EVALUATION OF MARKER AND MARKERLESS AUGMENTED REALITY (AR) APPS IN ENHANCING LEARNING TOWARDS TRAINING FOR WELDING PROCESS

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ABSTRACT

Welding plays an essential role in the development and fabrication of specific metals that must be joined perfectly. It is widely used all around the world and comes in handy in manufacturing, automotive, aerospace, and construction. Therefore, specialized workers are required for the welding process. Unfortunately, it is also a very dangerous process, and many accidents have been reported regarding welding-related injuries. Thus, this study aims to design and develop Augmented Reality apps as learning tools for welding processes and evaluate these AR app. The SOLIDWORKS, BLENDER and UNITY software were used in the design and development process of the AR apps. The evaluation of AR Apps was done by 20 students with Diploma in mechanical engineering part 3 from UITM' Pulau Pinang. Results gathered showed that the average Task Completion Time (TCT) for the AR Marker group was better (28.37% lower) compared to the AR Markerless group. Moreover, participants also gave positive feedback on learning through both AR apps, which are more efficient in aspects of accuracy, performance, and stability. Therefore, the implementation of AR apps will benefit new users who experience new processes earlier before having actual processes or machines. Also, this new technology will be expanded and used in any field of study, including education and other industries.

Keywords: *Welding, Training, Augmented Reality, Emerging technologies.*

1.0 INTRODUCTION

Industry requirements change every year as global competition drives continual technological advancement. Emerging Technologies are changing the way we work, play and live. Industry 5.0 refers to how intelligent robots and machines collaborate with humans while also aiming to be resilient and sustainable. Industry 5.0 strives to reintegrate human, environmental, and societal factors into the equation, whereas Industry 4.0 concentrates on technologies like the Internet of Things and big data [1]. The industry needs to transform into a dependable source of prosperity by ensuring that production adheres to environmental regulations and prioritizes the welfare of industry workers. Refer to Figure 1 for an overview of the Industrial Revolution.

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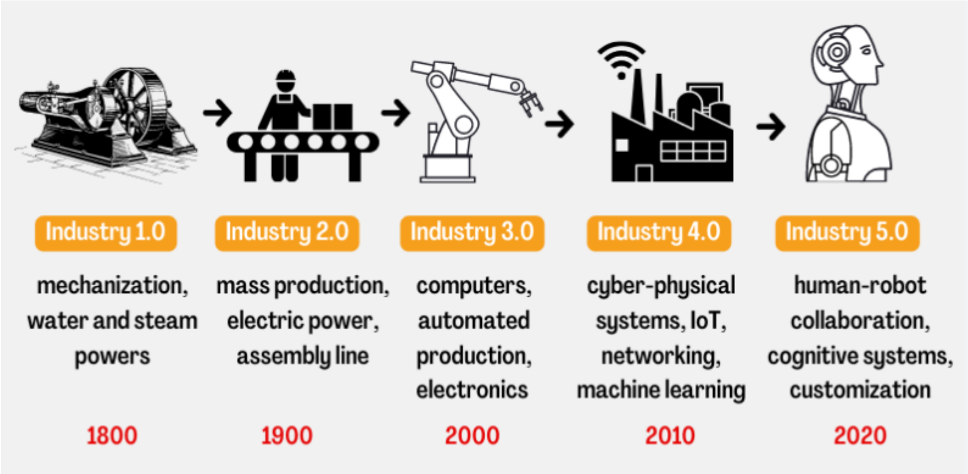

Figure 1: Overview of industrial revolution [2]

While Augmented Reality (AR) is applicable to a given industry, it is better to consider how it enables core competencies that reside in multiples across all industries. AR offers a useful interactive tool for reducing cognitive load by creating a connection between the physical task and supporting documentation by displaying the information without interfering with the user's ability to concentrate [3]. It is highly valuable in the manufacturing industry, where a variety of jobs, such as assembling and maintenance, must be accomplished as inexpensively and efficiently as possible. Moreover, sales and marketing, training and education, operational monitoring, maintenance operations, research and development, all these essential functions can benefit greatly from AR enablement. There are many types of displays used for AR content, such as HMDs, mobile devices (e.g., cell phones, tablets), screens (flat screens, TVs), projection-based AR and CAVE environments [4]. It also has a sense of presence, such as graphics, video, sound and touch feedback. Figure 2 shows an example of Augmented Reality glasses, while Figure 3 shows an Augmented Reality in the military industry.

