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Needs Analysis of Virtual Reality Implementation in Indonesian Medical Curricula: A Qualitative Study

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ABSTRACT

Virtual reality (VR) is an immersive technology that can be a learning tool for medical students. However, VR devices are costly and need high maintenance. In addition, prior research rarely integrates VR into medical education's pedagogical and learning aspects. Questionnaires and guidelines for implementing VR are also scarce. This study analysed the need for VR implementation in medical curricula in Indonesia using qualitative descriptive methods. A non-discriminative snowball sampling technique was used, and in-depth semi-structured interviews were conducted for data collection. Data analysis was carried out using thematic analysis. This study included nine respondents from five medical schools (three state and two private). The results show that the VR implementation process must consist of several stages: needs exploration, blueprint creation, multidiscipline or multi-centre collaboration, training provision, success stories and scientific evidence, appreciation, and evaluation. Readiness factors assessed during the needs exploration stage include human resources, curriculum, infrastructure, funding, and regulations. In conclusion, VR implementation in Indonesian medical curricula must be carried out in seven steps, and five essential readiness factors must be extensively explored to ensure that the implementation is successful, has educational value, and has further potential development in the future.

Keywords: *Virtual reality, Medical, Curricula*

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INTRODUCTION

Immersive technology, especially virtual reality (VR), has created a novel way to deliver students enormous amounts of medical information (1). VR allows its users, both students and teachers, to observe, practice, and teach basic medical science, such as anatomy (2) and clinical skills (3, 4). VR also provides a safe learning environment (5) that allows students to make mistakes, reflect on their performance, and acknowledge their strengths and limitations, which helps them increase their knowledge and skills (6). The benefits of VR come from its core characteristics: immersion, interaction, and imagination—or I3. These characteristics work harmoniously to create a rich and immersive digital environment that can profoundly impact user experiences. This "real" experience is generated through interactions between users, objects, and computer-generated environments (7). The user's presence in the virtual world is sensory i.e., motor, cognitive, and emotional. Three-dimensional spatial experiences are also created due to changes in perception and response to feedback after actions are carried out by users (8).

Various learning theories support the implementation of VR in medical education. One of the most referenced VR-related learning theories is constructivism theory, popularised by Dewey in 1916 (9). In constructivism theory, newly acquired information develops based on previously possessed information (10), which can be maximally integrated through immersiveness, flexibility, and active learning in VR (11). VR's main benefit is allowing users to indefinitely recreate and replay unmastered clinical skills. This feature improves information retention and student performance (12). In addition, learning schedules and progress monitoring facilitate self-paced and self-directed learning (13). The current development of multiplayer VR also supports the "see one, do one, teach one" medical slogan and interprofessional education (IPE) activities by maximising the teacher–student relationship and peer interaction in the digital classroom (1).

Numerous studies have demonstrated VR's potential (14–16). VR utilisation for teaching-learning activities could increase students' motivation and clinical performance by providing sufficient repetition for students to understand the topics or skills (14, 15). A systematic review by Clarke (16) also stated that students with VR learning intervention performed better than those with traditional methods. Although VR can be used as a future learning tool, various challenges must be solved before VR can be implemented into medical curricula. First, high-end computers, highly specialised developers and 3D modelers are the main factors in setting up and developing VR programmes, which makes the development process costly (17). User knowledge, attitude, eagerness to technology (18), and proper educational VR training (19) became non-technical issues for VR development. VR for educational purposes must be aligned with learning outcomes while creating active user involvement. In user-centred design (UCD), the integration of user viewpoint and application development process must be considered carefully to maintain user acceptance. Ignorance of these factors could lead to VR abandonment and hinder its implementation in medical curricula (1).

Furthermore, studies have not explored VR pedagogical aspects and the implementation process in Indonesian medical curricula (20). Most recent studies originate from developed countries such as the United States, England, Canada, and Germany (21). A systematic review by Barteit et al. (22) in 2021 revealed that only one study on VR in medical education originated from a lower middle-income country. Of the 27 studies in this systematic review, 25 came from high-income countries, and only two came from middle-income countries (22). To the authors' knowledge, VR development in Indonesia is still nascent. No VR applications have moved beyond the prototyping phase or been fully integrated into medical learning activities. Moreover, readiness surveys and implementation guidelines are scarce.

