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A system architecture for mixed reality systems in vocational schools in Indonesia

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ABSTRACT

In Indonesia, vocational schools are less favored compared to K -12 schools. Unfortunately, graduates from vocational schools do not fulfill the minimum requirements set by industries, particularly in the current era of industry revolution 5.0. This revolution aims to establish society 5.0, where humans and robots collaborate closely to achieve improved work outcomes. One technique to enhance the proficiency of graduates and prepare them for the workforce is by implementing a mixed-reality system. that will effectively address a multitude of issues and significantly enhance the caliber of graduates and before the implementation of mixed reality (MR) systems, it is necessary to create system architecture diagrams to ensures that the system can be utilized not only in specific schools but also in any vocational school in Indonesia. This study comprises 5 participants, including experts from both the professional and academic fields, who possess extensive knowledge in the domains of metaverse, MR systems, and information systems. The methodology employed in this study draws inspiration from James Martin's rapid application development (RAD). The result of this study is a validated system architectural diagram, endorsed by experts, which depicts a metaverse-based MR system designed specifically for vocational schools in Indonesia.

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1. INTRODUCTION

To begin with, vocational education is an educational approach that emphasizes the acquisition of practical skills for employment. Its primary objective is to train and equip students with the necessary abilities to excel in the competitive global business and industry sectors [1], [2]. Even though the changes have been made, the disparity between newly graduated workers and the industry still exists, and one approach to narrow this gap is to re-enhance or adapt vocational education and involve the industry party. The Indonesian government is paying more attention to the development of vocational schools, although changes from 1967 until 2021 have been made to make vocational schools better and to offer the same quality education as regular high schools, unfortunately, the outcome of those changes or improvements hasn't met the government's expectations. As the world is entering the 5th generation industrial revolution also known as industry 5.0, people are expected to work together and collaborate with robots and eventually will form society 5.0. Every single industrial revolution automatically required higher human competency, this situation is because technology is getting more advanced and advanced to make it more efficient and effective by combining technology and humans.

With technology, all the repetitive or dangerous tasks can now be replaced with machines, and human skills for something that can't be replaced with machines or any tasks that require more human touch. Because the technology is already there, they are now expecting the graduates to be ready-to-work products, instead, they must conduct training from the beginning for the fresh graduates. To bridge the existing disparity between vocational schools and the industrial sector, the Indonesian government has made efforts to narrow this gap by revising the curriculum from 1967 to 2021, as depicted in Figure 1.

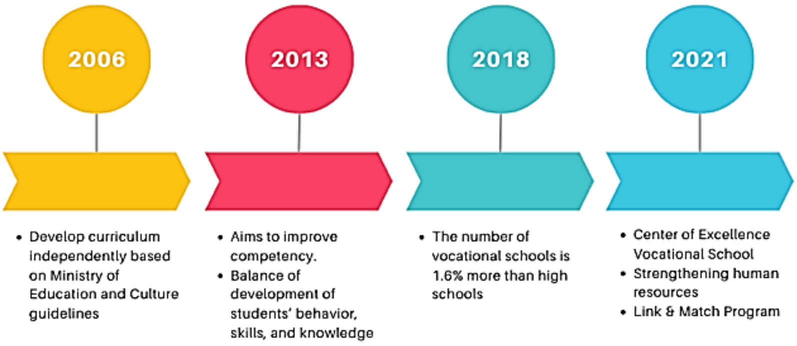

Figure 1. Government's effort to strengthen vocational schools [2]-[4]

Education, including vocational education, plays a crucial role in the economic growth of Indonesia. One effective approach to enhance the impact of vocational education is by enhancing the connection and alignment with the labor market [5]. Additionally, it has been discovered that bridging the divide between vocational education and industry requires addressing multiple aspects, including policies and strategies, curriculum development, learning processes, industry partnerships, quality assurance through accreditation, teacher development, fostering an industrial work culture, and enhancing infrastructure quality [6]. The current discrepancy may arise as a result of the equipment's quality throughout both the study and the practical assessments. The equipment mentioned in this case encompasses various machinery associated with vocational schools. This issue is prevalent in Indonesian vocational schools, where the quantity of available machines falls significantly short of the number of students. Additionally, many machines are in disrepair, and there is an inadequate supply of electrical power to operate all the necessary machines for the learning process [7]. In 2021, the government initiated a program called SMK Center of Excellence to demonstrate its commitment to enhancing vocational schools.

