Augmented Reality in Supporting Healthcare and Nursing Independent Learning

Narrative Review

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New advances in technology have brought challenges and opportunities for education and instructional methods. Compared with traditional education, the increased use of technology-enhanced blended learning in healthcare and nursing education requires students to take more responsibility for their learning. The use of advanced technology has resulted in independent learning skills becoming increasingly important. Many studies have reported a positive correlation between independent learning and success rates in an e-learning environment. This paper focuses on the potential contribution of augmented reality, which superimposes layers of virtual content on real physical objects. The paper initially presents a narrative literature review to identify augmented reality's strengths and challenges in facilitating independent learning and highlights several potential approaches for utilizing augmented reality in nursing education. However, it also reveals a lack of studies integrating augmented reality and independent learning theories such as self-regulated learning. The paper then addresses this gap by proposing a new learning approach to support independent learning.

KEY WORDS: Augmented reality, Independent learning, Nursing education, Self-learning

Augmented reality (AR) technology is still in the development phase. Compared with other more mature technologies in education, AR is in its early stages. A narrative literature review has been performed to overview the strengths and challenges of AR by reviewing any study that could be relevant to the topic.[1] The aim of critically reviewing the existing literature is to summarize and synthesize the state of knowledge and seek to understand any potential research.

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AUGMENTED REALITY DEFINITIONS

The most common definition of AR is a mixed environment that integrates digital information with physical objects in a meaningful way.[2] The phrase *augmented reality* was originally coined in 1990 by Tom Caudell and David Mizell from Boeing who created a head-mounted device for workers, displaying wiring schematics in an eyepiece while they assembled real wires for aircraft. Since then, AR has found numerous popular applications for tablet PCs, smartphones, and headsets such as the HoloLens and Google Glass. For example, superimposing direction arrows on a user's view of the real world for wayfinding or superimposing translated text on a view of a real sign or poster. One of the most popular applications was the game Pokémon Go, which enabled users to chase three-dimensional (3D) characters around their real environment.

AUGMENTED REALITY ADVANTAGES

Today, the phrase *augmented reality* has become more commonly used than *augmented virtuality* due to the advantages offered by AR systems. By using the real world, AR applications do not need to model every little detail of the reality, as these details are already physically present—it only needs to overlie the necessary digital elements to interact with the user in a meaningful way. Other advantages include the fact that the user can interact with the virtual information without losing contact with the real world,[3] and compared with virtual reality (VR), users of mixed reality and AR experienced less cybersickness.[4,5] It is also noted that AR seeks to simplify users' lives by bringing virtual information to their immediate surroundings,[6] and the affordability of mobile devices and the capability of their hardware to process digital information rapidly have made the widespread use of mobile AR feasible. This allows the user to interact with digital information naturally and acceptably. The benefits of AR, which include cost effectiveness, ease of use, portability, and independent operatability, are features explored by Akcayir and Akcayir's[7] systematic review, which claimed that smart devices offer an optimal platform for AR development applications. This therefore allows learners to engage in AR experiences using their own devices without the requirement for additional

equipment—AR applications can be downloaded at any time from the Internet to users' smart devices. The importance of the ease of access is highlighted by Carmigniani and Furht,[6] who defined a successful mobile AR system as an application that enables the user to focus on the AR experience rather than on computer devices; thus, they can move between digital and real worlds naturally. Integrating multiple devices could become critical in maintaining their stability, as using more devices leads to a greater risk of device failure.[2] In this way, mobile AR provides a more sustainable technology for daily learning and AR experiences. The significant advantages of AR compared with VR are presented in Table 1, which has been devised for this study.

The Benefits of Augmented Reality in Education

The advantages of using AR in education include the fact that it enables students to be immersed in a realistic experience and has attracted educators to use this creative way of enhancing learning. Recent studies have highlighted a positive impact of AR on education, by making the educational processes more active and influential. Many studies aim to determine the state of AR in education, including the trends, applications, benefits, challenges, and technical limitations.