Opportunities for immersive, hands-on experiences to improve knowledge and clinical skills are critical in medical education. However, in contrast to VR's benefits, the high costs of developing and procuring VR devices must be carefully considered, especially in settings with limited resources. Careful planning and preparation should be done from the early stage of VR implementation. To comply with these challenges, this study aimed to analyse the need to implement VR in the medical education curriculum in Indonesia. This study is expected to contribute to the identification of steps and determinants of VR development.

METHODS

Context

This study was conducted in Indonesia in 2023. Indonesia has 86 medical schools (state and private) across 38 provinces. Most Indonesian medical schools run a 5.5 years undergraduate programme (3–4 years of basic medical science and 1–2 years of clerkship) and a 4–5-year postgraduate residency programme. All competency-based medical curricula are based on the educational standards for the Indonesian medical profession established in 2012 and 2019 (23, 24). Based on these standards, medical students must acquire 726 diseases and 623 examination skills.

Furthermore, Indonesian medical graduates must meet seven core competencies based on the 2012 standards and nine core competencies based on the 2019 standards. This knowledge and skills were learned and acquired using various teaching methods, such as VR, which is currently used in teaching and learning activities. Although no studies are yet related to VR implementation in Indonesian medical education, Wiyono et al. (25) suggested that VR could assist teaching-learning activities and replace conventional teaching methods.

Research Team

This study was conducted by three researchers (LSA, AF, and DS). LSA brought valuable expertise to the research, including significant experience developing VR applications for medical learning activities. This technical proficiency contributed to a deeper understanding of the practical aspects and challenges of integrating VR into medical education. AF and DS are qualitative research experts with extensive experience conducting in-depth interviews and facilitating focus group discussions in various academic contexts. Their expertise in qualitative research methodologies provided a solid foundation for the design and execution of the study, ensuring the collection of rich and nuanced data through interviews conducted with medical teachers. The diverse backgrounds and complementary skills of the research team enabled a multifaceted approach to data analysis, allowing for a comprehensive grasp of information from medical education and technology perspectives. This collaborative synergy fostered a robust investigation into the need for VR implementation in Indonesian medical curricula, adding depth and credibility to the study's findings and conclusions.

Design and Study Respondents

This is a qualitative descriptive study (26). Exploration of the need to implement VR in the medical education curriculum in Indonesia was conducted through in-depth interviews with medical teachers experienced in developing VR. The inclusion criteria were as follows: (1) registered as a medical teacher at a medical school; (2) experienced in curriculum management, with adequate skills in information technology; and (3) experienced in VR development. Using snowball sampling, nine medical teachers were recruited for this study (27). This sampling method was chosen due to the limited number of medical teachers experienced in VR. Most teachers and their VR products are not widely recognised in the medical community. To widen the exploration, this study respondents' characteristics are based on the department representative, medical school status (state/private), and teaching audience (undergraduate/postgraduate). Nine respondents (six males and three females) from five medical schools in Indonesia (three state medical schools and two private medical schools) were involved in this study. The respondents taught different subjects, including anatomy, statistics, anaesthesiology, rehabilitation, and forensics. Although various trials to recruit surgeons, neurologists, and obstetricians have already been done, the doctors' tight schedules still hinder the interview. Table 1 shows the respondents' characteristics.

Table 1: Respondents' demographic information

Code	Gender	Institution	Teaching subjects (student level)
R1	Female	Universitas Indonesia (state institution)	Basic clinical skill (undergraduate) Anaesthesia (graduate)
R2	Male	Universitas Sebelas Maret (state institution)	Anatomy (undergraduate)
R3	Male	Universitas Surabaya (private institution)	Anatomy and statistic (undergraduate) Clinical skill (graduate)
R4	Male	Universitas Wachid Hasyim (private institution)	Basic clinical skill, pharmacology, digital and media literacy (undergraduate)
R5	Male	Universitas Sebelas Maret (state institution)	Research methodology, community health (undergraduate) Problem based learning (graduate)
R6	Female	Universitas Gadjah Mada	Forensic and medicolegal (undergraduate and graduate)
R7	Male	Universitas Gadjah Mada (state institution)	Anaesthesia (undergraduate and graduate)
R8	Female	Universitas Indonesia (state institution)	Geriatrics (graduate)
R9	Male	Universitas Gadjah Mada (state institution)	Neuroanatomy (undergraduate)