Figure 2: Augmented reality glasses [5]

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Figure 3: Augmented Reality in the military industry [6]

Throughout the years, welding technology has advanced to fit with our society's technological advancement. Welding is a commonly used process for joining metal parts. Even though in some industries, specifically automotive, welding is done primarily by robots or automated machines. Nevertheless, at some point, most of the welding still involves physical labour performed by people. Thus, producing new welders is an important endeavour for business and the field of vocational education [7]. In addition, in the future of technology, it is expected that the effectiveness of welding training activities will be improved with the involvement of a virtual environment. Other application areas, including medicine, aviation, and the military, have also used virtual reality as a training tool [8]. For example, commercial pilots train their skills in aviation through the flight simulator platform.

Moreover, introducing an AR app in the education sector is also the most significant step. It is a way to expose students to the advancement of modern technologies. Moreover, it will boost students' connection with physical environments and facilitate their learning. Furthermore, students will be more encouraged and motivated to learn due to the flexible learning environment given.

The combination of AR+AI or AR +IoT will be the next prominent direction in the upcoming years, with many industries and academia recognizing the importance of their adoption. Figure 4 shows the applications of Augmented Reality + IoT. The implementation of those technologies has excellent potential for smart industries to increase production speed and workforce training along with improved manufacturing, error handling, assembly, and packaging. Besides, processors will be less expensive, more efficient, and power-optimized in the forthcoming years. Then, this study is about the challenge that needs to be overcome in relating and applying interactive Augmented Reality Technology in training tools for welding processes.

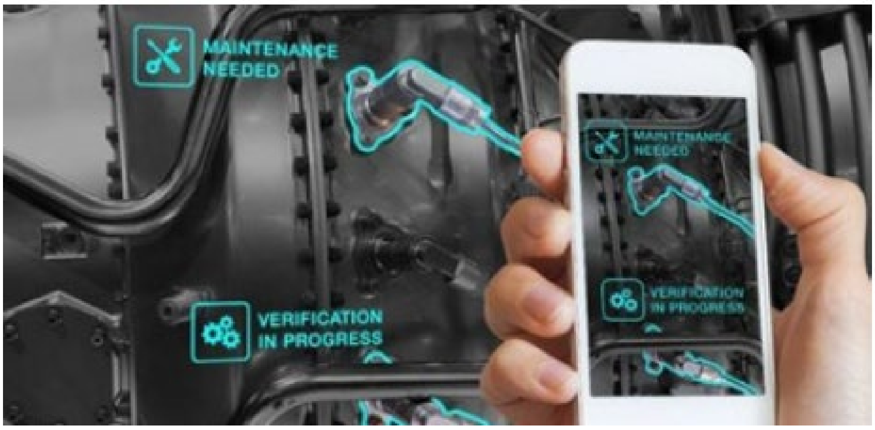

Figure 4: Augmented reality + IoT [9]

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2.0 METHODOLOGY

This study chose the Shielded Metal Arc Welding (SMAW) process as the virtual scenario for the learning and experience welding process using an AR app. This study aims to design and develop an Augmented Reality app as a learning tool for welding processes. Then, investigate the impact of marker and markerless AR apps in enhancing learning for the welding process in UiTMPP.

The finalized step focuses on the information regarding training tools, safety equipment and procedures for shielded metal arc welding. Table 1 is the apparatus needed for the Shielded Metal Arc Welding (SMAW) process and the list of safety equipment used for this study.

Table 1: Welding tools & Safety equipment

Welding tools and safety equipment	
Apparatus	Safety Equipment
1. AC or DC constant current power supply	1. Welding mask
2. Electrode lead	2. Gloves
3. Work lead	3. Protective boots
4. Electrode holder	4. Protective clothing
5. Ground clamp	
6. Welding electrode	
7. Chipping hammer	
8. Wire Brush	
9. Wire cutter	

2.1 Software and Hardware

The 3D models of relevant SMAW Training tools were designed using Solidwork software. The 3D file needs to be saved in STL format before importing into Blender. After creating the animated scenes, visual effects, art, motion graphics and interactive 3D applications in Blender. Then, from Blender convert 3D file into the .FBX file is to be used in Unity Software. All three AR apps were developed in the Unity Game Engine using the C# programming language. Refer to Figure 5 for the flow diagram for the AR architecture used in this study.

