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Eye-Style Model Using Intelligent Virtual Reality Technology to Promote Surgical Skill Accuracy

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***Abstract* – This research developed an eye-style model using intelligent virtual reality technology to enhance the accuracy of surgical skills in residency training. We also assessed the impact of the eye-style model in improving these skills. The sample comprised seven specialists chosen through purposeful sampling (four ophthalmologists and three information and communications technology experts). An eye-style model evaluation form served as the research instrument. The arithmetic mean and standard deviation were used as the statistical metrics. The results demonstrated that the eye-style model enhanced surgical skill accuracy in residency programs. The model was divided into four components: (1) a requirements analysis study with five subcomponents (learning objectives, residency analysis, content analysis, learning activity planning, and simulations); (2) teaching methods, comprising an introduction, an instrument overview, parameter setting, a wet laboratory, and laboratory simulation; (3) an evaluation of the accuracy of surgical skills using intelligent virtual reality technology; and (4) an analysis of feedback. All seven specialists agreed that the eye-style model, which utilizes intelligent virtual reality technology, was highly effective and suitable for enhancing surgical skill accuracy in residency programs. This was indicated by the high average rating given by the specialists (mean = 4.71, standard deviation = 0.45).**

***Keywords* – Accuracy of surgical skills, intelligent technology, surgery simulation, virtual reality.**

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1. Introduction

The Thai government has prepared the "National Strategy," a national development plan for 2018–2037. This plan envisions Thailand as a stable, prosperous, sustainable, and developed nation. It is founded on the principles of the Sufficiency Economy, a philosophy based on the fundamental principles of Thai culture. It is a method of development based on moderation, prudence, and social immunity, one that uses knowledge and virtue as guidelines in living. The goal is to cultivate good, competent, disciplined, and public-spirited individuals. These individuals should have the potential to think analytically and continuously adapt to new technology. The vision focuses on creating competitiveness by developing industries and medical services, including the development and usage of advanced medical technology to enhance quality of life. The national development plan involves changing learning systems to adapt to 21st-century developments. Technology must be applied to learning systems in medicine to improve healthcare quality and elevate care standards to international levels. The strategy emphasizes enhancing human resource potential by using learning systems that can adapt to twenty-first-century changes. This approach also catalyzes lifelong learning, develops people's potential throughout their lives, and advances national development. System reform will facilitate the measurement of the skills necessary for the 21st century. The reform involves acquiring knowledge through modern technology for maximum benefit and applying it throughout life [1].

Siriraj Hospital has initiated a future-focused reformation to prepare for educational reform, as articulated by the Faculty of Medicine Siriraj [2]. To achieve this objective, a strategy has been developed to elevate the curriculum to international standards. The strategy, known as "Leverage Curricula Toward International Standards," ensures that medical and health science curricula meet international standards through the following actions:

• In 2017, the Bachelor of Medicine Program was redesigned to meet the international standard quality criteria for basic medical education prescribed by the World Federation for Medical Education [3].

• In 2018, bachelor's degree programs and graduate programs, including master's and doctoral degrees, passed the assessment criteria of the ASEAN University Network (AUN-QA). Moreover, international master's and doctoral programs passed the assessment and received standard certification in 2019.

• In 2018, the medical residency program aligned its teaching standards with the postgraduate medical education criteria set by the World Federation for Medical Education.

In the Department of Ophthalmology's residency training program, graduates specializing in ophthalmology must meet the minimum qualifications for six core competencies: patient care, medical knowledge and skills, self-development and practice, interpersonal and communication skills, professionalism, and system-based practice [4]. Ophthalmological surgery, a mandatory component of the ophthalmology residency program, demands high surgical skills. Eye surgery is a delicate and complex procedure requiring precision and coordination. During surgery, ophthalmologists must simultaneously use their hands to manipulate surgical instruments and their feet to control the direction of the surgical camera. They must also stay alert to various sounds and auditory signals. Any errors during surgery could cause harm to the patient, possibly leading to disability. Surgical simulation using virtual reality is a field that is rapidly growing and evolving [5]. This approach can address the need for skilled surgeons beyond the traditional operating room. Haptic and force-feedback technologies are evolving to continuously update surgical education and improve patient outcomes before actual surgery is performed. Virtual reality simulation is a valuable addition to surgical education across various specialties [6]. It offers trainees a risk-free, hands-on experience to learn surgical skills, ultimately aiming to enhance patient safety. Simulators come in three primary forms: full-body simulators, sectional or desktop simulators, and virtual reality systems.

