from other students and student-student discussion were found to be productive, as they created a learning-friendly classroom. In his model about experience and learning, Edgar Dale (1969) observed that while people generally remember 10 percent of what they read, they tend to remember 70 percent of what they say and write, as in this way they simulate a real-life experience.

Table 4 below shows the number, type and nature of questions raised by the intervention and control groups. Students in the intervention group were found to raise more questions. As well, the questions by the intervention group were more probing and relevant.

Table 4. Number, type and nature of questions raised by the intervention and control groups

	Control Group			Intervention Group		
Activities	Number of questions	Type of questions: (probing, simple)	Nature of questions: relevant/irrelevant	Number of questions	Type of questions: (probing, simple)	Nature of questions: relevant/irrelevant
Unit 3 cover picture: Animals strategies of adapting to different environments	8	2, 6	1, 7	18	6, 12	8, 10
Activity 1 pictures: I adapt	10	4, 6	3, 7	14	6, 8	7, 7
Activity 2 pictures: Protection from harsh weather conditions	11	2, 9	4, 7	14	8, 6	4, 10

Activities	Control Group			Intervention Group		
	Number of questions	Type of questions: (probing, simple)	Nature of questions: relevant/irrelevant	Number of questions	Type of questions: (probing, simple)	Nature of questions: relevant/irrelevant
Activity 3 pictures: Protection from enemies	8	3, 5	4, 4	13	4, 9	8, 5
A picture of an aquatic environment	7	2, 5	2, 5	11	6, 5	7, 4
Unit 4 cover picture: Matter and temperature	8	3, 5	4, 4	12	6, 6	7, 5
Activity 2 pictures: solid, liquid, gas	6	1, 5	2, 4	8	3, 5	3, 5
Average No. of inquiries	**58**	**17, 41**	**20, 38**	**90**	**39, 51**	**44, 46**

Looking at the figures above in detail, one can notice that the average number of inquiries raised by the intervention group (90) was much higher than the figure for the control group (58), which supports the assumption that AR technologies not only enhance learners' responses, but also encourage such learners to ask more questions. This is also true for the types and nature of the questions, with those from the intervention group being more relevant (with an average of 44 vs. 20 for the control group) and more probing (39 vs. 17 for the control group).

Concentration

Regardless of how intelligent learners are, they still need adequate concentration/listening skills. Learners who pay attention during lesson demonstration are more likely to be prepared for productive in-class discussion. The use of the digitized content increased the concentration of students a lot. The novel strategy, where static pictures were turned into moving images, could explain the identifiable attention students have shown. By contrast, we noticed that many pupils within the control group seemed to be distracted. It is plausible to assume that concentration is key to effective learning. Concentrating students seemed to release their thought from all other things, instead focusing on the activity they were dealing with. Paying attention is found to be indispensible to acquire construct knowledge and respond whenever a response is needed. According to Theron Dumont, "the person that is able to concentrate utilizes all constructive thoughts and shuts out all destructive ones." (2012: 2).

Three pieces from the video (1 minute from the beginning of the recording, 1 minute from the middle and 1 from the last part) were played several times to give credence to the assumptions derived from observation. The focus was particularly on engagement of different types (visual, auditory, kinesthetic). With the AR group, the learners looked more engaged, as evidenced by the face expressions and body language during demonstration. The AR students were also more heavily immersed in terms of time, as learners maintained their engagement all the time the lesson was running. The affordances of combining learning, playing and watching at a time, it appears, have positively affected the way the AR students identified with the activities.

Participation

Watching the video of the AR-enhanced lesson, it was crystal clear that the technology used helped learners become more engaged. The revolutionary way of presenting content enhanced interaction and led to more active participation. In the demonstration of the lesson on animals, the pupils only needed to point the curser towards the textbook image of the animal, and an interactive 3D model of that animal came forth on the smart phone screen, allowing pupils to visualize animals as though they were in the real world, therefore activating the senses of hearing and seeing, as well as marked kinesthetic engagement. With learners gaining deeper, live information– with the textbook becoming interactive– the level of participation increased and the learners became eager to participate, now that they feel they have something to share with their classmates and the teacher.