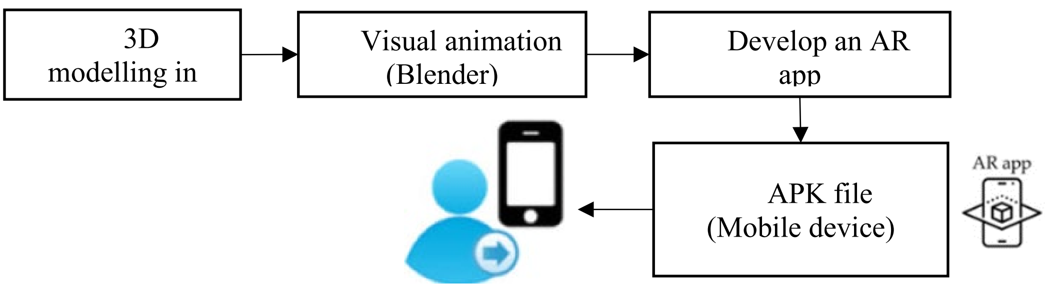

Figure 5: Flow diagram for AR architecture

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2.2 3D Modelling

Then, 3D models of relevant Shielded Metal Arc Welding (SMAW) Training apparatus and processes were created using SolidWorks software. Refer to Figure 6 and Figure 7 for the 3D model of welding machine and welding training tools.

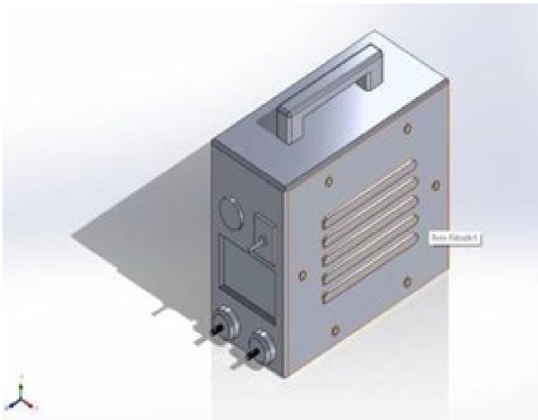

Figure 6: DC welding machine

Figure 7: Welding training tools

2.3 Development of AR apps

Figure 8 shows the process flow for the development of AR apps in the Unity system after completing the design 3D model in Solidwork and Blender. The Blender software was used to make animated movies, visual effects, artwork, motion graphics, virtual reality and 3D-printed objects [10]. Next, Unity software was used to develop AR apps. Unity provides users with the best and latest features for creating a realistic augmented reality experience. Besides, Unity's AI offers the greatest real-time object occlusion and tracking system. Moreover, it also provides new developers with a simple yet useful guideline for developing their first augmented reality app. Furthermore, with a unique AI-enabled vision technology, Unity recognizes and tracks flat images and 3D objects in real-time. Then, the QR code was created using a QR code generator website known as GET-QR. Then, the APK file was created before being integrated with mobile phones. The use of a QR code as an identifier is crucial for the functionality of the AR app. The virtual image will appear when scanning the QR code using a mobile device camera.

Next, the AR application's Main Menu, also referred to as the UI or user interface, was created. The construction is using "Canvas" to complete the UI creation process. Creating the different virtual scenes of fundamentals in handling Shielded metal arc welding required programming using C# languag. Then, build and run all scenes from Unity into an APK file to integrate with Mobile Android.

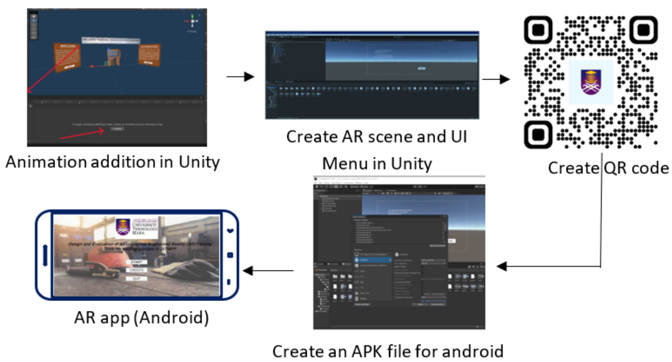

Figure 8: Process flow for the development of AR apps

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2.4 Experimental Work

A total of 20 students with a Diploma in mechanical engineering part 3 from UITM' Pulau Pinang were involved in this evaluation process. There were two groups assigned for this experimental work, a comparison between the AR Marker group versus the AR Markerless group. Although both AR Marker and AR Markerless share similar functionalities, they differ in how targets are set up. AR Markers can either be paper-based (scan the QR code or image) or physical objects with distinct patterns that cameras can swiftly identify and analyze, remaining visually distinct from their environment. On the other hand, AR Markerless technology does not require physical markers like QR codes or images. Instead, it tracks and detects the user's environment, pinpointing virtual content using location data from mobile devices such as GPS or accelerometers. Figure 9 shows the overview of the experimental work done for this study.

