Review TVET learning innovation: Augmented reality technology for virtual 3D laboratory

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Abstract. Currently the trend of using Virtual Augmented Reality (VAR) technology in the field of vocational studies has become a very sexy research topic with visual features that can display objects in 3D. Virtual Augmented Reality can help many things, especially in creating innovation in various industries. In this literature study, the advantages and disadvantages of VAR are clearly described in terms of developing a three-dimensional virtual laboratory for innovation in learning vocational techniques. Unfortunately, some technical problems of VAR technology cannot be fully implemented into vocational engineering learning. The purpose of this study is to show a study of the application of VAR technology with a literature review system method in an appropriate three-dimensional virtual laboratory framework. This analysis is carried out by screening a number of publications of up to 30 major studies published from 2009 to 2018. The results show the low application of VAR technology in education and the increasing application of VAR in industrial environments that lead to high complexity for selecting and developing vocational engineering learning with the VAR system. Subsequent research was also proposed to design and implement AR technology integration into a virtual three-dimensional laboratory specifically for vocational engineering.

1. Introduction
Augmented reality is becoming very popular with the increasingly cheap Android smartphone devices. Many Augmented Reality applications are used by manufacturing companies such as logistics, workshop layout evaluation, prototypes and virtual training. This Augmented Reality technology can help overcome difficulties in providing training facilities in the field of engineering, namely by integrating multimedia graphics for three-dimensional virtual laboratories [1]. Augmented Reality can interact with the physical environment through three-dimensional multimedia visualization directly and provide an interactive experience with the real-world environment through markers scanned by the camera [2]. Fields that have used AR Technology are: education, tourism, entertainment, marketing, operations, logistics, manufacturing, maintenance, and others.

Current vocational higher education in engineering requires a laboratory that is easily accessed by students as a practice tool that aims to provide skills knowledge directly through practical work [3]. Practical tools that are easily accessible can be realized through the application of augmented reality technology into the laboratory with three-dimensional visualization [4]. 3D image reconstruction for micro augmented reality integral imaging display systems [5]. However, current Augment Reality
technology has not been found to be comprehensive in one framework [6]. In addition, in vocational education, the concept of distance learning is currently widely used for teaching and learning. However, because the nature of the field of teaching in the vocational field requires practice and experimentation requires laboratory facilities to provide effective skills and direct experience becomes difficult to implement [7].

Users who have smart phones, tablet PCs, or Augmented Reality glasses can visualize virtual objects on the screen that are added to the real environment [8]. Recent studies in the field of Virtual Augmented Reality Technology are widely used for training technicians in companies that are carried out virtually through simulations in engineering studies [9,10]. Research in other fields that apply Virtual Augmented Reality Technology covers the fields of: tourism [11], industry [12,13], Medicine [14] and health [15].

Based on the description above, the purpose of this study is to present the state of art in AR for technology used in the context of a three-dimensional virtual laboratory. The author conducted a Review study systematically using the System Literature Review (SLR) method. The systematic preparation of this paper is divided into four parts, namely (1) Introduction, (2) The methodology used in the Review System, (3) Informing the results of reviews and reviews of the state of the TVAR application in vocational training and education, (4) Report conclusions and further future research opportunities regarding TVET learning innovation through the development of TVAR in a three-dimensional virtual laboratory.

2. Methodology
To evaluate the state of AR art in a three-dimensional virtual laboratory, the method used is the SLR approach. The SLR approach aims to conduct searches, assessments, comparisons, and analyze all research related to a particular research field. The methodology used by R. Amarini et al [16] in "Integrated Manufacturing A systematic review of augmented reality applications in maintenance" and the method used by E. Scott et al [17] "Adaptive 3D Virtual Learning Environments - A Review of the Literature."

![Figure 1. SLR methodology for this SLR [12]. In each one of 7 rectangles are reported each step name and its outcome.](image)

The SLR methodology aims to identify gaps in the literature so as to provide evidence of future research fields. The seven steps used to carry out this SLR are: (1) planning, (2) determining scope, (3) searching, (4) assessing, (5) synthesizing, (6) analyzing and (7) writing. The steps follow the particular methodology that will be explained in the following subsections. The following are the SLR steps as described in Figure 2.

