Education Tech Research Dev (2022) 70:1105–1124
https://doi.org/10.1007/s11423-022-10100-4

The effectiveness of using augmented reality (AR) to enhance student performance: using quick response (QR) codes in student textbooks in the Saudi education system

Sameer Mosa AlNajdi[1]

Accepted: 28 February 2022 / Published online: 4 April 2022

Abstract
Augmented reality (AR) is a new way to integrate virtual reality into the real world, and integrating AR into education offers opportunities for increasing student performance. The Saudi Ministry of Education integrated technology into its educational system by building an educational portal called iEN, which offers many technologies that support education, such as AR experiments, e-textbooks, learning games, video clips, and TV channels. This initiative made Saudi Arabia better prepared for the transition to remote education, which offered an easy and prompt shifting of the education system during the Coronavirus pandemic (COVID-19). The current study examined the effects of using QR codes as an AR to enhance student performance in Saudi education. The findings show that students who utilized QR codes in their education performed at higher levels than those who did not and demonstrated that students did not face any technical issues in integrating technology into their learning processes. However, that could be based on their generation of using technology (alpha generation), which became part of their lives.

Keywords Quick response (QR) codes · Augmented reality (AR) · Students' performance · Saudi education

Introduction

The place of education in the quest for sustainable development has served as an impetus for society. Such in Saudi Arabia, the goal has been invested in discussing how the capacity of education could enhance to meet the knowledge economy (Alnahdi, 2014). Education must be objectively restructured according to sustainability demands to achieve this goal. Various social factors should mediate this restructuring. The technological revolution represents a significant social factor for mediating this restructuring, as technology serves as a powerful social force for transforming the knowledge economy environment. However, this implies that

✉ Sameer Mosa AlNajdi
salnajdi@ut.edu.sa

[1] Education Technology Department, Faculty of Education and Arts, University of Tabuk, Tabuk, Saudi Arabia

the evolution of technology must be accompanied by a responsive curriculum reorganization aimed at meeting the demands of the knowledge economy.

The impact of technology on education is not new. Historically, the impact of technology begins with four industrial revolutions. Penprase (2018) notes that these technological revolutions shaped the future of education, gender, nature, and the form of work that calls upon hastening the re-skilling of the workforce, which all follow from the continued proliferation of technologies.

Reflection on the nature and form of this trend points to significant technological adjustments to education, such as augmented reality (AR) and the related quick response (QR) code strategies, which are gaining in popularity. However, the roles and contributions of the new technologies to learning have yet to be defined in diverse contexts. Specifically, how inclusive are AR strategies such as QR codes? How effective are they in diverse settings? What are their strengths and weaknesses? What actions are necessary to deliver the desired outcomes? This paper builds on a semi-experimental study to investigate the effectiveness of using QR codes in Saudi's educational process.

Research problem

The continued proliferation of technology in the world is influencing education in various ways, as integrating technology into education has become a required choice, offering a change in some learning processes to achieve desired outcomes (Alnahdi, 2014). AR is one of the new technologies trending globally, as organizations, companies, and institutes have started using AR to support their projects and products. Augmented reality has also been incorporated into educational processes; furthermore, QR codes as an AR technology offer an easy way to increase student performance. The Saudi Ministry of Education (MOE) adopted AR and QRs in student textbooks, a portal built as a co-environment. That opens to researchers a path to discover and discuss the adoption of this promising technological response that can support education. Therefore, the effectiveness of using AR in the Saudi education system constitutes the research problem investigated in this study to inform the practice.

Research aims and objectives

The proposed research aims to investigate the effectiveness of QR codes in supporting the educational process. The findings are intended to inform these practices of any existing weaknesses that need to be addressed. Several objectives have been considered to achieve this goal:

1. Enhancing student learning outcomes
2. Evaluating the effectiveness of AR integration in education
3. Providing feedback on using QR in the Saudi educational system

Methodology

Research question

This research focuses on one main research question: How effective is using augmented reality in education in enhancing student performance, using QR codes in students' textbooks in the Saudi educational system as the case study?

Literature review

Literature acknowledges the pivotal role of AR in education and its growing popularity. Karakus et al. (2019), in an explorative review on the nature and form of AR in education, reported that, in 437 publications between 1999 and 2018, AR research concerned itself with interactive learning environments, virtual reality, mobile learning, and e-learning environments. The collective findings indicate that AR plays a positive role in enhancing education in these contexts.

Khairuldin et al. (2019) described AR as technology-oriented learning that integrates virtual objects to natural learning scenes, filling in gaps of previously missing information in real-life education. In essence, AR supports the construction of knowledge through active, autonomous, and supportive practical learning. Moreover, the process of reconstructing knowledge from experiences should emerge from reflecting on the practices, recollecting, and making notes on the nature of the situation in education and attending to personal feelings, re-evaluating experiences, and integrating experiences gained with those that were pre-existing.

Indeed, according to Alnajdi et al. (2020), AR provided an opportunity to observe and learn from real action, and it can be extended to general education because it enables students to envision how theories apply. Even in e-learning, using AR can help make learning more exciting, interactive, and fun. In areas in which it has been applied, the approach has improved learners' scores, enhanced motivation, and fostered cooperative learning. AR provides the learning opportunity to observe and test theory and foster creative thinking and effective decision-making processes through integrating virtual reality with real life.

According to Huerta et al. (2019), AR could enhance the standards of technical education, fostering learners' engagement, skills, and competence, which is preferred over traditional methods. They explained that one could acknowledge theories as a source of basic knowledge that drives problem-based learning. The practice needs to be addressed by theories. Nevertheless, to be successful, one needs to observe beyond personal experiences and expectations systematically. It is this systematic observation that can help to build consistent knowledge and perspectives from experience.

