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REVIEW

Augmented reality and gamification in pharmacy education: A call for implementation in African countries and other low resource settings

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Abstract

Background: Augmented reality (AR) and gamification, which involve the use of mobile devices, tablets, and laptops to enhance learning experiences, are relatively new in tertiary education. This article calls for the implementation of AR and gamification in pharmacy education in African countries and other low-resource settings. **Method:** A search strategy was conducted using the following keywords: 'gamification', 'augmented reality', 'game-based learning', 'pharmacy education', 'African Countries' and 'low resource settings' on PubMed, PubMed Central and Google Scholar databases. **Results:** Pharmacy students in African countries and other low resources settings face challenges which include: a limited number of lecturers, underdeveloped infrastructure, paucity of knowledge, and restricted educational resources coupled with a lack of pedagogy related to teaching courses. Incorporation of AR and gamification systems into their learning process will enhance student motivation and understanding. **Conclusion:** Pharmacy schools and concerned stakeholders in African countries and other low-resource settings should consider the rapidly evolving technology by developing appropriate and productive AR and game-based learning concepts that would enhance learning experiences, given its numerous benefits.

Introduction

Augmented reality (AR) is an immersive technology that superimposes digital objects into the physical world; It creates a reality where users can engage with a virtual environment without losing the authenticity of the real world. For students, AR can provide a realistic learning experience. AR in education is a student-centred learning approach that augments traditional teaching methods such as face-to-face learning. AR enhances the understanding of complex and abstract topics by its ability to turn conceptual and difficult-to-visualise subject topics into fundamental and observable concepts, thereby increasing the motivation to learn. AR tools also serve as flexible learning platforms allowing easy accessibility and visitation of learning content at any time or location outside of classroom settings (Schneider *et al.*, 2020).

Gamification, also known as game-based learning, involves using game mechanics in a non-game context to digitally engage and motivate people to construct new knowledge, achieve their goals and solve real-world problems. Game mechanics are tools, techniques, and applications that increase users' interactivity, rewards, and motivation (Sera & Wheeler, 2017). Goals, competitions, badges, scores and leaderboards are examples of mechanics used to motivate learners (Dabbous *et al.*, 2022). Although commonly used in marketing strategies, gamification is now being introduced into educational programmes. It helps educators find the balance between achieving their set objectives and catering to evolving needs of students. A common problem students encounter in the learning process is a low willingness to complete a task due to a multitude of reasons (Huang & Soman, 2013). However, with today's digital generation, students are motivated to engage in gamification as it presents a tactic to transform a simple or mundane task into an addictive learning process (Dabbous *et al.,* 2022; Huang & Soman, 2013). An integration between gaming and teaching, as well as a balance between enjoyment and education, triggers interest among learners and enables them to meet the intended learning outcomes (Dabbous *et al*., 2022). Through virtual learning environments and classroom activities, gamification has been introduced to higher education. Gamification improves students' academic performance as a result of a change in teaching methods which leaves behind the traditional unidirectional teacher-student teaching model to incorporate gamified active learning through challenges and significant tasks (Manzano-León *et al*., 2021). Gamification helps to achieve learning outcomes through its innovative way of promoting active learning, which boosts information retention and performance (Dabbous *et al*., 2022). This learning process encourages specific behaviours, increases motivation and engagement, and reinforces desirable study habits (Huang & Soman, 2013; Manzano-*León et al.*, 2021). Socrative, Kahoot!, FlipQuiz, Duolingo, Ribbon Hero, ClassDojo, and Goalbook are among the most popular gamification tools for education (Kiryakova, Angelova, & Yordanova, 2014).

AR and gamification in pharmacy education has a wide range of uses. For example, pharmacy education requires continuous lessons on the use of medicines as students are required to have comprehensive know-ledge about an extensive range of medicines and devices. The students are also expected to be versatile in the application of this knowledge to optimise patient care through the provision of appropriate medication and device counselling. However, accessibility to these medicines and devices during the learning process is difficult because of cost, expiration, handling and storage, access restrictions such as for opioids, and product design or packaging changes over time. This difficulty also extends to when students are not in the classroom or not enrolled in a particular subject. However, using AR in pharmacy teaching provides a solution to these limitations both inside and outside of the classroom setting. By purchasing one product or device, media such as 360-degree photos or videos can be produced and the components of such product can be captured. This provides visual images superimposed with the natural world and can be incorporated into interactive learning modules, negating the need to purchase multiple medicines and devices every time they are needed (Schneider *et al*., 2020). In addition, students in Australia have described the use of AR for learning using HP Reveal as enjoyable, stimulating, motivating, and aiding their learning (Salem *et al*., 2020).

Similarly, in the context of gamification, incorporating different styles of games into pharmacy education aids students in preparing for real-life experiences. It can be used to expose them to several scenarios that they may encounter. Thus, allowing their critical thinking and communication skills to handle these scenarios best (Shawaqfeh, 2015). Gamification also increases learning outcomes through rewards, levelling-up, badges, and a leaderboard (Jones & Wisniewski, 2019; Kiryakova, Angelova, & Yordanova, 2014). Examples of gamification in pharmacy range from electronic flashcard quizzing via Quizlet and computer games to escape rooms and simulation games (Jones & Wisniewski, 2019). In the United Kingdom, a web-based game was developed by a university to allow pharmacy students to review various aspects of the curriculum in preparation for their licensing examinations. Designed as a timed multiple-choice trivia quiz, a post-intervention survey found that 59.3% of respondents claimed they would use the game for other works in the future, and 60.4% of respondents would appreciate a similar activity for other pharmacy modules (Dudzinski *et al*., 2013, as cited in Sera & Wheeler, 2017). Likewise, a study at the University of North Carolina Pharmacy School, United States of America, to determine the effects of adding games to traditional lectures concluded that most students found the games enjoyable and helpful for gaining confidence while exposing them to real-life experiences (Persky, Stegall-Zanation, & Dupuis, 2007). Similarly, participants of a pilot study of PharmacyPhlash, an educational board game developed for pharmacy students at the University of KwaZulu-Natal, South Africa, described the game as a fun way of reinforcing learning (Bangalee *et al*., 2021).