The objective of the link and match program is to foster engagement in the realm of employment across all facets of vocational education, encompassing a total of eight or more components. The 8+i aspects encompass two key elements. Firstly, there is a collaboratively developed curriculum that focuses on [8] enhancing soft skills and work character traits in addition to the relevant hard skills required for the professional world. Secondly, there is a strong emphasis on real project-based learning derived from real-world work scenarios. This approach ensures that the acquisition of hard skills is complemented by the development of soft skills and strong character traits. The program has greatly increased the number and involvement of teachers/instructors from industry and specialists from the world of work to a total of 50 hours every semester. Completion of a minimum of one semester of practical work experience in the field/industry, attainment of competency certification that aligns with international work standards and requirements (for both graduates and teachers/instructors), regular provision of technology updates and training for teachers/infrastructure from the world of work. Applied research is conducted to support the teaching factory by focusing on specific examples or identified requirements. Dedication to integration into the workforce, (i) diverse opportunities for partnership with the workforce [8]. The Center of Excellence Vocational School is anticipated to serve as a hub for enhancing quality and serving as a benchmark for other Vocational Schools, showcasing a range of exemplary practices and serving as a source of encouragement and inspiration for other Center of Excellence Vocational Schools.

Previous studies have demonstrated that incorporating the use of mixed reality (MR) systems has a substantial impact on student performance. This is because MR technology enhances creativity and provides improved visualization, resulting in better overall academic outcomes [9]. Consequently, integrating MR into educational settings appears to be a viable solution for enhancing vocational education and bridging the gap between academia and industry. Additionally, research has consistently shown that technology-based learning significantly enhances student engagement, which in turn leads to improved learning effectiveness. The interactive nature of MR systems further contributes to increased student engagement [10]-[12].

Student interest is significantly influenced by learning engagement. In addition to learning engagement, several other advantages significantly contribute to student interest, including authenticity, social presence, spatial presence, and emotiveness. The systematic literature review reveals numerous advantages of utilizing the MR system, with the most prominent being: (i) enhanced learning engagement, (ii) heightened interaction, (iii) increased motivation, (iv) improved teaching and learning effectiveness, and (v(a)) superior learning outcomes, along with (v(b)) experiential learning [13]. In Indonesia, there are various categories of vocational schools specializing in machinery, including both private and public institutions. Implementing a standardized MR system in schools poses several challenges. Firstly, not all schools have equal financial resources to invest in such a system. Additionally, the availability of development resources varies among vocational schools due to differences in their geographical locations and areas of focus. To address this issue, the management and operation of this MR system must be subject to government regulation and oversight, specifically within the purview of the Ministry of Education, Culture, Research, and Technology.

This paper introduces the system architecture of a metaverse-based MR system, designed to apply to vocational schools across Indonesia because system architecture serves as a fundamental framework for developing business solutions that address issues related to the efficient utilization of information technology [14]. The system architecture is designed to accommodate both the vocational school, which is situated in a remote location and likely lacks essential services, such as a reliable internet connection, and located in the main areas. One strategy to boost the quality of vocational school graduates is by implementing a MR system to improve the learning process and infrastructure. The subsequent section entails the process employed for creating the system architecture diagram. The methodology will be comprehensively elucidated, encompassing the specific actions undertaken by the authors at each stage.

2. METHOD

This study utilized a customized methodology inspired by rapid application development (RAD) by James Martin in 1991, which is a prototyping-based approach. The specific stage of this research is depicted in Figure 2. In total, there are five stages, two of which include an iteration stage. RAD fosters a cooperative environment in which business stakeholders actively engage in prototyping, generating test cases, and conducting unit tests, decision-making is decentralized, moving away from a centralized framework [15]. The customized methodology entails the involvement of respondents or experts from various sectors to directly examine the product and provide comments. Below is the detail of each stage.

