

The Development of Mobile AR-Based Module for Teaching and Learning Pneumatic System: A Needs Analysis

Siet Fah Lim* and Yusri Kamin

Department of Technical and Engineering Education, School of Education, Faculty of Social Science and Humanities, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia

ABSTRACT

Practical skills and theoretical knowledge are vital competencies that technical and vocational trainees need to master before joining the industrial workforce to perform tasks efficiently. Therefore, comprehensive instructional materials and training equipment are essential to ensure that the skills and knowledge are delivered effectively to trainees. This study aimed to identify the need to develop a mobile augmented reality module to teach and learn pneumatic systems in Malaysian vocational colleges. Descriptive research was conducted to determine the module's need, involving 13 subject-matter experts from various vocational colleges. A set of questionnaires consisting of three main themes: the need for the module, the module's user interface design, and the module's usability criteria with 49 items was used. The data collected were analysed using the Fuzzy Delphi Method. All three constructs showed high levels of expert consensus of more than 75% and a threshold value of ≤ 0.2 . Therefore, experts agreed that there was a need to develop a mobile AR-based module for teaching and to learn pneumatic systems with the stated user interface designs and usability criteria.

Keywords: Augmented Reality, Fuzzy Delphi Method, module development, needs analysis, teaching and learning pneumatic systems

ARTICLE INFO

Article history:

Received: 09 August 2021

Accepted: 04 October 2022

Published: 17 February 2023

DOI: <https://doi.org/10.47836/pjssh.31.1.03>

E-mail addresses:

sflim2@graduate.utm.my (Siet Fah-Lim)

p-yusri@utm.my (Yusri Kamin)

* Corresponding author

INTRODUCTION

With the advent of the Fourth Industrial Revolution, the technology in the industries has evolved correspondingly. In line with the evolution, changes should also be implemented to ensure that the knowledge and skills acquired by technical and vocational education students are compatible

with current industrial trends. For example, manually controlled machinery was replaced by more advanced machinery controlled by high-end and complicated technologies such as programmable logic controllers, electro-hydraulic systems, and electro-pneumatic systems. Thus, proper instructional material and delivery methods are essential to training skilful technical workers who are competent in carrying out their tasks in an industrial automation-based workplace upon graduation.

In Malaysia, the Ministry of Education emphasises the acquisition of practical skills and theoretical knowledge among vocational students, as these are essential components in developing a skilled workforce. Consequently, Malaysian vocational colleges allocate 70% of the students' learning time to vocational subject matters on practical skills acquisition while the remaining 30% to theoretical knowledge learning. For instance, the pneumatic system course requires students to understand their intangible concepts and be competent in applying what they have learned to their practice (Kurniawan et al., 2017).

Pneumatic systems are power transmission systems that use compressed air as the working medium (Rabie, 2009). Because of their lightweight and cost-effective properties, pneumatic systems have been widely used in various industries (Aravind et al., 2017). However, the pneumatic system is a complex and abstract subject requiring students' higher cognitive capacity, particularly their metacognitive skills, to master its learning content. Furthermore, due to its multifunctional

components and intricate working principles, the pneumatic system has been regarded as one of the most challenging mechanical-based subjects (Kurniawan et al., 2017).

Kurniawan et al. (2017) pointed out that the current method of teaching pneumatic systems, which relies on books, PowerPoint slides, and videos, is one of the factors leading to less effective learning. Given this situation, students tend to lose interest while struggling to understand perplexing learning concepts (Khramova et al., 2019). Using conventional theory teaching, displaying the complicated circuit's working state and the pneumatic components' hidden internal structure is pretty tricky. Students only managed to see the system's external parts during practical activities, which can hardly help them understand the actual working condition (Kurniawan et al., 2017; Xu et al., 2017). The instruction content must be delivered effectively to ensure the students understand the components' basic principles and complex circuit operations (Jabar et al., 2020). Towards this end, Kurniawan et al. (2017) recommended well-designed instructional resources to improve student's learning outcomes in the pneumatic system.

Furthermore, as a vocational subject, pneumatic systems instruction involves plenty of practical skills training and assessments achievable only with adequate, functional, proper, and up-to-date training equipment (Arief et al., 2018; Audu et al., 2013). Similarly, Andoko and Wirawan (2017) believe that adequate facilities are an essential requirement that colleges must fulfil to enhance graduate quality. Without proper equipment, much of the

content is delivered theoretically, and as researchers argue, practical skills content is far too complicated and challenging to be taught verbally (Md Nasir et al., 2020). Consequently, students may feel unmotivated to learn, leading to declining quality and competent graduates (Anindo et al., 2016; Ohwojero & Ede, 2013).

One way to promote a greater student understanding of pneumatic systems and complement the training equipment is by using multimedia. Multimedia learning is a popular teaching aid in delivering learning content that is interactive and animated to trigger students' interest, capture their attention, and boost their motivation (Ab Aziz et al., 2012; Asfani et al., 2016; Endres et al., 2020). Furthermore, multimedia resources support learners through their learning difficulties by helping them better comprehend through visualisation. Nonetheless, the suitability of teaching media depends on its characteristics; some of the more popular multimedia for educational purposes include web-based learning, Virtual Reality (VR), and Augmented Reality (AR).