Data Collection

This study was conducted from February to July 2023. Semi-structured, in-depth interviews were chosen as the primary data collection method to ensure the safety of the medical school's confidential VR projects. Nine in-depth interviews were held through the online meeting platform Zoom. A systematic review by Hennink and Kaiser (28) revealed that the adequate sample size for an in-depth interview to reach saturation ranged between 9 and 17 interviews. This number of interviews provides strong external reliability in homogenous and heterogenous populations (28). The respondents have already fulfilled the criteria of maximum variation sampling methods applied in this study that are based on department representative, medical school status (state/private), and teaching audience (undergraduate/postgraduate).

The interviews were carefully designed to explore various topics, including the challenges and successes encountered by the respondents in their efforts to incorporate educational VR applications into their teaching. In-depth interview guidelines were formulated by all authors (LSA, AF, and DS) and consisted of nine questions: opening questions to initiate the discussion, four core questions to delve deeper into specific areas of interest, and two closing questions to wrap up the interview. The list of in-depth interview questions is shown in Table 2. All respondents signed an electronic informed consent prior to interview. One author (LSA) moderated each interview, which lasted about 45–60 minutes to allow for in-depth and meaningful conversations with the respondents. To ensure accuracy and record all relevant information, each interview was recorded using audio and video. All research data were kept on a digital platform and accessible only to the research team.

Table 2: In-depth interview questions list

	Question
Opening question	1. Have you ever used VR?
	2. For what activities did you use VR?
	3. How is VR used at your institution?
Main question	4. In your opinion, do you think VR can be applied to the learning curriculum in medical education? *Probing questions* • What kind of VR implementation that can you imagine? • In what learning activities (large class/small group learning/skills lab/other) can VR be implemented? • Can you mention anything that needs to be prepared in VR implementation? • What type of VR should be applied to learning activities? (three-dimensional animation/skills training/IPE collaboration) • What kind of features are needed for medical student?
	5. What are the factors that influence the implementation of VR at your institution? *Probing questions* • What are the factors that inhibit VR implementation? • What kind of support do you need in providing written feedback to students?
	6. Do you think VR can be used as a student assessment method? How is it implemented? Can VR be used as a work-based assessment medium?
Closing question	7. What benefits might students get if VR is implemented in medical education? How to evaluate its effectiveness?
	8. What are your hopes for the development of VR in medical education?
	9. Are there any other comments?

Data Analysis

Recorded audio or video were transcribed verbatim. A thematic analysis was carried out using the Steps for Coding and Theorisation (SCAT) (29). This analytical approach allowed for systematically identifying and exploring key themes and subthemes in the data. To enhance the credibility of the findings, each author (LSA, AF, and DS) independently conducted the initial analysis of the first transcript to establish the primary themes and subthemes. Following this, LSA performed a thematic analysis of the remaining transcripts, continuously uncovering and refining the themes and subthemes. Throughout this process, collaborative discussions with AF and DS played a crucial role in validating the emerging themes, ensuring a comprehensive and robust data analysis. New codes and themes that emerged through discussion were added. Any disagreements were discussed and resolved by all authors.

RESULTS

Results showed that the need to implement VR was closely related to preparing a medical school to implement VR in its curricula. Furthermore, this study highlighted several readiness aspects that need to be assessed before developing and implementing VR. This aspect would determine how VR will be utilised in teaching learning-activities. Elaboration on each component is provided along with the representative quotes. The links between each theme and subthemes are shown in Figure 1.

