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THE INTEGRATION OF AUGMENTED REALITY AND VIRTUAL LABORATORY BASED ON THE 5E MODEL AND VARK ASSESSMENT: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Engineering education in aviation vocational education builds up skills and attitudes. Students must deal with the laboratory complexity, especially in radar training. Students must understand so much basic knowledge and enhance their skills. The high equipment cost and inflexibility of current learning make radar training less effective and cognitive. Augmented Reality (AR) integrated with laboratory activities is an opportunity to improve learning outcomes for vocational education training in an online learning platform. This study aims to find student learning problems in radar training and propose a framework for integrating virtual radar laboratories with Augmented Reality. This research used a descriptive analysis approach and a literature study. A survey at four Aviation Polytechnics in Indonesia results in cognitive load and troubleshooting skills as the main problem in radar training. The proposed framework concept for laboratory integration with Augmented Reality is added a learning style: the VARK framework and Augmented Reality design with a 5E-based model to make laboratory interaction design. Virtual laboratory integration with Augmented Reality with learning style proposed to enhance laboratory activity to achieve the troubleshooting capability on radar laboratory and make this learning more flexible and personalized.

Keywords: 5E-based model; augmented reality; learning style; radar training; virtual laboratoty

INTRODUCTION

The laboratory is a learning facility for testing knowledge in science and exact sciences in vocational science. Activities in the laboratory provide real learning experiences to acquire scientific skills in various learning practices. Equipment, materials, and measuring tools in the laboratory are equipment to test the truth of science through scientific work and process skills. The skills from learning in the laboratory provide real experience of applying the knowledge learned in the classroom (Raviv et al., 2019; Augustsson, 2021). One of the challenges of vocational education during the industrial revolution 4.0 is the application of Information, Communication, and Technology (ICT) at all levels of education to work (Mendonca et al., 2019; Khalaj & Shirazi, 2020; Lepmets et al., 2021). The laboratory is an important thing in vocational education, student enhance their skill and attitude, but during the COVID-19 pandemic, there is a challenge to prepare for laboratory achievement, not only in the pandemic situation but also in normal condition there are still ineffective training due to the facility and training equipment need a cost (Wolf, 2010; Dayagdag et al., 2019).

According to Kharoufah et al. (2018), 75% of airplane accidents are caused by human factors. Based on the National Transportation Safety Committee report, 60% of airplane accidents in the last ten years were caused by human factors

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(KNKT, 2016). Another factor is human error which has implications for more than 80% of plane crashes (Wiegman, 2003). From these data, one of the factors is cognitive function. According to Bloom's Taxonomy, cognitive function is a process of knowing, affecting, and interpersonal aspects (Wilson, 2016; Muhayimana et al., 2022; Prakash & Litoriya, 2022). In aviation navigation services, the safety and accuracy of aircraft movements are essential factors in air traffic (Shi et al., 2020). Monitoring aircraft movements using Radio Detecting and Ranging (radar) equipment, flight surveillance systems reduce accidents between aircraft, and radar development begins with Primary Surveillance Radar (PSR) to date is Monopulse Secondary Surveillance Radar (MSSR) (Chen et al., 2017). The importance of radar in aviation safety and the limited availability of radar equipment for practicum work in vocational education makes it necessary to study radar to determine its effectiveness in meeting operational needs (International Air Transport Association, 2009). Due to the importance of cognitive function in aviation education, personnel working in the aviation sector, per Aviation Law Number 1 of 2009, must have a certificate of proficiency from the training institute

Immersive technology, Augmented Reality (AR), is applied in various fields, such as health, military, aviation, manufacturing, and automotive. The application of AR for vocational education can reduce difficulties in the pedagogic process. Students enjoy technology. The technology is easy to use and reduces education costs (Dayagdag et al., 2019; Antera, 2021). Immersive technology, such as Virtual Reality, Augmented reality, and Mixed Reality, provide experience and engagement to students so that their learning motivation increases (Bryan et al., 2018; Dempo et al., 2022; Muhayimana et al., 2022). In aviation, augmented reality is for aircraft troubleshooting (Rios et al., 2013). In Air Traffic Management (ATM), AR is to show the movement of aircraft and vehicles around the airport, and Air Traffic Control (ATC) officers easily guide flight traffic (Safi et al., 2019). AR research in aviation education is a solution for updating methods and approaches to industrial development because the entire system requires high costs, and AR is more accessible from anywhere (Montalvo, 2018; Borgen et al., 2021).