Over the past few years, many studies have been conducted to investigate the effectiveness of AR technology applications in the educational field, especially in helping students with learning difficulties. The following studies are examples of AR applications as teaching aids for various purposes. First, there were studies conducted to see the suitability and sustainability of AR applications as an instructional tool to improve student's learning outcomes (e.g., Y. C. Chen, 2019; Hung et al., 2017;

Shieu et al., 2019) and it is potential to assist laboratory activities or practical skills (e.g., Bazarov et al., 2017; Herlandy et al., 2019). In addition, there were also studies to see if AR applications are effective in reducing the cognitive load (e.g., Buchner & Zumbach, 2018; Sambodo et al., 2018), increasing students' positive feelings and other affective domains in learning the subject matters (e.g., Baloch et al., 2018; Hanafi et al., 2017; Sambodo et al., 2018). All these studies displayed positive effects of AR technology on students' performance.

About the teaching and learning of pneumatic systems issues in Malaysian vocational colleges and the positive impacts of AR applications on students' learning, this study was conducted to establish the demand and urgency for formulating a mobile AR-based module for teaching and learning pneumatic systems. To be specific, the objectives of this study are:

1. To identify the need to develop a mobile Augmented Reality module for teaching and learning pneumatic systems in Malaysian vocational colleges.
2. To identify the user interface designs to be included in the mobile Augmented Reality module for teaching and learning the pneumatic systems in Malaysian vocational colleges.
3. To identify the usability criteria to be included in the mobile Augmented Reality module for teaching and learning the pneumatic systems in Malaysian vocational colleges.

Based on the research mentioned above objectives, we report the results of the needs analysis study based on the following research questions:

1. Is it necessary to develop a mobile Augmented Reality module for teaching and learning pneumatic systems in Malaysian vocational colleges?
2. What user interface design elements should be included in the mobile Augmented Reality module for teaching and learning pneumatic systems in Malaysian vocational colleges?
3. What are the usability criteria for the mobile Augmented Reality module for teaching and learning pneumatic systems in Malaysian vocational colleges?

LITERATURE REVIEW

An Introduction to Augmented Reality Technology

AR technology allows real-time interaction between real-world surroundings and virtual objects that coexist in the same space (Azuma, 1997; Klopfer & Sheldon, 2010; Peddie, 2017). The application of AR was first introduced in the military, science, and manufacturing fields before being extended to other areas over time, including education. Today, AR technology is available closer-to-home, to most smartphone users, offering fun interaction and convenience across various AR-based applications. In addition, AR's applicability spread to other industries over time, particularly in education.

Various technologies can be used as instructional tools and have significant potential to contribute to today's ever-changing learning environment. In particular, the multi-faceted benefits of AR have outshined several existing technologies. The primary purpose of Augmented Reality is to improve and enhance one's perspective of their environment by combining sensing, computer, and display technologies (Olwal, 2009). Having the capacity to develop a successful and usable AR application will undoubtedly provide users with numerous benefits. The possibilities of AR technology application in education will be discussed further in the following subtopic.

The Benefits of Using Augmented Reality Technology in Education

In the education realm, AR enables virtual object overlay on the real environment for more effective learning and teaching than most traditional methods (Ali et al., 2013; Bazarov et al., 2017). Moreover, students learning through the AR application can select skills or concepts they are yet to master and replay them until learning is complete (Wong et al., 2020). Besides, they also get to visualise intangible concepts for ease of learning (Akçayır & Akçayır, 2017; Wu et al., 2013) while being prompted to use metacognitive strategies such as planning, monitoring, and evaluating for active learning.

AR applications have been shown to help students better understand the content, particularly abstract concepts or hidden objects, by superimposing 360-degree

graphics in the natural environment (Arief et al., 2018; Martín-Gutiérrez et al., 2015; Yip et al., 2019). Students generally find it difficult to perceive abstract concepts, leading to misunderstandings that obstruct learning (Saidin et al., 2015). Furthermore, the virtual medium can replace expensive resources, such as equipment and supplies, to minimise practical work costs.

Because of its capacity to simplify learning content, AR technology has also been easier to understand and use (Y. C. Chen, 2019; C. H. Chen et al., 2017). In other words, it is well-accepted and satisfied by learners due to its ease of usage. In addition, learners gain better confidence if they can digest and comprehend the learning materials with less effort (Chin et al., 2019).

Furthermore, a study shows that AR-based teaching materials can help to improve the learning achievements of high achievers, but they also help to close the gap in students' overall learning abilities (Zhang et al., 2015). In their study, students' learning achievements improved in both high and low-performance groups, with low-performance students' results roughly similar to those in high-performance groups. Y. C. Chen (2019) reported similar findings: low-anxiety and high-anxiety learners performed equally well when introduced to an AR learning environment.

The Multimedia Learning Design and Usability

The ability of instructional media to grab the learners' attention and deliver the

learning content precisely is critical to its efficacy. According to Mayer (2009), integrating multimedia into instructions entails presenting the resources to learners and guiding their cognitive processing of the materials. Towards that end, adequate planning is critical in designing and developing effective instructional media to promote efficient cognitive processing among students. Therefore, several factors must be considered when selecting the optimal visual and auditory design attributes.