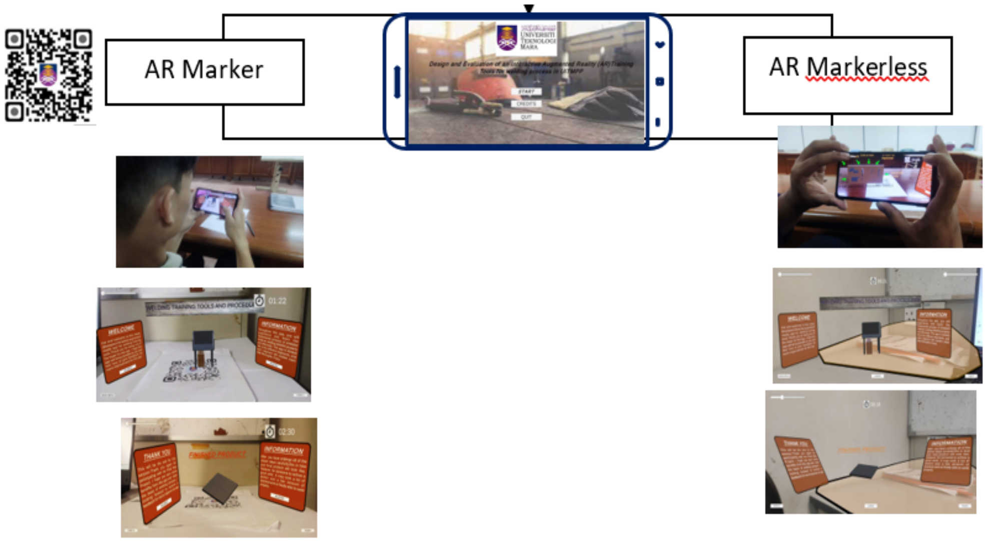

Figure 9: Overview of experimental work

2.5 Data and Analysis

This study used a mixed method research design, "Quantitative + Qualitative". Quantitative data is based on numbers and may be counted or measured [11]. Quantitative data also refers to observable, measurable, and numerical data that converts correlations into concrete facts and is used to support a hypothesis [12]. Quantitative data provides how many, how much, or how frequently something occurs, such as to understand why, how, or what occurred behind specific behaviours with the aid of qualitative data [11]. Qualitative data refers to descriptive and non-numerical data that aims to study phenomena and reveal the "why" behind them. Its goal is to explain and illustrate how different variables relate to one another [12]. Data is recorded throughout the entire experimental work. Qualitative refers to pre-questionnaire and post-questionnaire. Meanwhile, quantitative methods are used for task completion time (TCT), learning curves, and technical tests.

3.0 RESULTS AND DISCUSSION

3.1 Pre-Questionnaire

Data from the pre-questionnaire is used to analyze the qualitative results of participants' backgrounds. Participants were answered pre-questionnaire before running the experimental work. Table 2 shows the summary of the participant's background. A total of 20 participants, an average age of 19 years, from part 3 students of Diploma in Mechanical Engineering were involved in this study. They were divided into two balanced groups, 10

DOI 10.11113/jm.v48.562

participants in the AR Marker group and another 10 participants in the AR Markerless group. Data shows that 80% of the participants from the AR Marker have experience in welding, while only 60% of the AR Markerless groups are experienced in the welding process. Then, 90% of the AR Marker group have more experience with Augmented Reality compared with 80% of the AR Markerless group.

Table 2: Results for participant's background

Groups	No of Participants	Age	Welding Experiences	AR Experiences
AR Marker	10	19	0.8	0.9
AR Markerless	10	19	0.6	0.8

3.2 Task Completion Time (TCT)

Figure 10 shows the Task Completion Time (TCT) recorded for each task to be completed by each participant. Participants repeated the same task 5 times. Overall, both types of AR are constantly decreasing for the time taken to complete each task. However, AR Marker groups have a bigger decrease in the time taken to complete the task, resulting in lower average TCT than AR markeless groups. This finding shows that more repetition or rehearsal will result in more efficiency and may increase the feasibility of the implementation of this technology in educational and industrial training practices.

