The Use of Augmented Reality for Stroke Education

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Abstract

This research aimed to design and develop augmented reality (AR) media for stroke education using a research and development methodology. The study assessed the effectiveness of AR technology in educating patients, involving three AR experts and three stroke experts. The research followed four stages. First, a literature review on stroke pathophysiology, health literacy, and AR technology informed the development of semi-structured interview questions. Interviews with AR experts identified markerless AR technology as the most effective for knowledge dissemination. Second, the AR application was developed based on stroke experts' insights, covering four key topics recommended by the experts: 1) What is stroke? 2) Symptoms of stroke, 3) stroke prevention, and 4) stroke treatment. In the third stage, the media's quality was evaluated by both AR and stroke experts using questionnaires to gather both quantitative and open-ended feedback from all participants. Recommendations from these open-ended responses directly informed content updates. The final AR media (application) incorporated revised educational videos, resulting in more accurate and comprehensive stroke information accessible to users. Both AR and stroke experts rated it as "highly suitable" (mean = 5.00, SD = 0.00 for AR experts; mean = 4.74, SD = 0.21 for stroke experts), confirming its high quality in content and presentation. The iterative, expert-informed development process demonstrates AR's potential as a scalable, accessible tool for stroke education. Future research should assess the application's impact on patient outcomes and its potential integration into broader community health programs.

Keywords: augmented reality, stroke, health literacy

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Introduction

Non-communicable diseases (NCDs), such as cardiovascular disease, diabetes, cancer, and chronic respiratory diseases, are now the leading causes of mortality and morbidity worldwide, accounting for the majority of global deaths (World Health Organization [WHO], 2021). Unlike infectious diseases, NCDs are primarily driven by modifiable behavioral and environmental risk factors, including unhealthy diets, physical inactivity, tobacco use, and harmful use of alcohol, which lead to conditions such as hypertension, hyperlipidemia, and obesity (WHO, 2020).

Stroke, a major manifestation of NCDs, has emerged as a critical public health concern both globally and in Thailand. Stroke can be classified as either ischemic, resulting from vascular obstruction, or hemorrhagic, caused by blood vessel rupture (Lindsay et al., 2019; World Stroke Organization, 2022). The increasing prevalence and high mortality rates associated with stroke, along with its role as a leading cause of long-term disability, have significant socio-economic consequences at both the individual and national levels (Ministry of Public Health Thailand, 2017; WHO, 2020).

In Thailand, over 320,000 deaths annually are attributed to NCDs, with stroke ranking among the top three causes of mortality (International Health Policy Program Foundation, 2021). More than half of NCD-related deaths occur in individuals younger than 70 years, reflecting a substantial burden of premature mortality and emphasizing the need for effective prevention and education strategies (Policy and Strategy Section, Bureau of Non-Communicable Disease, Department of Disease Control, Ministry of Public Health, Thailand, 2017).

Given the complex pathophysiology of stroke and the importance of lifestyle modifications for risk reduction, improving public awareness and health literacy has become a central focus in contemporary prevention efforts. Health literacy, defined as the capacity to access, understand, and apply health information, is recognized as a key determinant of health outcomes and the effectiveness of health interventions (Kickbusch et al., 2006; WHO, 1998). Individuals with limited health literacy are more likely to experience poor health outcomes, increased morbidity, and higher healthcare costs (WHO, 1998).

Innovative educational technologies, such as augmented reality (AR), offer promising new approaches to enhance public engagement and understanding of health information. AR enables the integration of digital content with real-world environments, providing interactive and immersive experiences that can improve knowledge retention and motivation (Azuma, 1997; Gerup et al., 2020). In medical and health education, AR has been shown to facilitate comprehension of complex concepts and foster behavioral change more effectively than traditional media (Adapa et al., 2020).

Despite its potential, the application of AR in community-based health education, particularly for NCDs such as stroke, remains limited. Previous studies have largely focused on clinical training and anatomical education, with few interventions targeting patient or public health literacy regarding stroke prevention and management (Adapa et al., 2020; Gerup et al., 2020). Addressing this gap is essential to equip individuals with the knowledge and skills necessary to reduce modifiable risk factors and improve outcomes.

Therefore, this study aims to develop and evaluate an augmented reality-based educational tool designed to enhance knowledge and health literacy about stroke among the general

population in Thailand. By leveraging the interactive capabilities of AR, this intervention seeks to address the unique challenges of communicating complex health information and to promote preventive behaviors in populations at risk.