However, there are only a few studies of the integration of laboratories activity with Augmented Reality in the aviation field and online platforms, and mostly the study about augmented reality in the spatial gap (Thees et al., 2020), visualization, and cognitive load (Singh et al., 2019; Altmeyer et al., 2020; Dempo et al., 2022)

The integration of the radar laboratory with AR has not yet been created in a framework for Augmented Reality-based virtual laboratories. The AR design has not led to a laboratory activity model framework with a laboratory theory approach (Demircioğlu & Çağatay, 2014; Augustsson, 2021). This study aims to find student learning problems in radar training and propose a framework for integrating radar laboratories with augmented reality.

Based on interviews with instructors at the Indonesian Aviation Polytechnic Curug, practicum activities are less effective because there is only one radar equipment set. Students are divided into several groups, and the teacher will explain repeatedly. Besides being less effective, the drawback of this practicum is that students find it difficult to measure, analyze, and troubleshoot.

Integrating AR with documented laboratory activities is an opportunity to address the shortcomings of students' effectiveness, cognitive load, and troubleshooting abilities on radar equipment. Moreover, AR in online learning requires learning designs that can foster students' attitudes. Another factor in learning is the learner style, how the learner understands the material based on the learning style. According to Idrizi et al. (2018), assessments from Visual Auditory, Read/Write, Kinesthetic (VARK), or Visual Auditory Kinesthetic (VAK) are to improve learning achievement (Dutsinma & Temdee, 2020)

It has not paid attention to the learning style (Idrizi et al., 2018; Daoruang et al., 2019) of students who use the theory of self-efficacy (Bandura et al., 1999), which increases students' ability and self-awareness (Koorsse et al., 2010) on the level of ability and in a virtual laboratory framework with an evaluation model (Gangabissoon et al., 2020) which will provide feedback (Borgen et al., 2021). The feedback follows the purpose of education in vocational education, which provides abilities and skills (Antera, 2021).

METHODS

Based on its background and aim, this study will respond to the research question and identify the radar training and conceptual framework for integrating augmented reality as a virtual laboratory using a specific model. Descriptive analysis is employed to answer the first research question, and the online survey is given to four aviation polytechnics in Indonesia. Reviewing the literature and making a prototype of radar training with augmented reality are conducted to answer the second question (de Paiva Guimarães et al., 2017). Data were collected using survey methods and questionnaires about the dominant influence factor on radar training related to the cognitive parameter issues of students from four aviation polytechnics in Indonesia: Indonesian Aviation Polytechnic Curug, Aviation Polytechnic of Surabaya, Aviation Polytechnic of Medan, and Aviation Polytechnic of Makassar. Respondents are students who take a radar course. Figure 1 is the method used to formulate the framework.