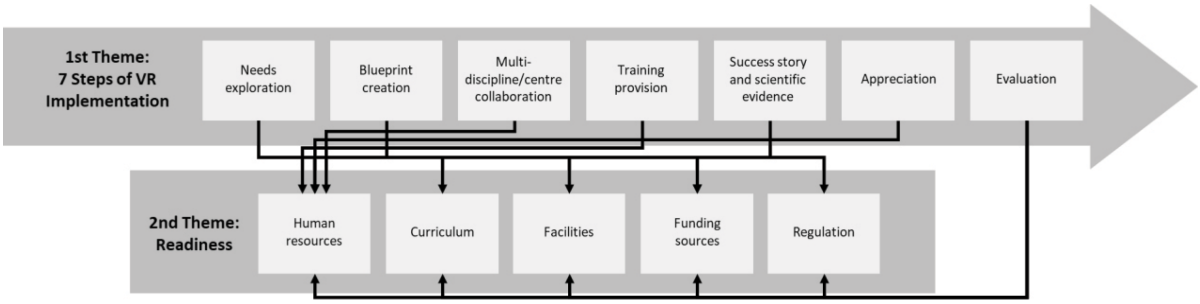

Figure 1: Emerging themes illustrating how VR should be implemented and factors that affect medical school readiness.

Seven Steps of VR Implementation

The findings showed that VR implementation in Indonesian medical curricula can only occur with proper planning, execution, and evaluation. The identified process includes needs exploration, blueprint creation, multidiscipline or multi-centre collaboration, training provision, success stories and scientific evidence, appreciation, and evaluation.

As the first step in VR implementation, some respondents preferred a pilot study and screening to explore the VR perspective in learning activities. Determining the potential user and their interest would affect sustainable VR usage. Clear user targets and activities define the VR technology and tools required in teaching-learning activities. The budget of medical schools would be closely related to the cost and duration of VR development.

> In 2015, we conducted a study and screening with a [medical] student. [We wanted to know, will there be any potential users if we develop a VR application? any students who use it? (R4, 3)

> Do not let it [VR] be unused after it is successfully developed. There are some reasons why needs assessment is important, such as its relation with cost, technology requirements, the duration of development, materials, and so on. (R4, 18)

Respondents also suggested that a needs assessment should be done first. This exploration could help medical schools identify and reveal current and future challenges. The opportunities and obstacles differ from one medical school to another. Each medical school has different capabilities to carry out technology-based learning.

> Each medical school [faces] different challenges. The difficulty I found here may not be found in another place. They may have different difficulties. We cannot generalise thoughts like "if it is needed here, then everyone would need it too". So, a multistep study is required, and a needs assessment should be done first. (R4, 37)

Needs assessments also provide an overview of the VR product's target market. VR should be marketed to medical schools rather than to a medical student.

> If we want to develop VR, we need to specify our target market. We need to target institutions, not individuals. (R7, 16)

Mapping learning materials that can be incorporated into a VR application in a blueprint was suggested to be done after needs exploration. Curriculum developers should decide on subjects or topics and VR roles in the learning activities. VR could replace or be a supplement that supports and covers the shortcomings of conventional learning methods.

> It is necessary to analyse which learning topics need VR and which ones can do without it. So we need to map out exactly which VR can replace and which ones must still be done conventionally, even if that means using things [such as mannequins] instead of real humans. (R6, 36)

Blueprints will guide others to continue developing and implementing VR in their medical schools. The roadmap availability will escalate other teachers' eagerness to utilise the product and continue its study and development in the future.

> I would tell them [my colleagues] that we have innovation and a roadmap [for future development]. They also give good responses and want to continue the development. (R7, 8)

Raising awareness and collaboration are crucial aspects. A respondent recommended to establish an event, such as a workshop or symposium, to generate awareness of VR products. A dynamic environment that supports the implementation of VR in medical curricula will be constructed during the discussion between individuals involved in this event.

> Holding events creates a better learning environment. If people gather, have discussions, and hold symposia or small workshops, there will be more staff [using VR]. (R1, 10)

While the main objective of the workshop and symposium was raising awareness of the community, recognising potential individuals who are interested in implementing VR in medical curricula is also important. These individuals should be involved in the future events or advanced workshops. Selecting a limited number of potential subjects could be a solution if medical schools have a limited budget to train more people.