In order to fully understand how the benefits of AR in education are perceived by practitioners, we undertook a review of the literature, in which we identified 24 review studies published between 2011 and 2020. The cutoff date of 2011 was informed by the increased interest since 2011 in the use of AR in a variety of disciplines, fueled by the developments in mobile technology and widespread smartphone usage.[7] Earlier studies exploring AR mostly provided a general overview, but more recently, studies have become more systematic or in a specific field such as surgery or anatomy. The studies identified here specifically reported one or more advantages for students of using AR in the educational process, and despite some limitations being acknowledged in the literature, Table 2 lists those benefits. These are summarized visually using a mind map (Figure 1), in which the numbers refer to the specific review studies listed in Table 2. The mind map illustrates how AR is an authentic, interactive, tangible, engaging, and visual learning instrument and highlights how most of the studies reported that AR is a *motivational learning strategy* that enhances students' learning and supports knowledge acquisition and retention. As motivation may affect students' academic achievement positively, the results of the review support Arici et al's[23] observation that motivation is one of the fundamental requirements for student success. Student success and motivation are key to enhancing learning. Other acknowledged benefits of AR include its ability to promote self-learning and enhance independence in learners. In addition, AR provides a creative way of interacting with materials. When the learners interact with both virtual and real-time information, this immediacy and immersion provides a natural experience to the user[29] and allows a smooth transition between the real world and the virtual world.[30] Well-integrated AR and organized relevant materials help to prevent incidental cognitive loads, which may lead to students' performances improving.[31] In addition to promoting realism-based practices, AR encourages self-directed learning between students.[32] It supports student-centered learning, which is a new learning approach that can replace traditional teaching methods by creating an active and self-based learning program. Augmented reality helps students to control their learning at their own pace and location.[8] This result is in line with the study findings showing that AR supports the students' ability for self-control and self-study.[33] Diegmann et al[14] claimed that student-centered learning with AR learning instruments could initiate a significant new education trend.

Table 1. Comparing AR and VR

AR	VR
AR is a technology that creates extra virtual layers on a physical object.	VR is an artificial digital world that replaces the real world entirely.
Affordable by using smartphone Less equipment (input/output in one device) No side effect Not losing the contact with a real world	Extra cost for the headset More equipment Cybersickness Losing the contact with a real world

AUGMENTED REALITY IN HEALTHCARE EDUCATION

Augmented reality has been utilized in many educational settings within the healthcare sector, for example, the practices of neurosurgery,[34] emergency care,[25] and medical training,[18] to reduce failure rate by improving performance accuracy[31] and learning anatomy.[28] Moreover, there are several potentials for adopting AR in a nursing setting, such as saving time, visual and individual instruments, supporting simulations, and reducing anxiety.[22] This section discusses three main themes: anatomy, training and acquiring skills, and clinical nursing education.

Anatomy

Conventionally, learning human anatomy is based on traditional techniques, including cadaver dissection, static anatomical illustrations, photographs, physical models, and 2D images in textbooks. In healthcare education, anatomy is fundamental, as the human body is the targeted investigation. Knowing that, sufficient anatomical knowledge leads to safe and quality healthcare practices, through understanding the decisions and actions taken.[35] Due to its importance, learning anatomy should be as effective as possible in terms of accurate information and resilience. In this way, cadaver

Table 2. The Educational Benefits of AR in General

	Article	Year	Field	Benefits
1	Yuen et al[8] (2011)	2011	Any	Motivation Enhanced learning Enhanced creativity Support independent learning and different learning styles
2	FitzGerald et al[9] (2013)	2013	Situated learning in outdoor settings	Motivation Engagement Support problem-solving activities Encourage independent learning
3	Bower et al[10] (2013)	2013	Learning by design	A creative way of learning that enhances students' knowledge and thinking
4	Wu et al[2] (2013)	2013	Any	3D and visual learning Real-time learning Visualizing the invisible content
5	Mekni & Lemieux[11] (2014)	2014	AR in different domains, education one of them	Visual learning Interactive learning Creative way of learning Enhanced learning
6	Antonioli et al[12] (2014)	2014	Any	Positive attitude toward AR in and outside the classroom Knowledge acquisition and retention Engaging learning Support independent learning
7	Bacca et al[13] (2014)	2014	Any	Motivation Engaging learning Enhanced learning Positive attitudes
8	Diegmann et al[14] (2015)	2015	Any	Motivation Support independent learning Accessible learning Interactive learning Creative way of learning
9	Tekedere & Göker[15] (2016)	2016	Any	Effective and efficient learning
10	Koutromanos et al[16] (2016)	2016	The natural sciences and took place within informal learning environments	Enhances active and authentic learning
11	Altinpulluk & Kesim[17] (2016)	2016	AR book	A creative way of learning Positive attitude
12	Barsom et al[18] (2016)	2016	Support medical professionals training	Enhance surgical training skills in a patient-safe environment Achieving the actual competence needed
13	Fatih & Omer[19] (2017)	2017	Formal education	Motivation Engagement Satisfaction Knowledge acquisition and retention Enhanced learning
14	Chen et al[20] (2017)	2017	Any	Motivation Realism Interactive Enjoyment Engaging learning Effective learning Positive attitude