Limited research, however, has been conducted on AR and gamification in pharmacy education in low-resource settings. Low-resource settings are settings with a complex network of interrelated concepts of financial pressure, suboptimal healthcare service delivery, underdeveloped infrastructure, paucity of knowledge, research challenges and considerations, restricted social resources, geographical and environmental factors, human resource limitations, and the influence of beliefs and practices (van Zyl *et al*., 2021). Low-resource settings include most low-income countries and some regions in the middle and high-income countries (Wootton & Bonnardot, 2015). Of the 28 low-income economies, according to the World Bank (2021), 24 are African countries. This paper calls for the implementation of AR and gamification in pharmacy education in Africa and other low-resource settings. The authors discuss the historical perspective, challenges, rationale for adoption, and a proposed framework.

Method

Search strategy

A search for relevant articles was conducted on three databases (PubMed, PubMed Central, and Google Scholar). The following keywords were used in the search: 'gamification', 'education', 'augmented reality', 'game-based learning', 'medical education', 'pharmacy education', 'low resource settings', 'history', 'rationale' and 'challenges'. Combinations meant to capture AR and gamification in pharmacy education, their rationale, framework design, history, and challenges were among the search terms.

Eligibility criteria

The articles that were included in this review were: (1) Studies conducted using game-based learning applications or AR to assess their use and impact amongst students in tertiary institutions, (2) Studies conducted on game-based learning and AR towards pharmacy education, (3) Studies on implementation of AR and game-based learning in tertiary education and (4) Studies that identified challenges in implementing the AR and game-based learning in tertiary education. Papers that were not written in English were excluded.

The search was restricted to articles published between 1997 and 2022. It contained articles that provided a timely overview and history of AR and gamification. The search included a thorough screening of full-text publications, reviews, and reports, with only those highly relevant to this study being chosen. The reference lists of the identified articles were screened, and articles were selected if they met the eligibility criteria.

Historical perspective

Technology's evolution can be seen in its influence on the world in the past 25 years, as new ideas, concepts, and products aimed at improving the life of mankind are introduced into different aspects of life, including the industrial, commercial, and educational sectors. A prominent are of technological innovation today is the concept of AR. While the idea of using virtual images to improve day-to-day activities in the real world has a long history, the concept of AR can be traced back to the work of a computer interface pioneer, Ivan Sutherland, in 1965. With Bob Sproull, Ivan Sutherland created the first prototype AR system, called 'Helmet Mounted Display' (Billinghurst, Clark, & Lee, 2015). Although the term 'Augmented reality' was coined by Tom Caudell and David Mizell in 1992, its application in the education sector has only been established recently. Researchers and educational professionals are now improving their learning systems by applying AR at primary, secondary, and tertiary levels.

Gamification, however, was introduced as an innovation targeted specifically to increase individuals' motivation and compliance by adopting elements from games. The concept of gamification began in 1961 when French sociologist Roger Caillois wrote an article titled Man, Play, and Games; In the article, he discussed sophisticated forms of games that entertain (Pandey, 2017). However, the first paper introducing the modern meaning of gamification to the world of academic research, written by Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke, was published in 2011 (Deterding et al., 2011; Pandey, 2017).

Results

Rationale for adoption in Africa and other low-resource settings

One of the most critical challenges faced by pharmacy students is understanding the content of the course; this often creates negative emotions and experiences, leading to increased rejection and dropout rates from pharmacy school (Mellado *et al*., 2014; Vidakis *et al.,* 2019). The limited number of lecturers, underdeveloped infrastructure, paucity of knowledge, research challenges, restricted educational resources, and lack of pedagogy related to teaching courses are challenges faced by pharmacy students in low-resource settings like Nigeria and wider Africa (van Zyl *et al*., 2021). Furthermore, enhancing the way students investigate and understand phenomena and concepts while promoting active and scientific thinking is critical (Hug, Krajcik, & Marx, 2005; Slykhuis & Krall, 2011). Therefore, the integration and adoption of AR and gamification in pharmacy education would significantly improve the learning and teaching processes in these low-resource settings. AR application has become more widespread with the rapid developments in handheld devices and subsequent ease of use which creates a student-centred approach to learning (Azuma *et al*., 2001). The design and predicted learning effectiveness of AR are underpinned by constructivist learning theory and situated learning theory. This enables students to be involved in active learning and experiential ways, which enables them to construct their own context, knowledge and understanding through reflection (Dunleavy, DeDe, & Mitchell, 2008; Wen *et al.*, 2019). A study by Thompson and Chapman (2022) involving 68 undergraduate pharmacy students revealed that AR increased their motivation towards learning when compared with a conventional method and, as such, is a useful learning tool. Moreover, with the success of digital games in education, gamification is becoming increasingly accepted as an effective learning strategy for creating highly engaging learning experiences. Many studies have investigated the effects of gamification, producing results in support of its potential to improve: motivation, engagement, and social influence while allowing students to immerse themselves in experiential learning (Groening & Binnewies, 2019; Lopez & Tucker, 2019). The adaptation of gamified concepts will enhance pharmacy students' positive learning outcomes, most especially in low-resource settings in low-and-middle-income countries, specifically the global south such as Africa.

