

DEVELOPING A WEB-BASED APPLICATION FOR CERVICAL CANCER SCREENING VIA VISUAL INSPECTION: ENHANCING TRAINING AND CLINICAL PRACTICE IN VIETNAM

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ABSTRACT

Background: Cervical cancer is the second most prevalent genital cancer among women, with higher incidence and mortality rates in Vietnam than in the United States and other developing Asian countries. In Vietnam, challenges, such as limited preventive resources and insufficient health education, have hindered the implementation of comprehensive cervical cancer screening. The Ministry of Health's National Action Plan (2016-2025) aims to address these gaps by promoting technological applications and training. Developing a web-based application that aggregates images describing cervical features in cervical cancer screening based on visual inspection with acetic acid (VIA) has not been implemented systematically in medical education and clinical training in Vietnam precisely or in resource-constrained countries in general.

Methods: Multimedia and database resources from Jhpiego's 2002 CD-ROM "Visual Inspection for Cervical Cancer" were extracted and transformed with Jhpiego's authorization. Multimedia content, originally in the Adobe Director with SWF files, was restructured for compatibility with HTML5 using SWF2JS. The

database was adapted to a MySQL platform to store the content and user data. The web-based application, deployed on a LAMP stack, uses PHP and Bootstrap for accessibility across multiple devices and includes user management, self-assessment, and content management functionalities.

Results: The application, which provides multilanguage support and user account management, currently serves 445 activated users, including doctors/lecturers, healthcare staff, and medical students. Average monthly access exceeds 9,000 visits, indicating high engagement with resources such as a cervical image library and interactive exercises. Piloted in Thua Thien Hue and introduced nationally, the application is now integrated into health science institutions and primary healthcare programs in Vietnam to aid cervical cancer screening and early detection.

Conclusions: The development of a web-based application for VIA cervical cancer screening training addresses the limitations of the previous CD-ROM-based methods, offering a more accessible, modern, and practical tool for healthcare personnel. By improving connectivity, data storage, and multi-platform compatibility, this tool strengthens cervical cancer prevention and control at the grassroots level, thus supporting Vietnam's national screening initiatives.

Keywords: Cervical cancer, early detection of cancer, health education, visual inspection with acetic acid (VIA), web-based applications.

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I. INTRODUCTION

Cervical cancer is the second most prevalent form of genital cancer in women, and its prevalence and mortality rates in

Vietnam are higher than those in the United States and some other Asian developing countries [1]. The development and survival of cervical precancerous lesions are relatively slow, with an average of 10-20 years. The primary cause of cervical cancer is infection with high-risk genital HPV types. To combat this malignancy, prevention and control strategies focus on the screening, early detection, and treatment of precancerous lesions [2]. Two crucial tools in the fight against cervical cancer are the HPV vaccine and early screening. The World Health Organization recommends using the “visual inspection after application of acetic acid” method (VIA) for cervical cancer screening in developing or under-resourced health facilities. This method is simple, cost-effective, provides immediate results, and has an acceptable sensitivity and specificity. However, it has limitations, such as a higher rate of false-positive results due to its subjectivity, depending on the reader's interpretation [3].

In Vietnam and other developing countries, comprehensive cervical cancer screening is not widely implemented because of limited resources for preventive and primary healthcare and insufficient focus on health education communication and technological advancements. The Ministry of Health in Vietnam initiated the National Action Plan for the Prevention and Control of Cervical Cancer (2016-2025) to address these challenges [4]. This plan aims to enhance training, capacity building, and technological applications to achieve early detection, reduce cervical cancer incidence and mortality, and align with broader health strategies and sustainable development goals [5].

In the past, training and teaching for cervical cancer screening through the "Visual inspection for cervical cancer" application in 2002 by Jhpiego was conducted using a CD-ROM-based system, which lacked connectivity, data storage, and the ability to share learning outcomes [6]. In the era of digital transformation 4.0, there is a need for a more convenient and modern tool to meet the requirements of connectivity, data storage, multi-platform compatibility, etc., for training and educating healthcare personnel at the grassroots level. In response to these issues, a web-based application called "Visual Inspection for Cervical Cancer" has been developed to focus on training, capacity building, and professional standardization, utilizing engineering, science, and technology applications to combat cervical cancer effectively in Vietnam and other developing countries.