Heinich et al. (2002) proposed basic visual and verbal design concepts. They suggested four basic visual design concepts that are acceptable and realistic to follow, including ensuring legibility, minimising the effort required to decipher messages, encouraging active audience involvement with the message, and focusing attention on its key points. Students utilising such instructional materials should be able to see both texts and visuals on display in this regard.

The effort required by the students to interpret and comprehend the messages being delivered to them should likewise be minimal. These may include how the underlying pattern is established in terms of alignment, shape, and balance, consistency of the treatment pattern, and the use of appropriate colour combinations. The selection of an appealing colour scheme is critical for increasing students' active participation (Heinich et al., 2002).

Verbal or text design is just as important as that visual design. In developing an instructional display, the lettering must be

carefully chosen to properly transmit the message (Heinich et al., 2002). The size, spacing, and style of the wordings are also factors to consider. Aside from that, items and materials displayed in the media should be shown in three dimensions to convey the viewers' understanding of the subjects. The 3D digital model stores the geometry, texture, animation, and scene required in engineering and teaching subjects (Solmaz et al., 2021). These 3D interfaces can help people learn more effectively by allowing them to quickly and intuitively access larger volumes of information.

Heinich et al. (2002) also mentioned the importance of audio in instructional multimedia design, noting that it is increasingly used in today's self-paced learning. In designing audio, a designer should use a natural and conversational voice, as humans respond positively to a similar voice. In addition, various vocals should be used to maintain the learners' interest in what is being said.

A media's usability is influenced by its user interface design. Usability is defined as the usefulness and satisfaction of a system to help people achieve their goals by performing task sequences (Zhang & Walji, 2011). Ko et al. (2013) developed usability principles for smartphone AR applications based on the following aspects: user information, user cognition, user support, user interaction, and user usage. Among the most significant elements included in the five usability aspects are availability, learnability, responsiveness, and low physical effort.

Similarly, Sambodo et al. (2019) assessed an Android-based augmented reality application covering four aspects using a comprehensive questionnaire. They are (1) Device quality, which includes functionality, interactivity, ease of use, and interface design; (2) Service quality, which includes accessibility, personalisation, and responsiveness; (3) Knowledge quality, which includes content use and adequacy; and (4) aspects evaluated in the augmented reality system.

Ismail et al. (2019) conducted another study to assess the usability of the generated teaching kit. A group of experts, including subject matter experts, and the teaching representation kit, were involved in this study. They find that the positive usability score derived from expert validation includes a teaching kit that is easy to handle, beneficial subject content, and useful AR application content. Therefore, AR's correct user interface design and usability should be thoroughly defined to create and develop useful AR-based educational media to boost students' learning.

METHODS

The needs analysis was conducted quantitatively involving 13 subject-matter experts in the pneumatic systems discipline, who were carefully identified and selected to provide expert ideas and opinions in improving the content of the mobile AR-based module. The sample selection was based on characteristics such as being experienced in teaching and learning pneumatic systems and being

directly involved in Electronic Technology Programme curriculum development in Malaysian vocational colleges. All the samples selected are subject matter experts with more than ten years of involvement in the related field. Ideally, ten to 15 experts are required for the Delphi Method (Adler & Ziglio, 1996). However, researchers believe that only a few experts are sufficient for such an analysis (Noh et al., 2019). Ridhuan and Nurulrabihah (2020) argued that having too many experts may obstruct the selection of accurate data and cause the researcher to struggle to moderate the group effectively. Therefore, a panel of 13 experts was deemed adequate and appropriate for conducting the needs analysis following the Delphi Method. An online meeting via the Google Meeting platform with the 13 experts was conducted. The researcher explained the needs analysis study and the questionnaire to the experts during the meeting in detail. The questionnaires were sent to the experts by e-mail. They

were given ample time to answer the questionnaires before returning them to the researcher at the end of the meeting.

Instrument

The seven-point Likert-type scale questionnaires were distributed to the experts to measure their levels of agreement. The experts stated their levels of agreement on every item based on the seven following anchors: “Extremely Disagree,” “Strongly Disagree,” “Disagree,” “Somewhat Agree,” “Agree,” “Strongly Agree,” and “Extremely Agree.” They were built based on the themes identified; the 49-item questionnaire incorporated three general themes: the needs for mobile AR modules, mobile AR module user interface design, and mobile AR module usability criteria. Table 1 shows the themes and the item distribution of the questionnaire.

Two sets of validation forms, content and language validation forms, were produced for instrument validation. Two content and

Table 1
Themes and items distribution of needs analysis questionnaire

Theme	Number of Items	Item
The Need for Mobile AR Module	7	The importance of practical skills in vocational courses; the importance of adequate training equipment for optimum practical skills mastery; the pneumatic system teaching and learning problem; the smartphone usage in teaching and learning; and the mobile AR module usage to aid teaching and learning
Mobile AR Module User Interface Design	19	Visual design, text design, object and material display, and audio design
Mobile AR Module Usability Criteria	23	Ease to use, accessibility, responsiveness, use of the content, user’s cognitive and low physical effort
Total	49	

language experts validated the instrument. At the end of each structured question, an open-ended section is provided for the experts to write additional suggestions. In addition, a pilot test was done involving ten lecturers who were not part of the study's sample. From the data collected from the pilot test, Cronbach's Alpha coefficient was calculated to determine the reliability of the questionnaire.