Gamification in higher education involves applying game-based mechanics and aesthetics (such as achievements and scoring systems) to motivate and support learning activities within the classroom or embedded within a virtual learning environment (VLE) (Kapp, 2012). The mechanics of gamification include aspects such as role-play, rules, cooperation and competition, resistance, problem-solving activities, feedback mechanisms, and resources to promote or impede progress, and all of these closely resemble video games (Des Armier Jr., Shepherd, & Skrabut, 2016). Students can develop their understanding through problem solving or exploring learning activities within the gamified environment because memory is activated through collecting or matching tasks. Other aspects of the gamified environment are avatars, challenges, narrative and changes can positively impact learning and motivation (Kapp, 2012; Kapp, Blair, & Mesch, 2014). A survey conducted by Project Tom-orrow found that gamification increases student achievement (Caise, 2019). Palomino and colleagues (2019) found that traditional teaching methodologies implemented alongside gamification also achieve positive results. Gamification is therefore a useful addition to traditional teaching methods as it has the potential to enhance student achievement. Tsay, Kofinas and Luo (2018), however, found that learners achieved higher scores overall in practical assignments, but performed poorly in written assignments with less participation in class activities. Therefore, it would be important to consider the specific goal and context of the implementation that would align it to the highest likelihood of success and the decrease potential effects on other learner behaviours. This should serve as a caveat to the implementation of gamification.

Furthermore, according to van Loenen (2019), serious games can make use of both low-cost and high-cost simulators, and they are scientifically validated since they are validated by researchers and experts during the development phase. Many serious games in the field of e-health have been developed in the last decade (Roubidoux, Chapman, & Piontek, 2009), and these games deal with a variety of aspects such as surgeon training, radiography operations, cardio-pulmonary resuscitation (CPR), and patient care. Gostin (2000) highlighted the importance of well-trained and educated healthcare professionals to avoid medical errors. This indicates that the use of serious games in health education can provide an additional means to develop an interest in learning, training, and evaluating the performance of patients and health professionals. From the patient’s perspective, games can have direct or indirect positive physiological and psychological effects on individuals (Watters, Oore, & Kharrazi, 2010), which is precisely the aim of serious games in healthcare. Watters, Oore and Kharrazi (2010) investigated the use of games for children with long-term treatment regimes, where the motivation for compliance is a critical factor in the termination of the treatment.

Students can use AR to learn from their mistakes, obtain feedback from teachers instantaneously, reflect on their mistakes, and try again. This could be very helpful for pharmacy students learning about patient safety, critical care, prescription errors, and how to have difficult conversations (Coyne *et al*., 2019). The interactive 3D environment afforded by AR can provide different perspectives that may make difficult topics embedded in the pharmacy curriculum easier to understand and conceptualise. For example, students could follow the journey of a drug through the human body to learn about pharmacokinetics (Coyne *et al*., 2019). Also, some topics are tedious and/or boring for students to learn; AR can add an element of fun through interactivity or even gamification (Upwork, 2018). Shawaqfeh revealed that memorising the brand and generic names of drugs could be developed into a game to increase engagement (Shawaqfeh, 2015).

Whilst face-to-face pharmacy teaching allows students to interact with real medications and devices, which helps them become more comfortable with them, it requires that students purchase a vast number of different drugs and devices in order to use them in class. The acquisition of these products can be costly, and in some situations, the cost of these products may prevent them from being purchased for classroom usage. AR, on the other hand, can provide visual images of products and equipment for usage both inside and outside the classroom, as well as images of foil strips from tablets or other components contained within the packaging for use in AR resources (Schneider *et al.,* 2020). According to Wijma and colleagues (2017), an AR simulation movie depicting dementia through the eyes of a patient was found to assist carriers with insight and understanding. Furthermore, AR could be used to allow pharmacy students to see what it is to be a patient, with AR providing the movement of a drug through the body on the anatomical, cellular, and molecular level to see how drugs are distributed, how they affect various organs, structural changes to the drug during its journey, metabolism, and elimination (Coyne *et al*., 2019). AR is also proving to be useful in patient care by providing opportunities to understand patients, helping patients overcome phobias, distracting patients from pain, and motivating patients to change their lifestyle (Miloff *et al*., 2016; Morris, Louw, & Grimmer-Somers, 2009). In providing an experiential learning opportunity for students, both AR and gamification learning have been proven to be effective e-Learning supports that can be used to simulate and assess clinical techniques. They provide unlimited access to practice sessions, along with the quick feedback needed for effective learning while also allowing for a standardised assessment of the skills acquired by students (Duta *et al.,* 2011). Given the numerous benefits of AR and gamification, low resource settings should incorporate these systems into their learning process so as to enhance pharmacy student motivation and under-standing.

Discussion

Proposed framework

AR and gamification technology have been simplified to be readily accessed and operated via tablets, personal computers, and mobile phones (referred to as Mobile AR) in the form of apps that improve visual learning and critical thinking (Behmke *et al*., 2019). Several studies using AR-based games and applications to understand the influence of AR and gamification in education have demonstrated this; For example, Tosti and colleagues (2014) found that the AR-based and gamified approach increase learner's motivation through its ability to provide rapid feedback and relevant learning information.

In China, researchers investigated how environmental education, mobile AR, and gamification may be combined to function at a low cost and be accessible at tertiary institutions (Mei & Yang, 2019). The study by Mei and Yang (2019) used ARIS as a design tool to create a mobile AR-based platform for learning and teaching. It enabled increased student interaction with the campus environment. ARIS focused on using the features, such as plants, in understanding English terms associated with the campus environment. Botanical plants will need to be sampled for identification. The identified features from sampling are converted into meaningful data, which is important in creating an AR-based platform such as ARIS to aid students learning in pharmacy education. There is a need to begin employing the physical and social environment to design concepts such as plant puzzles, nomenclature, and other pharmacognosy concepts.

The overall AR-based learning experience would have to be monitored. AR-based learning should increase overall learning from the theory covered in the classroom, ensuring that concepts taught in classes can be better understood. AR game-based learning will help promote experiential learning in pharmacy education in low-resource settings, such as Africa. Transforming the usage of low-impact lessons into a more exciting experience that adds to students' knowledge (Lu *et al*., 2021).