II. MATERIALS AND METHOD

1. Materials

The multimedia data and database were sourced from the CD-ROM of the "Visual Inspection for Cervical Cancer" software, developed and released in 2002 by Jhpiego, an organization affiliated with Johns Hopkins University, USA. The Melinda Gates Foundation funded this project through the Alliance for Cervical Cancer Prevention. The extraction was carried out with official authorization from Jhpiego. All images, SWF files, and text in our web-based app are translated into Vietnamese and used with the consent of Jhpiego.

2. Study methods

Study design

Cross-sectional study: Collect data from registered users at a single point in time using the web version.

Longitudinal study: Monitor how users adapt to the web app over time

Study contents

Multimedia resources transformation

The application was originally developed using the Adobe Director platform, which offers powerful multimedia capabilities and integration with shockwave flash technology (SWF) for creating electronic lecture products. However, owing to the discontinuation of Flash technology in many browsers and Adobe's decision to stop further development of the platform from January 27, 2017, continuing to maintain and develop the application beyond that date became impractical. To address this issue, the source code of the application was restructured using a set of backward-compatible libraries to ensure full compatibility with displaying data, images, and videos from SWF files on the HTML5 platform. This transition allows applications to be efficiently supported on various web browsers across different platforms.

SWF2JS (<https://github.com/swf2js/swf2js>) was utilized as part of this process to facilitate the conversion from SWF to JavaScript. The JavaScript-based FlashPlayer emulator processes Adobe Animate (Flash) SWF files in real-time, converting them to HTML. It supports SWF files from Flex, Flash, Animate, and is compatible across all platforms

Database transformation

The web-based application database uses the MySQL platform, a prevalent database management system. The full database was built based on the analysis of data stored in a

CD-ROM. The main data table was constructed with the following fields: PhotoID, ThumbnailName, FullScreenName, Category, SCJImage, LesionImage, Q1Answer, Q2Answer, Q3Answer, Q4Answer, and Q5Answer.

The data table storing answers to review questions has the following fields: Id, PhotoID, VIA_Classification, and Management. To store and differentiate each learner's results, we designed database tables that included a user data table, content data table, and self-evaluation data table with the following fields: Id, User_email, Exam_type, Answers_text, Score, and Date.

Web-based app structure

The initial software was a standalone application compatible with Windows and Mac operating systems, enabling offline operation on individual computers with limited functions. Evaluation tests were conducted by displaying the results on a personal computer or printing them for instructor review. In this study, we migrated this application to a web-based platform, leveraging the Hypertext Preprocessor (PHP) for the back end and the Bootstrap framework for the front end. This transition enhances accessibility, as the web application is optimized for compatibility across all devices and browsers, promoting user friendliness and ease of access. The web-based application functions comprehensively as a content management system (CMS), integrating all essential content organization and management features, user management, and permission settings. Additionally, it includes capabilities for self-directed learning and self-assessment, allowing users to engage independently with educational materials and conduct evaluations (Table 1).

Table 1. The main functions of the “Visual inspection for cervical cancer” web-based application

Functions	Description	Account type
Instructions	It provides detailed usage instructions and video tutorials on features such as account management, interactive exercises, and self-assessment tests.	Guest users Registered users
Overview	Offers multimedia-rich lecture content on “Visual Inspection for Cervical Cancer Screening.”	Guest users Registered users
Gallery	A cervical image library is classified into three groups: cancer, VIA positive, and VIA negative.	Guest users Registered users
Interactive exercises	Cervical imaging exercises for observation, classification, and decision-making based on image analysis.	Guest users Registered users
Registration/Sign-in	Includes account registration, login, authentication, and password recovery features.	Registered users
User information	Manages account details, password changes, saved library images, and test completion records.	Registered users
Trainer activities	Mid-term evaluation with an interactive questionnaire of 20 random cervical images, each with 3-5 questions. User responses are stored in personal history.	Registered users
Testing history	Logs all training activities, including answers and scores.	Registered users
Users Management	Offers account listings, status tracking, login history, test counts, and data export options in XLSX or CSV format.	Administrator
Content Management	Allows adding, editing, and deleting website content.	Administrator