Objectives

1. To design augmented reality media to communicate knowledge about stroke.
2. To develop augmented reality media to provide education about stroke.

Literature Review

Augmented Reality (AR) in Education and Health

Augmented Reality (AR) technology has become increasingly prominent in educational innovation, owing to its ability to seamlessly integrate digital content with the real world in real time. Within this domain, AR systems are typically classified as either marker-based or marker-less. Marker-based AR utilizes physical markers, such as QR codes or specially designed patterns, to trigger the display of virtual information, offering precise content localization and relatively straightforward implementation (Azuma, 1997; Craig, 2013).

However, this method is constrained by its dependence on the presence and recognition of physical markers within the user environment. Conversely, marker-less AR employs technologies such as GPS, gyroscopes, and advanced computer vision to detect and map the physical context, enabling virtual overlays without predefined markers (Milgram, 1994). This approach supports greater flexibility, adaptability, and immersion, which are particularly advantageous in mobile and ubiquitous learning environments. Empirical studies indicate that both AR modalities can enhance learner engagement and knowledge retention (Masmuzidin & Aziz, 2018), yet marker-less AR has demonstrated distinct advantages for health education, notably by facilitating access to interactive educational resources without the limitations imposed by physical markers (Adapa et al., 2020). Accordingly, the adoption of marker-less AR frameworks is increasingly recognized as a critical strategy for maximizing the reach and impact of digital interventions aimed at improving health literacy, including applications in stroke education.

Stroke: Epidemiology, Risk Factors, and the Need for Public Education

Stroke is widely recognized as a critical public health issue and remains one of the leading causes of death and long-term disability worldwide (WHO, 2020). The global burden of stroke is significant, with an estimated 12 million new cases annually and millions more living with its long-term consequences. In Thailand, stroke ranks among the top three causes of death, with rising incidence and mortality rates observed over recent decades (International Health Policy Program Foundation, 2021; Ministry of Public Health, 2017). This trend has substantial implications not only for individual health outcomes but also for the nation's economic and social stability, given the high costs associated with long-term care, rehabilitation, and productivity losses.

The pathophysiology of stroke is complex, encompassing two primary subtypes: ischemic stroke, resulting from the obstruction of cerebral blood flow, and hemorrhagic stroke, caused by the rupture of cerebral vessels and subsequent intracerebral bleeding (Lindsay et al., 2019; World Stroke Organization, 2022). Ischemic stroke accounts for approximately 80% of cases

and is most often attributable to atherosclerosis, embolism, or small vessel disease. Hemorrhagic strokes, though less common, are associated with higher mortality and are frequently linked to chronic hypertension, vascular malformations, or aneurysms.

Multiple modifiable and non-modifiable risk factors contribute to stroke incidence. Major non-modifiable risk factors include advancing age, male gender, and a family history of cardiovascular or cerebrovascular disease (Phadungwanitchakul, 2017). In contrast, modifiable risk factors such as hypertension, diabetes, hyperlipidemia, smoking, excessive alcohol consumption, obesity, and physical inactivity play a crucial role in determining individual and population risk. There is compelling evidence that targeted interventions to reduce these modifiable risks can lead to significant reductions in stroke incidence and recurrence.

Despite the preventable nature of many strokes, numerous studies have documented persistent gaps in public knowledge regarding stroke symptoms, risk factors, and appropriate emergency responses (Nilnanet N., 2019; World Stroke Organization, 2022). Early identification of stroke warning signs—such as sudden weakness, facial drooping, speech disturbances, and loss of balance—is essential for prompt medical intervention and improved prognosis. However, surveys conducted in both urban and rural Thai populations reveal that a significant proportion of individuals are unable to accurately recognize these symptoms or are unaware of the importance of seeking immediate medical attention (Policy and Strategy Section, Bureau of Non-Communicable Disease, Department of Disease Control, Ministry of Public Health, Thailand, 2017). These knowledge deficits are further compounded among older adults, those with lower education levels, and individuals residing in resource-limited areas.

Traditional approaches to stroke education, including public campaigns, community seminars, and printed informational materials, have yielded only modest improvements in awareness and health-seeking behavior. Barriers such as limited accessibility, low engagement, and cultural beliefs about disease further limit the effectiveness of these interventions (Chandoevwit et al., 2020). As a result, there is increasing interest in leveraging technology-driven solutions—such as digital applications and interactive media—to deliver accessible, engaging, and tailored stroke education, particularly among high-risk and underserved groups.