Another study in Hong Kong, China, assessed students' understanding of a fourth-year undergraduate Chemistry course using an app developed by the City University of Hong Kong (CityU) (Lu *et al*., 2021). An AR-based flipped learning was presented to supplement the students' learning and programmes using 3D-model references, Adobe Photoshop, chemical items, interactive and gesture control, AR image identification, and game logic software. The gaming app allowed students to identify a chemical by providing information about its properties, usage, and toxicity. Students were allowed to evaluate the principles of misplaced chemicals in a relational environment such as their own homes. Their lecturers also required them to form cohorts to conduct a mini-research on the chemicals assigned to them and present their findings to others. The experience allowed collaboration as team members before gathering to discuss their findings. Students from different groups can learn from their colleagues' mini-research and receive comments on their work. This AR tool was also designed for online self-learning, in which students can access and review unclear topics and courses at their leisure (Lu *et al*., 2021). The fashion of learning that this AR-based learning proffers for the students is a credible method of designing and learning educational concepts and lessons. Therefore, collaboration, self-learning, and discussion should be considered while incorporating AR-based technology design in pharmacy education in Africa and other low-resource settings.

Between March and October 2018, researchers at the University of Newcastle, Australia, investigated AR in pharmacy education, which resulted in the creation of the AR MagicBook device. AR can generate visual images of items and devices utilised inside and outside the learning environment. The app includes trigger images produced from photographs of medication boxes, videos, and cartoons to deliver medication information such as the generic name, pharmacology, indications, and prescriptions. As a result, when a mobile device such as a tablet or an iPhone with HP Reveal installed is held over a medication box, it instantly displays drug information (Schneider *et al*., 2020). Although, naloxone was employed in this study (Schneider *et al.*, 2020), additional drugs of therapeutic importance in pharmaceutical care and clinical practice can be synced into the app to achieve the same learning goals in wider pharmacy education, especially in a more practical setting like industry, hospital, and community pharmacy. Students' knowledge of medicines will be improved significantly with the inclusion of exercises in their modules to test their cognitive ability regarding the lessons they have learnt.

Researchers have also previously used AR in healthcare education settings by simulating neurons, membranes, and cardiovascular system components like the heart and blood. Smartphone apps project 3D structures and connect them to anatomy textbooks (Pantelidis *et al*., 2018). Shawaqfeh, in a review, highlighted specific game-based learning approaches in pharmacy schools found to enhance critical thinking among students. The approaches were concept mapping for a pharmacy communication course, patient simulation utilising mannequins for a critical care pharmacotherapeutic class, and crossword puzzles for interactive teaching in clinical pharmacy. Incorporating various types of these games into the pharmacy curriculum may help students prepare for real-life experiences by introducing them to potential scenarios (Shawaqfeh, 2015). There are enough topics that concern real-life experiences in pharmacotherapy and clinical pharmacy. With the rising focus of pharmacy education in pharmaceutical care and patient counselling, it will be critical and instrumental to design an AR invention that simplifies concepts in areas where the focus is being centred.

According to the findings of the studies: (1) the use of AR-based and gamified apps is reachable in low resource settings, and (2) AR increases the quality of learning and will benefit undergraduate pharmacy students.

AR-based apps and games can be used to create online self-paced modules with explicit instructions before or after a physical class. Lecturers will need training on how to utilise the platform in the conduct and assessment of their courses. Specifically, a study similar to the ones identified in several articles (see: Behmke *et al*., 2019; Lu *et al*., 2021; Mei & Yang, 2019; Pantelidis *et al.*, 2018; Schneider *et al.,* 2020; Shawaqfeh, 2015) can be undertaken in Africa and other low resource settings to assess students' perceptions and acceptance of AR in learning. AR and game-based applications utilised as learning resources must be compatible with today’s educational system to remain popular and effective for students. Their implementations must be transferable to different formative settings (Schneider *et al.,* 2020). Because AR frequently uses a computer or smartphone as hardware for running AR applications (Pantelidis *et al*., 2018), emphasis should be on ensuring that students in Africa and other low-resource settings have access to digital facilities and training in tertiary institutions if necessary. This can be achieved by establishing a long-term framework that addresses pharmacy school inconveniences and secures the benefits of students from varied backgrounds. In addition, pharmacy schools in Africa and other low-resource settings should continue to look for ways to include productive AR-based learning into their curriculum.

Landers and colleagues (2015) identified a gap in the current theories of gamified instructional design; therefore, there is a need for studies to create theoretical knowledge and background for gamification in education, especially in advanced schooling. Two instructional design processes relevant to psychology were identified: learning and motivational theories. This highlights the ways game elements in gamification are used to influence the pattern of learning. The motivation theories were identified as expectancy-based, goal-setting, and self-determination theories. It further suggested that gamification must be designed to control a specific character, attitude, or behaviour. The theory pointed out that the result of the targeted behaviour will differ depending on the exact nature of the mindset. If gamification is to augment learning experiences by creating better experiential learning experiences, then it must be that experiential learning experiences will improve learning directly. Similarly, in their work, Bedwell and colleagues (2012) mentioned some specific aspects of games in gamification, such as action language, assessment, control, immersion, environment, human interaction, and rules/goals. It is also critical that learners consider the reward for such gamification necessary when learning via game-based learning. When designing the game instructions for learning, it should be ensured that goal setting and progress are likewise monitored (Reiners & Woods, 2015).

The Octalysis framework, a concept developed by Chou (2015), consists of eight core drives that express the motivation exhibited by gaming users. It examines and evaluates the characteristics embedded in a game application to ensure that the intended goal of effective learning is met. Chou (2015) examined numerous game applications and determined the underlying motivation based on their success. These core drives may be identified in the design of a framework for a game-based learning application. It also emphasises the importance of monitoring and management when using gamification. The Octalysis Framework, alongside Gamification Design Framework, has since been used in an investigation of five commerce products in Indonesia (Yudhoatnojo & Ramadana, 2016). The eight core drives of the Octalysis Framework are epic meaning and calling, development and accomplishment, empowerment of creativity and feedback, ownership and possession, social influence and relatedness, scarcity and impatience, unpredictability and curiosity, and loss and avoidance (Yudhoatnojo & Ramadana, 2016; Chou, 2015). Players will be unmotivated and may abandon the game if the core drives are not discovered in gamification. Chou exemplified the catalysis processes further into 'Level I,' 'Level II,' and 'Level III,' all of which could be resourceful in the design of game applications for tertiary education (Chou, 2015).