Deployment environment

The application was deployed on a LAMP stack hosted on a Linux system, featuring the Apache HTTP Server Project v2.4.57 as the web server and My Structured Query Language (MySQL) v5.7.31-cll-lve as the database management system. It operates on

an Intel Xeon Processor E5-2683V4 with 16 cores and 32 threads, supported by 16 GB of RAM. The server setup includes a public IP address that is accessible via a registered domain name, ensuring robust performance and user accessibility.

III. RESULTS

1. Implementing the web-based application

The fully functional web-based application features a responsive design, ensuring a seamless user experience across different devices and screen sizes. In

addition, it supports multiple languages, enhancing accessibility for diverse users. The application is hosted on the Hue University of Medicine and Pharmacy server and is accessible via the following URL: <https://via.huemed-univ.edu.vn> (Figure 1).

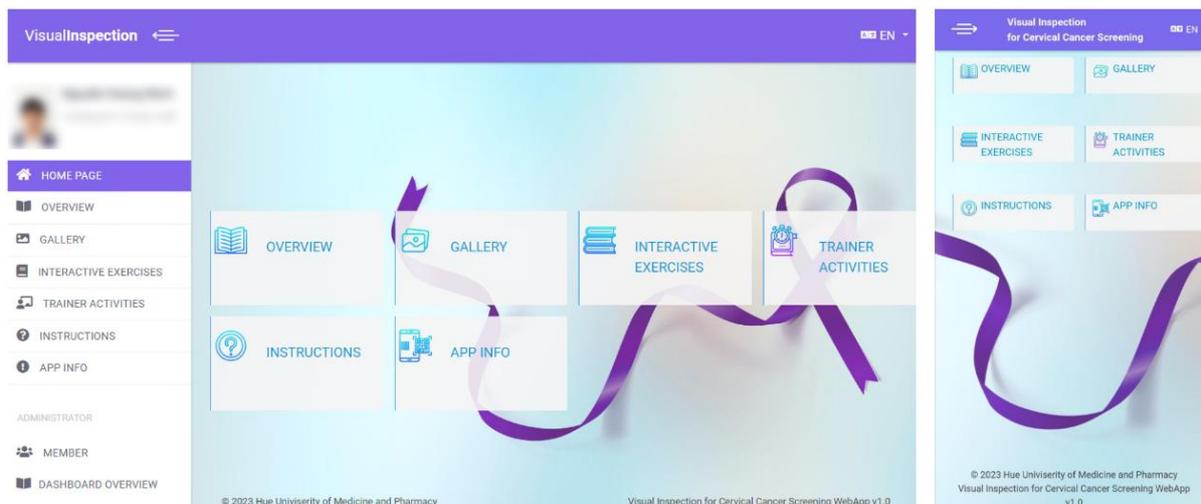


Figure 1. The application's homepage interface displays the homepage layout on large-screen devices (left) and mobile devices (right) for optimal user experience across different screen sizes.

2. The main features of the “Visual Inspection for Cervical Cancer” web-based application

User account management

Major web-based app features remain accessible to unregistered users, including lectures, libraries, and interactive exercises. However, the account management function serves as a means for user authentication and authorization for account creation. Upon

registration, users must verify their email addresses and grant them access to additional features. These features encompass the ability to save images of interest in a personal gallery and store self-evaluation results. This convenient organization of training courses allows users to monitor their learning progress while enabling instructors to evaluate the effectiveness of their teaching methods more accurately (Figure 2).