Data Analysis Using the Fuzzy Delphi Method

Data obtained from the questionnaires were analysed using the Fuzzy Delphi Method (FDM) to obtain expert consensus. Each expert played the role of a respondent, having recorded their levels of agreement based on the seven-point Likert scale and expressed their opinions at the end of the questionnaire.

The FDM presented two main functions: triangular fuzzy numbers and defuzzification. A fuzzy number is a generalisation of a regular, real number. It refers to a connected collection of alternative values rather than a single one, with each possible value weighing between 0 and 1. The values m_1 , m_2 , and m_3 represented fuzzy triangular numbers, written as (m_1, m_2, m_3) , and used to produce fuzzy scales like the Likert scale, where numbers were exhibited as odd numbers. The higher the numbers were in the fuzzy scale, the greater the accuracy of the data obtained. The data collected from this study were transferred to a table to find the fuzzy values, represented by n_1 , n_2 ,

n_3 , and the mean value (m_1, m_2, m_3) . The threshold values (d) were identified not to exceed 0.2 (≤ 0.2) to reach expert consensus for every item, while the expert agreement percentage was greater than 75% ($\geq 75\%$). The following formula was applied to calculate the threshold value (d).

$$d (\tilde{m}, \tilde{n}) = \sqrt{1/3 [(m_1-n_1)^2 + (m_2-n_2)^2 + (m_3-n_3)^2]}$$

Concerning the formula above, if the threshold value obtained was smaller or equal to 0.2, it meant that the experts had reached a mutual agreement, but if the d value was greater than 0.2, another round of data collection was needed to ensure the validity of an item. Apart from the threshold value, FDM also enabled the process to determine expert consensus based on percentage, which must be 75% or more for each item or the entire construct (Table 2).

Table 2
The level of expert consensus

Score range between quartiles	Consensus definition
0.00 – 1.00	High consensus
1.01 – 1.99	Moderate consensus
≥ 2.00	No consensus

Source: Ridhuan and Nurulrabihah (2020)

RESULTS

The findings of this study were divided into three themes: the need for a mobile AR module, user interface design, and the usability of the AR module (Table 3).

Table 3

The Threshold Value (d) and the Expert Consensus Percentage (%) of the needs analysis for a mobile AR Module

No.	Theme	Threshold Value, d	Expert Consensus Percentage	Consensus Level	Fuzzy Score
1.	The Need for Mobile AR Module	0.166	89.3%	High	0.671
2.	Mobile AR Module User Interface Design	0.097	92%	High	0.707
3.	Mobile AR Module Usability Criteria	0.077	97.5%	High	0.743

The Need for a Mobile Augmented Reality Module

The theme, measuring the need for a mobile AR module, was made up of seven items: the importance of practical skills in vocational courses like the pneumatic system; the importance of adequate training equipment for optimum practical skills mastery; the pneumatic system teaching and learning problems; the smartphone usage in teaching and learning; and the mobile AR module usage to aid in teaching and to learn the pneumatic system. The threshold value (d) for these items was $0.166 \leq 0.2$, while expert consensus was high at 89.3% (Table 2). Furthermore, all the items' fuzzy scores were greater than α -cut = 0.5; thus, all items were accepted. From the values obtained, all experts agreed that practical skills and theoretical knowledge are important components in vocational courses like pneumatic systems. Therefore, it was essential to have sufficient training equipment for students to master the related practical skills. Moreover, they agreed that the difficulties in comprehending complex learning content and insufficient training equipment in vocational colleges impeded teaching practical skills and learning. As a result, they consented that mobile AR is suitable

to use as a complementary teaching tool, especially for learning intangible concepts in vocational colleges with inadequate pneumatic training equipment to support the teaching and learning process.

The Mobile Augmented Reality Module User Interface Design

The mobile AR user interface design theme consisted of 19 items from the following elements: visual design, text design, audio design, and object display. A threshold value (d) of $0.097 \leq 0.2$ for the items represents a high level of expert consensus (Table 2). The expert consensus percentage was 92%, indicating that experts agreed with all the identified mobile AR user interface design characteristics. In addition, all 19 items' fuzzy scores were greater than the α -cut value = 0.5. The group of experts recognised that uninterrupted audio, attractive illustrations, 3D object usage, neat space and shape, and text font size were among the top characteristics of mobile AR user interface design.

The Mobile Augmented Reality Module Usability Criteria

The mobile AR module usability theme consisted of 23 items that covered the following elements: ease of use, accessibility,

responsiveness, learning content, and users' cognitive and physical efforts. The expert consensus percentage was 97.5%, displaying high strength levels, while the threshold value (d) was $0.077 \leq 0.2$. The highest expert consensus was for the responsiveness of the mobile AR module, denoted by such elements as fast response, high operating speed, easy to stop, revert, and no delays. Other high levels of expert consensus were also demonstrated for items under the learning content element, such as clear labels and easy language. The experts also strongly agreed upon the user's cognitive-related items, like the consistency of terms used and the clarity of instructions.