2.1. Step 1 - planning
The earliest step in carrying out the literature review system as described in Figure 1, namely: determine the time scale of the project, identify the database to be used and choose software for managing references. Search database for SLR [18] and has been determined based on publisher reference resources indexed by ISI and Scopus for this project, namely:
In addition to using the above reference sources and the characteristics of research topics that are rapidly developing, manual searches have also been carried out both online available and published by non-academic institutions such as government agencies, industry and society [19]. The software used is Mendeley (mendeley.com), this software is very practical to manage and easy to use. Besides other support such as the pdf viewer and the Microsoft plugin, the word is integrated online.

2.2. Step 2 – scope
Defining actualized scope in correctly formulating research questions that can be answered. This has been defined as the result of repetitive processes between (i) initial brainstorming, (ii) literature search and (iii) PICOC (Population, Intervention, Benchmarking, Results and Context) application framework. PICOC elements are: Population, Intervention, Comparison, Results and Context. For this research, the population consists of virtual laboratory fields for technical and vocational education. The intervention considered is the use of Augmented Reality technology.

The research question in this literature study is defined as follows:

- How has the application of Virtual Augmented Reality (TAR) technology for the past ten years?
- Can the application of TVAR in the Three-Dimensional Virtual Laboratory produce new learning innovations on TVET?

Table 1. Publisher database in review literature.

| No | Keyword                     | Year          | Publisher          | Filter |
|----|-----------------------------|---------------|--------------------|--------|
| 1  | AR in Virtual Laboratory    | 2009-2018     | IEEE               | 14     |
| 2  | AR in Virtual Laboratory    | 2009-2018     | Science Direct     | 25     |
| 3  | AR in Training              | 2009-2018     | SAGE               | 14     |
| 4  | AR in education             | 2009-2018     | Journal Health     | 15     |


To answer the research question above, the database is sought from four sources, namely IEEE, Science Direct, Sage, JHE. The first column is for the database sequence number, the second column for the search keyword, the third column for the search year, the fourth column for the publisher column, the fifth column is the result of the journal selection.

2.3. Step 3 – searching
Search is divided into three keywords, the first keyword is placed in the IEEE publisher and ScienceDirect uses keywords ("augmented reality in virtual laboratory"), the second keyword is placed on Sage using keywords ("Augmented Reality in Training") and the third is placed in the Health Engineering Journal uses keywords ("augmented reality in education"). It has been chosen based on the research questions and key concepts stated in Section 2.2. The IN "conjunction is used to provide the first, more detailed screening. The result of this search step that was updated on February 17, 2019 is the collection of 1266 documents. Because this phase has been done for each database separately, the final number of 1266 documents includes duplicates. Further details are shown in Figure. 2. It is worth mentioning that this step does not involve reading the title or abstract of the document found.
2.4. Step 4 – assessment
Assessment aims to narrow down hundreds of search results documents by selecting documents related to research to answer research questions. Inclusion and exclusion criteria have been used to filter the first document: Primary Criteria: (1) The main study representing the use of Virtual AR laboratories, (2) major studies that represent sophisticated AR technology. Secondary Criteria: (1) Not in English, (2) Not below 2009, (3) Not a social field, (4) Not related or applicable to industrial environments.

Table 2. Quality criteria selected for this project.

| Description                                                                 | QC1 | QC2 | QC3 | QC4 | QC5 |
|----------------------------------------------------------------------------|-----|-----|-----|-----|-----|
| The document is clear                                                      |     |     |     |     |     |
| The methodology is well exposed and detailed                               |     |     |     |     |     |
| The technology and case studies are not obsolete                          |     |     |     |     |     |
| The study results are applicable to all engineer laboratory cases          |     |     |     |     |     |
| Analytical results are provided                                            |     |     |     |     |     |

Selection criteria are based on the inspiration of findings from several journal reviews that have been published and the author's experience [17-19]. The document search results from the four databases listed in table 1 are separated in three different parts: first, the document search is done through the google scholar page browser by including the keyword ending with the database as writing the keyword "Augmented Reality in Virtual Laboratory IEEE" followed by opening link and read the relevance of the research topic; Second, utilizing the search facility from the source database by entering keywords namely "Augmented Reality" followed by reviewing the objectives, methods and results of research through abstracts followed by reviewing the introduction and conclusions; Third, the authors compile the documents that have been assessed from four database sources into Microsoft excel by compiling the database and the year of publication starting in 2009 until 2019.