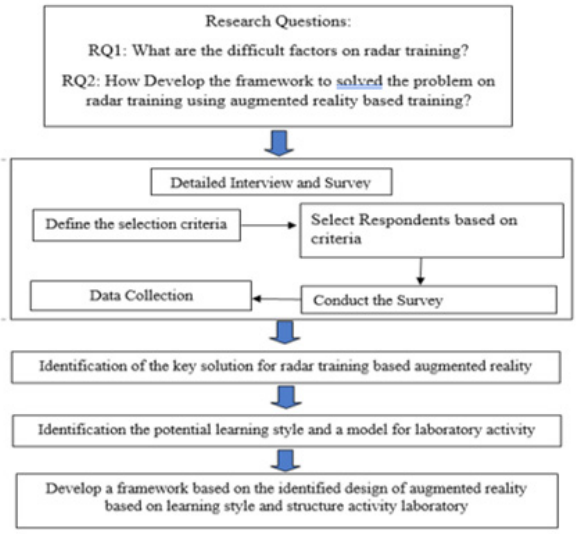

Figure 1. Research Framework

From Figure 1, interview and survey data were obtained using a questionnaire (Fowler, 2014; Creswell & Plano Clark, 2018; Khan & Salah, 2020). With descriptive research to describe the phenomenon of the data, the survey uses Google Form with eight questions. The next stage to answer RQ 2 is to conduct a literature study with the keyword ("Virtual Laboratory*" OR "Online Laboratory*,") and ("Augmented Reality" OR "Immersive Technology"), "Virtual Laboratory," and "Problem-solving Skills." From the Scopus database from 2018 to 2022, from these keywords, abstracts are screened 137 articles into 46 articles proper research. Then we use bibliometric analysis with the Vos Viewer application to get the recent trends on virtual laboratories and factors in virtual laboratories. From the information system domain, we synthesize nine factors as presented in Figure 2.

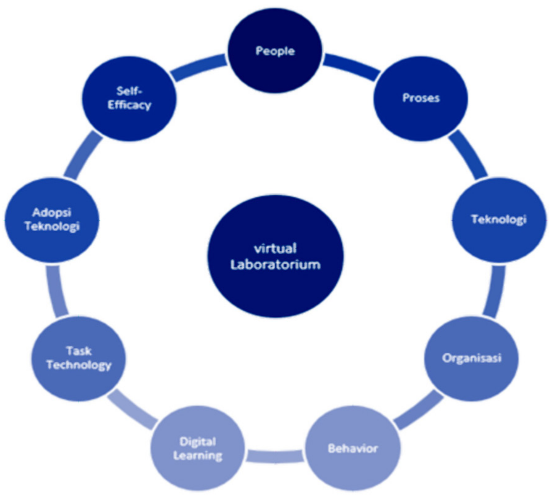

Figure 2. Recent Topic on Virtual Laboratory

By bibliometric analysis, we found that behavior is one of the factors that influence virtual laboratory and problem-solving skills. Learning style positively affects students' behavioral intention to use immersive technology (Fatahi et al., 2015). The survey data were obtained from 168 respondents who study at air navigation engineering study from four aviation polytechnics. The data is interpreted to create a conceptual framework for integrating the radar laboratory. With practical experience at the airport, respondents know the shortcomings of their abilities when learning radar. The radar instructors are from four aviation polytechnics in Indonesia: Indonesian Aviation Polytechnic Curug, Aviation Polytechnic of Surabaya, Aviation Polytechnic of Medan, and Aviation Polytechnic of Makassar, as mentioned in Table 1.

Table 1. Respondent Data (N=168)

Aviation Polytechnic	Number of Respondents	Percentage
Indonesia Curug	85	50,6%
Medan	33	19,6%
Surabaya	32	19%
Makassar	18	10,7%

The data were made in a descriptive analysis to answer research questions, what the factors in radar learning then related to Bloom's Taxonomy stage, look for factors causing the lack of achievement of cognitive factors, and how augmented reality design can overcome problems in radar learning, facilities, and infrastructure for learning. After identifying the difficult factors of radar training, it was proposed to develop a framework for integrating radar laboratories with augmented reality.

RESULTS AND DISCUSSION

This section provides the answer to research questions. To identify the difficult factor in radar training, online survey data was collected from students from four aviation polytechnics in Indonesia through a questionnaire to find out the factors that influence the success of radar learning from the cognitive aspect (Chen et al., 2017)

Table 2. Survey and Respondents' Answer

Question	Content of Response	Percentage
The difficult part of radar learning	Theory	85%
	Practice	25,5%
Materials needed when starting radar learning	Block diagram simulation	81,5%
	Understanding equipment blocks	69,6%
	Visualization with pictures	59,5%
	Interactive material	35,1%
	Memorizing part of the radar	24,4%
Required skills	Troubleshooting	76,8%
	Radar beam analysis	55,4%
	Operating radar	51,8%
	Maintenance	43,5%
The hardest part of learning radar	Fault finding	68,3%
	Measurement and interconnection, pulse shape	65,9%
	Repairing module	47,9%
	Data processing	37,1%
Study time	Ineffective	76%
	Effective	23%
The difficulty level of learning radar	Difficult	80,6%
	Easy	10 %

Based on Table 2, the difficulties experienced by students in learning activities are understanding the material in theory, simulating block diagrams, troubleshooting, fault-finding analysis, and ineffective learning time. Meanwhile, the achievement of radar practicum laboratory skills is based on training manuals and radar maintenance guidelines: use of measuring tools, skills to operate radar equipment; skills in analyzing and interconnecting equipment and transmission lines to the antenna, troubleshooting skills, the skills to analyze problems, and the skills to make reports and conclude from practicum results. So there is a difference between learning achievement and student ability. The following is a description of the respondents' results.