(continues)

Table 2. The Educational Benefits of AR in General, Continued

	Article	Year	Field	Benefits
15	Akcayir & Akcayir[7] (2017)	2017	Any	Decreases cognitive load Engaging learning Enjoyment learning Support independent learning Promote self-learning Visual and tangible learning
16	Ozdemir et al[21] (2018)	2018	Any	Enhance learning and academic achievement
17	Wüller et al[22] (2019)	2019	Nursing	Has a positive effect on nursing education
18	Arici et al[23] (2019)	2019	Science education	Motivation Enhance learning Positive attitude
19	Quintero et al[24] (2019)	2019	Educational inclusion	Motivation Interesting and interactive learning Low cost Knowledge acquisition and retention
20	Munzer et al[25] (2019)	2019	Emergency medicine and training	Realistic simulation Enhance training skills
21	Garzón et al[26] (2019)	2019	Any	Motivation Accessible learning Knowledge acquisition and retention Self-learning
22	Uruthiralingam & Rea[4] (2020)	2020	Anatomy	Motivation Useful and effective tool for learning anatomy
23	Gerup et al[27] (2020)	2020	Healthcare education	Effective learning and training tool Patient safety Knowledge acquisition and retention
24	Chytas et al[28] (2020)	2020	Anatomy	A highly acceptable and enjoyable anatomy teaching tool Visual 3D learning Enhance academic achievement

dissection has been rated the gold standard for learning human anatomy[36] for medical students but not in nurse education. Other challenges associated with learning anatomy include its complexity, as learners find difficulties in learning and remembering anatomical information.[4,36] A possible explanation for this difficulty could be practical limitations, such as difficult concepts in a large group of students, leading to passive participation during the class, and a massive amount of material to be learned.[35] This issue is confirmed by Triepels et al[37] who found that, although students believed in the importance of sufficient anatomical knowledge, almost half of them rated their knowledge as insufficient, and the study suggested that using 3D techniques could help to solve this issue. With a 3D model, students can rotate and manipulate structures from different views to recognize the anatomical structures.[25] In contrast, a scoping review study by Azer and Azer[38] argued that there was no substantial evidence that using 3D models is better than traditional teaching methods, yet 3D models in digital and physical formats were favored by students in comparison with textbooks. A recent systematic review by Triepels et al[36] stated that computer-based, virtual, or AR learning methods were more effective anatomical instruments in general compared with traditional methods based on learners' test scores. Students were motivated and interested in using the new visual methods to learn anatomical structure. Several advancements in technologies and techniques have provided more resources that aid in teaching anatomy and providing easy access to educational resources, such as AR and VR.[4] Augmented reality provides adequate 3D visualization of anatomical structures[28] that can also help to understand the shape and location of the organ.[39] Previous studies' findings reported significant improvements in acquiring anatomical knowledge by utilizing AR learning instruments.[27,40] A recent systematic review study by Uruthiralingam and Rea[4] revealed that most of the articles were on the use of AR and VR in anatomical education, with Chytas et al's[28] study showing that AR can be an accepted anatomy learning instrument offering enjoyable learning.