In summary, stroke remains a substantial and growing public health challenge in Thailand and worldwide. While risk factor modification and early recognition are well-established strategies for reducing the burden of disease, persistent gaps in public knowledge highlight the need for innovative, scalable, and culturally appropriate educational interventions. This context underpins the rationale for exploring the use of emerging technologies, such as augmented reality, to enhance stroke literacy and promote timely and effective responses to stroke events

Health Literacy and Its Role in Stroke Prevention and Management

Health literacy has emerged as a critical determinant of health outcomes, particularly in the context of non-communicable diseases such as stroke. Defined as the ability to obtain, process, and utilize health information to make appropriate health decisions, health literacy influences individuals' capacity to understand risk factors, recognize symptoms, and engage with prevention and treatment strategies (Nutbeam, 2008; World Health Organization, 1998).

Numerous studies have demonstrated a strong association between low health literacy and adverse health outcomes, including delayed hospital presentation, poor adherence to medical advice, and reduced engagement in preventive behaviors (Ahmadvand et al., 2018; Kickbusch et al., 2006).

In the context of stroke, limited health literacy significantly undermines individuals' ability to prevent and manage disease. According to the Ministry of Public Health (2017), people with inadequate health literacy often struggle to access, understand, and evaluate health information, resulting in suboptimal health behaviors and delayed use of health services. This problem is particularly acute among populations with lower educational attainment or those living in underserved areas, where opportunities for health education and information access are limited. As such, improving health literacy has become a key priority for stroke prevention and control initiatives at both individual and population levels (Ministry of Public Health, 2017).

Traditional educational approaches, including pamphlets, lectures, and media campaigns, have shown limited success in effectively improving health literacy, particularly among high-risk groups. These methods often fail to account for differences in baseline knowledge, cognitive abilities, and learning preferences. In response, there is growing interest in the use of digital and interactive technologies, such as augmented reality (AR), to deliver targeted, accessible, and engaging health education. Emerging evidence suggests that AR-based interventions may enhance understanding, retention, and application of health information, thereby supporting improved health behaviors and outcomes in stroke prevention and management (Adapa et al., 2020).

Sample

A purposive sample of six experts participated in this study, including three stroke experts and three augmented reality (AR) experts. Stroke experts were individuals from the fields of medicine, nursing, nutrition, or anatomy, each with at least three years of experience providing care, treatment, or support to stroke patients in hospital settings. AR experts were recruited through the researchers' professional networks and personal referrals, with eligibility requiring a minimum of three years' experience in the development or application of AR technologies. Individuals with less than three years of relevant experience or without direct expertise in the required fields were excluded. Prior to participation, all experts were informed about the study's objectives and provided written informed consent.

Methodology

This study used a Research and Development (R&D) methodology, approach with the primary aim of designing and developing an augmented reality (AR) media application to enhance public knowledge about stroke. The study was conducted in four phases, as outlined below.

Phase 1: Literature Review and Knowledge Synthesis

The first phase focused on collecting and synthesizing comprehensive knowledge regarding stroke and AR technology. The researcher conducted an extensive review of academic papers, textbooks, and relevant online resources to gather essential information about the causes, symptoms, prevention, and treatment of stroke, as well as up-to-date advancements in

AR technology. This knowledge base served as the foundation for the subsequent development of research instruments.

Based on this foundational knowledge, the researcher designed a semi-structured interview form. This form was intended to collect in-depth expert opinions to ensure that both the content and technological aspects of the AR media would meet the highest standards.

Phase 2: Expert Interviews and Content Development

The next phase involved the recruitment and interviewing of experts. Three experts in AR technology devepment and three experts in stroke were selected through purposive sampling. In-depth interviews were conducted with these experts using the developed semi-structured form. The AR experts provided insights on suitable AR technologies for educational purposes, while the stroke experts contributed essential medical information and guidance on structuring educational content.