> ...There will be a socialisation [to VR implementation]. [We will hold] more advanced workshop to identify champions, who can be invited to our future events. (R2, 16)

> ...With the budget limitation in our setting, champions role are strategically important. If we are in the ideal setting, it will be better to include all people to get advance workshop. (R8, 21)

It is important to note that not all participants would apply the knowledge they acquired. Some of them came because they were interested in the topics but still scared to participate in VR development.

> Yes, we already held this kind of course—a VR introduction course—which taught lecturer how to develop VR. There are some [teachers] who are interested but have not developed their own. (R2, 19)

Mapping learning content and providing ideas for VR are tasks that medical teachers could accomplish, but not for coding and producing VR modules. A respondent suggested that collaborating with an engineer or programmer would help medical teachers to produce a VR module. The engineer and programmer would be the parties responsible in developing the educational VR products.

> Learn and collab. Because I cannot learn [to code], I will provide ideas. To realise [the ideas], we should look for the right person—a programmer, an engineer. Then you have to be able to collaborate. (R2, 16)

Numerous factors must be considered during the partner selection process. Partner's integrity was the most important factor stated by the respondent. Continuity in all steps of development must be maintained to ensure future projection. During the selection, medical school should assess whether the developers are solely profit-based or passionate about improving the value of medical education. Furthermore, assessing and discussing the business contract, especially for the revision and maintenance section, before beginning VR development could help the medical school and developer reach a mutual agreement.

> For me, the most important factor is integrity. If not, they [VR developers] only look for the profit. After development, if we need revisions, they will not do them. They will bring up the contract [to avoid revision]. It is annoying. (R6, 43)

Collaborations between medical schools in Indonesia and policymakers at the national level also need to be constructed. VR products must be developed based on the medical school national standards, which all medical school in Indonesia have used. Involving a national medical organisation as the facilitator could help to integrate all factors related to the medical education VR development.

> So it must be a multi-centre [development]. Maybe a medical education team will develop it—with AIPKI [Indonesian Medical Education Forum] and the Ministry of Health providing [as the facilitators]. So I hope, in the future, we can share because all institutions have the same targeted standards [medical competency]. (R4, 41)

To get support from key stakeholders and the academic community, the respondents suggested providing data for implementing VR. These data would become the foundation to rationalise VR implementation in the medical curricula. Data can be originated from a small pilot study. During the initial stages of VR implementation, the study does not have to be comprehensive; it can be limited to the areas covered by the teacher's expertise.

> In the past, we needed to provide various things to convince institutions to buy high-fidelity [tools]. So we must tell to institutions we will provide [scientific] data to support our cause. (R1, 10)

> ...We could create an example [pilot study] within a small scope, for example, in our areas of expertise. (R7, 23)

To encourage teachers to develop and participate in VR implementation, stakeholders should provide rewards, especially for the teachers who succeed in developing and implementing their VR into teaching-learning activities. All respondents agreed that rewards would encourage and accelerate the creation of ideas to develop VR.

> If the [stakeholder's] goal is to develop VR even further in the future, [I believe] rewards can speed things up. If there is a reward—maybe from superiors or the key stakeholder, for example—if the dean wants the study programmes to have a VR development, [rewards] will greatly speed up [VR development]. Motivation. That is the motivation for creating VR. (R5, 22)

However, one of the respondents thought user feedback was still more important than rewards. VR products should be tested with medical students as the primary audience. User feedback would highlight areas that need to be evaluated and improved.

> But what is far more influential [for a teacher] is user acceptance. The user should provide feedback and evaluate the results of using VR. That is highly influential on the development of VR. (R5, 23)

Besides being evaluated by medical students, the teacher and the development team could also evaluate VR with colleagues with similar competencies to the teaching staff. A validation test should be given to ensure the accuracy of the module that will be delivered to the medical student.

> Well, my expert field is pain. I will do a validation test on my friends who are interested in pain. I will invite them personally to give a validation test [to VR product]. (R7, 38)

Evaluation of VR products must be carried out using validated tools. Currently, there are no VR-specific validated evaluation tools translated into bahasa Indonesia, which has become one of the limitations faced in Indonesian medical education. The study to validate VR evaluation tools was ongoing and not ready to be published. Since no validated tools were available, most Indonesian VR products were evaluated using custom build-user feedback. The assessment was based on the user's perception after using VR for teaching and learning.