Training and Acquiring Skills

Many AR applications have been viewed as valid and reliable methods for medical professional training for some time and provide fundamental and situated learning experiences. For example, in a high-risk environment such as the operating

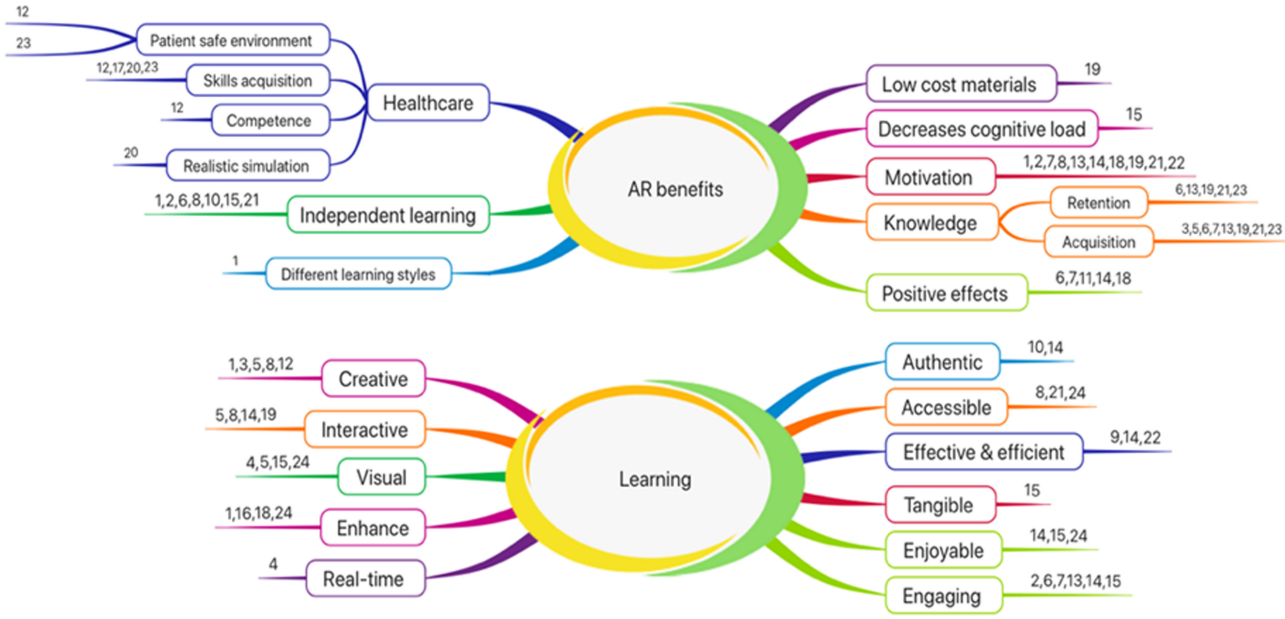

FIGURE 1. Mind map of the benefits described in Table 2.

room, AR has the potential to bridge the gap between achieving the required competence and the real world. Better training for surgeons in a virtual environment, ultimately, leads to making fewer mistakes in the operating room by creating an authentic simulated experience that enhances learning acquisition and retention.[18] Bifulco et al's[41] study approved the feasibility of using AR to guide the untrained user with limited knowledge to correct usage of electrocardiogram medical devices with minimal errors. The study reported that all the participants completed the electrocardiogram test with only AR-supported instruction; they were able to carry out the completed test firstly on a manikin and then on a real patient. The possible explanation for achieving independent training could be the well-designed procedure. Additionally, AR has been used in training medical staff using an ultrasound simulator with a head-mounted display, where the system allowed the user to visualize the simulated ultrasound slice and human anatomy, as well as the training procedure including synchronized feedback. In reality, teaching staff how to use ultrasound can be achieved through training on volunteers who are generally in a healthy condition. However, the use of AR simulation can enhance the training by including unhealthy patient cases such as internal bleedings.[42] Similarly, low-cost AR had been used in radiology training and education to simulate ultrasound-guided procedure, which included images and anatomy for interventional radiology[43]; however, due to there being no specific mechanism for actual feedback in the study, participants did not feel that the procedure was realistic. It is well reported that feedback is an essential feature in effective learning in simulation-based education.[44] Educational feedback allows students to self-assess and monitor their progress. Thus, feedback and careful analysis of tasks should be considered when developing an AR learning instrument in a clinical setting.