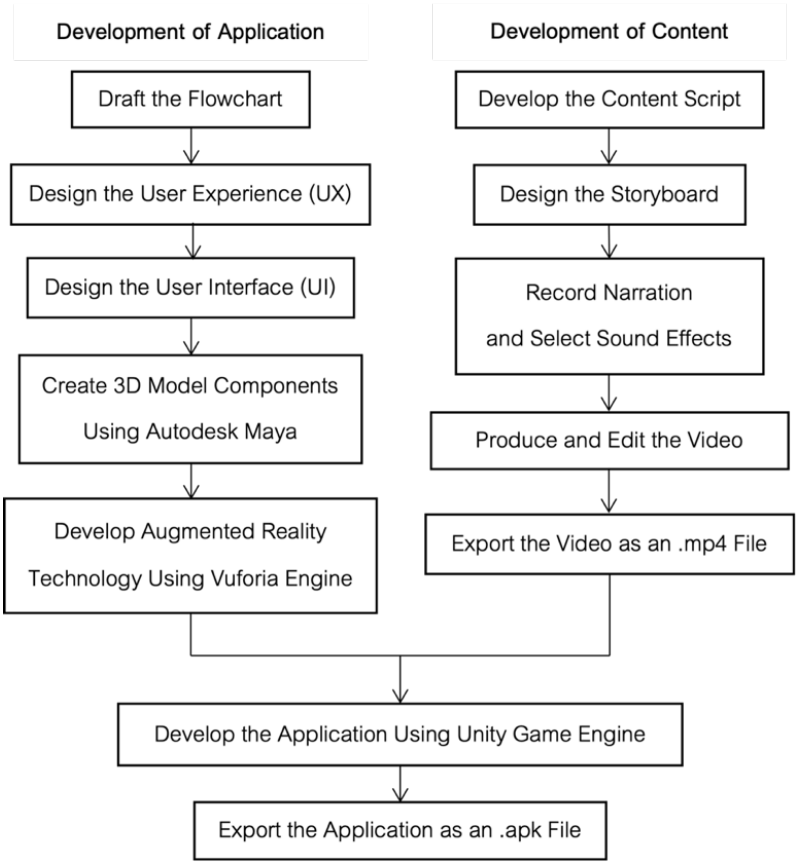
According to the consensus of the AR experts, markerless AR technology was identified as the most appropriate for the project, allowing users to conveniently access content anytime and anywhere through compatible devices. The AR media was designed as an application (.apk) for Android devices, ensuring accessibility via official app distribution platforms.

The interviews with stroke experts resulted in the identification of four key educational topics for the AR media:

1) What is stroke? covering the definition and types of stroke.
2) Stroke symptoms explaining acute and non-acute symptoms, including speech difficulty, facial drooping, arm weakness, walking imbalance, and attention issues.
3) Stroke prevention detailing risk reduction and secondary prevention.
4) Stroke treatment emphasizing the importance of rapid medical intervention.

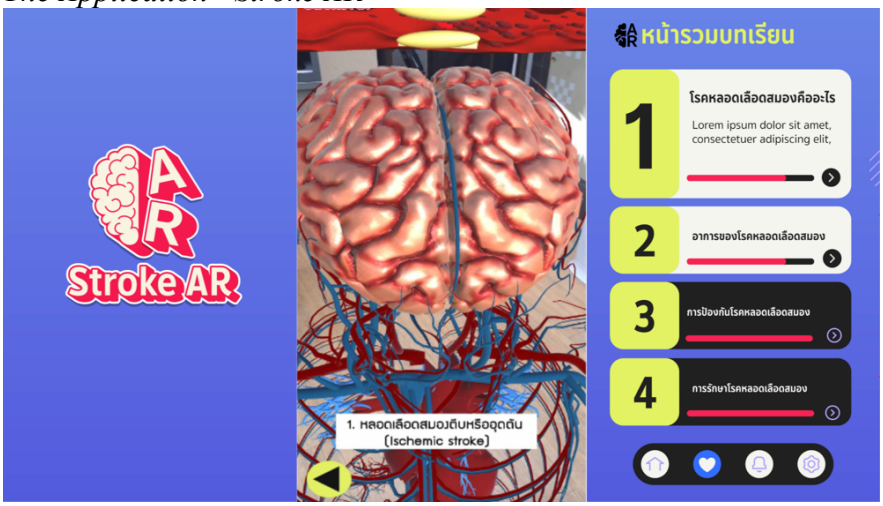
Guided by the results of experts interviews, scripts and storyboards were developed and used to create four educational videos. The subsequent application development followed a multi-stage process, as illustrated in Figure 1.