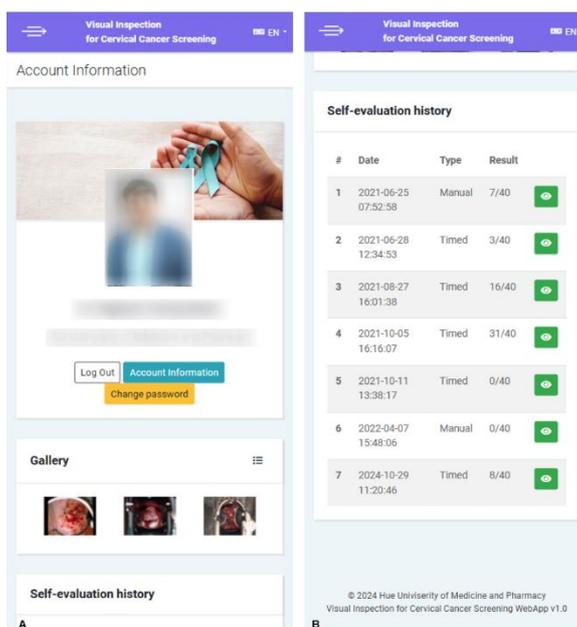


Figure 2. User profile page interface

(A) Showcases main user functions and access to the personal image library. (B) Displays self-evaluation history, including detailed information such as date, mode, score, and test review options.

The cervical image library

The library comprises 111 cervical images categorized into three primary groups: cancer (six images), VIA positive (52 images), and VIA negative (53 images), all sourced from the original software. Users can click on each image to access an enlarged view of the cervical image. Depending on the

classification, users can highlight the squamocolumnar junction (SCJ) and lesions for observation and memorization. Registered users can save any images in their library for quick access and review in the future or remove them from the library (Figure 3).



Figure 3. Image gallery interface.

(A) Displays a categorized list of the three primary groups of cervical images. (B) Presents a detailed view of a single cervical image. (C) Enables toggling the highlight for the Squamocolumnar Junction (SCJ) in purple and lesions in yellow on the cervical image, with an option to save the image to the personal library.

The interactive exercises

The interactive exercise is open to all users, and learners can self-study the content provided by the application without limitation. This feature allows users to review the knowledge shared in the "VIA" technical overview by answering feedback-driven and interactive questions like cancer image classification. Users must identify the squamocolumnar junction on the image by clicking on the suspicious area, performing VIA classification, and locating the lesion regions. The system will give feedback after the user selects it and show more information related to the feedback. The images are randomly selected from the library and organized into question sets, ranging from 1

to 10 questions each. At the end of each question set, the application will summarize the user's responses (Figure 4).

1. Select the number of questions: the application will randomly select images from the available library, learners choose the appropriate set of questions according to their ability

2. Answer questions and provide feedback. There are three types of questions: yes/no, multiple-choice, and indicating by clicking the SCJ and lesion area on the image.

3. Explain to the learner about all related information

4. Report results to learners

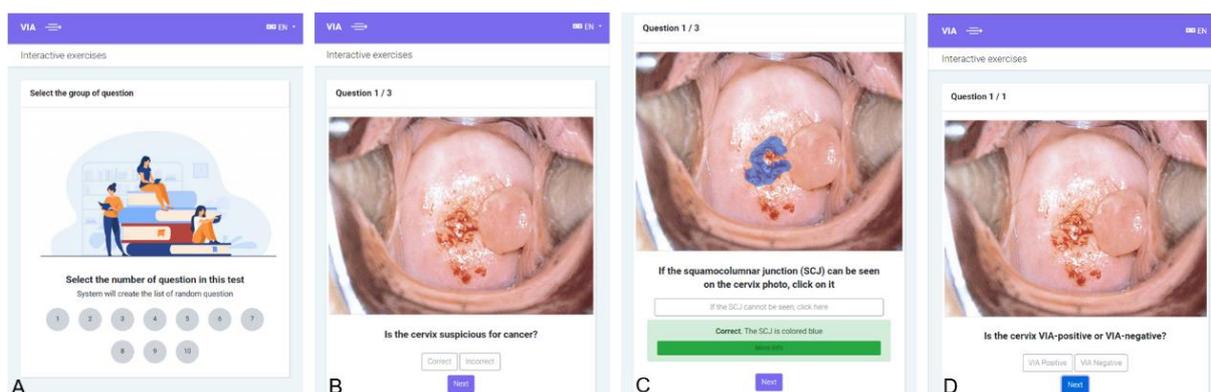


Figure 4. Interactive exercise interface.