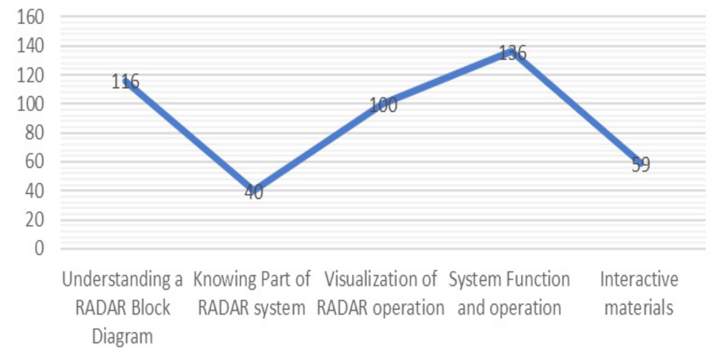

Figure 3. Radar Training Requirement Chart

Figure 3 shows the students' requirements in radar learning. There were 136 students (81%) who required an understanding of the system function and operation, 116 students (71.6%) required an understanding of the Radar block diagram, and 100 students (59.5%) required visualization of the radar operation. Based on the achievements of the Radar practicum, which consists of 6 criteria, the shortcomings of this understanding are according to Bloom's theory. This requirement refers to the revised Bloom's taxonomy. The description of radar learning is in Table 3 (Lajis et al., 2018).

Table 3. Bloom Cognitive Competency

Level	Description
Knowledge (C1)	There is no real understanding The concept of radar is known
Comprehension (C2)	Understand how the radar concepts work
Application (C3)	Apply the knowledge in the new scenario by example Guided by the lecturer
Analysis (C4)	Analyze a radar problem Solve a radar problem on their own
Synthesis (C5)	Generalize what he learned for a new problem Make a conclusion
Evaluation (C6)	Compare various solution Make a conclusion based on various solution

Table 2 and Figure 2 show that the highest requirements are found in system functions and operations. It shows the importance of this need. Based on Figure 2, students' skills are in C2, implying that students need to know how the concept of radar works. However, in radar learning based on PM 87 of 2021, maintenance levels at levels 3 and 4 require students' skills to make generalizations from the problems and find solutions (Ministry of Transportation, 2021). These skills are found at level C5 (understand problems) and level C6 (make improvements/solutions to problems). The data also has implications for the gap in students' abilities. Two levels are required to reach the repairability standard at levels 3 and 4.

Next, the third question aims to discover the skill gap in the radar practicum. From Table 2, we get a description of the answers from the respondents, as shown in Figure 3.

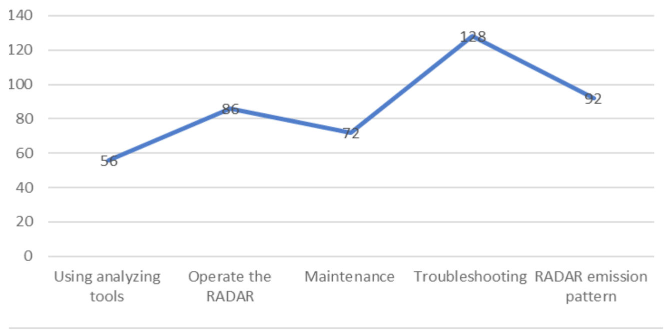

Figure 4. Gap Skill on Radar Practicum

Figure 4 shows students having difficulty in troubleshooting during the radar practicum. However, in education, this term can be equated with problem-solving skills or skills that involve several skills or the strategic use of scientific schemes and knowledge to take the necessary actions to find solutions (Torres, 2003). Based on radar learning guidelines and an assessment to get a rating or certificate of proficiency for radar equipment. Technicians need this ability to maintain radar equipment to operate properly. Furthermore, the following data were obtained from the respondents in the fourth question to determine the problem-solving skill or troubleshooting gap.