In a systematic review of AR in education, Bacca et al. (2014) reported a growing interest in creating a unique setting in education. Their review focused on AR's uses, limitations, advantages, challenges, future, and effectiveness. They reported various findings; Firstly, AR is mainly applied in higher education, especially in science, humanities, and art faculties. Secondly, in the contexts in which they are applied, their focus has mainly been on motivating learners. Thirdly, marker-based AR works through scans and marking to bring up an augmented reality experience such as an object, text, video, or animation. This type of AR is the most common, followed by location-based AR, which stands for marker-less, position-based, and other technologies that rely on GPS. This trend is attributable to the availability of sensors embedded in mobile devices, such as the digital compass,

GPS, accelerator, gyroscope, and digital compass, and the possibility of using global position systems. Fourthly, marker-less AR requires significant improvements in algorithms for accurate tracking. At the same time, the use of an add-on console, such as Microsoft Kinect in Xbox, allows users to interact without using a controller or other intermediary device, which becomes increasingly more popular. The main goal of applying AR is to expound on explanations on the main topics of interest, including providing additional information using platforms such as educational games and lab experiments (Bacca et al., 2014).

Also, Bacca et al. (2014) observed various strengths and limitations of AR, and the notable benefits include supporting learning gains, motivation, collaboration, and interaction. AR has been particularly effective in enhancing student engagement, fostering positive attitudes, and enhancing performance. On the other hand, the limitations include placing too much emphasis on virtual information, the intrusive nature of AR, and the inherent difficulties in maintaining superimposed information. Moreover, AR is not inclusive to diverse learners, especially those with disabilities. At the same time, they acknowledged that many of the studies reviewed used mainly samples ranging between 30 and 200 participants.

Overall, the insights presented in the literature laud the use of AR in education. Nevertheless, the limitations noted potentially overshadow AR's benefits to education. More importantly, the review opens the question as to whether the findings can be generalized to different types of AR and educational contexts. For instance, is Saudi Arabia any different? Are the strengths and weaknesses observed unique? How do they lend themselves to diverse cases and contexts of QR codes?

The relationship between augmented reality and quick response codes

The literature acknowledges the significant relationship between AR and QR code technology. In particular, QR codes effectively fit in AR because of their innovative nature. Law and So (2010) described QR codes as two-dimensional barcodes decoded by QR scanners and mobile phones. Data such as contact information, SMS messages, plain text, and URLs can be embedded in QR codes available for access. Indeed, this feature makes them part and parcel of AR learning.

Indeed, according to Law and So (2010), QR codes aim to fulfill three elements of AR learning: location independence, time independence, and meaningful content. In this case, location independence refers to learning that is not limited to specific locations, implying it can be carried out in formal and informal, indoor, and outdoor settings. On the other hand, time independence refers to learning that can take place outside of class time. Finally, meaningful content describes the content that is diverse and suitable for learners in different contexts. In this regard, at their best, QR codes are a means to AR learning.

According to Downer et al. (2016), AR learning embedded with QR codes can significantly benefit. One of its defining characteristics is goal-directed, enabling it to guide preparing instructions to accomplish defined goals and objectives. The second defining characteristic is the interdependence of the underlying steps. The arrangement primarily emphasizes a whole-system approach that aligns objectives, evaluation, and instructions. Thirdly, it is defined by a closed system. The standard system view spans significant training and education delivery processes, including conducting the needs assessment, specifying objectives, task analysis, selecting media, producing material, formative and summative evaluation, and developing assessment strategies. Overall, these approaches are linear in the sense that they lay out the generic procedural framework, including the steps for analysis, design, development, implementation, and evaluation of instructions. Secondly,

its input and output structure and learning assessment, task analysis, and objectives effectively support the gradable learning forms.

However, a typical learning system needs to be created to fulfill various requirements, especially a research and synthesis theory. In one way, it needs to be aligned to how humans conceive and attribute stimuli in the environment. Secondly, it also needs to capture information and how it is derived and disseminated. Thirdly, it needs to mirror the system concepts and the interrelationships with the intervening factors that deter or promote the realization of the desired goals. Lastly, it needs to reflect the needs of the knowledge economy (Rabu et al., 2019). Discussions on and attempts to improve education by making it interactive for learners in Saudi Arabia have taken place. It is interesting whether the learning arrangement effectively fits this arrangement.

The importance of the use of quick response codes in education

The relevant literature acknowledges the crucial role of QR codes in revolutionizing the learning process. It also highlights various areas of concern that invite debate on its effectiveness. For instance, in exploring the concept of QR codes and their benefits to digital education, one article noted that the two concepts are intertwined in that "the digital education system is nothing but education using gadgets" (Goyal et al., 2016, p. 452). The influx of technologies, security, legitimacy, and the process of accessing digital information has presented significant challenges, as information technology holds numerous benefits for education. The use of a digital information system can now be likened to automating education by making it easy to access academic content. QR codes represent overcoming the underlying challenges and constitute a cryptographic approach for securing information, such as learning content, video clips, documents, exams, and certificates.

The use of QR codes is reported to touch on various facets of education, such as problem-based learning. Santoso et al. (2019) stated various benefits in their study on the use of QR in a teacher education program. Firstly, students assisted by QR demonstrated significantly improved outcomes compared to their counterparts who relied solely on direct instruction learning. Secondly, students subjected to problem-based learning who were assisted with QR codes had the mathematical problem-solving ability to improve their post scores compared to their counterparts. Considering these gains, Santoso et al. (2019) recommended that instructors invest in QR codes to develop engaging learning environments and enthusiastic students. Leone (2015) explained that these gains attributed them to the QR code being a tool for personalized, inclusive, and interdisciplinary learning experiences.