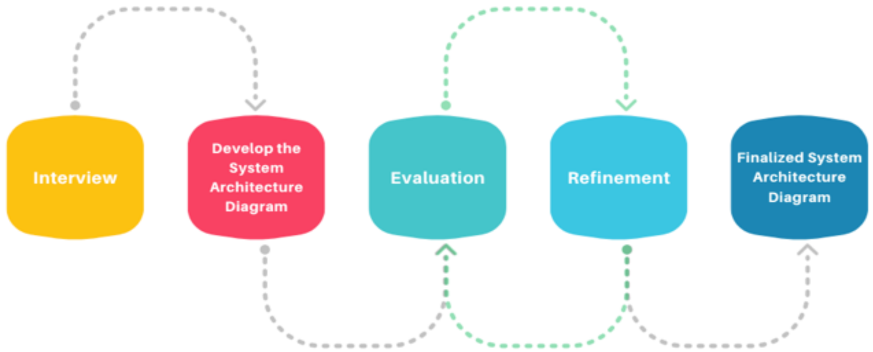

Figure 2. The methodology

2.1. Stage 1 - interview

Within a methodology, the interview stage commonly denotes a particular stage in a research or data-collecting process, during which researchers employ interviews as a means of acquiring information or data. This stage is crucial for acquiring comprehensive insights, viewpoints, and opinions from participants, and it is imperative to uphold flexibility and adaptation, particularly in qualitative research where unforeseen discoveries may emerge during interviews. The objective is to collect comprehensive and intricate data that enhances comprehension of the research subject. This study comprised nine individuals, consisting of three males and two females. Among these participants, 60% were affiliated with academic institutions, while 40% were recognized as field specialists. We extended an invitation to them to serve as our experts due to the direct correlation between their research and engagement with the fields of extended reality technology and education. The purpose of this interview is to ascertain the appropriate system architecture diagram from both academic and practical perspectives.

2.2. Stage 2 – development of system architecture diagram

Creating an initial system architecture diagram is an essential stage in building a system or solution after conducting interviews to collect pertinent information. The system architecture diagram provides a visual representation of the overall structure and components of the system, demonstrating their interactions to accomplish the intended functionality. The objective is to develop a thorough system architecture diagram that corresponds with the knowledge acquired from interviews and efficiently conveys the system's design to all pertinent stakeholders. At this phase, the authors will generate a preliminary system architectural diagram, utilizing the findings from the interviews.

2.3. Stage 3 – evaluation

To assess the system architecture diagram, it is important to gather feedback from the same interviewees. This will help ensure that the architectural design aligns with their requirements, expectations, and insights. It will also increase the likelihood of meeting their expectations and aligning with the requirements gathered during the interviews. Continuous communication and collaboration are essential for improving the system architecture and guaranteeing its success. The authors will forward the system architecture diagram they have generated to the interviewee and have discussions to solicit input and suggestions for potential refinements to enhance the diagram.

2.4. Stage 4 - refinement

Revise the system architecture diagram based on the input received. Revise the document to address any issues, including suggested changes, and ensure that the final version appropriately reflects the agreed-upon design of the system. Improving the system architecture diagram after evaluation entails integrating input from the interviews and making necessary revisions to ensure that the representation accurately reflects their requirements and expectations. To enhance the chances of developing a strong and well-matched depiction of the system, it is important to actively integrate input and improve the system architecture diagram through review. Acknowledge that the design of system architecture frequently involves a repetitive and incremental approach. Should any further input or modifications happen, be ready to revise the diagram accordingly. Upon obtaining the findings from the evaluation stage, the authors will revise the system architecture diagram and ensure that all feedback has been incorporated. Upon completion of the refining, the iteration phase of the review will commence.

2.5. Stage 5 – finalized system architecture diagram

Upon completion of the evaluation and refinement steps, the system architecture diagram will be finalized. This version embodies a meticulously deliberated, polished, and authorized representation of the overarching framework and constituents of the system. The finalized system architecture diagram is an essential point of reference during the project's development and implementation stages. The system architecture is a dynamic document that may require regular revisions as the project advances. Continuously update stakeholders about any important modifications and ensure that the design stays in line with the changing requirements of the project.