Figure 2. Main framework of the selection process for primary studies.
The initial search results obtained a total of 1266 documents from four databases filtered through predetermined criteria as shown in table 2 are 66 documents. Document evaluation is done by extracting all documents and referring to the criteria, namely (1) the source and content of the document is clear, (2) the methodology can be well and detailed exposed, (3) technology can be applied in various cases or dynamically in vocational engineering laboratories, (5) Analysis results are acceptable. Furthermore, document identification is carried out by determining the quality of documents for the extraction of qualitative and quantitative data with the criteria used based on Santos [20]. Document scores are based on criteria ranging from 0 to 5 based on QC for each of the 68 documents selected as shown in phase II in figure 3 by setting QC points of 0.5.

Subjectivity is a factor in applying document quality criteria, this is not used to exclude any study from this literature review system. Each article identified from 68 articles made a valuable contribution to this SLR. However, as a material for reader studies in Table 3, a report on quantitative and qualitative results can be provided which can give the reader a tool to assess the quality of qualitative results expressed in the results and discussion.

2.5. Step 5 - synthesize and analyse
To answer research questions Q1 and Q2, a table is needed that can link the selected articles in this SLR. General features, trends, AR technology tracking methods and fields can be seen in a summary example in table 3 which shows a portion of 68 articles analysed and compared [21].

The table above is made into 82 columns and 8 lines, the first column is used for the main characteristics in this study which includes articles, application fields, virtual laboratories, developed platforms, tracking methods, visualization, hardware needed and design solutions, while the next column is used to fill in data for 68 articles to be selected and analysed. These main characteristics have been chosen based on the paper and the author's expertise in the field. For example, it is not uncommon to find sections dedicated to hardware, tracking and interaction methods in all AR studies [16, 17]. In addition, the authors group articles into three main parts that are in accordance with the fields studied, namely (1) Education (2) Training (3) Industry. Grouping aims to facilitate the process of assessment and analysis of articles; efforts have been put in to find more comprehensive categories for each characteristic recorded in the figure 3.

![Figure 3. Example summary of systematic literature review.](image)

2.5.1. Application field. The study of the article referred to in the field of application that applies Augmented Reality technology is divided into three main groups, namely: (1) Field of Education, (2) Field of Training, (3) Field of Industry. The selection process, in fact, is based on an analysis of the articles selected for this study and statements collected from 68 articles. Other considerations in the fields of education, training and industry are divided into subgroups, but the authors only do so when needed.
2.5.2. **Virtual laboratory.** The characteristics of virtual laboratories consist of a series of experiments carried out using Augmented Reality technology. The main task characteristics in the lab are divided into four parts:

- Introduction to Practical Materials
- Practical Tasks
- Practical Evaluation
- Practical feedback

In each article that covers the development of the AR system, the authors identify several practical activities that can be supported by the technology developed.

2.5.3. **AR hardware.** In general, hardware that supports the development of three-dimensional virtual laboratories according to K. Helin et al [22], consists of devices used in the AR system. The hardware required has been divided into 6 categories: (1) Head Mounted Display (HMD), (2) Hand Held Display (HHD), (3) Desktop PCs, (4) Projectors, (5) Haptic, (6) Sensors. In some articles, the author uses more than one of these hardware devices or mentions the possibility of using a different hardware solution. The HHD category includes mobile phones, tablets and other devices, especially sensors that are used to retrieve data from other environments or devices.

2.5.4. **Development platform.** The AR technology development platform uses the main software, namely: (1) Blender to create 3D models, (2) Framework for programming languages, (3) SDK (Software Development Kit), (4) Unity software for animation. To build and develop virtual laboratories, the software needed to create 3D models is needed, besides that it also requires high-level programming languages such as Python, Java, C# by making functions according to needs that are packaged in the form of SDK. The next tool is Unity which is packaged in ARkit and Game Engine as software for managing 3D models, animating, writing program code and simulating hardware, either HHD, HMD or others.

2.5.5. **AR marking.** Augmented Reality works based on image detection, and the image used is a marker. The principle works is that a calibrated camera will detect the marker that is given, then after recognizing and marking the marker pattern, the webcam will calculate whether the marker matches the database that is owned [23]. If not, then the marker information will not be processed, but if appropriate, the marker information will be used to render and display 3D objects or animations that have been made previously.

2.5.6. **User interface AR.** Technological interaction method of augmented reality with users from 68 articles, namely with text, audio, video and static and dynamic 3D models or 3D animation [24]. By using a device such as an android mobile phone user after installing an AR technology application can interact directly like a designer with the help of AR technology, designers who were previously only able to see each design result in a 3D screen, would be able to be more interactive with the design results. For example, when a designer makes the design of a building or building, he can feel directly and as if it were real in every room of the building or building, he designed. Of course, this greatly helps the performance of a designer, where they can ensure every detail of the design to fit the concept that has been made.