The ACRS approach employs an acronym for four different words: attention, relevance, confidence, and satisfaction. It emphasises that game applications must attempt to catch the attention of end-users learners and offer realistic requirements and experiences for the learners in order to establish their confidence in using the game application. There is a connection between intrinsic and extrinsic motivation, and their coexistence aids in the completion of various tasks. Intrinsic motivation creates confidence in learners to execute a task. It gives learners the ability to decide and be able to connect with other competitive learners. Extrinsic motivation will help learners focus attention and stimulate their performance by displaying rewards after a successful performance (Kapp, Blair, & Mesch, 2013).

A gamified simulation's features can vary. However, critical metrics, such as using single or multiple players and puzzle elements to engage pharmacy students in their pharmacy education, should be identified. In this approach, the enjoyment is preserved, and students can recognise real-world scenarios and solve them. In simulation design, creating simulation feedback is necessary to continue engaging with learners for continued learning with rewards, points, badges, and leader boards. The other part of the simulation where interactivities occur will identify missions, challenges, puzzles, and collaborative efforts. This concept of interactivities and feedback was developed by Pirker and Gütl (cited in Reiner & Woods, 2015). Also, in the process to gamify educational simulations, steps that link the challenges with the feedback loop are ordered as follows: Pedagogical goal, interactive simulation elements, game participants, feedback types, and challenge design (Reiner & Woods, 2015).

To achieve the intended results, instructors in tertiary education must use game-based learning with caution. This is because incorporating various gaming components into educational learning without a robust design will be less effective in enhancing learning experiences and supplementing real-world realities (Kapp, Blair, & Mesch, 2013). The numerous recognised structures and frameworks act as pointers and guides to guaranteeing the successful design of gamified learning content in pharmacy education. These frameworks create concepts and ideas for instructional design, implementation, credibility evaluation, and game-based learning monitoring. In a structural gamification system for tertiary education, the avenues students may use to cheat in the system should be critically analysed. In reducing this form of malicious acts by students, Kapp, Blair and Mesch (2013) suggested that aligning the avenues for cheating with the goals of game-based learning is vital in reducing cheating. Aside from the narrowing of chances to cheat, students are focused on attaining the set goals for their game-based learning.

Challenges and limitations involved in the utilisation of AR and Gamification

Despite the growing interest in AR and the vast range of research being conducted in developed and developing countries, significant problems and issues in social acceptability, technology, and usability still exist and must be addressed (Essel *et al.,* 2022). According to the World Health Organization (WHO), more than a billion people worldwide live with a disability, and this number is expected to double by 2050 (WHO, 2018). Despite significant attempts and the demonstrated benefits of AR in special education, the majority of AR applications for education still lack accessible features (Garzón, Pavón, & Baldiris, 2019). Wu and colleagues (2013) reported that very few technologies are designed for students with special needs. A study by Georgia Tech's Wireless Engineering Rehabilitation Research Center indicated that wireless devices such as smartphones or tablets are used by 92% of people with disabilities (Moris *et al*., 2016). Thus, it can be deduced that mobile technologies play a critical role in providing autonomy to students with disabilities. In this respect, including accessibility features in AR apps has the potential to leverage the technology's various benefits to improve special needs education (Garzon, 2021).

Usability is another issue associated with AR applications with several reported studies on the complexity of using AR systems in education (Akçayir & Akçayir, 2017; Dey *et al*., 2018; Garzón, Pavón, & Baldiris, 2019; Radu, 2014). This is due to the multiple senses and simultaneous tasks required from students when using the AR system, which may overload their attention, thereby affecting the usability of AR systems (Akçayir & Akçayir, 2017). The usability of Second-Generation AR in Education (2GARE) applications, however, has improved notably compared to First-GARE applications (Garzon, 2021). Usability difficulties may cause time loss for students and may require excessive additional lecture time (Wu *et al*., 2012). Gavish and colleagues (2015) found that an AR-using group required considerably longer mean training periods than a non-AR-using group. Therefore, to help overcome this challenge of AR in education, it is critical to consider design strategies that favour the usability of AR applications in order to ensure that they can be easily implemented in any educational context, as well as identify how new deployment technologies can improve AR system usability (Garzon, 2021).

Furthermore, most AR applications are designed to be implemented on a specific platform and lack cross-platform support, which affects their dissemination. Consequently, to reach more users, developers of AR applications must go through repeated development cycles to accommodate multiple platforms, increasing production time and costs (Qiao *et al*., 2019). Furthermore, application-based AR necessitates a lengthy and time-consuming download and installation process. This leads to users deleting the app after a few uses in order to free up space on their devices, and other potential users opting not to download it at all. To improve adoption, the number of barriers to accessing the AR experience for the end user must be reduced, which can be accomplished by eliminating the requirement to download or update AR programmes (Garzon, 2021).

More so, when it comes to integrating AR applications into learning activities, there is a paucity of pedagogical techniques. Several studies have found this problem, indicating that most teachers use AR applications without considering pedagogical aspects, limiting the effectiveness of the interventions (Huang, Chen, & Hsu, 2019; Turan, Meral, & Sahin, 2018). AR-related learning activities typically include novel approaches like participatory simulations and studio-based teaching. The nature of these instructional approaches, however, is considerably different from conventional teaching methods which is teacher-centered, delivery-based orientation (Kerawalla *et al.,* 2006; Mitchell, 2011; Squire & Jan, 2007). Garzón, Pavón and Baldiris (2019) reported that educational applications based on AR must transcend technological aspects, as the technology by itself does not ensure success in the learning process. Therefore, it is necessary to identify which pedagogical approaches are the most appropriate for each educational setting to encourage stakeholders to consider technology together with pedagogical strategies to guarantee the best AR for education (Garzon, 2021).