3. RESULTS AND DISCUSSION

3.1. Stage 1 - interview

The authors start the interview with the field expert to get the technical requirements for the mixed-reality system before starting to concept the diagram. The first session was with respondents 1, 2, and 3, who said that the mixed-reality system is possible and very promising if it's used for vocational school teaching and learning. Participant 1 also adds that "it is possible to make an application that can be downloaded by any vocational school in Indonesia. In fact, this is the best way to do it". He also said that "the government should be responsible for content development to deliver the same experience for any students in any vocational school". The authors paid attention to those 2 statements and made sure to accommodate his input in the diagram. Participant 2 added that "the problem that normally he faced was the issue of internet connection, so it is wise if the app is already pre-installed on the device". and he also agreed that "the government in the Ministry of Education, Culture, Research, and Technology should be a regulator for the implementation of this state-of-the-art technology for any vocational schools throughout Indonesia, or otherwise this might not work". Participant 3 agreed with participant 2 that the application should have already been installed before the mixed-reality system was delivered to any vocational schools to reduce hassle. He also said that "using mixed-reality system such as Microsoft Hololens will open the opportunity for any students or teachers in a particular vocational school to collaborate with other vocational schools or industry. Using Microsoft technology, for example, the industry can also jump into the equation to add valuable training or challenges for students". MR refers to the integration of the physical and virtual realms to generate novel environments and depictions, where digital and physical elements coexist and interact instantaneously [16]. MR, in contrast to virtual reality (VR), integrates the physical world with VR to provide captivating new encounters. Unlike VR, MR is not confined to either the physical or virtual realm, but rather combines elements of both. MR has the potential to greatly enhance the educational system, allowing students to participate in interactive sessions from their own homes. Microsoft and other brands are enhancing their products to increase the accessibility of MR in education. This is aimed at enabling students to engage in experiential learning, hence enhancing the benefits of MR for teaching and learning [17]. Microsoft introduced its inaugural HoloLens in March 2016, followed by the release of its latest MR smart glasses, HoloLens 2, in February 2019. During the exhibition, they showcased their MR smart glasses, with an application developed using the unreal engine.

The second interview session was with 2 academics (participants 4 and 5), who said that the content is one of the main issues for such a system. Content development will take the most time, must make sure that the content is suitable for most or any type of students and can accommodate their learning style. Since the mixed-reality system leans towards practical study, they also agree with the authors to adopt and combine the experience learning method from David Kolb, the cone of experience model by Edgar Dale, and the TPACK framework from Rosenberg and Koehler, all will be explained below.

The experiential learning method focuses on actively constructing knowledge and emphasizes the interaction between individuals and their environment [18]. William James proposed the concept of radical empiricism, which combined two prominent branches of Western philosophy: empirical and rational empirical schools. William James posited that all individuals must possess firsthand experience and that all knowledge is derived from such experiences. Furthermore, he asserted that humans ascertain what is correct by substantiating it via their encounters. Experimental learning places learning as the focal point of the learning process, whereby students' experiences serve as a guide for their learning and determine their level of comprehension. The appeal of experimental learning lies in the acquisition of practical knowledge by students, who also have complete autonomy over their learning experience. Under these circumstances, students have the opportunity to proactively generate diverse experiences tailored to their learning process. David Kolb's idea of experiential learning offers a structured framework that facilitates students' comprehension of learning material by offering tailored experiences that align with their learning patterns [19].

The cone of experience paradigm was developed by Dr. Edgar Dale in his work titled "audiovisual methods in teaching" in 1946. The cone diagram illustrates a taxonomy of the learning process that encompasses both abstract and concrete learning events [20]. Dale recommends employing many media in education to effectively attain learning objectives, potentially beyond the intended targets. Dr. Edgar Dale categorizes three learning modalities based on learning experience using his cone of experience model. The first type is symbolic experience or symbolic learning experience, wherein pupils acquire knowledge abstractly. The second type of experience is referred to as iconic experience, which involves learning by observation. The third and final type is direct, intentional experience, which is learning by actively engaging in a specific activity [21], [22]. TPACK is a pedagogical framework designed to enhance teachers' ability to effectively instruct and involve students through the utilization of technology [23]. The TPACK framework seeks to integrate teachers' knowledge, pedagogical practices, and the role of technology in education to positively influence students' learning outcomes [24].