Nursing Clinical Education

In any healthcare curriculum, clinical education is an essential component, since clinical practice occurs when the learners are exposed to real patients in a clinical setting environment.[45] Alternatively, patient simulation is a practical approach for training students before entering the clinical environment, utilizing patient manikins that allow learners to acquire mandatory skills and practice without worrying about harming real patients.[46] Practicing with a manikin can be achieved in a clinical or simulation laboratory. The terms "clinical skills lab," "clinical lab," and "skills lab" throughout this work refer to patient simulation training approaches. The goal of a clinical skills lab in nurse education is to prepare students to develop, apply, and practice the theoretical knowledge and skills as safely and effectively in their preparation to become professional nurses.[47] Moreover, most universities adopt clinical skills labs, considering the facilitation of nursing students' clinical preparations. They improve the transition as smoothly as possible to the real-life nursing experience, by bridging the gap between theory and practice and providing a safe environment for nursing students to practice the necessary skills. Consequently, the clinical lab is essential to nursing education in order to achieve clinical learning outcomes and improve students' competence, knowledge, and confidence.

Simulating a clinical situation by blending digital elements with the physical skills in a learning lab creates a promising opportunity for the education of nursing professionals in a safe environment.[18] However, developing practical knowledge in nursing education is crucial, yet it can be a complex process that is sometimes difficult to teach. The primary evidence in the literature states that integrating blended learning, which utilizes technology-enhanced teaching alongside traditional approaches in clinical education, offers the opportunity to improve clinical competencies among healthcare students.[45] Within the clinical skills context, where outcomes are measured in terms of clinical competence, the challenge for educators is to maintain the careful balance between giving instruction and promoting inquiry, so that efficient and effective skills acquisition occurs in a short time.[48] Augmented reality, on the other hand, can build capacity in the clinical skills session, as having the AR resources available on mobile devices and at the bedside reduces the learner's frustration from not getting immediate support from the session facilitator.[49] It is important to acknowledge that AR teachers can support an active role in directing the students and facilitating their learning, rather than being the center of the learning experience. Providing students support to facilitate the development of clinical skills education is another challenge.[45] Camba and Contero[50] stated that learning a complex concept can be improved if the teachers incorporate teaching methods that are interactive and student-centered, and take advantage of new technology. In this regard, AR technology supports attractive and engaging learning materials by promoting the development of visualization, self-assessment, and self-regulated learning. Moreover, AR has been used in nursing education to provide a more authentic learning experience than manikins can. It holds the promise of improving the realism of the simulation lab, and students have reported that practicing in a real environment enhances their motivation.[51]

Situational learning describes the uniqueness of healthcare education, when the learners are required to be in a real or simulated environment to boost their familiarity with a clinical setting.[52] Alternatively, it has been suggested that an effective technology-enhanced environment could play a role in learning outside the lab.[53] In addition, another review study of the use of AR in medical education revealed that AR helps to facilitate real-life situational learning, which leads to enhanced competencies in clinical procedures.[52] In recent times, the COVID-19 pandemic has brought unprecedented challenges to many schools of nursing worldwide, since learners are restricted from attending face-to-face classes and gaining "hands-on" clinical experience. Most schools have been required to shift to an online teaching format only. Consequently, there is a need to find an online clinical replacement solution during the crisis.[54] Augmented reality and VR simulations have been used alongside other educational strategies during the pandemic to support clinical competency utilizing the online format.[55] The current study gathered data before the pandemic took hold, and the results reported here must therefore be understood in that context. Further studies will be required to gain an accurate understanding of the very recent changes to the use and effectiveness of AR in education in response to the pandemic. There is evidence that practicing simulated experiences at any level is an effective way to support students' learning and the development of clinical skills.[56] An authentic experience provides more reliable patient information that is similar to clinical practice. Accordingly, the importance of realism in a clinical lab cannot be neglected. A pilot study by Vaughn et al[51] integrated AR (wearable Google Glass) on top of a mannequin to project a simulated video of a patient scenario into the student's field of vision. The result showed that enhancing realism in clinical simulations increased the students' confidence to perform necessary tasks in a real clinical environment. An equivalent experience was reported by Chaballout et al,[46] who showed the feasibility of AR in enhancing realism in the clinical lab by using Google Glass. However, technical challenges were also reported. For example, it took longer to train participants on how to use Google Glass, which may affect their perception of the usefulness of AR as a learning instrument. Thus, the affordability of mobile AR provides one of the best platforms for setting a real clinical or laboratory environment as a background to classroom activities.[52] Moreover, the enjoyment of interacting with AR may impact on nursing students' learning and motivating them to be active learners.