Figure 1
Development Process of an AR Application



For the most abstract or complex topics, particularly the definition and symptoms of stroke, 3D animations were created using Autodesk Maya. The content for these topics was transformed into three-dimensional visualizations through polygon modeling and sculpting techniques, helping users to better understand challenging concepts such as different types of stroke (hemorrhagic and ischemic) and typical symptoms. The application, titled "Stroke AR" integrates these visualizations into an augmented reality experience, with the user interface and AR functionality demonstrated in Figure 2.

Figure 2
The Application "Stroke AR"



Phase 3: Expert Evaluation

With content finalized, the AR media was developed as the "Stroke AR" application using the Unity Game engine. The user experience (UX) and interface (UI) design prioritized simplicity and intuitiveness, allowing users to access any of the four educational topics in a non-linear fashion according to their interest. Graphic elements for the application were created in Adobe Illustrator, following established color theory and psychological principles. The primary color palette consisted of natural, human-body-inspired reds (#8B0000, #FF4040, #F5B7B1), paired with complementary colors (white, purple, green) to enhance readability and emotional impact. All text was designed to be bold, clear, and at least 12 pixels in size for accessibility on small screens.

Phase 4: Media Revision and Finalization

In the final stage of development, the prototype AR media was subjected to rigorous evaluation and iterative improvement. Both AR technology experts and stroke experts participated in the assessment, providing both quantitative ratings and open-ended feedback. The evaluation focused on the quality and accuracy of video content, clarity of information delivery, and the technical effectiveness of the application. Based on expert recommendations, the prototype underwent systematic revision, with particular attention paid to content accuracy, accessibility, user engagement, and overall usability. Video content was refined for greater clarity, medical explanations and terminology were made more accessible, and additional interactive features were incorporated to enhance user learning and retention. All feedback was integrated to produce a comprehensive, user-friendly final version of the AR application.

Results

Three AR technology experts and three stroke experts evaluated the prototype using a five-point Likert scale. AR technology experts rated content appropriateness and technical presentation with a mean score of 5.00 (SD = 0.00), the highest possible score. Stroke experts rated the application with a mean score of 4.74 (SD = 0.21) for both content and presentation. Both sets of evaluations exceeded the predetermined quality benchmark of 3.50, indicating strong expert approval from both technical and medical perspectives.

Discussion

In addition to quantitative scores, qualitative feedback from experts identified several areas for further improvement. Experts emphasized the importance of distinguishing more clearly between different types of stroke, particularly between ischemic (thrombotic and embolic) and hemorrhagic types. They recommended the use of more accessible language, replacing complex medical terminology with layman’s terms to enhance understanding. Additional suggestions included expanding information on post-treatment care, lifestyle modifications, and the importance of medical follow-up to reduce recurrence. From a technical perspective, feedback highlighted the value of further categorizing information, adding engaging interactive elements such as quizzes and games, and ensuring content could be easily and quickly located within the application. All of these suggestions were systematically incorporated into the final version. The completed “Stroke AR” application features updated video content, improved content organization, and enhanced accessibility, resulting in a

comprehensive and user-friendly resource for stroke education. This revision process, informed by expert input, led to greater technical innovation and educational effectiveness.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the evaluation relied on a small sample of expert reviewers, comprising only three AR technology experts and three stroke experts, which may limit the generalizability of the results. The assessment did not include end-users or patients, so user experience and effectiveness in real-world settings remain to be validated. In addition, the application was developed and tested on a specific platform, which may restrict accessibility for users with different devices or operating systems. The scope of the educational content was focused primarily on the definitions, symptoms, and prevention of stroke, leaving other important aspects such as rehabilitation and long-term care for future development. Finally, the study did not include a long-term follow-up to assess knowledge retention, changes in health literacy, or behavioral outcomes among users. Future research should address these limitations by involving a broader range of stakeholders, testing with target end-users, expanding content, and conducting longitudinal studies to evaluate educational impact.

Conclusions

The final augmented reality (AR) application, developed through an iterative, expert-informed process, achieved high standards of content accuracy and usability for stroke education. Expert feedback led to improvements in clarity, accessibility, and user experience, resulting in a comprehensive tool that addresses key gaps in traditional stroke education methods. While broader real-world testing is still needed, these results highlight the potential of AR technology to enhance health literacy and support preventive behaviors. Future research should include end-users in evaluation, expand the educational content, and assess the long-term impacts of AR-based interventions on knowledge retention and health outcomes.

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