3.2. Stage 2 – development of system architecture diagram

Upon gathering all the necessary data from the interview session, the authors endeavored to construct the preliminary rendition of the system architecture diagram for a MR system rooted in the metaverse, specifically designed for vocational schools in Indonesia. The authors diligently endeavored to integrate as many of the suggestions supplied by the responders as possible into the diagram creation process. The authors also acknowledge the involvement of the industry in terms of providing training and collaborating with the government to develop the curriculum for vocational schools, as depicted in Figure 3. By using cloud services, other vocational schools can also engage in collaborative teaching and learning using mixed-reality computing systems. Furthermore, during the material development process, the government should employ the experiential learning approach, cone of experience, and TPACK as their guiding principles. The government assumes responsibility for formulating the syllabus and collaborating with educators and companies in the process.

3.3. Stage 3 – evaluation and stage 4 – refinement

When the system architecture V1 finished, the authors conducted another interview with all 5 respondents to review the results. During the interview, there is feedback and additional information that hasn't been addressed before. But before the interview session, the author feels that the elements of a metaverse-based MR system must be defined to make the system architecture clearer.

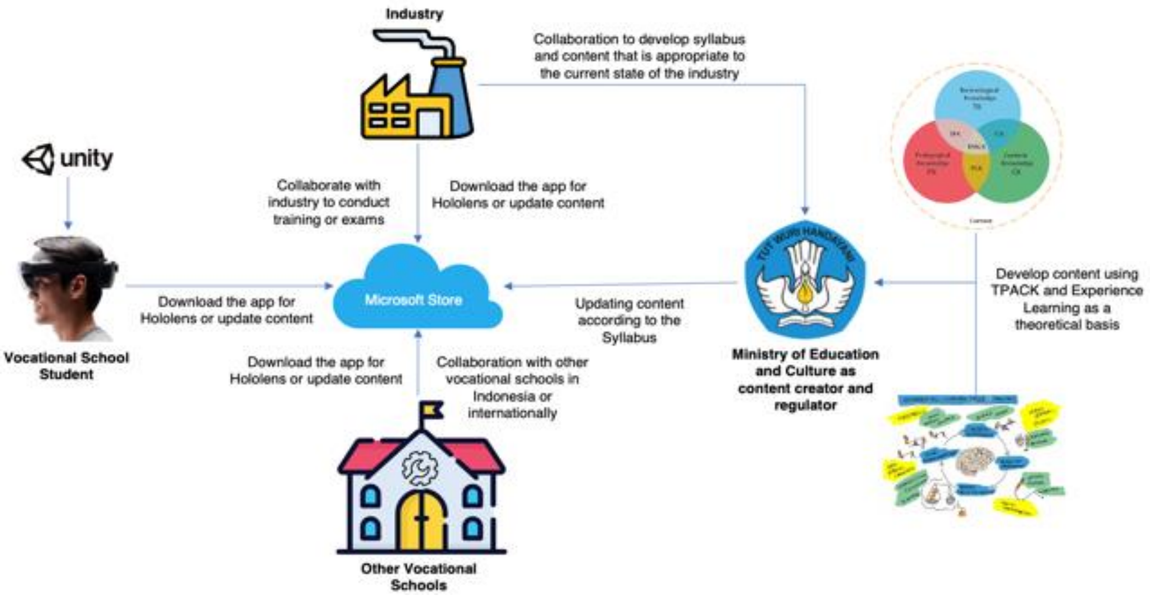

Figure 3. System architecture version 1

The authors obtained significant insights into the components of the metaverse from the findings of the prior research. The metaverse encompasses four distinct types: augmented reality (AR), lifelogging, VR, and mirror world or digital twin [25]. The primary component of AR is human-computer interaction, sometimes known as HCI. This encompasses the selection, execution, and mobility of the users. This aspect is crucial since it will enhance the user experience. The authors only identified the camera as the sole component of lifelogging. This is intriguing because any wearable gadget that tracks individuals' physical activity, including heart rate monitoring, is likewise classified as lifelogging. However, there is still a prevalent misunderstanding regarding lifelogging. The third category of metaverse is VR, wherein two elements exhibit equal frequency: 3D representations encompassing both human figures and environments, as well as movement recognition. These two parts are inherently comprehensible in terms of their significance. The mirror world, also known as the digital world, consists of three key aspects: 3D models, physical systems, and real-time monitoring. These elements are equally represented in terms of their presence and importance [26]. In the next research, the authors conducted interviews with nine experts from the metaverse and MR fields, including academia. The primary objective of these interviews was to gain insights into their perspectives on various types of metaverses and the elements of MR specifically designed for vocational schools within a metaverse. Following the completion of interviews, the writers synthesize the results with previous research to develop a questionnaire that may be used to ascertain the essential features. The authors employed a Likert scale in their questionnaire, with a rating of 1 indicating strong disagreement and a rating of 5 indicating strong agreement. The authors administered questionnaires to the identical group of nine experts with whom we had previously spoken. Subsequently, the authors evaluated the dependability of the questionnaires after a total of nine experts completed them. Subsequently, we collectively determined that the components of metaverse-based MR systems can be classified into four distinct categories: hardware, software, content, and communication [27]. All these categories will be incorporated into the forthcoming version of the system architecture diagram.