These simulators improve trainees' learning and performance, permitting repeated practice until competence is reached. Deanery [7] defines "simulation" as the replication of real-life events or procedures. Virtual reality is a virtual tool that can mimic real situations and be displayed on a computer [8]. This tool creates a real-time virtual world using computer graphics. Sensors respond to a user's gestures and commands through various sensory ports. This creates an impressive experience, stimulating interest and allowing for situation control. Virtual reality is a human-computer interface enabling highly interactive visualization [9]. Utilizing a three-dimensional scene and associated hardware as controls, virtual reality must provide sufficient detail and speed to create a simulation that closely resembles real-life situations. This makes virtual reality an interesting alternative for training in dangerous environments. Lowood [10] describes virtual reality as the use of computers to simulate reality through interactive devices. These devices send and receive data, allowing a person to interact with a three-dimensional screen. The screen displays animations in the environment, immersing the user in a computer-generated environment. The authors of study [11] discuss the development of intelligent technology, or artificial intelligence-based technology, in medicine. This technology is rapidly advancing and is being adopted in existing clinical workflows.

This approach has potential for use in health systems around the world. The growing popularity of intelligent technology in healthcare, investigations, and ophthalmology applications is noted in paper [12]. It offers new roles in the learning process, surgical training, and opportunities for medical improvement in ophthalmology residencies. Integrating intelligent technology training into situational awareness curricula can promote best practices and multiuser training scenarios. Additionally, using a virtual operating room environment for the surgical team can enhance collaborative and interpersonal skills. According to surgeons, evaluating the accuracy of surgical skills in trainees with limited experience is demanding and time-consuming [13]. With an increasing number of surgical procedures being performed annually, there is an unprecedented need for accurate, objective, and automatic assessment of trainees' surgical skills to improve surgical practice. The authors of study [14] demonstrated a method for tracking instruments during robotic surgery, providing a way for surgeons to evaluate the surgical skills of trainees. Automatic and quantitative assessment methods can now replace Lee's approach. Paper [15] emphasized that having well-developed surgical skills are vital.

Receiving continuous feedback on surgical skills represents a significant step toward automatic assessment. There is a link between surgical skills and clinical outcomes, which indicates the need to enhance skills and minimize adverse results. Accuracy measures the number of correct actions a student performs [16]. In robotic surgery, a higher accuracy rate is considered better. They also noted that being a gamer does not correlate with increased accuracy in this context. The importance of surgical skill accuracy, especially in residency programs such as ophthalmological surgery, is well recognized. An eye-style model using intelligent virtual reality technology has been developed to increase surgical skill accuracy. Seven specialists from two different domains assessed this educational model. The group included four experts in ophthalmology and another three experts in information and communication technology.

2. Methodology

The study employed the following methods and techniques.

2.1. Objectives

This study had two objectives:

1. An eye-style model was developed using intelligent virtual reality technology to enhance the precision of surgical skills during residency.
2. The eye-style model was assessed using intelligent virtual reality technology to enhance the precision of surgical skills during ophthalmology residency.

2.2. Methods

The methodology for developing the eye-style model using intelligent virtual reality technology encompassed several steps.

Initially, a literature review was conducted to develop a framework with an eye-style model. This review included relevant studies on surgical simulation [5], [6], [7], [17], virtual reality [8], [9], [10], and the accuracy of surgical skills [13], [14], [15], [16]. The overall aim was to increase the accuracy of the surgical skills of ophthalmology residents.

The preliminary analysis involved three steps:

- **Context analysis:** This step assessed the compatibility of a model with the environment. For example, it evaluated adaptability and support for current global conditions. It also examined how digital-age technologies can foster learning.
- **Learner analysis:** This step involved examining learners to develop education approaches for a future digital university society.
- **Learning analysis:** This step involved the division of content into appropriate steps. The consistency of the results was also ensured from basic to advanced lessons.

The eye-style model was synthesized using intelligent virtual reality technology to enhance the accuracy of residency surgical skills. The development of the model focused on surgical simulation, virtual reality, and the accuracy of surgical skills.

The model was reviewed by experts in relevant fields with the intention that their feedback would provide guidance and enhance the accuracy of the surgical skills of ophthalmology residents. To this end, a research instrument was created. The model was evaluated on a five-point Likert scale: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. The following established standards for suitability were used: 1.00–1.80 (lowest average), 1.81–2.60 (low average), 2.61–3.40 (medium average), 3.41–4.20 (high average), and 4.21–5.00 (highest average). The consistency of the questions in the model evaluation form was measured.

The refined model evaluation form was distributed to seven specialists selected by purposive sampling. These experts (four ophthalmologists and three information and communication technology experts) used a Likert scale to evaluate the eye-style model. The outcomes were subsequently compiled.