Furthermore, the time constraints and funding issues, such as the high costs related to Digital game-based learning and technology-enhanced learning for theological education, are challenges faced by low-resource settings. For instance, in South Africa, students struggle with connectivity issues, very high internet costs and some issues relating to digital literacy (Sawahel, 2019). In order to address this, African universities need to create innovative spaces dedicated to game-based learning in order to facilitate the implementation of the systems.

Conclusion

This study reviewed the need to implement AR and gamification in pharmacy education in Africa and other low-resource settings with insights on the historical perspective, challenges, rationale for adoption and a proposed framework for the implementation. AR and gamification technologies have demonstrated the potential to provide motivating, engaging and compelling solutions in the educational and learning context in higher education institutions. Focusing on health courses such as Pharmacy; however, a large investment in providing appropriate resources for training pharmacy students is necessary. AR and gamification provide a viable alternative to the traditional provision of physical resources, including expensive infrastructure that students require to put theory to practice. More so, these technologies show pedagogical promise of deepening the student learning experiences, allowing for more opportunities for work-integrated learning experiences and reflection. This is particularly important in developing countries in Africa that have complex networks of interrelated pressures of finances, suboptimal healthcare service delivery, underdeveloped infrastructure, paucity of knowledge, research challenges and human resource limitations. AR and gamification have not yet been fully adopted in developing countries with low resource settings due to the problems of funding two-dimensional computer screens, expensive simulation mannequins and limited research on the application of AR and gamification in pharmacy education. Notwithstanding the challenges that are posed by these technologies, their potential benefits are both economical as well as pedagogical in nature. Students can access these benefits and potentially overcome some of the issues by using the widespread accessibility of mobile platforms such as mobile phones to access the technologies and engage in ubiquitous experiential learning. Therefore, the incorporation of AR and gamification in pharmacy schools in low-resource settings, such as Africa, will provide pharmacy students and tutors with more engaging teaching and learning experiences.

Authors' contributions

YB conceptualised the study. MA, HJ, JO, ES, AA, and BO drafted the manuscript. YB, OA and AD critically reviewed the paper. The authors read and approved the final manuscript.

Conflicts of interest

None.

References

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

Arth, C., Grasset, R., Gruber, L., Langlotz, T., Mulloni, A., & Wagner, D. (2015). The history of mobile augmented reality. *arXiv preprint arXiv:1505.01319*. https://doi.org/10.48550/arXiv.1505.01319

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B., (2001) Recent Advances in Augmented Reality; Institute of Electrical and Electronics Engineers (IEEE), **21**, 34–47

Bangalee, V., Oosthuizen, F., Perumal-Pillay, V. A., Suleman, F., & Walters, F. (2021). Pharmacy students experience with PharmacyPhlash - a pilot educational board game. *Currents in Pharmacy Teaching and Learning*, **13**(3), 292-301. https://doi.org/10.1016/j.cptl.2020.10.016

Bedwell, W.L., Pavlas, D., Heyne, K., Lazzara, E.H., & Salas, E. (2012). Toward a taxonomy linking game attributes to learning: An empirical study. *Simulation & Gaming*, **43**(6), 729–760. https://doi.org/10.1177/1046878112439444

Behmke, D. A., Brannock, E., Kerven, D., Lutz, R., Paredes, J., Pennington, R., Rose, J., Deiters, M., Camp, M., & Golovan, A. (2019). AR Chemistry: An Undergraduate, Technology-Based Research and Development Initiative To Incorporate AR Molecular Models in the Chemistry Curriculum. In T. Gupta & R. E. Belford (Eds.), *ACS Symposium Series*, **1318**, 53–64. *American Chemical Society.* https://doi.org/10.1021/bk-2019-1318.ch004

Billinghurst, M., Clark, A., & Lee, G. (2015). Others,' *A survey of augmented reality,' Foundations and Trends R in Human–Computer Interaction*, **8**(2-3), 73-272. http://dx.doi.org/10.1561/1100000049

Borrachero, A.B., Brigido, M., Mellado, L., Costillo, E., & Mellado, V. (2014). Emotions in prospective secondary teachers when teaching science content, distinguishing bygender. *Research in Science & Technology education*, **32**(2), 182-215

Caise, K. (2019). Transform Teaching Through Technology, Kindle version, Available from: https://www.amazon.co.uk/Transform-Teaching-Through-Technology-Caise-ebook/dp/B06XKJGFL2/ref=sr_1_1?crid=1JJKJX160VD1X&keywords=Transform+teaching+through+technology&qid=1667917748&s=digital-text&sprefix=transform+teaching+through+technology%2Cdigital-text%2C110&sr=1-1

Chou, Y. (2015). Actionable Gamification: Beyond Points, Badges and Leaderboards. Available from: https://yukaichou.com/gamification-book/

Dabbous, M., Kawtharani, A., Fahs, I., Hallal, Z., Shouman, D., Akel, M., Rahal, M., & Sakr, F. (2022). The Role of Game-Based Learning in Experiential Education: Tool Validation, Motivation Assessment, and Outcomes Evaluation among a Sample of Pharmacy Students. *Education Sciences*, **12**(7), 434. https://doi.org/10.3390/educsci12070434

Des Armier Jr, D., Shepherd, C.E., & Skrabut, S. (2016). Using Game Elements to Increase Student Engagement in Course Assignments (online), *College Teaching*, **64**(2), 64-72. https://doi.org/10.1080/87567555.2015.1094439

Dey, A., Billinghurst, M., Lindeman, R.W., & Swan, J.E. (2018). A systematic review of 10 years of augmented reality usability studies: 2005 to 2014. *Frontiers in Robotics and AI*, **5**, 37