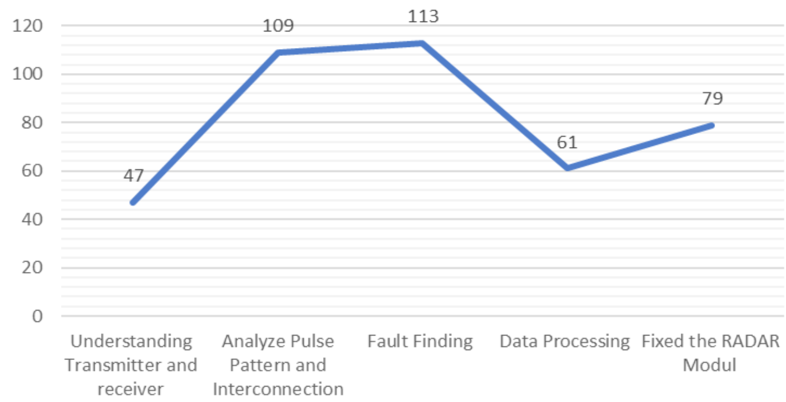

Figure 5. Problem-solving Skill Gap

From Figure 5, 113 students (67.2%) expressed their inability to find fault or cause of damage; in technical terms, it is called fault finding. Then, 109 students (64.8%) could not analyze the radar's pulse shape, interconnection, and using a measuring instrument. Seventy-nine students (47%) were unable to repair the radar module, and 61 students (36.3%) were unable to practice data processing. The fault-finding skill gap in the radar practicum is the highest answer and refers to Table 3 at Bloom's Taxonomy level. The gap to finding this error is at level C5, or the ability to pinpoint problems and make efforts to repair the damage.

Based on the syllabus from the radar practicum, the requirement for this study is 316 hours consisting of 112 hours of theory and 204 hours of practice. The material in the practicum is equipment engineering (48 hours), radar maintenance (40 hours), and troubleshooting (32 hours). The availability of practicum tools is limited. Even the other three polytechnics do not have practicum equipment. So, efforts are needed to fulfill the practicum of radar. With the details of the syllabus, cognitive abilities are needed to know radar and maintenance techniques so that students can analyze damage properly. To answer RQ 2 by conducting a literature review from the Scopus database and developing the framework to solve radar training problems using augmented reality-based training. The online learning platform facilitates interaction between students and teachers and enhances problem-solving skills. The platforms use Learning Management System (LMS). A learning management system facilitates access and management of radar learning and is more accessible for students. This proposal consists of the following: (1) Learning Management System ; (2) Learning Style in VARK assessment method; (3)Structured Augmented Reality with 5E based model ; (4) Positive Engagement Evaluation Method; (5) Troubleshooting Scenario; (6) Post Test; (7) Reporting.

Augmented reality is embedded with Learning Management System (LMS), where AR is a Shareable Content Object Reference Model (SCORM) and implemented in Moodle (de Paiva Guimarães et al., 2017). With LMS, learning and practicum activities can be monitored. The influence of learning style in online learning is considered in this framework, so VARK assessment to placement what kind a type of the learner (Visual, Auditory, Read/Write, Kinesthetic), this type related to the design of Augmented Reality visualization, the visual type, the learner is interested in visual material. Using images and colorful content shall stimulate the learners. In the auditory style, the learners like to discuss and exchange ideas. The suitable learning style is lecture and group discussion. Read/Write learners like to read and learn from documents, books, and contents by themselves and summarize what they have read. The Kinesthetic, the learner like applying the theory into practice (Khongpit et al., 2018)