3. Framework

The independent variables were simulation, virtual reality, and medical residency. The dependent variable was the eye-style model, developed to enhance the accuracy of residents' surgical skills (Figure 1).

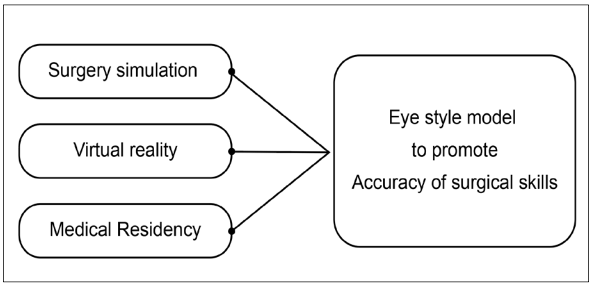

Figure 1. Framework

4. Results

The eye-style model incorporates intelligent virtual reality technology to enhance the accuracy of surgical skills in ophthalmology residency training. The model has four components.

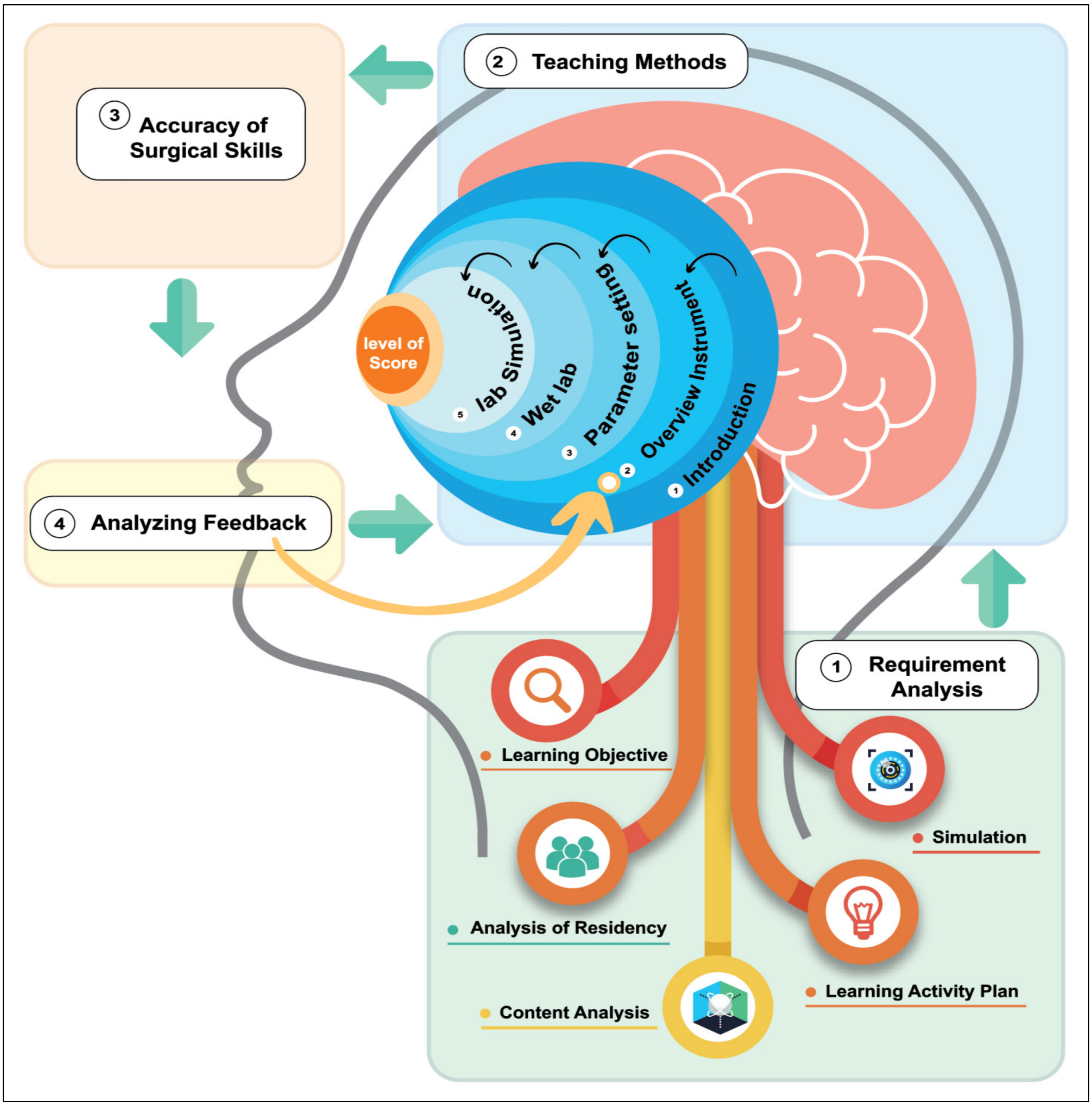

Figure 2. Eye-style model to promote surgical skill accuracy

4.1. Component 1

This component addresses the requirements analysis and has the following subcomponents:

4.1.1. Learning Objective

The learning objectives must be clearly defined. They should detail the content analysis and establish measures for success.