Moreover, Chicioreanu et al. (2015) acknowledged the challenges students face in accessing learning resources, further applauding the significance of QR codes in addressing these weaknesses. They particularly noted that colleges have been bombarding learners with hundreds of pages of information online that are so useful that the students must access them. Links can easily be clicked on a web page to direct users to the content sought. However, these links are difficult to pass on to learners in the classroom setting because of their long and complex combined string of characters. QR codes were created to enable quick access to information, and they can now be even more easily accessed because of the ubiquity of technologies such as tablets and smartphones that can scan the square QR. QR codes are popular technologies because of their relatively large capacity for quick decoding and their capacity to hold large amounts and multiple kinds of information. In questioning whether learning how to use QR codes is appropriate training, Chicioreanu et al. (2015)

explained that QR technology enables various functions that support education, including transferring data such as teacher contact information, sharing additional resources, posting tutorials, interacting with course handouts, experiencing virtual tours, playing educational games, and completing interactive polls.

The technological merits of QR codes are best discussed in detail by Law and So (2010), who singled out their versatile nature. For instance, they reported that QR codes could carry much information, such as a long multilingual text, automated messages, business cards, linked URLs, and any other type of information that can be incorporated into the conventional two-dimensional barcode. They further noted that a QR code could typically hold up to 7,089 numeric characters, 1,817 Kanji characters, 4,296 alphanumeric characters, and 2,953 binary bytes. This memory capacity makes them preferable to Data Matrix, Maxi Code, and other 2D codes. Powered by mobile devices, it is easy for users to connect and access information with relative ease.

Some merits and demerits inherent to QR code-embedded learning are also mentioned in the literature. For instance, Chung et al. (2019), in their report on their inquiry into the use of QR codes in children's classrooms, noted that the codes are exciting for children who participated in their study. In their further examination of experiences with the use of QR codes, Law and So (2010) reported that many learners in junior schools found QR code-embedded learning to be engaging. However, many learners in this group were not well prepared for mobile learning. They reasoned that the education system could certainly not expect junior students to carry mobile devices to school. Other cases of using the QR in the math trial activity were expensive and unsuitable for significant learners.

Moreover, while it is pretty easy to use mobile devices to scan QR codes, students in junior classes often tilt their mobile devices while snapping codes, reflecting a lack of adequate knowledge on the use of mobile devices. Lastly, the reliance on 2G and 3G networks provided by mobile carriers is expensive and potentially overshadows the benefits of QR codes. Moreover, Abdul Rabu et al. (2019) acknowledged that the users' motivation mediates the use and acceptance of QR codes. This motivation is not always guaranteed. So (2011), in questioning why the academic world has been slow to adopt QR codes, hypothesized that instructors are lagging because they have not mastered the use of the technology. It then seems that the benefits of QR to education may not be straightforward because various factors mediate it.

iEN: national education portal in Saudi Arabia

The Ministry of Education (MOE) in Saudi Arabia created a portal for education called the "iEN," an Arabic word that means eye, which can be found at https://ien.edu.sa/ which was designed to provide co-environments to support the learning process, see Appendix A, has three sub-portals: (1) books and lessons, (2) iEN revisions, and (3) additional resources. The portal provides more than 100 AR experiments, video clips, exercises, whole textbooks, learning games, and general information. Users can access all this information using the QR codes provided in their textbooks, see Appendix B. The three sub-portals of the iEN are separated into four levels according to the target audience: students, teachers, principals, and parents. Users can sign up to create an account and sign to their accounts to access the portal's functions and tools, to use the portal's list to find new resources and to review the users' guide based on their character, see Appendix C (iEN, 2020; MOE, 2020). Also, users can access the Q&A section to find answers, contact the help center, and make

suggestions. The intelligent portal corresponds with both Android and iOS smartphones and tablets.

Four main access points are available to parents: eBooks, iEN reviews, additional resources, and "my children," which enables them to create exams for their children and follow their children's progress in courses, see Appendix D. Teacher accounts contain two main sections: information board, which has 11 access points, and teacher services, which has five access points. The access points make a quantity of information and services available to teachers, such as contacting their students through the students' community, creating question banks, and issuing worksheets to the virtual learning community. A feature called "my students," which is a learning community, allows teachers to exchange knowledge and discuss educational issues with their students and provides support and complete follow-up to students using a variety of strategies, see Appendix E. Student accounts also contain two sections: information board, which has eight access points, and student services, with five access points. These 13 access points offer free learning features, including a library of educational and targeted videos related to extracurricular activities and self-evaluation services, which enable students to evaluate their performance and send their results to their teacher, see Appendix F (iEN, 2018).

The iEN portal enabled the Saudi MOE to shift quickly from traditional education to distance education during the coronavirus (COVID-19) pandemic. Use of the iEN portal was an additional option in semesters before the lockdowns associated with the COVID-19 pandemic, but after schools closed on March 9, 2020, the MOE linked the iEN with Future Gate (FG), a virtual school created and established by the MOE offered free to all public schools across the country to support the traditional school. However, due to the pandemic, the MOE combined the iEN and FG under the Unified Education System (UES) and made the iEN more effective by developing the portal and adding more functions in each sub-portal to support parents, teachers, and students.