LIMITATIONS IN AUGMENTED REALITY RESEARCH

Despite the rising interest in AR and a large number of development studies, there are still many obstacles and problems that need to be overcome. Technical limitations are the most significant challenges reported in many of the studies, for example, complex devices[26] and usability.[7,9,13,19,25] Other problems were caused by cameras, the Internet, or indoor users, and a lack of technical skills.[57] Another limitation that is often reported is the small sample size in short-term studies,[13,14,19,22] since the generalizability of published research in small sample sizes is problematic, and researchers have suggested the need for future longitudinal studies. Additionally, a scoping review in nursing reported that there is a lack of use of objective data to evaluate AR systems.[25] Below is a brief description of some of the limitations found in the literature, classified as technical limitations, distractions, and teacher resistance.

Technical Limitations

The technology still has hardware and software obstacles that need to be addressed. An AR system has to handle a massive amount of information in reality. Consequently,

the hardware should be robust, easy to use, portable, and fast enough to process and present the digital content. It also requires some form of Internet access or devices connected to each other. Ensuring a sustainable quality of the signal and sufficient charge of the batteries depends on the devices used and the Internet service providers. For example, using wearable glasses with hand gestures for an AR system in a large classroom may be infeasible, and the class duration might not be adequate to complete all of the learning activities. Moreover, the limited market for wearable devices is another obstacle, alongside the short battery life and poor wireless connection of those devices.[19] Additionally, difficulty and usability issues cause time to be wasted and additional lecture time being required,[7] and technical problems and minor crashes reduce students' motivation to use the technology.[19] Although usability is the primary technical issue reported, mobile AR applications have been reported to be more usable than desktop applications.[26]

Distraction

The technological ability required to use AR systems demands more attention, which can be a distracting factor. The essential skills required to manipulate and interact with the digital content could be a challenging experience for the first-time user. The novelty of the technology may also distract students by focusing on shiny devices rather than the learning experience.[9] Students who used the AR documents have reported that too many items on the page can also be distracting.[19] Moreover, different levels of students' visual ability can affect their interaction with the system. Students with high visual ability can easily create a mental map of both environments compared with those with low visual ability.[4]

Teacher Resistance

School restrictions or teacher resistance could be encountered when adopting AR in a classroom, and some teachers have expressed worry over how they can manage all the technologies, as well as overcome technical difficulties during their classes.[12] Other educators were concerned that when students experience the creativity of AR, they may not go back to their previous methods of learning.[12] Augmented reality can change the teacher-centered approach into a student-centered format, and teachers have reported that learners engaged in their learning experience with AR and took responsibility for their learning, meaning that the educators become facilitators for their learning.[58] Furthermore, the teachers' ability to use the technology[7] and lack of technical skills, such as programming experience, or developing 3D or multimedia content,[57] are possible reasons why teachers resist using the technology. Although implementing AR in a classroom is considered a low-cost technology, due to the affordability of the mobile devices, designing and developing the system may be too costly.[24] Inflexible content is another issue when teachers are unable to revise or create AR learning activities in an AR system that has been developed by the AR company.[2] A study reported that the expensive retraining of staff on how to utilize the system can be one reason against using AR in a healthcare setting.[59] Recently, the new generation of smart devices has been integrated with AR features, and this development of mobile augmented reality technology could overcome some of the hardware limitations. Accordingly, it is always important to consider technology capability and pedagogical aids when designing AR learning activities. Wu et al[2] stated that instructional design should include carefully distributed information and flow between the two worlds and various devices. Further research needs to be undertaken in usability studies for AR applications in education, along with guidelines for designing AR-based educational settings.[13]

RELATED WORK

The number of empirical studies focusing on AR in nursing is limited, and most have evaluated the AR prototypes used in a broad clinical setting or nursing education.[22] This result is unsurprising, and a similar result has been reported in other disciplines. A possible explanation, besides the expensive development of an AR system, is that there is a lack of technically skilled workers. According to the Immerse UK Web site,[60] mind and skills gaps are barriers of immersive United Kingdom's economic growth, and there is a lack of technically skilled and creative workers, so a leader who understands both the technical and creative aspects of the technology is needed. Not having sufficient skills when graduating from universities is another reported issue. Those challenges prevent researchers from developing large-scale AR projects.