> We are conducting a validation study for VR assessment. We need to create validated tools to assess VR acceptability. That is our input for future VR implementation. That was the lack we faced today. (R1, 37)

> The first evaluation should assess whether they like [VR] or not. If we want to assess the effectiveness, we need validated tools. That is why in our previous study, we assessed students' perception. (R2, 25)

The drawbacks of VR usage should be assessed before VR is implemented widely in medical curricula. The price of sophisticated VR hardware was still high, limiting its usefulness in teaching and learning activities. The ratio between VR hardware and students was not proportional, creating a long queue to use VR. Alternatively, a respondent suggested using cardboard VR if the medical school found a limitation in obtaining funding.

> It is impossible if we want to use one VR hardware on one-on-one examinations, exam duration was only 30 minutes, simultaneously done by 50 students. The exam duration will be too long if [VR] is used interchangeably by the students. (R2, 26)

> We developed a cardboard VR because standalone hardware's cost was too high. So we not yet trying to develop that [using VR head mounted device (HMD)]. (R4, 9)

The respondents mentioned VR's side effects as essential aspects that must be evaluated. Headaches were the most common motion sickness symptom faced after using VR. Movement methods, especially locomotion, in the digital environment, affected the risk of motion sickness. This problem could be reduced by limiting usage duration.

> There are some obstacles [to use VR], especially for one who has never used VR. Some of them experienced headaches [after using VR]. This became an evaluation for us. Using the locomotion method, the duration of user usage should not be too long. If they watch video [inside VR], then they could use it for a longer duration. (R1, 38)

The government can also evaluate VR innovations in a regulatory sandbox. Sandbox evaluations have been used for technology in the clinical field and should also be applied to medical education.

> There is no regulatory sandbox for that [medical education VR] development. Currently, regulatory sandboxes are only [available] for startups in telemedicine. Why is not there one for educational VR? (R4, 39)

Readiness

In this study, respondents mentioned several factors that could determine overall readiness to implement VR in medical education, including human resources, curriculum, facilities, funding, and regulation.

Assessment of stakeholder and teacher perceptions and readiness should be done before VR implementation. A respondent also reported that stakeholders' narrow-mindedness would be an internal obstacle to implementing VR. One of the reasons for the resistance was a lack of digital literacy, which resulted in stakeholders and teachers not being open to using VR in the classroom.

> The obstacles are internal and external. As for the internal ones, are they open-minded about the new technology [VR]? (R4, 33)

> Literacy. Digital literacy. We wanted to develop an application, but it turned out that our fellow teachers did not even know [about VR]. (R4, 17)

Difficulties in adapting to the latest technology can also cause teaching staff to be reluctant to switch to more up-to-date teaching media. Most senior teachers are already comfortable with traditional teaching methods and do not wish to switch to more modern teaching methods. The transition from traditional teaching methods to modern methods needs time and cannot be forced. Therefore, VR implementation must start with teaching staff interested in the information and technology field.

> So far, the biggest obstacle is that lecturers kept saying, "I do not want to". In human resources theory, some subjects want to use new things, while others prefer to use traditional things; that is the toughest challenge. It [development and implementation] takes time. Like in the past when we switched from conventional learning models to student-centred models, it also took quite a long time to get used to, right? (R6, 41)

> But for technology-enhanced learning, only a limited number of people have a passion. We should start with these teachers. (R1, 6)

Technical teams should be recruited to assist teachers when teachers use VR in their class activities. Preparing and sorting out VR devices before and after classroom activities should be the responsibility given to the technical team.

> For me, the teacher should be assisted by a technician. Teachers must know how to use VR, but still, the technician should be there to help if something wrong happens. In our experience, we are always accompanied by Mr. X during simulation class. We asked him to help us to prepare all systems. (R1, 11)

On the student's side, although most medical students are digital natives, knowledge transfer on VR adoption still needs to be given before independent usage is permitted. Their ability to use VR correctly would determine VR device health. Damage to VR devices happen due to student negligence, which increases the cost of maintenance.