Design of experiment

A semi-experimental method was employed, for this study, in one of the middle schools in Tabuk, in the northern region of Saudi Arabia, which has a population of 667,000. According to the Tabuk Education Administration (TEA) (2019), the region has 1459 schools, 352 of these schools are middle schools and have 47,078 students (TEA, 2019). Two classes were chosen randomly to include control and experimental groups in this study. Each class contained 33 students; both had completed the last unit in the traditional classroom setting. The control group in the experiment was taught the lesson traditionally without using the QR or iEN functions.

In contrast, the experimental group was taught to enhance learning using the enrichment content available through the QR and iEN. Before the lesson began, the students completed an exam for the unit, see Appendix G, as a pre-test, and then students started learning through traditional ways and using QR codes to transfer to the iEN portal. QR codes were provided at the beginning of each lesson see Fig. 1. These codes transfer the individual scanning the code to the AR environment, which contained seven enriching video clips that enhanced knowledge; two of these clips provided experimental explaining, and the other five clips explained the lesson in an avatar video, see Appendix H. Two video clips provided asynchronous teaching, a clip summarizing the lesson in a knowledge map, and an e-book. In the experimental group, students learned the lesson through traditional teaching methods, watching the video clips in class, and completing other exercises provided on

Fig. 1 QR code of lesson in student textbook (MOE, 2020)

the iEN after school (e.g., activity practice, self-evaluation). After the experiment, students completed a post-test to determine the QR codes' effects on student learning. On pages 60–61 of the textbook, a post-test is given as a revision test at the end of the course. Only traditional teaching methods were used.

Results

Students, in the beginning, took the pre-test to measure their knowledge. The results of the pre-tests showed a minimal difference of 0.12 (Mean Difference: 5.65–5.55 = 0.12) between the two groups' performance, which indicated no statistically significant difference existed between the two groups at $\alpha \leq 0.05$, reflecting their homogeneity (Table 1).

However, following the experiment, the post-test was taken, and the results indicated a difference of 3.27 between the two groups, as shown in Table 2, which was statistically significant at $\alpha \leq 0.05$ (Mean Difference: 13.21–9.94 = 3.27), with the experimental group students outperforming the control group students. Based on these results, this study agreed with the findings from Ozcelik and Acarturk (2011) of the benefits of using the QRs provided in the students' textbooks, which supported the use of QR in student textbooks make learning more accessible and more effective. The current study's findings also agreed with many other studies, such as Liu et al. (2007) and Rivers (2010). Students showed higher results and scientific improvement because they enjoyed and benefited from using the QRs and the iEN portal.

Table 1 Pre-test results

	N	*M*	*SD*	*df*	*T*	Sig
Control group without Use of QR nor iEN	33	5.55	1.80	64	.27	.79
Experimental group with Use of QR and iEN	33	5.67	1.83			

Table 2 Post-test results

	N	*M*	*SD*	*df*	*T*	Sig
Control group without use of QR nor iEN	33	9.94	1.78	64	7.28	.00
Experimental group with use of QR and iEN	33	13.21	1.87			

Furthermore, students in the experimental group had been advised to use the portal by completing assignments provided on the iEN, including the practice activity creating exams through the "evaluate yourself" function. The assignments through the iEN were completed by 91% of the participated students, and only three students failed to do the practice activity due to Internet access issues, and only one failed to access the self-evaluation. Those assignments offered direct feedback, so students could redo them multiple times until they obtained the correct answers. More details are provided in Table 3.

Results showing significant differences between both control and experimental groups attributable to the experimental group, this finding agreed with (Sahin and Yilmaz, 2020; Tait et al., 2020), which reported that students who were in the experimental group were delighted and found it helpful and easy to use, and they prefer to use AR in their future learning. In addition, they deal with using the AR technology easily and reach a higher level of performance and achievement than students in the control group.

Also, results proved that using AR in education can offer positive opportunities and impacts to develop the education and support students, as Tsiavos and Sofos (2019) stated that, (1) learning benefits, (2) offering a motivating environment, (3) engaging students, (4) help students to focus on the lesson, (5) changing students' attitudes positively about the lesson, (6) students' excitement, (7) increasing students' eagerness, (8) increasing students' knowledge, (9) integrating virtual reality in the real-world to enhance locative perception, and (10) developing students' observation.

Discussion

A review of the literature indicated that the impact of technology on the education curriculum is inevitable and significant. This inevitability follows from the fact that education and technology are intertwined. Indeed, education cannot exist as an island; it must exist to fulfill the needs of society. Since social needs are dynamic, especially those influenced by technology, education must respond through curriculum change. Augmented learning and the use of related technologies such as QR codes lend themselves to the discussion to

Table 3 Evaluation results of iEN assignments

Assignments provided on iEN	*N*	# of students who completed tasks	Percentage that achieved goal first time	Percentage that achieved goal second time
Practice activity	33	30	80	100
Self-evaluation	33	32	84	100

enhance the potential of education. These technologies offer various advantages to education and learning processes.

In this current study, students showed their interactivity by using the QR codes in engaging, inclusive, and personalized ways, which motivated and steered them to perform better in different subjects and contexts. After the experiment, students were asked for their perceptions of using the QRs. Also, they stated that they started using QRs in other textbooks to understand lessons better and prepare for the new lessons through the AR clips. These comments agreed with feedback reported in many study results (Hwang et al., 2011; Liu et al., 2007; McCabe & Tedesco, 2012; Rikala & Kankaanranta, 2012; Rivers, 2010). Students in those studies reported an improvement in their performances and achievement. They were motivated and enthusiastic during using the QRs in the learning process, which made them more comfortable dealing with the lessons and decreased their stress. A few students in this study reported their limited ability to use the QRs at home based on limited ownership of smart devices and access to the Internet, but that did not affect their class activities.