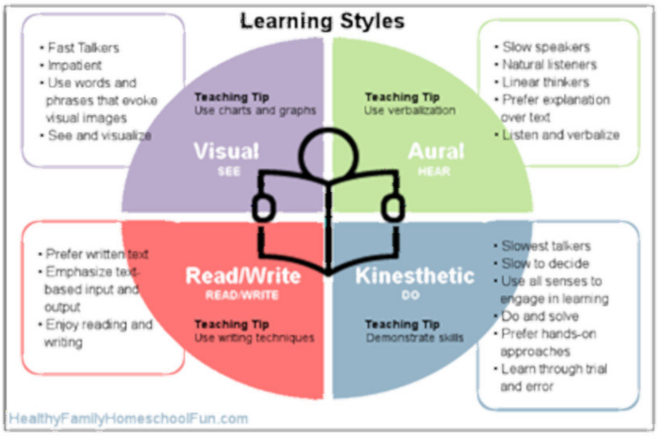

Figure 6. VARK Learning Style

As a Figure 6, the VARK learning style determines students' success in learning virtually, while a Visual Audio and Kinesthetic (VAK/VARK) learning style was carried out. This assessment is to determine students' learning styles (Teli et al., 2021) with online or blended learning. In the blended learning model, learning style is one of the successes in preparing learning designs (Daoruang et al., 2019). AR applied to the learning process in science class shows that its application can improve students' learning outcomes and better self-control skills. (Karagozlu, 2018). The integration of AR with laboratory activities forms a virtual learning environment, a virtual laboratory that uses computer-based software simulation. Figure 7 presents the concepts of augmented and virtual reality between hands-on, remote, and virtual laboratories (Onime & Abiona, 2016).

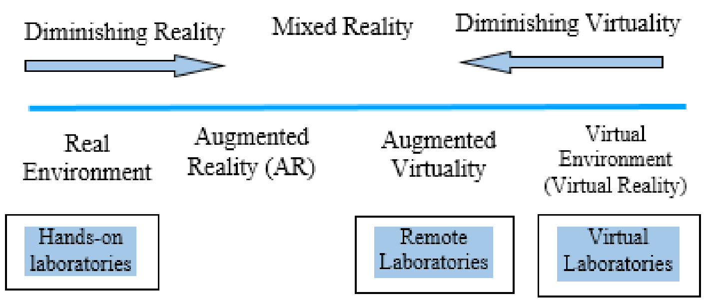

Figure 7. Engineering laboratories in Reality – Virtuality Context

Augmented Reality integration with a virtual radar laboratory is an effort to reduce problem-solving skill gaps and cognitive load and make learning more adaptive (Pantho & Tiantong, 2015). The information in the dashboard convinces students to know their success in learning and practice (Koorsse et al., 2010) and to establish a virtual learning environment and the integration of AR with laboratories that are cost-effective for education providers (Ahmed et al., 2017; Douglas et al., 2017).

Practicum design with augmented reality requires a framework for laboratory activities in learning storyboards. The framework for this laboratory activity used a 5E-based model, with design steps in Table 4.

Table 4. 5E-based Model on Radar Practicum

Dimension	Activity
Enter/Engage	Giving brainstorming to build a radar concept
Explore	Experimenting: Module input/output analysis, interaction with AR application to show a radar block diagram calculate, measure, and identify the code from the radar, interact to install the measuring instrument on the radar connector interact with AR to translate Asterix format perform interconnection for transmission line identification, analysis of signals interrogation, and reply carry out the configuration for the radar strategy of the SLG displayed in the AR app perform troubleshooting by interacting with the application for a malfunction of a module
Explain	Results discussion
Elaborate	Students are given an example of an operation error case. Example: The target on the radar does not appear on the ATC monitor screen, so students find the source of the problem by interacting with the AR application.
Evaluation	Troubleshooting, how radar emits, effects for flight operations, and displays for ATC to use to guide aircraft

Immersive technology for education can be used for laboratory activities. In Akcayir's research, Augmented Reality for laboratory science improves laboratory skills. Students are more interested because the material is in the form of images, videos, and text, which is different from the traditional practice of using modules. In addition, using AR in laboratory experiments requires less time than in traditional laboratories. Changing the model from traditional to AR can change students' behavior in laboratory activities (Akçayir et al., 2016). Changes in behavior in practicum learning are relevant to the context of competency learning presented by ICAO. Competence combines knowledge, skills, and attitude to complete tasks according to predetermined standards (Borgen et al., 2021). The test in this study carried out MSSR radar learning with a high cognitive load but less attention to the learning style and less adaptive learning (Sasakura & Yamasaki, 2007). So that the difficulty factor in student understanding is because the learning content does not interest students, and that learning style affects students' learning achievement (Idrizi et al., 2018). Learning with the e-learning learning style model based on the Visual Audio Reading Kinesthetic (VAK / VARK) framework is suitable for use so that the selection of learning content is more appropriate (Daoruang et al., 2019; Dutsinma & Temdee, 2020).