(A) Questions selection panel. (B) Cancer image classification module. (C) Identification of squamocolumnar junction. (D) VIA (Visual inspection with acetic acid) classification tool.

Self-evaluation feature

This feature comprises two key components: VIA classification and clinical management decision-making. VIA classification allows participants to classify the images of the cervix into different categories, such as normal, abnormal, or precancerous. Clinical management decisions enable learners to decide on each image, such as whether to refer the patient for further testing or treatment. The application provides a self-evaluation tool to help learners do the

test after reading lectures and self-learning in the library. There are two modes of self-evaluation feature: manual and timed. Twenty random images are displayed for 20 seconds each to allow participants enough time to assess them. Depending on the learner's preference, the images can be switched to the next one automatically or manually. The assessment results are stored in the database to be analyzed and used to improve the evaluation function (Figure 5).

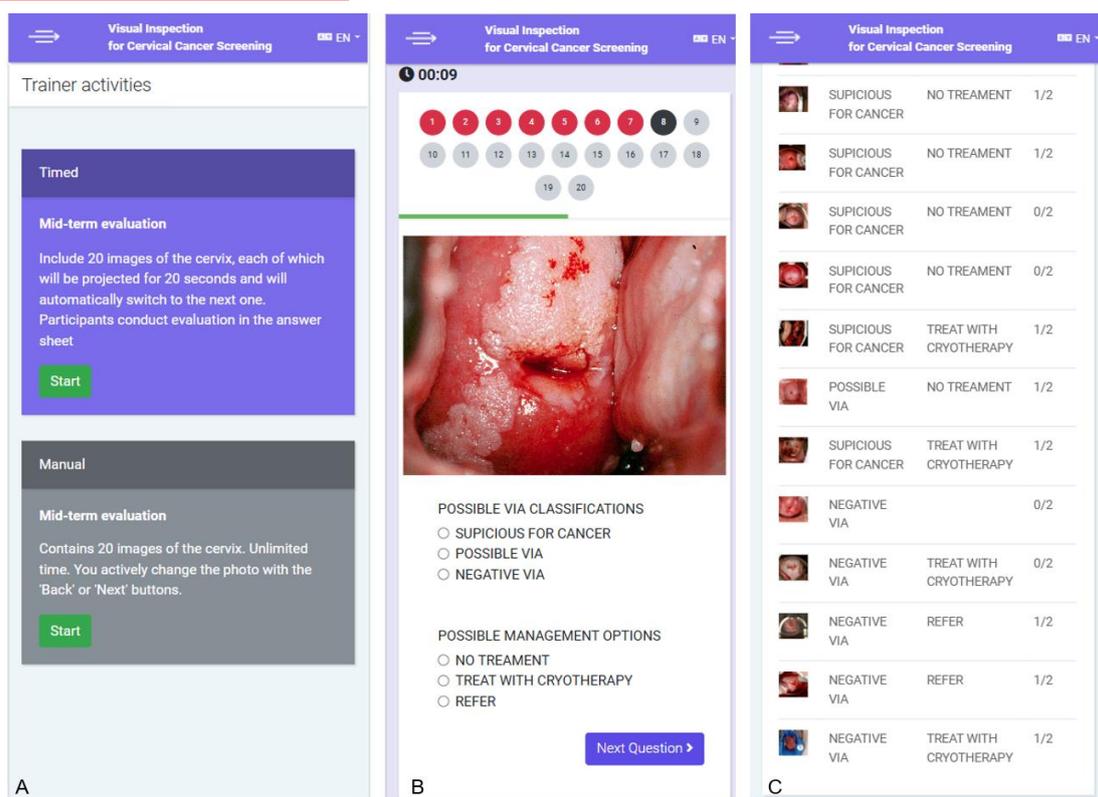


Figure 5. Process of Self-Evaluation Feature

(A) Choosing the timing mode for self-evaluation. (B) Display of the question interface. (C) Summary report of the self-evaluation results