Table 5. Students' Participation

Intervention Group								
Item / Activity	1	2	3	4	5	6	7	Average
Students participated	14	22	14	25	23	12	11	17.3
Students linked what they learned to their own real-life experiences (movies, videogames, 3D TV)	11	10	9	12	10	4	10	9.42
Student-student interaction about the lesson	12	22	14	25	18	12	8	15.86

Control Group								
	1	2	3	4	5	6	7	**Average**
Students participated	13	10	10	18	11	8	8	11.14
Students linked what they learned to their own real-life experiences (movies, videog-ames, 3D TV)	0	1	2	0	0	0	0	0.43
Student-student interaction about the lesson	10	6	8	10	8	6	6	7.71

As shown in the Table above, the participation level for the AR group was much higher than that of the control group 17.3 and 11.14, respectively). This was also the case for linking learned material to real-life experiences (an average of 9.42 students within the AR group against an anemic 0.43) figure for the control group). Finally, students–student interaction within the AR group was more pronounced compared to the control group (an average of 15.86 students against 7.71 students).

Conclusion

Many of the most important forms of e-learning are AR technologies, a present-day response to the awkwardness, boredom and monotony of traditional learning. AR was found to foster interaction, dialogue and in-classroom discussions, and learners have the opportunity to avail themselves of collaborative learning and motivate one another in an exciting atmosphere. When AR applications are integrated into classroom learning, and when teachers nurture the culture of exploration in learners (e.g., encouraging them to use smart phones for didactic purposes), students can engage in an effective world which stirs up the use of their imagination to explore the potentials of the new world. All this takes place in an interactive way, which will keep learners' eyes peeled for finding out how their reality will develop during the lesson, so that in each meeting there is a new journey of discovering a new world.

Technology-enhanced reality is not a new notion, but in Palestine it started to make its way into classrooms only in 2016. Our results suggested a positive correlation between the use of AR and the performance of students in classroom. Teachers should not spend too much time thinking about how much knowledge learners need to acquire; rather they should know how to have highly-motivated, active learners. Today, AR applications have made the school books content more interactive with the help of a smart phone and a projection screen. Such technologies have made it possible for teachers to convert a still textbook picture into a real-life moving image, which enriches the learners' experience and unleashes their potentials. This process of transforming the content can effectively make things easier. Reading about how big cats chase their prey might not be particularly appealing, but watching the prides of lions moving around in the plains can be much more perceivable.

The results of the intervention study have also shown many positive aspects, including increased verbal and written expression, effective idea generation, more interaction with images, more inquiries on the part of the learners, greater concentration, and better participation. When students are effectively involved and adequately satisfied, deep learning becomes possible, and the knowledge acquired is more likely to remain alive in the student's long-term memory. It is easy then for the learner to retrieve information when it is needed.

What is more, the use of AR technologies is particularly effective when it comes to enhanced learner participation. The pupils in the intervention group seemed to better understand the materials presented to them, which created an interactive atmosphere where pupils started to ask questions, and respond to questions raised by their teacher and by other students, as well. This comes as no surprise, as AR-enhanced demonstration offers the privilege of seeing and feeling at the same time, which increases learners' sensory responses, thus taking the experience to a higher level of engagement.

When students are more engaged, the process of learning becomes faster as students' vigor is focused on the AR-enhanced materials. By supporting the learning experience and enriching it with interactive content, learners become more curious to investigate, and technology is always there to meet their instructional needs and create a hands-on experience, which can be possible only through real life situations or their virtual life simulations. In boosting engagement, pupils were found to evoke different experiences and link them to what they learn, which stirs their curiosity and sets their imagination free. Ultimately, this creates an environment where learners are able to generate ideas and know more about the world.