Following the completion of the aforementioned research, the authors carried out the initial session of the second interview with respondents 1 and 2. During the interview, respondent 1 stated that "mixed-reality technology, like the Microsoft HoloLens, operates on a similar system as mobile phones. The entire program will be packaged in a standard mobile application manner, and users will need to update the application to access the latest information. The application can be pre-installed on Microsoft HoloLens and users can simply connect to the internet to update the application in the event of any significant or minor changes to the content or curriculum or even the application as a whole". Respondent 2 concurred with the notion and emphasized the need to support schools lacking adequate internet connectivity, particularly those situated in distant regions. Respondent 2 proposed that "the system architecture should incorporate a server specifically for schools lacking a reliable internet connection, to store the updated application. The concept entails downloading the application from an alternative source and subsequently transferring it to the internal server". When the mixed-reality system requires an update, it simply retrieves it from the local server through downloading. Another possibility is for them to allow the server to download the new application overnight, and subsequently, the MR system can update it from the local server in the morning. The authors concur with the comments provided by both respondents and will make the necessary adjustments accordingly. In a separate session, the authors interviewed respondent 3, respondent 3 emphasized the need to "include the components of the metaverse in the upcoming edition of the system architecture diagram for improved clarity", which is aligned with [28] that the system architecture focuses on the application level and encompasses the essential concepts and properties of a system within its environment. This includes its elements, relationships, and the principles guiding its design and evolution. Based on the authors' prior research involving one of the respondents, who is also referred to as respondent 3, we can deduce that there are three distinct categories of components: hardware, software, content, and connectivity. The system architecture diagram should incorporate those categories. The final interview session entails doing the second interview with respondents 4 and 5. Both individuals expressed strong optimism over the improvement and concurred with the feedback provided by the remaining three participants. Respondent 4 proposed the removal of the TPACK and experiential learning icons from the preceding system architectural model. Instead, they recommended incorporating the components of MR systems, which aligns with the idea made by respondent 3. Respondent 3 stated that the system architecture diagram is a design that provides an overview of the system, and as such, it should only display high-level information. The two icons in question appear to be more technical. Respondent 4 concurred with the input provided by respondent 3 and suggested using the arrows as a verb to convey the purpose of the arrows and ensure that the diagram accurately represents the industry's position as a curriculum partner and in giving training. It is necessary to clarify the role of the additional vocational school [29]. Stated that system architecture is a collaborative approach that enables several stakeholders to visually design a system, discover its inefficiencies, and suggest enhancements.

3.4. Stage 5 – finalized system architecture diagram

Following the completion of the second interview session, the authors compiled the feedback provided by the respondents while reviewing the initial iteration of the system architectural diagram as shown in Figure 4. Respondent 1 provided more details regarding the application within the MR system, which bears a resemblance to a mobile phone. The MR system requires the application to be downloaded, or it can be pre-installed in the hardware. Users must update the application when there are updates to the teaching and learning content or the syllabus. Respondent 2 stated that there are two potential methods for updating the application. If the schools possess a satisfactory internet connection, they can directly update it from the cloud server. Furthermore, suppose they lack a reliable internet connection. In that case, they can download the application onto their internal server and subsequently update it from there, or they can update it via USB. Respondent 3 requested the authors to incorporate the constituents of MR systems into the system architectural diagram to enhance clarity regarding the components. Respondent 4 contends that the system architectural diagram is a diagram that provides a broad overview of the system.