However, a review of the literature has identified that AR is used to learn either anatomy or pathophysiology, which forms a theoretical component of the curriculum, or to learn to understand a patient's scenario, which is a practical component. It also reveals a lack of studies designing an AR system to connect the theory and practice. This section describes five studies conducted in teaching theory or practice by utilizing AR technologies. Those studies have been chosen as a representative sample from the literature, and other studies may use different devices or approaches.

Study 1

The ability to learn about human anatomy can sometimes be difficult for students to visualize the different elements. Hamrol et al[61] have developed an application that is divided into four main sections: (1) lecture, (2) exercise, (3) immersive exercise, and (4) test. In the lecture mode, the lecturer used a predefined scenario to carry out class activities on a specific physiological, pathophysiological, or anatomical problem.

In the exercise mode, students were able to interact freely with the virtual human body. They utilized standard computer monitors as display screens during their practical classes. The third mode was immersive exercise, in which the user was wearing an head-mounted display, which was equipped with markers of the optical tracking system. The user has been moving around the virtual body by literally moving around the room. In the fourth section, the authors suggested adding a test mode, but it was not functional and was not used during the evaluation phase. Even though the concept of the interactive 3D application has a positive influence on the educational process, the system was reported as hard to operate. This was especially true in the immersive mode, as a qualified AR technician was needed every time to ensure the comfort and safety of the HMD during the exercise. Also, students were not able to practice the immersive mode outside the classroom due to the difficulty with making the system available to the students. Unfortunately, the very complicated input/output devices led to the need for a simpler and cheaper solution. Moreover, missing the pedagogical approach is another limitation. The study did not clearly consider learning theories while developing the system. According to our review of AR in education, most studies did not define using the pedagogical approach. Instead, they just focused on integrating AR technology into classroom activities and evaluated the findings concerning educational outcomes.[19]

Study 2

The development of human anatomy knowledge is key in allowing students to progress with their learning and become competent practitioners. Salmi et al[40] have developed a prototype of the mobile AR application called Human Anatomy as an educational instrument. It was designed to enhance students' motivation in learning skeletal structure in a complex subject such as anatomy. This subject includes learning anatomy in the practical dissection laboratory, where the students expose the structure of the human body and internal organs. The study adopted ubiquitous learning concepts, which mean learning takes place in the workplace, educational places, and the home. The simplicity and mobility of the mobile device allow more effective learning and the assimilation of knowledge. With the MAR application, students should be able to enhance their learning environments and improve their ability to retain information. An experimental method was conducted to measure the reliability of the Human Anatomy application, and the study results showed that students were satisfied with MAR features and interested in utilizing it in their learning process. Also, they rated the object manipulation with the highest score, which led to MAR having a substantial capacity to convey information and make learning interactive. According to the authors, object manipulation was considered as one of the essential factors in the MAR learning atmosphere. Moreover, the study stated the positive impact of MAR in stimulating students' learning environments and promoting their motivation to learn. Studies have showed that the level of motivation and enhancing the learner's experience could lead to a more robust student-centered learning concept and impact the ability of individuals to achieve their learning objectives in their learning process.[62,63] There is a need for further investigation into the effects of MAR on students' independent learning.

Study 3

Realism in simulation is an important factor in allowing the students to gain confidence and knowledge in the procedures in a safe environment. Traditionally, manikins have a limited capacity to be able to provide sufficient realism in the simulation lab. Vaughn et al[51] have described the piloting of an innovative hybrid simulation to incorporate video film using an AR headset designed to increase the perception of realism in high-fidelity simulation. While students performed assessments on a mannequin in a simulated lab scenario by wearing Google Glass, a wearable head device was simultaneously projecting video onto the students' field of vision. The video combined visual images and cues seen in a real patient and created a sense of realism that the mannequin alone could not provide. It allowed learners to more fully engage in the scenario and understand what is happening to the patient. A simulated patient is an actor who portrays specific physical symptoms in a scenario to fulfill the learning objectives. The video displayed these clinical manifestations and functioned as a prompt for students in their assessment of the patient. The students who completed the simulation were then asked to respond to a Web-based survey immediately following the experience. They reported that the simulation gave them confidence that they were developing skills and knowledge to perform necessary tasks in a clinical setting and that they met the learning objectives of the simulation. Also, they stated that using such a learning instrument better prepared them for caring for a patient in respiratory distress, explicitly improving their recognition of signs of respiratory distress and improving their knowledge base. An unexpected result from the study was that students reported that they found that realism enhanced their motivation. The realism of the technology contributed to independent problem solving, which they found motivational.