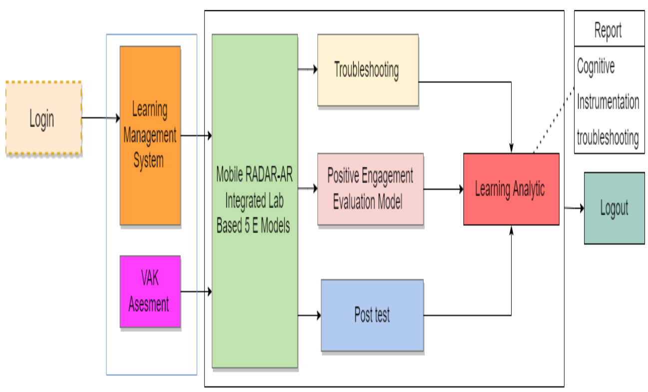

Figure 8. Conceptual Framework Integrated AR Radar Virtual Laboratory (IAVRL)

Figure 8 is the proposed framework for Integrated Radar laboratory-Augmented Reality. This framework consists of several stages: (1) Student login and VARK assessment, (2) access to the radar courseware in LMS with selected learning style, (3) Evaluation consisting of Troubleshooting ability scenario, Positive Engagement Evaluation Model and Post Test, (4) Reporting. This course is available in LMS. Learners access LMS and use Android smartphones to scan the marker of Augmented reality. By VARK assessment, this AR design is more personalized and follows learners' style.

AR design for radar laboratory activities using a 5E-based model framework. Laboratory activities based on the 5E model effectively provide an understanding and reduce laboratory conceptual errors compared to traditional laboratories. The 5E model's activities include: Enter/ Engage, Explore, Explain, Elaborate, and Evaluate. All stages in the model show that laboratory activities are more effective than traditional laboratories (Demircioğlu & Çağatay, 2014).

The proposed Conceptual framework for Integrated AR Radar Virtual Lab (IARVL) is a combination of learning styles (Lwande et al., 2019; Teli et al., 2021). Mobile AR (MAR) based AR interaction is installed on LMS (Elfeky et al., 2020). With this combination, the learning process and practicum can be appropriately recorded. Evaluation of student engagement in the practicum results with a positive engagement evaluation model design (Gangabissoon et al., 2020) and provided feedback for students through learning analytics with input data from the LMS. Using data mining methods, the analytical learning process will be displayed on the student dashboard (Aljohani et al., 2019). Learning analytics using deep learning algorithms provides 96% accuracy in performance evaluation. This analytical learning model uses a Logistic Regression support vector machine that can be used for the decision-making process to see students' learning achievements (Waheed et al., 2020).