References

Abualrob, M., & Abu-Alrub, E. (2018). An Analysis of the Palestinian Old and New Third Grade Science Textbooks' Activities, *Journal of the Arab American University*, 4 (2), 49–68.

Abualrob, M., Al-Saadi, S. (2019). Performance-Based Assessment: Approach and Obstacles by Higher-Elementary Science Teachers in Palestine. *Journal of Education and Learning,* 8, (2). https://doi.org/10.5539/jel.v8n2p198

Abualrob, M. (2019). Determinants of Building 21st Century Skills in Palestinian Elementary Schools, *Higher Education Studies Journal*, 9(2). https://doi.org/10.5539/hes.v9n2p108

Ahmad, I. (2016). *The role of augmented reality in developing visual thinking skills in science for ninth grade male students in Gaza* (Master's Thesis). Gaza: Al Azhar University.

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, *20*, 1–11.

Aqel, M., & Azzam, S. (2017). Role of augmented reality technologies in enhancing performance of chemistry seventh grade students in the Gaza Strip. *International Journal of Learning Management Systems, 6*(1), 27–42.

Bruner, J. (1961). The Act of Discovery. *Harvard Educational Review*, *31*, 21–32.

Caudell, T., & Mizell, D. (1992, February, 9). Augmented reality: An application of heads-up display technology to manual manufacturing processes. *Proc. Hawaii Intl Conf. System Sciences*, *2*, 659–669. Retrieved from https://tweakimg.net/files/upload/329676148-Augmented-Reality-An-Application-of-Heads-Up-Display-Technology-to-Manual-Manufacturing-Processes.pdf

Cai, S., Chiang, F.K., & Wang, X. (2013). Using the augmented reality 3D technique for a convex imaging experiment in a physics course. *International Journal of Engineering Education*, *29*(4), 856–865.

Creswell, J.W. (2019). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*, 6th Ed. Harlow: Pearson.

Dale, E. (1969). *Audiovisual Methods in Teaching*. NY: Dryden Press.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. *Journal of Science Education and Technology*, *18*, 7–22.

Garcez, A., Duarte, R., & Eisenberg, Z. (2011). Production and analysis of video recordings in qualitative research. *Educação. Pesquisa*. *37*(2), 249–260.

Kukla, A. (2000). *Social Constructivism and the Philosophy of Science*. London: Routledge.

Lee, K. (2012). Augmented Reality in education and training, *TechTrends: Linking Research & Practice to Improve Learning*, *56*(2), 13–21. https://doi.org/10.1007/s11528-012-0559-3

Liu, T.Y., & Chu, Y.L. (2010). Using ubiquitous games in an English listening and speaking course: Impact on learning outcomes and motivation. *Computers and Education*, *55*, 630–643.

Ministry of Education and Higher Education. (2017). Monitoring and Evaluating Report, Ramallah, Palestine. Retrieved from http://www.lacs.ps/documentsShow.aspx?ATT_ID=34117.%20

Qeshta, A. (2018). *The Impact of Using Two Patterns of Augmented Reality in Improving the*

Scientific Concept and Scientific Sense in Science among Female Seventh Grade (Master's Thesis). Gaza: The Islamic University of Gaza.

Shelton, B.E., & Hedley, N.R. (2004). Exploring a cognitive basis for learning spatial relationships with augmented reality. *Technology, Instruction, Cognition and Learning*, *1*(4), 323–357.

Sotiriou, S., & Bogner, F. (2008). Visualizing the Invisible: Augmented Reality as an Innovative Science Education Scheme. *Journal of Computational and Theoretical Nanoscience* *1*(1), 114–122. https://doi.org/10.1166/asl.2008.012

Theron, D. (2012). *The power of concentration.* Massachusetts: Hampton Roads Publishing.

Wu, H., Lee, S., Chang, H., & Liang, J. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, *62*, 41–49.

Yuen, S., Yaoyune, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange*, *4*(1), 119–140.