DISCUSSION

This study ascertains that all experts agree that practical skills and theoretical knowledge are essential components in teaching and learning the vocational course pneumatic systems. The essential practical skills of pneumatic systems to be acquired by the learners are designing pneumatic circuits, selecting appropriate pneumatic components, installing the pneumatic circuits, performing functionality tests, and troubleshooting the pneumatic systems accordingly.

In vocational colleges, practical skills training is a prominent feature of the student learning experience. To produce a skilled workforce, learning for technology-based students encompasses 70% practical skills acquisition and the remainder 30% theoretical knowledge (Technical and Vocational Education

Division, 2019, 2022). Practical skills acquisition is a prerequisite in work-based programmes (Audu et al., 2014; Li et al., 2017; Okwelle & Ojotule, 2018), with each skill set mastered distinct to a respective area of expertise that contributes to optimum productivity at the workplace (Ifeanyichukwu et al., 2018). Hands-on skills allow graduates to operate a range of equipment and tools, whether operating, servicing, or maintaining, leading experts to collectively agree on the importance of the availability of a comprehensive range of training equipment in vocational colleges.

The lack of sufficient pneumatic system training equipment has led experts to use smartphones as an alternative for teaching and learning purposes, such as downloading simulations and videos. Experts agree that integrating multimedia instruction, such as a mobile AR module, into teaching is highly beneficial for vocational students. Herlandy et al. (2019) point out that AR has the potential as a virtual laboratory to substitute practical activities that students cannot complete due to laboratory equipment restrictions or challenging demonstrations. Furthermore, it allows students to access learning outside classroom hours and a flexible practicum. In addition, using AR technology in teaching and learning is cost-effective (Arief et al., 2018; Diegmann et al., 2015; Ferrer-Torregrosa et al., 2015). Purchasing physical training equipment and materials is usually prohibitively expensive. A virtual laboratory may also accommodate more students at once.

As for the characteristics of the mobile AR user interface design and its usability, experts agree on the designs listed with high consensus levels and grant that the mobile AR module, when used, must be responsive; this is in line with suggestions from several scholars like Dünser et al. (2007), Ko et al., (2013) and Sambodo et al., (2019). Students should not experience long pauses between commands and responses (Aadzaar & Widjajanti, 2019; Dünser et al., 2007). Expert consensus is also high for items like clear labels and easy language. According to Nielsen (1993), the language used in an application should be familiar to users and not system-oriented phrases. Dünser et al. (2007) identify several design principles regarding usability criteria, one of which is reducing the user's cognitive load. Cognitive load stems from users' interaction with an overload of instructional activities that may interfere with completing the task. Ko et al. (2013) proposed consistency throughout the module to reduce cognitive load, with experts strongly agreeing with the consistency of terms used in modules.

Visual and audio design aspects are ranked highest among the user interface design elements. Experts agree that uninterrupted audio, attractive illustration, 3D object usage, neat space and shape, and text font size are important characteristics of the mobile AR module interface to promote ease of learning. Interpreting and understanding messages and information from modules will require minimal effort, especially with the underlying pattern established in the multimedia. The

significant factors that affect the underlying pattern are the alignment of elements, shape, balance, style, and suitable colour combinations (Heinich et al., 2002). For example, to establish this underlying pattern using alignment, the key elements of a display are placed in such a way that they have a clear visual relationship to one another; viewers spend less time trying to make sense of what they see and can focus on understanding the message.

Apart from visual design, verbal or text design is equally important. In designing instructional material, it is advisable that the lettering is selected with much care so that it will be able to convey a message efficiently (Heinich et al., 2002). Several characteristics should be considered, such as style, size, and spacing, with three-dimensional objects and interactive displays conveying an idea more effectively (Heinich et al., 2002). The lettering style should be consistent and blend well with the rest of the image. For explicit informational and instructional purposes, a plain font style is ideal. The size of the letters determines legibility. The lowercase letter should be used to ensure the best legibility, and capital letters should be added only where customarily required. According to the standard rule of thumb, lowercase letters should be 1/2 inch high for every 10 feet of distance viewers (Heinich et al., 2002). Apart from the size of the letters, the spacing between the lines of the written material is also significant. As a result, the vertical space between the lines should be slightly less than the average height of the lowercase letter.

CONCLUSION

The analysis of the data collected from the study affirmed that experts collectively agreed that both theoretical knowledge and practical skills mastery are fundamental in vocational education to produce a competent workforce. However, insufficient training equipment and related tools often impede practical skills teaching and learning for vocational courses in the vocational college workshop. Thus, designing and developing a mobile AR module is vital to support and aid vocational college students in mastering practical skills, especially when vocational training equipment and tools are not readily available.

The characteristics of mobile AR make it suitable for practical skills instruction through three-dimensional virtual object overlay onto a real environment. Several essential elements of the user interface design and the usability of the mobile AR module showed high levels of expert consensus. Therefore, user interface design, such as visual design, text design, object and material display, and audio design, should be considered in designing and developing mobile AR-based modules. At the same time, the usability criteria such as ease to use, accessibility, responsiveness, use of the content, and user's cognitive and low physical effort should be applied to direct the design and development of a mobile AR-based module.