> Even students might not be able to operate their virtual devices well. It means that before we lend it to students, training should also be involved. Otherwise, the accident could happen, and it might damage the equipment. If it [VR device] breaks, the investment needed is also significant. (R9, 31)

The second factor was the curriculum. Respondents suggested that VR modules should incorporate specific learning objectives. Not all learning goals can be achieved using VR. Some learning objective can be managed using conventional tools such as video.

> The most important thing is, if we want to develop VR, first [we need] to specify the learning objectives. (R5, 38)

> In terms of the educational aspect, if the learning objective is to form a mindset and increase knowledge, then in my opinion, videos will be more useful. However, if it is for skill formation, the animation format, which has a more immersive form [VR], could be more useful. (R8, 8)

VR could be utilised to show things that students cannot see directly, such as disease mechanisms. Also, displaying a rare case could add more value to VR implementation in classroom activities.

> There are some simulations that can be carried out in skills laboratories, but there are some that cannot be replicated, such as in pathological conditions, and we hope this VR technology can fill the gaps in skills laboratories. (R9, 46)

> However, as the scarcity of several cases increases, it makes me feel the need to document them [in VR] also increase because I think someday we will not have access to them [rare cases] anymore. (R6,1)

Another specific condition that VR can replicate is invasive skills, primarily surgery-related. The respondents thought that a large amount of hard work would be needed if medical schools wanted to replicate the layered human body in three-dimensional environments.

> If the skills we want to replicate only involve physical examinations, we can suffice it with mannequins. However, it would need a simulation when it comes to skills that require dissections such as in surgeries. Indeed, creating the three-dimensional models is not simple, but I think it is necessary. (R6, 29)

Since the objective and the benefit of VR implementation are already known, a respondent suggested deciding on the features the VR would need. These features support the knowledge transfer process during classroom activities. Teachers also need to be aware of the availability of other learning media, which can overlap with VR. Excessive kinds of learning tools simultaneously given in the classroom will reduce VR usage duration.

> First, we need to do the assessment...we know the benefit and the limitation [of VR's feature]. [We] ought to know the features of VR and the media used to transfer the information [to the student]. (R4, 13)

> Yes, because of time limitations. Learning duration is insufficient if we have to try all of these [modalities]. There are many modalities available, wet cadavers, plastinated cadavers, mannequins, VR, and AR. If we try them all, it is not possible. (R2, 6)

Funding is a critical problem emerging in all projects, even in developed countries. The respondents suggested convincing key stakeholders to help find funding for the development processes. Others suggested using grants provided by medical schools.

> Always funding...When I was in Sweden, all the problems pertained to funding, and the question they usually asked was, "Where do we get funding support?" and the answer was standard, convince the institutions [key stakeholders]. (R1, 36)

> In our medical faculty, there is an annual grant for IT development that can be used for VR development. (R9, 34)

Regulation is another factor related to VR development funding. Regulation must be established actively. Lecturers and VR developers should not only passively wait for key stakeholders to take action and launch regulation on VR implementation.

> Like I said earlier, the regulation. We have to establish [the regulation]. We cannot be like a football referee—that regulation has to be created, and there is a system [lecturer, developer, stakeholder] responsible for establishing the policy. (R7, 30)

On the other hand, a respondent suggested that stakeholders have the knowledge and a wider point of view towards the implementation of VR in medical education. Short-, medium-, and long-term vision should be defined clearly to direct the development of medical education VR.

> Stakeholders need to know [and] have a bigger picture, a broader one [on VR development]. They must have a much bigger vision toward 5–10 years in the future. (R8, 16)

DISCUSSION

This study found that VR implementation in Indonesian medical curricula should be carried out in seven steps—needs exploration, blueprint creation, multidiscipline or multi-centre collaboration, training provision, success stories and scientific evidence, appreciation, and evaluation. There are five essential readiness factors—human resources, curriculum, facilities, funding resources, and regulation—that must be extensively explored to ensure successful implementation. From these themes, it can be concluded that VR implementation is an organisational transformation and innovation diffusion process. The seven steps are similar to Kotter's 8-step change model, which focuses on planning, implementing, and evaluating organisational transformation management (30, 31). This result could be applied to different specialist departments in both the preclinical and clinical phases of medical education, as various experts from undergraduate and graduate levels are included. The results contribute to the literature on VR implementation in lower-middle-income countries' medical curricula. This study also provides additional support for adoption through provider-centred designs such as the one proposed by Zweifach and Triola (32).