Dunleavy, M., DeDe, C., & Mitchell, R. (2008) Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. *Journal of Science Education and Technology*, **18**, 7–22

Duta, M., Amariei, C., Bogdan, C., Popovici, D., Ionescu, N., & Nuca, C., (2011). An overview of Virtual and Augmented Reality in dental education. *Journal of Oral Health and Dental Management,* **10**(1), 42-49

Essel, D., Thompson, J., &Chapman, S. (2022). The effect of an augmented reality educational tool on the motivation towards learning in pharmacy students: an evaluative survey. *International Journal of Pharmacy Practice,* **30**(Supplement_1), i30-i31

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality*, **23**(4), 447-459

Garzón, J. (2021). An Overview of Twenty-Five Years of Augmented Reality in Education. *Multimodal Technologies and Interaction*, **5**(7), 37

Gavish, N., Gutiérrez, T., Webel, S., Rodríguez, J., Peveri, M., Bockholt, U., & Tecchia, F. (2015). Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks. *Interactive Learning Environments*, **23**(6), 778-798. https://doi.org/10.1080/10494820.2013.815221

Gostin, L. (2000). A public health approach to reducing error: medical malpractice as a barrier. *JAMA*, **283**(13), 1742–1743. https://doi.org/10.1001/jama.283.13.1742

Groening, C., & Binnewies, C. (2019). 'Achievement unlocked!' – The impact of digital achievements as a gamification element on motivation and performance. *Computers in Human Behavior*, **97**, 151-166. https://doi.org/10.1016/j.chb.2019.02.026

Huang, T.C., Chen, M.Y., & Hsu, W.P. (2019). Do learning styles matter? Motivating learners in an augmented geopark. *Journal of Educational Technology & Society*, **22**(1), 70-81

Huang, W.H.Y., & Soman, D. (2013). Gamification of education. *Report Series: Behavioural Economics in Action*, **29**, 11-12

Hug, B., Krajcik, J.S., & Marx, R.W. (2005) Using Innovative Learning Technologies to Promote Learning and Engagement in an Urban Science Classroom. *Urban Education*. **40**, 446–472

Jones, E.P., & Wisniewski, C.S. (2019). Gamification of a mobile applications lecture in a pharmacy course. *Medical Reference Services Quarterly*, **38**(4), 339-346. https://doi.org/10.1080/02763869.2019.1657728

Kapp, K.M. (2012) The Gamification of Learning and Instruction Game-Based Methods and Strategies for Training and Education. San Francisco: Pfeiffer

Kapp, K.M., Blair, L., & Mesch, R. (2013). *The Gamification of Learning and Instruction Fieldbook : Ideas into Practice*. San Francisco: Pfeiffer. Available from: https://books.google.com.ng/books?id=NaYzAQAAQBAJ&pg=PA1&source=gbs_toc_r&cad=3#v=onepage&f=false

Kapp, K.M., Blair, L., & Mesch, R. (2014) The Gamification of Learning and Instruction Fieldbook : Ideas into Practice. San Francisco, CA: Wiley

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). 'Making it real': Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality*, **10**(3), 163-174

Kiryakova, G., Angelova, N., & Yordanova, L. (2014). Gamification in education. *Proceedings of 9th International Balkan Education and Science Conference*

Landers, R. N., Bauer, K. N., Callan, R. C., & Armstrong, M. B. (2015). Psychological theory and the gamification of learning. In: Reiners, T., Wood, L. (eds) Gamification in Education and Business. *Springer, Cham.* 165-186. https://doi.org/10.1007/978-3-319-10208-5

Lopez, C.E., & Tucker, C.S. (2019). The effects of player type on performance: A gamification case study. *Computers in Human Behavior*, **91**, 333-345. https://doi.org/10.1016/j.chb.2018.10.005.

Lu, A., Wong, C.S.K., Cheung, R.Y.H., & Im, T.S.W. (2021). Supporting Flipped and Gamified Learning With Augmented Reality in Higher Education. *Frontiers in Education*, **6**, 623745. https://doi.org/10.3389/feduc.2021.623745

Manzano-León, A., Camacho-Lazarraga, P., Guerrero, M.A., Guerrero-Puerta, L., Aguilar-Parra, J.M., Trigueros, R., & Alias, A. (2021). Between level up and game over: A systematic literature review of gamification in education. *Sustainability*, **13**(4), 2247. https://doi.org/10.3390/su13042247

Mei, B., & Yang, S. (2019). Nurturing Environmental Education at the Tertiary Education Level in China: Can Mobile Augmented Reality and Gamification Help? *Sustainability*, **11**(16), 4292. https://doi.org/10.3390/su11164292

Miloff, A., Lindner, P., Hamilton, W., Reuterskiöld, L., Andersson, G., & Carlbring, P. (2016). Single-session gamified virtual reality exposure therapy for spider phobia vs. traditional exposure therapy: study protocol for a randomized controlled non-inferiority trial. *Trials*, **17**, 60. https://doi.org/10.1186/s13063-016-1171-1

Mitchell, R. (2011). Alien Contact!: Exploring teacher implementation of an augmented reality curricular unit. *Journal of Computers in Mathematics and Science Teaching*, **30**(3), 271-302

Morris, L.D., Louw, Q.A., & Grimmer-Somers, K. (2009). The effectiveness of virtual reality on reducing pain and anxiety in burn injury patients: a systematic review. *The Clinical journal of pain*, **25**(9), 815-826

Palomino, P.T., Toda, A.M., Oliveira, W., Cristea, A.I., & Isotani, S. (2019) Narrative for gamification in education: why should you care? Proceedings of the IEEE 19th International Conference on Advanced Learning Technologies (ICALT). *IEEE*. 97-99. https://doi.org/10.1109/ICALT.2019.00035

Pandey, A. (2017). A brief history of gamification. XRDS: Crossroads, *The ACM Magazine for Students*, **24**(1), 13-13. https://doi.org/10.1145/3123774