3. User engagement and application utilization

The application currently has 445 activated users, including medical professionals from diverse fields across Vietnam. The average monthly number of visits to the system using resources such as overview knowledge, library, and interactive exercises is approximately 9,000. The data is extracted from Webalizer v2.23 and Advanced Web Statistics v7.8 (build 20200416) on the Cpanel web host manager. In addition, data on registered users with 445 accounts with various target groups such as doctors/lecturers, healthcare staff, and medical students (Table 2).

Table 2. User engagement and activation summary

Category	Data
Total activated users	445
- Doctor/lecturer	38 (8.54%)
- Healthcare staff	381 (85.62%)
- Medical student	26 (5.84%)
Frequency for self-evaluation	
- Users accessing once	11 (2.47 %)
- Users accessing twice	31 (6.97%)
- Users accessing more than 3 times	403 (90.56)
Total self-evaluation	8212

The VIA web-based app was piloted in Vietnam as part of a training initiative for provincial trainers under the World Bank-funded grassroots health project. This is Vietnam's first application focused on the VIA test content for cervical cancer screening. It is built on technical guidelines recommended by the World Health Organization before 2022, utilizing information technology to support the "Training of Trainers" (ToT) program for primary healthcare. This application enables self-learning, assessment, and integrated monitoring features.

The pilot demonstrated broad adoption of the VIA web-based application across Thua Thien Hue province and beyond. It is now being widely introduced in healthcare training institutions nationwide. It reaches medical facilities from the central to the commune level through conferences, seminars, continuous medical training, and specialized courses. The app has also been incorporated into the Ministry of Health's grassroots medical capacity-building program, promoting cervical cancer screening and early detection in primary healthcare across many provinces in Vietnam (Figure 6).



Figure 6. View of the training session in Quang Tri province, Vietnam

IV. DISCUSSION

Practical applications, such as Jhpiego's CD-ROM-based software developed for specific devices and software platforms in research projects, can become obsolete by the project's conclusion. Our study developed and implemented a web-based application, "Visual Inspection for Cervical Cancer," as a

training tool to address the need for accessible and standardized education in cervical cancer screening for Vietnamese healthcare training. In low-resource settings with limited access to cervical cancer screening services, visual inspection with acetic acid (VIA) combined with cryotherapy offers a viable solution through a "see and

treat" or "single visit" approach. This method is feasible and acceptable within such contexts, demonstrating safety and efficacy in practice. The VIA-based "see and treat" approach addresses the high demand for cervical cancer screening by providing immediate treatment in a single visit, making it a practical and efficient strategy for underserved populations [7]. Mobile applications are powerful tools for enhancing knowledge and skills, making them valuable adjuncts in medical education due to their affordability, versatility, independence from regional constraints, online and offline accessibility, simulation capabilities, and flexible learning features [8]. Our application is designed to help learners enhance their ability to interpret VIA results through flexible, anytime-anywhere learning. We have a high user engagement, with 445 activated accounts from diverse medical backgrounds and an average monthly access of 9,000 visits. The application successfully integrates multimedia resources, interactive exercises, and a cervical image library, effectively supporting user learning and self-assessment in VIA techniques. Piloted at the provincial level and expanded to national training programs, the app has shown potential to enhance cervical cancer prevention and early detection efforts within Vietnam's primary healthcare framework.

The web-based application offers several strengths, notably its accessibility across multiple devices, user-friendly interface, and multiple language support, which facilitate its use among healthcare providers in various regions of Vietnam and other countries. The application ensures comprehensive storage and retrieval of educational content, images, and self-evaluation data, fostering a cohesive learning experience. However, the study's

limitations include potential variability in user proficiency with the VIA technique, as accuracy still depends on individual interpretation skills. Additionally, to uphold Jhpiego's copyright on all content, we have not added new images, data, or clinical cases to the database. Consequently, the limited diversity of scenarios may lead learners to achieve high scores after only 4-5 self-assessments.