As the benefits of QR codes in educational contexts such as in Saudi Arabia were under debate, AR did not apply in the Saudi education system until the MOE established the iEN. As an additional note, due to the pandemic, use of the iEN increased, with more than 7 million accounts created, and the number of QR scanning passed 100 million (MOE, 2020).

Conclusion

This study was conducted during the first semester of the 2019/2020 academic year and highlighted the benefits of using AR to make the learning process more effective. After the science teacher shared the differences and the positive results with his students, he started to apply the experiment with all his classes. However, before finishing the article to report the funding, the world experienced Coronavirus (COVID-19) pandemic. Based on the pandemic, all education switched to a distance learning context, and schools in the whole world have been closed. In Saudi Arabia, the readiness of the digital environment due to the integration of technology before the pandemic helped the MOE more easily shift the education process from the traditional classroom setting to the distance education format; students were able to use the AR lessons provided on the iEN and using the virtual school (FG). Utilizing AR in Saudi education started before the pandemic been occurred, which helped students transition easily and allowed teachers to expand the process and possibilities of making education more effective. QR codes in schools have increased over the years, and their role became more effective by offering teaching clips, e-textbooks, AR experiments, and learning games and developing a following from teachers, parents, and principals. Lastly, in this study, the findings agree with those of other studies about the effectiveness of AR and QR in education and how it contributes to enhancing and improving student performance. The integration of AR and QR in education can be attributed to many factors, including those provided in the studies reviewed, such as connecting knowledge with actual exercises.

One of these factors is students' characteristics, as today's students are considered the alpha generation for their skilled use of technology. Alpha generation is the last generation of using technology, this generation was born in 2010, and years after, they were born with the new technologies and live-in digital entertainment. Technology became part of their lives, and they could not imagine their lives without it (Tootell et al., 2014). They deal with

technologies in many contexts, such as the games they play that are built on AR, so the technologies have become part of their daily lives.

Offering the iEN portal allowed the Saudi Ministry to shift education quickly from traditional education to distance education during Coronavirus (COVID-19) pandemic. Using iEN was an additional option in the previous semesters, but after schools closed on March 09, 2020, the Ministry of Education linked iEN with Future Gate (FG), a virtual school created and established by the Saudi Education Ministry which offers free to all public schools all over the country to support the traditional school system. However, during the pandemic, MOE combined iEN and FG under one system called Unified Education System (UES). Also, MOE developed and added more functions into the iEN portal to make it more effective, such as offering for parents examing their children. Also, for students offers a free learning feature, which has a library of educational and targeted videos that can be invested in curricular and extracurricular activities. In addition, teachers have the ability through a feature called "my students" to create a learning community that allows teachers to exchange knowledge and discuss educational issues with their students and provides supporting and full following-up to students with various strategies.

So (2011) found some teachers revising or trying not to use QR and AR because they lack the skills to use technology, so I recommend searching more studies to review the constraints and obstacles of adopting AR and QR in education and finding solutions. In addition, researchers could start to design environments to merge virtual reality (VR) in education to build AR environments based on instructional design models. Finally, researchers could study how the AR environment affects MOOCs' massive open online courses.

In addition, to make the AR more effective, it should build based on instructional design models to ensure it matches learners' needs characters and motivates them. According to Iqbal et al. (2019), using the ARCS model (Attention, Relevance, Confidence, and Satisfaction) helps to evaluate the system and AR to make it fit and appropriate for learners, for that, a study could review and analyze the whole website iEN through instructional design models. Alalwan et al. (2020) mentioned that teachers participating in their study reported that a lack of their skills in instructional design adversely affects the willingness to use AR properly. Also, the stalemate of the content material in AR systems and the hardness of requesting modify limit teachers from making any modifications based on students' needs in line with the curriculum.

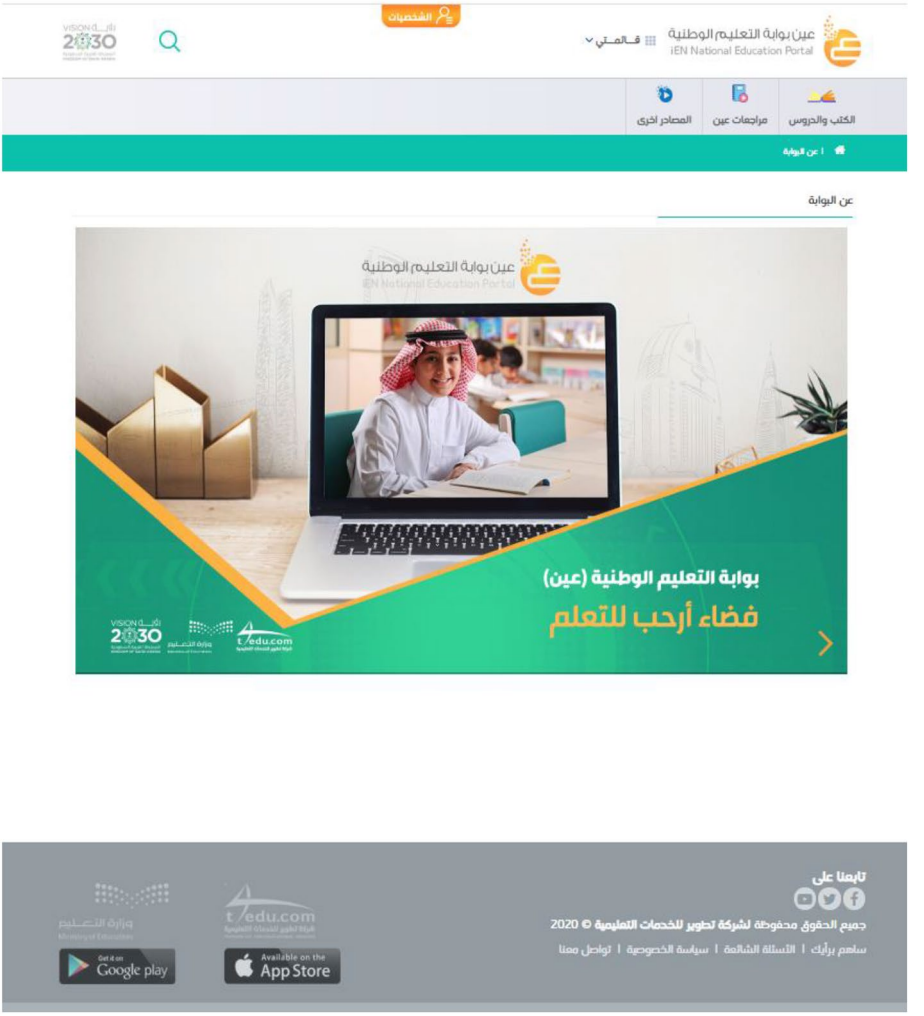
This study pointed out the necessity of researching future studies to review and analyze ARs environments for checking the design through instructional design models to ensure their fitting and occasioning to education and students' needs and characteristics.