4.1.2. Analysis of Residents' Needs

A learner analysis assesses whether residents' needs align with those of the proposed model. Ophthalmology residents should be capable of utilizing ophthalmology surgery simulation equipment enhanced with intelligent virtual reality technology. The residents must have a background in ophthalmology and be skilled in taking patient histories, performing examinations, learning basic surgery techniques, and using ophthalmic surgical instruments.

4.1.3. Content Analysis

This process verifies that the content aligns with ophthalmology surgery simulations employing intelligent virtual reality technology and assesses curriculum difficulty. It identifies necessary learner content, connects it to each learning objective, and aids in developing suitable instructional media and evaluative tools.

4.1.4. Learning Activity Plan

The learning activity plan must align with the instructional objectives and content. Ophthalmology residents should have comprehensive knowledge of the theoretical and practical aspects of ophthalmic surgery.

4.1.5. Laboratory Simulation

A simulation procedure training room is needed to serve as a training center for ophthalmic procedural skills. For instance, the Siriraj Ophthalmic Skills Laboratory features ophthalmic surgical tools that necessitate the concurrent use of both hands along with foot-controlled surgical cameras. The tools also simulate the various audio signals encountered during each procedural step. Learners must develop the ability to fully control these devices to replicate the demands they will face in live surgical settings.

4.2. Component 2

This component outlines the teaching methods by using the following processes to facilitate learning:

4.2.1. Introduction

Learners should be encouraged through presentation programs and smart boards, stimulating interest, and reinforcing foundational surgical knowledge.

This phase should include discussions and questions to which students can respond.

4.2.2. Instrument Overview

Tools are introduced through demonstrations, videos, and e-learning. The lesson should guide the selection and use of surgical instruments, enabling learners to choose and employ them correctly in eye surgeries.

4.2.3. Parameter Setting

Standardized steps for device parameter adjustments are proposed. Students should gain proficiency in setting parameters on actual surgical equipment.

4.2.4. Wet Laboratory

A simulation reflecting actual surgery was created by presenting scenarios and using a pig's eye mannequin, which closely imitates authentic surgical experiences.

4.2.5. Laboratory Simulation

The development of surgical skills is fostered through intelligent virtual reality technology that provides a virtual experience of surgery.

4.3. Component 3

This component evaluates the accuracy of surgical skills. After training with intelligent virtual reality technology, scores reflect the practical skill levels attained.

4.4. Component 4

This component involves the analysis of feedback from learners and improvements to the eye-style model. The accuracy of the surgical skills of resident ophthalmologists is enhanced by using intelligent virtual reality technology (Figure 2).

Assessment of Results

The results of the assessments of the eye-style model by the seven experts are presented in Table 1. Their assessments revealed that the model effectively promoted the accuracy of the surgical skills of ophthalmology residents. All seven experts deemed the model to be highly suitable.

Table 1. Arithmetic mean and standard deviation of results from seven experts

Description	Results		Suitability
	Mean	S.D.	
1. Eye-style model is consistent with the principles and concepts that are the basis for developing the teaching model.	4.86	0.38	Highest
2. The model elements consist of requirements analysis, teaching methods, accuracy of surgical skills, and feedback analysis.	4.57	0.53	Highest
3. The sequencing of elements in developing the eye-style model is clear and continuous.	4.86	0.38	Highest
4. The eye-style model presents each element in a consistent relationship with one another.	4.86	0.38	Highest
5. The ordering of elements in the eye-style model makes sense and is easy to comprehend.	4.71	0.49	Highest
6. An overview of elements of the eye-style model is covered and completely related to the objectives of the research.	4.71	0.49	Highest
7. The learning management process of the eye-style model can be used in practice.	4.43	0.53	Highest
Overall average	4.71	0.45	Highest

SD - standard deviation.
The standards for suitability were as follows: 1.00–1.80 (lowest average), 1.81–2.60 (low average), 2.61–3.40 (medium average), 3.41–4.20 (high average), and 4.21–5.00 (highest average).