Similar digital tools for cervical cancer screening, such as Jhpiego's original CD-ROM-based application, have provided a foundation for educational programs but were constrained by the lack of connectivity, data storage capabilities, and multi-platform accessibility. In our study, the emphasis shifted toward empowering primary healthcare workers through capacity building rather than focusing on diagnostic support, a choice influenced by the limited size of the image database available for training. The integration of mobile applications in cervical cancer screening, particularly in low-resource settings, has shown significant promise in enhancing the accessibility and accuracy of diagnostic processes. Studies such as those on digital cytology with AI emphasize the practical benefits of slide digitization and AI detection of atypical cells, which can improve screening efficiency and accuracy. Additionally, smartphone-based VIA has been evaluated for its effectiveness in low-resource settings, demonstrating its potential to improve screening outcomes. AI-assisted cervical cancer screening using smartphones offers a cost-effective and scalable solution, as evidenced by research on deep-learning models for identifying precancerous lesions [9]. Furthermore, integrated mentorship training programs for VIA screening and digital cervicography using smartphones

have been developed to enhance the diagnostic competencies of healthcare providers. These advancements underscore the unique contributions of mobile applications in bridging the gap between traditional methods and advanced, resource-intensive solutions, making cervical cancer screening more accessible and effective in low-resource settings [10]. Integrating these insights into the "Visual Inspection for Cervical Cancer" app can further enhance its impact, adaptability for primary healthcare providers in developing countries, focus on low-resource training and adaptability for primary healthcare providers in developing countries. The app's deployment within Vietnam aligns with WHO-recommended screening practices and fills a critical gap between resource-intensive AI solutions and traditional, less interactive training methods.

The web app's high engagement and broad adoption can be attributed to its alignment with national health goals and the inclusion of essential VIA learning resources in an easily accessible format. The application's bilingual support enhances its reach, accommodating healthcare providers with limited English proficiency. Additionally, interactive exercises and self-assessment capabilities make the learning process more dynamic, which may explain the high average access rates. Its integration into the Ministry of Health's capacity-building program further underscores its relevance and necessity in Vietnam's healthcare education infrastructure.

Based on initial use in provincial training courses for trainers (ToT) and teaching implementation at the University of Medicine and Pharmacy, Hue University, Vietnam, we found that this VIA web-based application is capable of using widely in the conditions of

Thua Thien Hue province in particular and Vietnam in general. The application is widely disseminated for Health Sciences training schools nationwide, for medical facilities from the central, provincial, district, and commune levels through conferences, seminars, continuing medical training and training courses, and integrating them into the grassroots medical capacity building training program of the Ministry of Health of Vietnam.

The findings suggest that the web-based application can be instrumental in healthcare training providers, especially in rural and under-resourced areas. Future actions should focus on incorporating real-time feedback and advanced AI-assisted tools to enhance diagnostic accuracy, especially for providers with limited experience in VIA. Expanding the app's language capabilities and including additional training modules in clinical management of abnormal VIA findings could further increase its utility. Additionally, longitudinal studies to evaluate the application's impact on clinical outcomes, such as early detection rates and adherence to follow-up, would provide valuable insights into its effectiveness as a public health tool. At the same time, adding rich data and images of diverse clinical cases will be implemented in the future.

V. CONCLUSIONS

The development of a web-based application for training and teaching "visual inspection for cervical cancer screening" in Vietnam is a significant step towards improving cervical cancer prevention and control in the country. The web-based app addresses the limitations of the previous CD-ROM-based system by providing a more

convenient and modern tool that meets the requirements of connectivity, data storage, and multi-platform compatibility. This will allow for more efficient and practical training of healthcare personnel at the grassroots level, which is essential for increasing the reach of cervical cancer screening programs.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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