For future research, it is recommended to explore further the main components and elements that should be included in

the design and development of mobile AR modules for effective teaching and learning practical skills, especially for pneumatic systems. In short, there is an urgency to produce a mobile AR module for teaching and learning pneumatic systems in Malaysian vocational colleges as an alternative to actual training equipment.

ACKNOWLEDGEMENTS

The authors of this paper want to thank all the subject matter experts for their cooperation and willingness to participate in the needs analysis study, which contributed to the findings of this paper.

REFERENCES

- Aadzaar, R. M., & Widjajanti, D. B. (2019). Multimedia: An alternative to improve self-regulated learning and mathematical problem-solving skills. *Journal of Physics: Conference Series*, 1320(1), 1-7. <https://doi.org/10.1088/1742-6596/1320/1/012086>
- Ab Aziz, N. A., Ab Aziz, K., Paul, A., Yusof, A. M., & Noor, N. S. M. (2012). Providing augmented reality based education for students with attention deficit hyperactive disorder via cloud computing: Its advantages. *14th International Conference on Advanced Communication Technology*, 577-581.
- Adler, M., & Ziglio, E. (Eds.). (1996). *Gazing into the oracle: The Delphi method and its application to social policy and public health*. Jessica Kingsley Publisher.
- Akçayir, M., & Akçayir, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1-11. <https://doi.org/10.1016/j.edurev.2016.11.002>

- Ali, D. F., Md Nasir, A. N., Buntat, Y., Minghat, A. D., Hussin, M. N. K., Mokhtar, M., & Nordin, M. S. (2013). Virtual environment courseware in engineering drawing to enhance students' visualization skills. *Proceedings of the Research in Engineering Education Symposium*, 1-8.
- Andoko, & Wirawan, W. A. (2017). Needs analysis of automotive workshop equipment based on Indonesian national standards. *World Transactions on Engineering and Technology Education*, 15(4), 410-415.
- Anindo, J., Mugambi, M. M., & Matula, P. D. (2016). Training equipment and acquisition of employable skills by trainees in public technical and vocational education and training institutions in Nairobi County, Kenya. *International Journal of Advanced Research*, 3(4), 103-110.
- Aravind, K., Subramanian, R. B., Subramanian, V. S. S., Srivyassram, V., Hayakawa, Y., & Pandian, S. R. (2017). An affordable build-your own computer control system for electropneumatics education. *Conference on Information and Communication Technology*, 53(9), 1689-1699.
- Arief, U., Wibawanto, H., & Nastiti, A. (2018). Augmented reality technology for vocational education the disruption era. *International Conference on Indonesian Technical Vocational Education and Association*, 73-76. <https://doi.org/10.2991/aptekindo-18.2018.16>
- Asfani, K., Suswanto, H., & Wibawa, A. P. (2016). Influential factors of students' competence. *World Transactions on Engineering and Technology Education*, 14(3), 416-420.
- Audu, R., Kamin, Y., Musta'amal, A. H., & Saud, M. S. (2014). Assessment of the teaching methods that influence the acquisition of practical skills. *Asian Social Science*, 10(21), 35-41. <https://doi.org/10.5539/ass.v10n21p35>
- Audu, R., Musta'amal, A. H., & Sukri, M. A. (2013). Provision of workshop tools and equipment: Necessity for technical vocational education graduates skills acquisition. *2nd International Seminar on Quality and Affordable Education*, 74-78. <https://doi.org/10.13140/2.1.2787.0724>
- Azuma, R. T. (1997). A survey of augmented reality. *Presence*, 6(4), 355-385. <https://doi.org/10.1016/j.chaos.2009.03.056>
- Baloch, S., Qadeer, S., & Memon, K. (2018). Augmented reality, a tool to enhance conceptual understanding for engineering students. *International Journal of Electrical Engineering & Emerging Technology*, 1(1), 41-48.
- Bazarov, S. E., Kholodilin, I. Y., Nesterov, A. S., & Sokhina, A. V. (2017). Applying augmented reality in practical classes for engineering students. *IOP Conference Series: Earth and Environmental Science*, 87(3), 1-7. <https://doi.org/10.1088/1755-1315/87/3/032004>
- Buchner, J., & Zumbach, J. (2018). Promoting intrinsic motivation with a mobile augmented reality learning environment. *14th International Conference on Mobile Learning*, 55-61.
- Chen, C. H., Huang, C. Y., & Chou, Y. Y. (2017). Integrating augmented reality into blended learning for elementary science course. *ACM International Conference Proceeding Series*, 68-72. <https://doi.org/10.1145/3029387.3029417>
- Chen, Y. C. (2019). Effect of mobile augmented reality on learning performance, motivation, and math anxiety in a math course. *Journal of Educational Computing Research*, 1-28. <https://doi.org/10.1177/0735633119854036>
- Chin, K. Y., Wang, C. S., & Chen, Y. L. (2019). Effects of an augmented reality-based mobile system on students' learning achievements and motivation for a liberal arts course. *Interactive Learning Environments*, 27(7), 927-941. <https://doi.org/10.1080/10494820.2018.1504308>
- Diegmann, P., Schmidt-Kraepelin, M., van den Eynden, S., & Basten, D. (2015). Benefits of augmented reality in educational environments