Limitations

This study has some limitations. The first limitation was grade level. The study was conducted on second grade in middle schools (contains grades from seventh through ninth grade; first, second, and third grades) in Saudi Arabia. Also, it applied during the first academic semester of 2019 at TEA. Another limitation was the study's focus on a science course. Specifically, a lesson about alkaline liquid and acidic liquid, all materials were available by scanning the QR code provided in students' textbooks.

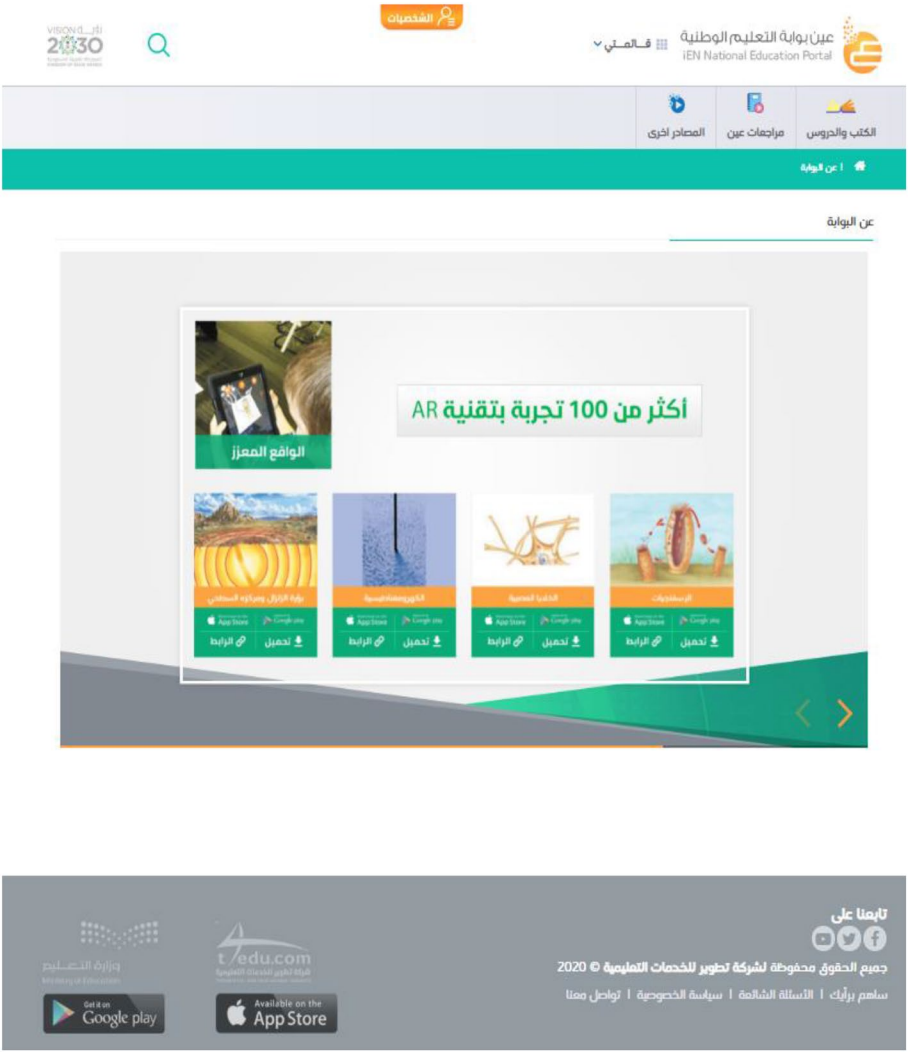
Appendix A: iEN main page

This is a screenshot of the iEN portal home page, from this page users can log in and access all the benefits in the portal, it has three sub-portals: books and lessons, iEN revisions, and additional resources



Appendix B: AR experiments

This screenshot of the AR experiments is available on iEN portal, so they could use their smart devices to transfer more than 100 experiments pictures provided in their textbooks to AR experiments



Appendix C: Roles and characters to join iEN

To join and login to iEN portal there are four levels: students, teachers, principals, and parents. Users can sign up to create an account and sign to their accounts to access the portal's functions and tools