2.5.7. **Writing the AR application program code.** In software development using AR technology in the field of education, writing systems are programs that allow non-programmers, usually instructional or technology designers, to easily create software with programming features. This programming feature built on 68 articles is hidden behind buttons and other tools, so the author does not need to know how to program. In general, authoring systems report the use of AR technology in articles through graphics,
interactions, and other tools needed in virtual laboratory software with AR technology [2]. The three main components of the writing system are: content organization, content delivery control, and type of assessment. Content organization allows users to compile and sort learning content and media. Control of content delivery refers to the ability for users to manage the speed of content delivery, and how students engage with content.

3. Results and discussion
This SLR study aims to answer and discuss research questions as a result of synthesis and analysis in 68 articles, the research questions in question are:

- What is the current state of virtual augmented reality technology in the fields of industry, education and training?
- Can the application of AR virtual technology into the 3D Virtual Laboratory support TVET learning innovation?

To answer and discuss the research questions above, the author presents answers separately in the following sub-sections.

3.1. Answers to the first question: the current state of Virtual Augmented Reality Technology in the fields of industry, education and training
Based on the analysis findings and summaries of 68 articles to illustrate the state of the art of AR applications in the fields of industry, the education and training identified provided include the following fields: AR applications for industry, education, training and supporting device methods for augmented reality technology.

Figure 4 shows the percentage of application fields that apply AR technology from 68 articles selected and grouped by the authors in this main SLR study, namely: Industry (23%), virtual laboratories (20%), marketing (9%), medicine (14%), education (16%), warehouse (11%) and entertainment (7%). These results are in line with T. Masood and J. Egger who also found aviation, industrial plants and automotive as the largest areas of interest for AR in maintenance [25]. It can be justified by the fact that it includes automotive, railroad, military industry plus some use of AR technology in general virtual laboratories that have not been classified by the author.

![Figure 4. Field of AR application in 68 article review.](image_url)

3.1.1. Augmented reality application. Augmented reality technology can be applied in many aspects of our lives as seen in this paper [26,27], as application in several fields summarized from 68 articles identified shows that the industrial environment applies AR technology to help workers understand the work environment and operational standards of procedures. Augmented reality technology can be applied in many aspects of our lives as seen in the example described in this paper. Some industries that have implemented applications that use AR technology, including manufacturing industries that carry out automotive assembly and repair, as shown in figure 5 below this.
In addition to the manufacturing industry, in line with J. Scholz and K. Du [28-29] marketing also applies AR technology that is integrated into the web marketplace to provide consumers with experience of the products to be purchased, users can directly interact with trying products to be purchased, Choose the colour and design of products offered through Android mobile devices, desktop PCs or other visual devices. Research conducted by M. Y. and colleagues investigated the potential of AR as a tool for e-commerce through two studies focusing on the effects of two functional mechanisms of interactivity and vividness. Another study compares consumer evaluations from AR-based product presentations with presentations of traditional web-based products with respect to a variety of consumer evaluations [30].

Research conducted by T. Verbelen and friends on amazon companies as the largest e-commerce company has integrated AR technology with a web marketplace to increase sales by providing easy access to consumers, in addition infrastructure support is also provided as shown in the figure 6,7 and 8 below [31-35].

![Figure 5. Static cloudlets can be provided by a corporation in a corporate cloudlet [4].](image)

Architecture is a field of engineering that applies AR technology to carry out baggage simulations, as presented by Julie Milovanovic and Guillaume Moreau who carry out studies in field architecture showing various possible uses of systems to accompany designers, lay people and decision makers in the architectural design process [27].

The application of AR in archaeological education according to Domus enables people or visitors to experience directly about historical heritage buildings with virtual designs combined with virtual application programs based on Android mobile phones [36].

3.1.2. Laboratorium virtual AR. Three-dimensional virtual laboratories utilizing augmented reality or AR technology are accessible practical facilities that are conveyed through cellular and mixed reality to be possible in education, shifting pedagogy from using two-dimensional images and videos to facilitating learning through an interactive mobile environment. In medical and health education this becomes very important, where the acquisition of knowledge needed usually requires direct, self-directed, and direct experience [37]. Presented is the insight gained from the implementation and testing of mixed reality technology in the anatomy and physiology classrooms [9]. With the aim of exploring how interactions with these devices help in spatial learning and the transfer of knowledge in health and medicine.