This study found that stakeholders' openness to a novel approach could accelerate VR implementation. Open-minded stakeholders who are the first to implement VR are categorised as early adopters. In contrast, those who rejected VR even after data on VR implementation was provided are considered laggards (33). Laggards should not be included in early-phase symposia or workshops, as they would not benefit from them (34). The reluctance to use VR devices as learning media will hinder the VR implementation process in the future (35, 36). Negative perspectives can also affect students' success in achieving learning goals. The feeling of reluctance experienced by students can be closely related to the side effects (nausea, dizziness, headache, and disorientation), features (realism and interaction) and issues while using VR (disconnection, ambient noise, and white flash) (37).

The four-component instructional design (4C/ID) model, a task-centred instructional design model, as explained by Frerejean et al. (38), could describe how VR will be incorporated into the medical curriculum. VR should include instructional design as part of its development. 4C/ID can break complex tasks into smaller individual tasks. This instructional design could benefit students and VR developers, as they only need to focus on simple individual tasks. While students can repeatedly learn each small task and reflect on their mistakes, teachers and developers could evaluate the learning process and student outcomes. These become a basis for deciding the following features needed for the learning activities.

The final stage of implementing VR in medical education is a comprehensive evaluation. The results of this study show that evaluation is crucial for VR development. Suggestions and criticisms could become a source of improvement throughout the development process.

The plan–do–check–act cycle can be carried out so that the evaluations and improvements do not stop after the first evaluation is completed (39, 40). Small periodic evaluations are also related to small tasks and evaluations in the 4C/ID model, as more straightforward evaluations will result in faster improvements than more complex ones (41).

The study' result indicate that the lack of validated VR effectiveness evaluation tools impedes VR implementation. Respondents discussed efforts to create widely applicable assessment questionnaires to overcome this obstacle. Other studies lack uniformity in the use of questionnaires to assess VR effectiveness. For example, Sapkaroski et al. (42) used a questionnaire with a Likert scale to determine student perceptions after using VR. In contrast, Kolla et al. (43) used a questionnaire with open questions to assess students' perceptions after using a VR anatomy for learning activities.

This study's findings have implications for the development of VR in medical education. Medical schools need to establish policies related to the seven VR implementation steps identified in this study. The development team must be able to fulfil every implementation step, from needs exploration to evaluation. A structured guide that covers various needs—such as determining the features, maximising the benefits, reducing the negative implications, and guiding financial plans—is also needed for medical teachers and VR developers in developing VR.

This study has several limitations. Due to the small sample size, the results cannot be generalised to all medical teachers in Indonesia. The second limitation is that all the respondents came from medical schools in Java. However, this was the country's first study exploring the need to implement VR in medical education. To the best of the authors' knowledge, there are no other studies related to VR in an Indonesian medical setting. The study also recruited respondents with VR development experience, which helped them explain the process and challenges more clearly.

Further studies should focus on producing validated VR implementation readiness questionnaires and guidelines for developing VR in medical education. A survey of medical students and teachers would help elucidate stakeholders' expectations. Additionally, studies designed to explore VR effectiveness and side effects will be crucial for determining the importance of VR implementation in Indonesian medical curricula.

CONCLUSION

The implementation of VR in Indonesian medical curricula must be carried out in seven steps—needs exploration, blueprint creation, multidiscipline or multi-centre collaboration, training provision, success stories and scientific evidence, appreciation, and evaluation—with five readiness factors—human resources, curriculum, facilities, funding resources, and regulation—that must be extensively explored to ensure that the implementation is successful, has educational value, and has further development in the future.

ETHICAL APPROVAL

Ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Indonesia, Cipto Mangunkusumo Hospital (number KET-412/UN2.F1/ETIK/PPM.00.02/2023).

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