5. Discussion

The eye-style model utilizes intelligent virtual reality technology to enhance the surgical skills of ophthalmology residents. This is achieved through surgical simulation, virtual reality, and assessment of surgical skill accuracy. The model comprises four components. The first component is a requirements analysis, which includes the subcomponents of learning objectives, analysis of residents' needs, content analysis, learning activity planning, and laboratory simulation. The second component focuses on teaching methods. These methods aim to stimulate the interest of ophthalmology residents and integrate the basic knowledge needed for various surgical procedures. Its subcomponents are an introduction, instrument overview, parameter setting, wet laboratory, and laboratory simulation. The third component evaluates the surgical accuracy of the residents. The fourth component involved analyzing feedback from experts on the suitability of the eye-style model and suggestions for improvements.

The assessment results from the seven experts involved in this study revealed the following:

• The eye-style model aligns with the principles and concepts fundamental to developing the teaching model.

The eye-style model was deemed most appropriate (mean = 4.86, standard deviation [SD] = 0.38).

• The elements of the eye-style model (requirements analysis, teaching methods, accuracy of surgical skills, and feedback analysis) were considered highly suitable (mean = 4.57, SD = 0.53).

• The sequence of elements involved in the development of the eye-style model was clear and continuous, and it was rated as most appropriate (mean = 4.86, SD = 0.38).

• The eye-style model presented each element in a consistent relationship with the other elements. This presentation was viewed as most appropriate (mean = 4.86, SD = 0.38).

• The ordering of elements in the eye-style model was suitable, easy to comprehend, and considered most appropriate (mean = 4.71, SD = 0.49).

• The overview of the eye-style model's elements was comprehensive and objective, covered the research needs, and was deemed most appropriate (mean = 4.71, SD = 0.49).

•The learning management process of the eye-style model was practical for use and was rated as most appropriate (mean = 4.43, SD = 0.53).

The eye-style model utilizing intelligent virtual reality technology markedly enhanced the accuracy of ophthalmology residents' surgical skills. The model is considered highly appropriate, aligning with the findings [18]. His randomized controlled study examined the effectiveness of virtual reality technology in surgical training. The research aimed to evaluate the impact of virtual reality-enhanced surgery on the confidence and competency of surgical professionals. With technological advancements, surgical training methods are evolving to include augmented and virtual reality experiences. Such immersive virtual reality experiences improve physicians' proficiency and confidence when performing surgeries. Instructional methods that use augmented and virtual reality experiences may eventually lead to advancements in digital university society learning. Moreover, virtual reality simulation training is emerging as a practical learning management process. This development aligns with the findings of [19], who conducted a double-blinded randomized controlled experiment. The experiment utilized virtual surgery simulations for pedicle screw insertion training. The goal was to assess the effectiveness of virtual reality training simulations for surgical graduate students. The study confirmed the accuracy of the simulator, showing that the virtual reality training model for pedicle screw placement surpassed conventional training in terms of precision, success rate, and efficiency. This finding suggests the potential of this technique for training spine surgeons.

Virtual surgical activities combined with cataract surgery training can significantly improve ophthalmology residents' cataract surgery skills [20]. Such integration elevates overall training satisfaction and helps residents develop confidence, resilience, decision-making, and processing speed during actual surgeries in their early phases of practice. This innovative method sets a new standard for developing a structured, uniform ophthalmology residency training program for cataract surgery. Similarly the critical impact of surgical skills on safety and patient well-being is emphasized in [21]. Traditional surgical skill assessments can be labor intensive and lack consistency and repeatability. A proposed unified multipath framework for automated surgical skill assessment addresses various skill components, such as surgical instrumentation and intraoperative event patterns. Combining multiple skills yields better outcomes than does a single-skill focus. Retinal surgery simulator training could evaluate and potentially enhance a broad array of retinal surgery skills [22]. Future research should follow the present review framework and seek to refine the study designs. In conclusion, simulation offers substantial educational benefits for ophthalmology residents.

6. Conclusion

The eye-style model enhances the accuracy of residents' surgical skills by incorporating virtual reality technology as a training tool. This approach increases the training's potential and provides a learning experience that applies innovative concepts and technologies. These can support and respond to the current global situation, fostering learning suitable for the digital age. In the future, in a digital university society, it will be possible to use a simulation model for ophthalmology surgery. This approach will enhance learning experiences across various subjects. An assessment by seven experts determined that the eye-style model was highly appropriate for ophthalmology surgery simulation. With a mean score of 4.71 and an SD of 0.45, the model can be used to improve the precision of surgical procedures performed by ophthalmology residents.

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