![Figure 6. patient examination simulation using virtual augmented reality [10].](image)
According to A. Bernardo that the architecture of a prototype of a three-dimensional virtual laboratory with augmented reality technology, based on the real environment [38]. Focus is also placed on user interactions, through the interaction architecture definition that uniformly handles input and tracking. Both of these architectures are component oriented, supporting white box reuse [39,40].

Online teaching in science and engineering that emphasizes practical training applies new concepts in virtual laboratories and remotely: augmented remote laboratory (ARL) [41]. ARL was tested in the first and second years of industrial engineering and computer engineering faculties, respectively, in the School of Engineering, University of Huelva, Huelva, Spain. By using augmented reality techniques, ARL allows students to experience sensations and explore learning experiences which, in some cases, can exceed those offered by traditional laboratory classes. The effectiveness of this methodology for remote laboratory work is evaluated by comparing it with practical sessions in the laboratory at the university itself with the same group of students [42].

Applications in nursing education are many health care professionals who are familiar with simulation-based training using virtual laboratories for cardiopulmonary resuscitation training or other medical emergencies, such as contrast reactions [43]. Because Head-Mounted Displays are very complicated, visualization is done on a computer screen [44].

Game-based learning system integrated with augmented reality, teaching and learning processes through virtual laboratories. The game includes two stages (the exploration phase of AR and the virtual experiment stage). The results show that students improve their learning significantly after the match and scores in each dimension of flow and acceptance are both high [45].

3.1.3. AR hardware and software. AR technology hardware in literature studies from 68 articles are grouped into 8 main parts, namely: (1) TFT-Display, (2) VR / AR Head Mounted Display, (3) Speaker/earphone, (4) Gamepad, (5) Keyboard and Mouse, (6) Microphone, (7) Haptic, (8) Camera. In detail the hardware for AR application technology.

Haptic augmented reality allows users to feel the sensation of real objects coupled with synthetic haptic stimuli made by the haptic interface [46,47]. For example, the user feels a soft sponge as if it is harder rubber. This demonstration presents an augmented reality haptic framework in which the rigidity of real objects is modulated with additional virtual haptic feedback. The haptic interface is expanded with a force sensor, and an efficient and effective algorithm for contact detection and stiffness modulation is implemented with closed loop control. This work can serve as the initial building block towards a general haptic augmented reality system.

3.1.4. AR development platform. The method for designing and developing the augmented reality application platform consists of four main stages, namely: (1) designing and creating a new model, (2) training, (3) redesigning, (4) testing. That stage is very important. Some articles from 68 selected documents develop platforms with methods that are almost the same in substance.

3.1.5. AR Markers. Markers or markers on augmented reality from 68 articles use a tracking tool using a camera that allows to add virtual objects in real scenes. Augmented reality (AR) utilizes a virtual environment in which computer-generated images are superimposed on real-time display of the physical environment, conveyed through direct camera feed [48-51]. Augmented Reality through the use of physical markers in the physical environment, which are detected and tracked through live video feeds to imply where digital content will be provided in three-dimensional space; or through alternative tracking systems such as GPS that track digital content estimating physical position in relation to user position and rotation in the physical environment [23]. An example of using a marker is shown in figure 7.
3.1.6. \textit{AR user interactions}. Interaction between AR users and applications can be done through human head display devices such as Android mobile phones, Smartphone tablets or other devices. These interactions use more productive methods to increase learning interactions and increase the level of understanding and acquisition of information by students [5]. In detail the interaction is shown in figure 15, where users can directly interact with the surrounding environment. For example, human anatomy training using puppets is combined with anatomical simulation applications [38].

3.1.7. \textit{Learning outcome}. Learning objectives through the application of AR technology are comprehensive and allow the creation of fully automated manual Augmented Reality from examples of videos and their presentations that are driven by the context in AR. Records of single reference workflows are sufficient for practical systems [52]. With the availability of additional reference records, the system not only increases precision and memory but is also able to estimate the specific nature of certain tasks, such as the level of accuracy needed and the difference in uncertain and intended actions. The approach presented is the first to combine classic AR with machine learning, classification and basic reasoning methods, which lead to cognitive systems, aware of the state of the scene and user actions [53].

Besides the purpose of learning through the application of augmented reality technology serves to measure capabilities in a three-dimensional virtual laboratory for learning or entertainment, and can support future research on assembly construction [54].