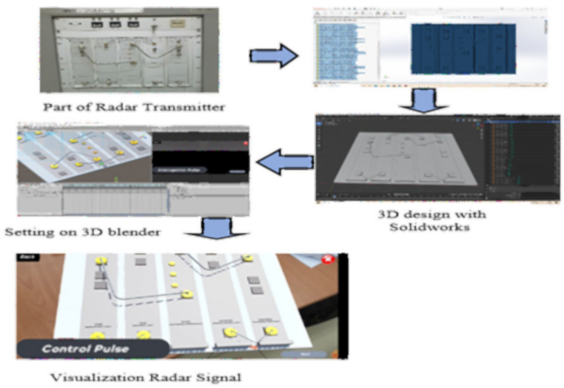

Figure 9. AR Radar Design Stages

Prototyping radar on AR, as shown in Figure 9, develop Augmented Reality design using markers and cellphones or gadgets. The manufacturing process begins with drawing a 3D radar model object and, in this study, using the Solidworks application (Cekus et al., 2019). Furthermore, the 3D image is combined with the 3D Blender application to create a virtual object whose format follows the application on the game engine. This design used Unity 3D (Hernández-Chávez et al., 2021), a game engine, to create applications for this AR application based on android mobile (Södervik et al., 2021). Next is the marker on Vuforia. The Vuforia SDK software has many facilities and libraries that can be used to build mobile AR (Cieza & Lujan, 2018). Radar practicum with AR provides visualization of relatively difficult radar operations by looking at the signal's shape, measuring, and discussing the results will provide a student learning experience (Akçayir et al., 2016). The respondents' answers show that fault-finding analysis is the highest factor in students' difficulties during practicum. This is relevant to the cognitive ability of students by 85%. Difficulty in understanding theory is related to analysis skills or troubleshooting and problem-solving skills.

AR for laboratory activities provides visualization in understanding the structure of objects, can be used to set up cognitive levels, and creates flexibility in learning. Chang and Yu (2018) mention the characteristics of AR design: devices, types of AR applied, interaction modes, and learning activities. In addition to the AR design, the integration of activities for more effective learning in this integration system is the platform used. Learning Management System (LMS) is used to run online/virtual laboratories for monitoring student activities based on storyboards from learning (Demircioğlu & Çağatay, 2014).

Integrating AR with laboratory activities to build a virtual laboratory will reduce the cost of providing vocational education (Radosavljevic et al., 2020). Science requires teaching aids, measuring tools, materials, and practicum needs (Chang & Yu, 2018). The Learning Management System put the radar training course in Indonesian curricula named *Alat Pengamatan Lalu Lintas Udara Lanjutan*. This module consists of a pretest, while the e-module includes AR mobile marker, evaluation, and post-test, as shown in Figure 10.

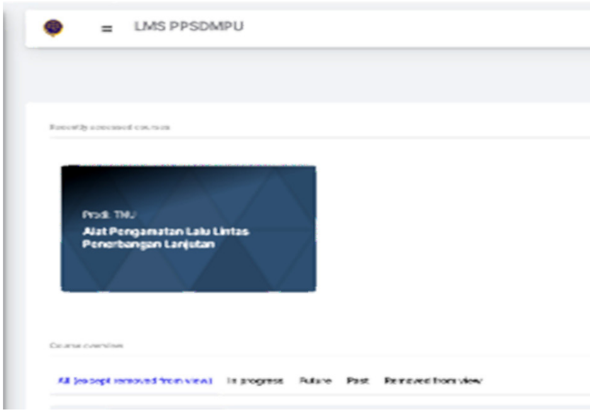

Figure 10. Learning Management System

Activities in the laboratory provide a real learning experience for students because it provides a learning experience to acquire science skills. Problem-solving skills were acquired through radar practicum, which is integrated with augmented reality in an online platform. It can be accessed from anywhere and anytime. The students learning experience can be monitored for their achievements by looking at the dashboard of study results when they finish carrying out virtual practicums. The evaluation uses Positive Engagement Evaluation Model (PEEM), the framework to evaluate the use of new technology to engage the user. The attributes include goals, attention, content, concentration, identity, interaction, collaboration, and satisfaction (Rutledge & Neal, 2012). This evaluation is created in LMS. Students fill out the evaluation, and by the learning, analytics will calculate three inputs from the troubleshooting scenario, PEEM, and post-test. Learning analytics in a virtual learning environment is used to predict student performance, and the deep artificial neural network shows better accuracy than support vector machine and logistic regression (Waheed et al., 2020)

CONCLUSION

Augmented reality-integrated virtual laboratory for radar learning provides opportunities for increasing learning outcomes. More interesting learning can reduce cognitive load. Integrating the laboratory with the LMS to make radar learning activities in a Virtual Learning Environment (VLE) provides easy access for students to learn radar, both theory and practice. Independent learning increases self-regulated learning ability. In learning, it is formed by being reported in the form of a dashboard to find out students' success. The cognitive factor is the dominant factor in the success of radar learning. Learning style assessment makes a virtual laboratory more personalized, flexible to access the material, and exercise makes it students easy to learn and achieve their cognitive ability. For future research, learning analytics is recommended to increase self-regulated learning ability.

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