Appendix D: Parent account services

A screenshot of the parent's page in iEN, which has four main access points are available to parents: eBooks, iEN reviews, additional resources, and "my children," which enables them to create exams for their children and follow their children's progress in courses

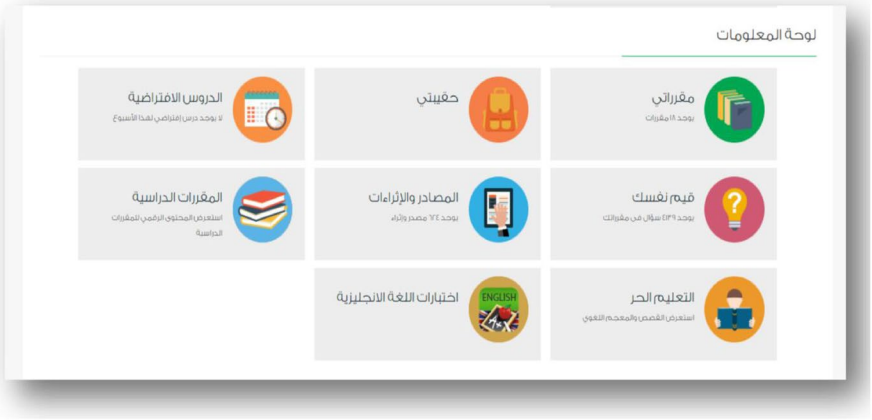
Appendix E: Teacher account services

A screenshot shows the main page of the teacher's account contains two main sections: the information board, which has 11 access points, and teacher services, which has 5 access points. These points allow teachers to use iEN to provide e-learning and supporting materials

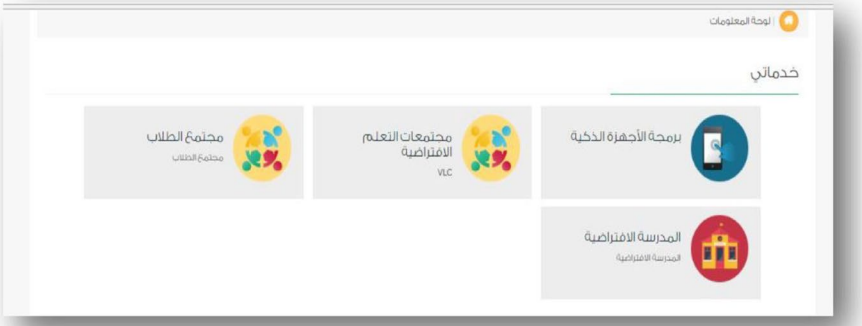
Appendix F: Student account services

A screenshot shows the main page of the student's account contains two main sections: the information board, which has 8 access points, and student services, which has 5 access points. These points allow students to use iEN to help and enhance students' learning

١. حساب الطالب



خدمات الطالب



Appendix G: Revision test

Screenshot of the revision test provide at the end of the unit, which was used as a pre-test and post-test in this study completed an exam for the unit


اختبار مقنن

الجزء الثاني: أسئلة الإجابات القصيرة

استخدم الصورة أدناه في الإجابة عن السؤال ١٠.

١٠. أكمل الجدول بتحديد ما إذا كانت كل جملة فيه تمثل ملاحظة أو استنتاجًا أو فرضيةً.

الجملة	ملاحظة أو استنتاج أو فرضية
يحتاج النبات إلى كمية كبيرة من الماء	
النبات له أوراق كبيرة	
ليس للنبات أزهار	
قد يكون شيء ما أكل النبات	
إذا نقل النبات إلى مكان آخر سيكون أفضل	
قد يحتاج النبات إلى أشعة شمس أكثر	
سيصبح النبات أفضل عند استعمال مبيد حشري	

١١. كيف تصبح الفرضية نظرية؟

١٢. ماذا يحدث إذا لم تدون الملاحظات كما ينبغي؟

١٣. ما الفرق بين الاستنتاج والفرضية؟

استخدم الصورة في الإجابة عن السؤال ١٤.

١٤. ما نوع المخلوط؟ اذكر ثلاثة أمثلة عليه.

١٥. المذاب في صورة حبيبات أو قطع يذوب أسرع منه إذا كان في صورة قطعة كاملة. فسر ذلك.

١٦. قارن بين تركيز المحلولين: المحلول (أ) يتكون من ٥ جرامات كلوريد الصوديوم مذابة في ١٠٠ جرام ماء، والمحلول (ب) يتكون من ٢٧ جرام كلوريد الصوديوم مذابة في ١٠٠ جرام ماء.

١٧. صف كيف تستخدم أوراق تباع الشمس لتحديد الرقم الهيدروجيني pH لمحلول؟

الجزء الثالث: أسئلة الإجابات المفتوحة

١٨. لماذا تشكل التجارب على النبات مشكلات أقل مما لو أجريت على الإنسان؟

١٩. افترض أن عالمًا يدرس مرضًا ما مثل السرطان، فما أهمية التواصل في المعلومات التي يجدها؟ اذكر عدة طرائق يتواصل بها العلماء لتبادل البيانات التي يجدونها.

٢٠. وضح من خلال قطبية جزيئات الماء الموضح في الشكل كيف يذيب الماء المركبات الأيونية؟

شحنة جزئية سالبة

شحنة جزئية موجبة

٢١. لماذا تعدّ المشروبات الغازية من محاليل (سائل–غاز)؟

٢٢. فسر تغير نسبة الغاز إلى السائل مع الزمن في علبة المشروب الغازي المفتوحة.