3.1.8. \textit{Answers to the second question}: \textit{Virtual AR technology into a virtual 3D laboratory can support TVET learning innovation}. The answer to this question must be found in discussions, conclusions, and subsequent works from the papers analysed in this SLR. The development and implementation of communication and information technology, both in the public space and in the TVET environment [5], is an integral part of the modern world. Before the integration of innovative technology in education, the most common teaching method was direct interaction between teachers and students in the classroom through their presence [55]. The main part of this research is the design and implementation of three-dimensional virtual laboratories using AR for TVET are:

- Vocational education and training.
- AR ToolKit Virtual Laboratory.
- Supporting hardware.

3.1.9. \textit{Vocational education and training}. With increasing interest in developing the education sector, the use of technology in classrooms is increasingly gaining attention throughout the world. In fact, emerging technologies have great potential to improve the learning and teaching process. Augmented reality (AR) and virtual reality (VR) are some technologies that help improve education [56]. Current changes in work culture require workers to acquire many skills through AR technology that offer the potential for conducting experiments through innovative virtual vocational laboratories [57].

In addition, facilities provided by three-dimensional virtual laboratories are designed to develop mobile learning tools (MobiCAD) by applying AR technology to the TVET environment in an integrated
manner [58]. The three-dimensional component model can be dynamically carried out by adding models that are used to use blender into the ARKit library through a unity program to ensure the prototype is reliable and meets the needs of the TVET environment.

Vocational education organized by higher education institutions requires practical facilities that can be easily accessed to gain knowledge and build experience. In this way, AR can be one of the technologies that support vocational education can potentially combine the development of AR games that are applied in education [59,60].

Not only in the educational environment, some industries have investigated that AR is very possible to use a company to support employee training activities such as training in robotic industrial employees [61]. One of the main advantages of AR technology is that it can connect trainees with instructors in real time even though they are in different locations. If the instructor also uses the same AR device, then it is certain to see clearly what the trainee is doing. Of course, this will have the potential to make each training more interactive and interesting [62].

Figure 8. Implementation of training with AR technology in industrial environments [18].

3.1.10. AR ToolKit virtual laboratory. In designing and developing virtual laboratories with Mixed-Reality (MR) using ARToolKit. As a result of this effort, he was able to provide prospects in the development of the MR laboratory. In line with the development of virtual laboratories, we will evaluate the educational benefits and uses of AR in virtual laboratories [49]. Augmented Reality (AR) virtual labs have advanced as a solution to one of the common old problems of dangerous lab conditions, costs etc. However, the marker-based AR virtual lab offers limited freedom for users. Recognizing the impact of a stable and flexible AR virtual lab on the current education system, unmarked virtual AR laboratories will be more relevant [63,64].

With AR technology virtual laboratories can be integrated through industry practices [65], as well as simulation of industrial environments, never. In the future, the lack of facilities, equipment and laboratory space that have become the main obstacles for the university will be overcome. Likewise, maintenance [66] and management of laboratory equipment are also problematic because of the large number of lecturers and students who use this facility.

Rendering of components in the virtual AR laboratory is done through Blender [67]. Unity is used to develop a virtual reality environment [5]. Experiments include the full use of Vive gear, where students are in a truly deep 3D virtual reality environment, which includes the use of controllers to simulate the actual environment [68].

4. Conclusion
The results of this SLR objective are answers to research questions regarding the latest application of AR technology in various fields and the potential for AR development for the development of digital practicum facilities in the form of virtual laboratories designed and developed through AR technology. The 3D virtual laboratory with AR is no longer just a feature because the technology laboratory continues to change to XR (Extended Reality), a combination that uses VR to experience the environment and AR to change its appearance.

In the future, a combination of technologies will emerge virtual XR laboratories as the latest innovation in the vocational education environment to accelerate the development of Augmented Reality
and Virtual Reality. In the short term, the authors believe that the virtual AR laboratory will become a new innovation in the vocational education environment because every student will easily carry out the initial practical activities digitally by having an AR device that can be easily accessed.

In addition, the author looks at the strengths and weaknesses of 68 articles in this SLR. The advantages of being easily accessed and implemented in the technical field can develop virtual AR laboratories for vocational education including mechanical engineering, electrical engineering, civil engineering. The weakness is that there is no cloud architecture to accommodate and access all data in a virtual laboratory framework for vocational education. Therefore, the authors believe that this SLR can provide clear understanding and contribution to the development of virtual laboratories with AR technology.

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