Pantelidis, P., Chorti, A., Papagiouvanni, I., Paparoidamis, G., Drosos, C., Panagiotakopoulos, T., Lales, G., & Sideris, M. (2018). Virtual and Augmented Reality in Medical Education. In G. Tsoulfas (Ed.), Medical and Surgical Education—Past, Present and Future. InTech. https://doi.org/10.5772/intechopen.71963

Persky, A.M., Stegall-Zanation, J., & Dupuis, R.E. (2007). Students perceptions of the incorporation of games into classroom instruction for basic and clinical pharmacokinetics. *American Journal of Pharmaceutical Education*, **71**(2)

Qiao, X., Ren, P., Dustdar, S., Liu, L., Ma, H., & Chen, J. (2019). Web AR: A promising future for mobile augmented reality—State of the art, challenges, and insights. *Proceedings of the IEEE*, **107**(4), 651-666

Radu, I. (2014). Augmented reality in education: a meta-review and cross-media analysis. *Personal and ubiquitous computing*, **18**(6), 1533-1543

Reiners, T., & Wood, L.C. (2015). Gamification in Education and Business. *Springer*. (online). https://doi.org/10.1007/978-3-319-10208-5

Roubidoux, M.A., Chapman, C.M., & Piontek, M.E. (2002). Development and evaluation of an interactive Web-based breast imaging game for medical students. *Academic radiology*, **9**(10),1169–1178. https://doi.org/10.1016/s1076-6332(03)80518-4

Salem, S., Cooper, J., Schneider, J., Croft, H., & Munro, I. (2020). Student acceptance of using augmented reality applications for learning in pharmacy: A pilot study. *Pharmacy*, **8**(3), 122. https://doi.org/10.3390/pharmacy8030122

Sawahel, W. (2019). Africa: Gamification of education could engage students in COVID-19. 26 November 2020 (online). Available from: https://www.universityworldnews.com/post.php?story=20201123063309960

Schneider, J., Patfield, M., Croft, H., Salem, S., & Munro, I. (2020). Introducing Augmented Reality Technology to Enhance Learning in Pharmacy Education: A Pilot Study. *Pharmacy*, **8**(3), 109. https://doi.org/10.3390/pharmacy8030109

Sera, L., & Wheeler, E. (2017). Game on: The gamification of the pharmacy classroom. *Currents in Pharmacy Teaching and Learning*, **9**(1), 155-159. https://doi.org/10.1016/j.cptl.2016.08.046

Shawaqfeh, M.S. (2015). Gamification as a learning method in pharmacy education. *Journal of Pharmaceutical Care & Health Systems,* **10**(2). http://dx.doi.org/10.4172/jpchs.S2-004

Slykhuis, D., & Krall, R. (2011) Teaching Science with Technology: A Decade of Research. In Proceedings of the Society for Information Technology & Teacher Education International Conference, Nashville, TN, USA, pp. 4142–4151

Squire, K., & Jan, M. (2007). Mad city mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology*, **16**(1), 5-29. https://doi.org/10.1007/s10956-006-9037-z

Tsay, C.H., Kofinas, A. & Luo, J. (2018) Enhancing Student Learning Experience with Technology-Mediated Gamification: An Empirical Study (online). *Computers & Education.* **121**, 1–17. https://doi.org/10.1016/j.compedu.2018.01.009

Turan, Z., Meral, E., & Sahin, I. F. (2018). The impact of mobile augmented reality in geography education: achievements, cognitive loads and views of university students. *Journal of Geography in Higher Education*, ***42***(3), 427-441

UPwork. Virtual Reality and Gamification: Two Biggest Trends in EdTech (online). Available from: https://www.upwork.com/hiring/for-clients/virtualreality-gamification-edtech-trends/

van Zyl, C., Badenhorst, M., Hanekom, S., & Heine, M. (2021). Unravelling 'low-resource settings': a systematic scoping review with qualitative content analysis. *BMJ global health*, **6**(6), e005190

Vidakis, N., Barianos, A.K., Trampas, A.M., Papadakis, S., Kalogiannakis, M., & Vassilakis, K. (2019) Generating Education In-Game Data: The Case of an Ancient Theatre Serious Game. In CSEDU 2019—Proceedings of the 11th International Conference on Computer Supported Education; SciTePress: Heraklion, Greece, **1**, pp. 36–43

Watters, C., Oore, S., & Kharrazi, H. (2010). Games for children with long-term health problems. In *Educational Gameplay and Simulation Environments: Case Studies and Lessons Learned* (pp. 286-301). IGI Global

Wen, Y., & Looi, C.K. (2019) Review of Augmented Reality in Education: Situated Learning with Digital and Non-digital Resources. In Learning in a Digital World; Díaz, P., Ioannou, A., Bhagat, K.K., Spector, J.M., Eds.; Springer Science and Business Media LLC: Berlin, Germany, 179–193

WHO (World Health Organisation). (2018). Disability and Health; WHO: Geneva, Switzerland

Wijma, E.M., Veerbeek, M.A., Prins, M., Pot, A.M., & Willemse, B.M. (2017) A virtual reality intervention to improve the understanding and empathy for people with dementia in informal caregivers: results of a pilot study. *Aging & mental health*, **22**(9), 1115–1123. https://doi.org/10.1080/13607863.2017.1348470

Wootton, R., & Bonnardot, L. (2015). Telemedicine in Low-Resource Settings. *Frontiers in Public Health*. https://doi.org/10.3389/fpubh.2015.00003

World Bank. (2021). World Bank Country and Lending Groups. *World Bank Group.* Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

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

Yudhoatnojo, S.B., & Ramadana, R. (2016). Analysis on gamification features usage on Indonesia ecommerce sites using Octalysis Framework. In *The 2nd International HCI and UX Conference in Indonesia, Jakarta, Indonesia,* 1-5