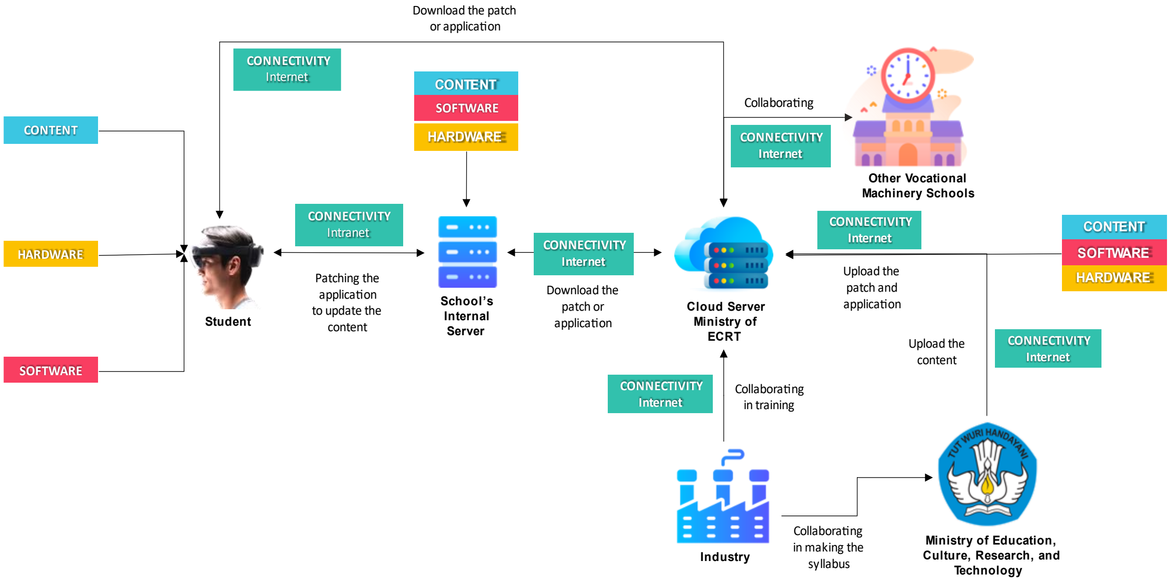

Figure 4. Finalized system architecture diagram

4. CONCLUSION

MR is a cutting-edge advancement within extended reality. Machine learning revolutionizes AR. MR integrates AR and VR to provide users with an enhanced degree of experience. This is achieved by allowing users to interact with digital elements within their real-world surroundings physically. MR enables the manipulation of digital pictures that are superimposed over the physical environment. Prominent examples of MR technology include Microsoft HoloLens and the Lenovo Explorer. Currently, MR technology is being employed across various domains, including education, healthcare, defense, and other sectors. The primary objective of MR is to enhance education by elevating competency levels, providing additional experiential learning opportunities, and facilitating other educational benefits. Implementing the MR in education institutions, the vocational school area is the least that has implemented the MR system compared with K12 schools and universities, and according to the authors' previous research K-12 schools (55%) had most of the MR systems implemented possibly due to factors such as finances, and easier content development. Universities were the next highest category (32%); the diversity of majors makes content development harder. Vocational schools (13%) had the fewest MR systems because, in vocational schools, they have not utilized technology as much as others and are more focused on hands-on practice. Our research makes two distinct contributions: an academic perspective and a practical perspective. Our system architecture diagram provides valuable insight for future researchers regarding the implementation of MR systems in vocational education, from an academic standpoint. From a practical perspective, our finalized system architecture should effectively support the introduction of MR systems based on the metaverse in vocational schools, namely in Indonesia. This figure includes both vocational schools in remote regions with unreliable internet access and vocational schools in central areas where a reliable internet connection is considered normal.

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