- A systematic literature review. *Proceedings of the 12th International Conference on Wirtschaftsinformatik*, 1542-1556. https://www.researchgate.net/publication/312147184_Benefits_of_Augmented_Reality_in_Educational_Environments_-_A_Systematic_Literature_Review%0Ahttp://aisel.aisnet.org/wi2015http://aisel.aisnet.org/wi2015/103%0Ahttps://aisel.aisnet.org/cgi/viewcontent.cgi
- Dünser, A., Grasset, R., Seichter, H., & Billingham, M. (2007). Applying HCI principles to AR systems design. *Proceedings of 2nd International Workshop on Mixed Reality User Interfaces: Specification, Authoring, Adaptation*, 1-5.
- Endres, T., Weyreter, S., Renkl, A., & Eitel, A. (2020). When and why does emotional design foster learning? Evidence for situational interest as a mediator of increased persistence. *Journal of Computer Assisted Learning*, 36(4), 1-12. <https://doi.org/10.1111/jcal.12418>
- Ferrer-Torregrosa, J., Torralba, J., Jimenez, M. A., García, S., & Barcia, J. M. (2015). ARBOOK: Development and assessment of a tool based on augmented reality for anatomy. *Journal of Science Education and Technology*, 24(1), 119-124. <https://doi.org/10.1007/s10956-014-9526-4>
- Hanafi, H. F., Said, C. S., Wahab, M. H., & Samsuddin, K. (2017). Improving students' motivation in learning ICT course with the use of a mobile augmented reality learning environment. *IOP Conference Series: Materials Science and Engineering*, 226, 012114. <https://doi.org/10.1088/1757-899X/226/1/012114>
- Heinich, R., Molenda, M., Russell, J. D., & Sharon, E. S. (2002). *Instructional media and technologies for learning* (7th ed.). Merrill Prentice Hall.
- Herlandy, P. B., Al Amien, J., Pahmi, P., & Satria, A. (2019). A virtual laboratory application for vocational productive learning using augmented reality. *Jurnal Pendidikan Teknologi dan Kejuruteraan*, 25(2), 194-203. <https://doi.org/10.21831/jptk.v25i2.26504>
- Hung, Y. H., Chen, C. H., & Huang, S. W. (2017). Applying augmented reality to enhance learning: A study of different teaching materials. *Journal of Computer Assisted Learning*, 33(3), 252-266. <https://doi.org/10.1111/jcal.12173>
- Ifeanyichukwu, O. A., Uzoagulu, P. A. E., & Ifeyinwa, O. C. (2018). Availability and adequacy of workshop facilities for skill acquisition among undergraduates in technology vocational education in universities in South East Nigeria. *International Journal of Scientific and Research Publications*, 8(6), 159-174. <https://doi.org/10.29322/ijsrp.8.6.2018.p7824>
- Ismail, M. E., Zakaria, A. F., Ismail, I. M., Othman, H., Samsudin, M. A., & Utami, P. (2019). Design and development of augmented reality teaching kit: In TVET learning context. *International Journal of Engineering & Technology*, 8(1), 129-134. <https://doi.org/10.14419/ijet.v8i1.1.24792>
- Jabar, A. R., Pairan, M. R., Noh@Seth, N. H., Ahyar, N. A. M., Jambari, H., & Lokman, N. H. (2020). Exploring the potential of augmented reality for teaching school computer science. *CEUR Workshop Proceedings*, 2731, 91-107.
- Khramova, M. V., Bukina, T. V., Aleksandrova, N. A., & Kurkin, S. A. (2019). Research on the development of elementary school students' attention in computer science lessons. *Proceedings of the 2019 IEEE International Conference Quality Management, Transport and Information Security, Information Technologies IT and QM and IS 2019*, 515-518. <https://doi.org/10.1109/ITQMIS.2019.8928344>
- Klopfer, E., & Sheldon, J. (2010). Augmenting your own reality: Student authoring of science-based augmented reality games. *New Directions for Youth Development*, 128, 85-94.
- Ko, S. M., Chang, W. S., & Ji, Y. G. (2013). Usability principles for augmented reality applications in a