الوحدة ١ اختبار مقنن

الجزء الأول: أسئلة الاختيار من متعدد

استخدم الصورة في الإجابة عن السؤال ١.

١. أي خطوات الطريقة العلمية توضحها الصورة أعلاه؟
أ. الملاحظة جـ. الفرضية
ب. استخلاص النتائج د. جمع البيانات وتحليلها

٢. ما الذي يصف أو يتوقع سلوك الأشياء في الطبيعة؟
أ. الفرضية جـ. الاستنتاج
ب. القانون د. النظرية

٣. عند دراسة العلاقة بين ذائبية مادة ودرجة الحرارة، يكون المتغير المستقل هو:
أ. كتلة المادة جـ. ذائبية المادة
ب. درجة الحرارة د. كتلة المذيب

٤. تعدّ أجهزة الحاسوب والمجاهر من الأمثلة على:
أ. الفرضيات جـ. التقنية
ب. المتغيرات د. الثوابت

٥. أي مما يأتي يستعمل في اختبار الفرضية؟
أ. التجربة جـ. القانون
ب. النظرية د. المتغير

استخدم الشكل أدناه في الإجابة عن السؤالين ٦ و ٧.

تركيب الهواء الجوي

٦. أي مما يأتي يصف الغلاف الجوي؟
أ. مشبع جـ. راسب
ب. محلول د. كاشف

٧. ما الغاز الذي يعدّ مذيبًا للهواء الجوي؟
أ. النيتروجين جـ. بخار الماء
ب. الأكسجين د. ثاني أكسيد الكربون

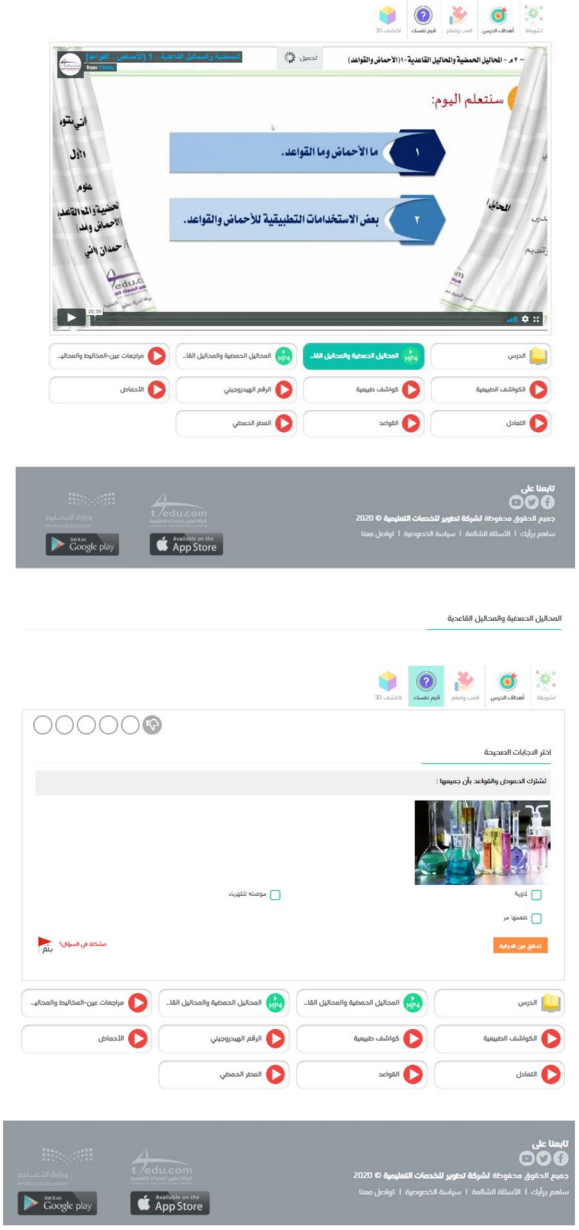
٨. ما الخاصية التي تشترك فيها المحاليل المائية؟
أ. تحتوي على أكثر من ثلاث مواد مذابة.
ب. لا يوجد فيها مواد صلبة أو غازية مذابة.
جـ. جميعها عالية التركيز.
د. الماء هو المذيب فيها.

استخدم الرسم في الإجابة عن السؤال ٩.

٩. ما العبارة الصحيحة مما يأتي؟
أ. كلوريد البوتاسيوم أكثر ذوبانًا في الماء من السكر.
ب. بازدياد درجة حرارة الماء تقل ذائبية كلوريد البوتاسيوم.
جـ. السكر أكثر ذوبانًا في الماء من كلوريد البوتاسيوم.
د. لا تؤثر درجة حرارة الماء في ذائبية المادتين.

Appendix H: Lesson pages

Screenshot of one of the lessons pages in iEN, this page provides clips to explain experiments, other clips explained the lesson in an avatar video, video clips provided asynchronous teaching, a clip summarizing the lesson in a knowledge map, and an e-book



Acknowledgements I would like to thank the Education Administration in Tabuk for their support, and the Scientific Research Deanship in University of Tabuk for their granting of this study under grant number S-1440-0036.

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Sameer Mosa AlNajdi Associate professor of Education Technology at University of Tabuk. Hold a Ph.D. in Curriculum and Instruction from Indiana State University in 2014, in the track of Educational Technology, and had Instructional Design Certificate from Indiana State University, USA, 2014. Chairperson of Education Technology Department. Former chairperson of Curriculum and Study Plans Unit at Education and Arts College, Former Dean of Deanship of Development and Quality, Former official spokesman, and former member of the university's board in University of Tabuk.