Study 4

Ferrer-Torregrosa et al[64] have developed a new learning instrument called ARBOOK. It was designed based on AR technology focusing on teaching the anatomy of the lower limb. The book had two sections: descriptive and cards. The card was a marker that can be recognized by a webcam

connected to the desktop computer. Then, the virtual 3D model appeared on the screen. Students were able to interact with the model and modify the actual position of the virtual structure by moving the card. The study investigated the role of AR in terms of motivation and independent learning. A total of 211 students were divided into two groups. The control group received standard teaching sessions supported by books and videos. The ARBOOK group received the same standard sessions but additionally used the ARBOOK instrument. The study result showed statistically significant differences between the two groups with better scoring for the AR group. The study concluded that ARBOOK is significantly better than conventional methods in promoting motivation and autonomy. The authors stated that, with current technologies, the development of instruments promoting self-learning and autonomous work must be seriously considered for anatomical training and other sciences. The motivational learning environment can lead to students developing self-learning skills.[64]

Study 5

Rahn and Kjaergaard[62] have worked on a proof-of-concept that an AR application creates an illusion of seeing a person's lungs breathe within that person. The app was developed to show a set of natural-sized, moving and breathing lungs. In the production of the actual images of the lungs, a realistic and accurate representation was more important than a fancy and appealing "wrapping" and interface. The application focused on the lungs, as understanding their working is complicated. The system had an iPad application and T-shirts with printed logos as markers. Students worked in groups of 4-5. For the experiment, three students wore the T-shirts with a tag positioned on the front and back of the shirt. The iPad was providing the illusion of lungs being located and moving inside the person wearing the T-shirt. This allowed other students to investigate with the iPads. The results showed that the AR app provided a much more realistic image of the lungs than a textbook. Students viewed the images that became available through AR as an essential factor in their whole-body understanding in the subject of anatomy and physiology. Their focus was on the topic, and they sought knowledge of the human body's structure and functions. Also, the system made the reading less "heavy" due to the image appearing immediately, authentically displaying what the organs look like and how they work. In terms of the degree to which the app presents real or realistic images and movements, students judged this as more illustrative than other apps they have previously worked with. It was clear that the 3D images provided students with knowledge of the position of the lungs inside the body. Thus, the images aided students in the adaptation of their already constructed mental images.

Despite many studies concluding that AR enhances independent learning and supports shifting to a student-centered learning approach, the five studies we have scrutinized did not describe how the individual AR systems were designed to achieve those outcomes. In Table 3, we summarize those five studies and note that in none of them was self-assessment used as a learning approach to underpin the claims that AR

Table 3. Proposed Solution

Article	Learning Theory	Anatomy	Pathophysiology	Scenario	Self-assessment	Input/Output Devices
Hamrol et al[61] (2013)	NA	√	√	X	X	Large-screen projection for lecturer Standard computer monitors or mobile application for home studying Head-mounted device for immersive exercises
Salmi et al[40] (2015)	Ubiquitous learning	√	X	X	X	Android tablet
Vaughn et al[51] (2016)	NA	X	X		X	Google Glass
Ferrer-Torregrosa et al[64] (2015)	NA	√	√	X	X	Digital webcam connected to a computer
Rahn & Kjaergaard[62] (2014)	Social constructivist Inquiry-based science education	√	√	X	X	iPad
Proposed MAR	Self-regulated learning	√	√	√	√	Mobile device

Abbreviation: NA, not applicable.

enhances independent learning. We therefore propose a new learning approach that might support self-regulated learning by connecting the theory to practice and adding self-assessment and feedback features to the AR systems.

CONCLUSION AND FUTURE WORK

In conclusion, this research has presented a comprehensive overview of AR technology in education, summarizing the current state of knowledge and identifying the literature gap. Several potentials approaches for utilizing AR in nursing education have been identified, such as promoting self-learning and facilitating a student-centered approach. However, the literature review revealed that there was a lack of studies integrating AR and self-learning theories (such as self-regulated learning). Our future research will address this gap by proposing and evaluating features to be incorporated into the AR learning environment designed to enhance students' independent learning.

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