- smartphone environment. *International Journal of Human-Computer Interaction*, 29(8), 501-515. <https://doi.org/10.1080/10447318.2012.722466>
- Kurniawan, W. D., Budijono, A. P., & Susanti, N. A. (2017). Developing computer assisted media of pneumatic system learning oriented to industrial demands. *Jurnal Pendidikan Teknologi Dan Kejuruan*, 23(3), 304-309. <https://doi.org/10.21831/jptk.v23i3.13417>
- Li, H., Zhou, L., & Yuan, Y. (2017). The main problems faced by higher vocational education and the countermeasures. *7th International Conference on Education, Management, Information and Mechanical Engineering*, 76, 1564-1567. <https://doi.org/10.2991/emim-17.2017.315>
- Martín-Gutiérrez, J., Fabiani, P., Benesova, W., Meneses, M. D., & Mora, C. E. (2015). Augmented reality to promote collaborative and autonomous learning in higher education. *Computers in Human Behavior*, 51(Part B), 752-761. <https://doi.org/10.1016/j.chb.2014.11.093>
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.
- Md Nasir, A. N., Ahmad, A., Udin, A., Wahid, N. H. A., & Ali, D. F. (2020). Teachers' practical teaching methods for electronic course in vocational colleges. *Journal of Technical Education and Training*, 12(1), 189-196.
- Nielsen, J. (1993). *Usability engineering*. Academic Press.
- Noh, N. M., Siraj, S., Halili, S. H., Jamil, M. R. M., & Husin, Z. (2019). Application of Fuzzy Delphi method as a vital element in technology as a tool in design thinking based learning. *Asia Pacific Journal of Educators and Education*, 34, 129-151. <https://doi.org/10.21315/apjee2019.34.7>
- Ohwojero, C. J., & Ede, E. (2013). Tools and equipments as a means of enhancing practical skill acquisition in automobile workshop in Nigerian secondary schools and technical colleges. *Open Science Repository Education*, Article e70081988. <https://doi.org/10.7392/openaccess.70081988>
- Okwelle, P. C., & Ojotule, D. I. (2018). Constraints to students' effectiveness in practical skills acquisition in technical colleges in Kogi State, Nigeria. *International Journal of Innovative Scientific & Engineering Technologies Research*, 6(1), 1-9.
- Olwal, A. (2009). *An introduction to augmented reality*. Research Gate. https://www.researchgate.net/publication/221402836_Introduction_to_Augmented_Reality
- Peddie, J. (2017). *Augmented reality*. Springer International Publishing.
- Rabie, M. G. (2009). *Fluid power engineering*. The McGraw-Hill Companies, Inc.
- Ridhuan, M. J. M., & Nurulrabihah, M. N. (2020). *Kepelbagaian metodologi dalam penyelidikan rekabentuk dan pembangunan*. Qaisar Prestige Resources.
- Saidin, N. F., Halim, N. D. A., & Yahaya, N. (2015). A review of research on augmented reality in education: Advantages and applications. *International Education Studies*, 8(13), 1-8. <https://doi.org/10.5539/ies.v8n13p1>
- Sambodo, R. A., Prayitno, B. A., & Karyanto, P. (2019). The development of ECO AR learning media based on augmented reality technology on the topic of ecosystem. *AIP Conference Proceedings*, 2194, 020108. <https://doi.org/10.1063/1.5139840>
- Sambodo, R. A., Prayitno, B. A., & Karyantoo, P. (2018). The effectiveness of augmented reality technology based - Interactive multimedia implemented to improve students learning outcome ecology at high school level. *Advances in Social Science, Education and Humanities Research*, 262, 262-264. <https://doi.org/10.2991/ictte-18.2018.47>

- Shieu, Y.-M., Hsu, Y.-C., Sheng, M., & Lan, C.-H. (2019). Impact of an augmented reality system on students' learning performance for a health education course. *International Journal of Management, Economics and Social Sciences*, 8(3), 195-204. <https://doi.org/10.32327/IJMESS.8.3.2019.12>
- Solmaz, S., Alfaro, J. L. D., Santos, P., Van Puyvelde, P., & Van Gerven, T. (2021). A practical development of engineering simulation-assisted educational AR environments. *Education for Chemical Engineers*, 35, 81-93. <https://doi.org/10.1016/j.ece.2021.01.007>
- Technical and Vocational Education Division. (2019). *Diploma Teknologi Elektronik* [Diploma in Electronics Technology]. Ministry of Education Malaysia.
- Technical and Vocational Education Division. (2022). *Kolej vokasional* [Vocational college]. Ministry of Education Malaysia. <https://bpltv.moe.gov.my/kolej-vokasional/>
- Wong, T. L., Xie, H., Zou, D., Wang, F. L., Tang, J. K. T., Kong, A., & Kwan, R. (2020). How to facilitate self-regulated learning? A case study on open educational resources. *Journal of Computers in Education*, 7(1), 51-77. <https://doi.org/10.1007/s40692-019-00138-4>
- Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers and Education*, 62, 41-49. <https://doi.org/10.1016/j.compedu.2012.10.024>
- Xu, L., Cai, L., & Nan, X. (2017). Research on teaching reform of hydraulic and pneumatic transmission based on OBE. *7th International Conference on Education, Management, Computer and Medicine*, 59, 397-403. <https://doi.org/10.2991/emcm-16.2017.75>
- Yip, J., Wong, S. H., Yick, K. L., Chan, K., & Wong, K. H. (2019). Improving quality of teaching and learning in classes by using augmented reality video. *Computers and Education*, 128, 88-101. <https://doi.org/10.1016/j.compedu.2018.09.014>
- Zhang, J., Liu, T. C., Sung, Y. T., & Chang, K. E. (2015). Using augmented reality to promote homogeneity in learning achievement. *Proceedings of the 2015 IEEE International Symposium on Mixed and Augmented Reality - Media, Art, Social Science, Humanities and Design*, 1-5. <https://doi.org/10.1109/ISMAR-MASHD.2015.17>
- Zhang, J., & Walji, M. F. (2011). TURF: Toward a unified framework of EHR usability. *Journal of Biomedical Informatics*, 44(6), 1056-1067. <https://doi.org/10.1016/j.jbi.2011.08.005>