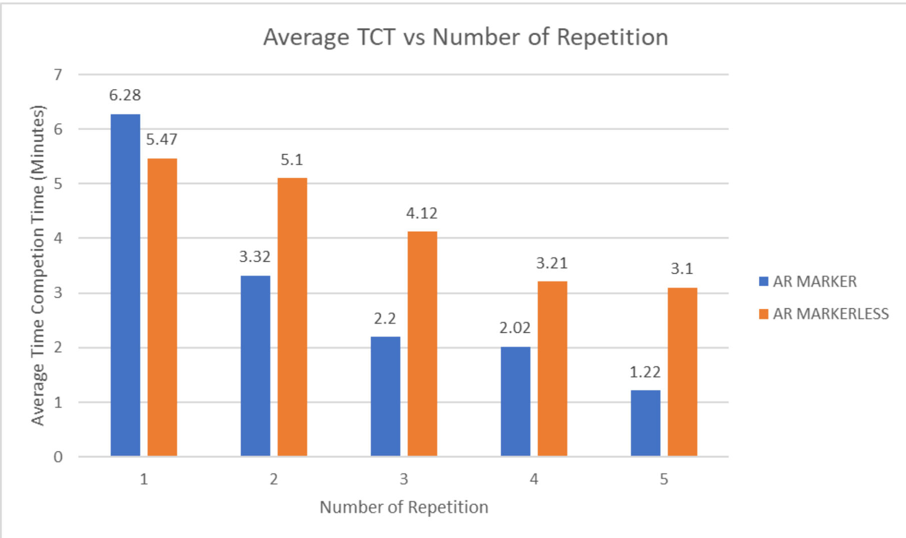

Figure 10: Task Completion Time (TCT)

Figure 11 shows the result for the average Task Completion Time (TCT) taken for both types of AR groups. It has shown that the AR Marker has a better result (less) for the TCT, 28.37% (3.008 minutes) compared to the TCT for the AR Markerless with an average time of (4.1994 minutes). It shows that AR Marker groups revealed improvements in overall TCT compared to AR Marker groups. This finding is also similar to a previous study done by Cheng, Jack (2017), because the AR marker tends to have higher accuracy and is more stable compared to AR markerless [13]. Moreover, learning and training using AR provide new users with learning-by-doing, and they can perform these simulations

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repeatedly everywhere and anywhere they need. Besides, 90% of the participants in the AR marker already had experience using AR technology before this, while only 80% of the participants who used AR markerless had experience in AR technology. This criterion may also greatly affect the resulting outcome.

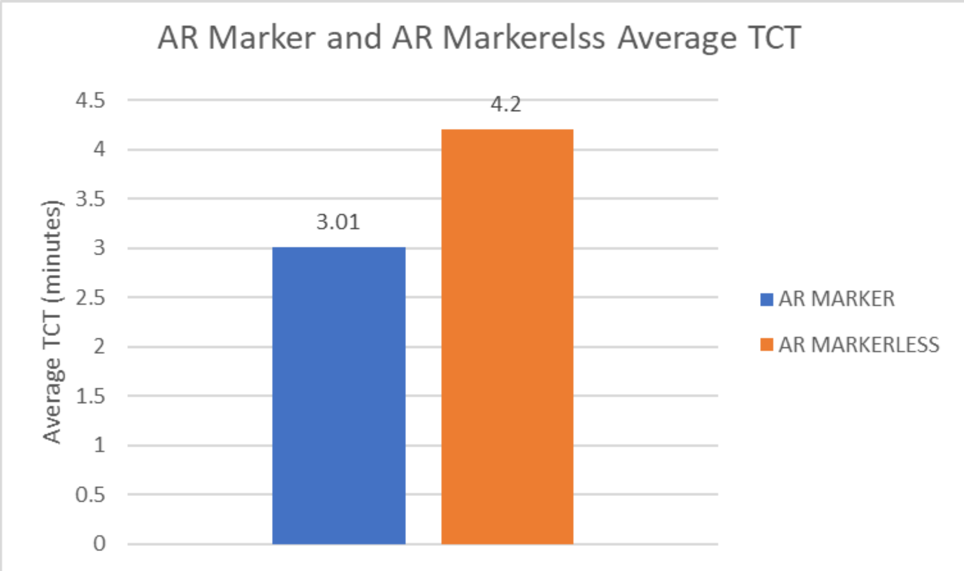

Figure 11: The average Task Completion Time (TCT)

3.3 Learning Curve

Figure 12 shows that the average score for the learning curve decreased as the number of repetitions participants took increased as they gained experience and knowledge. However, the AR Marker group decreased more dramatically (better result) than AR Markerless in each trial. The learning curve in this context was also influenced by the quality of both AR apps, the complexity of the task, the individual's learning capabilities and number of repetitions given.

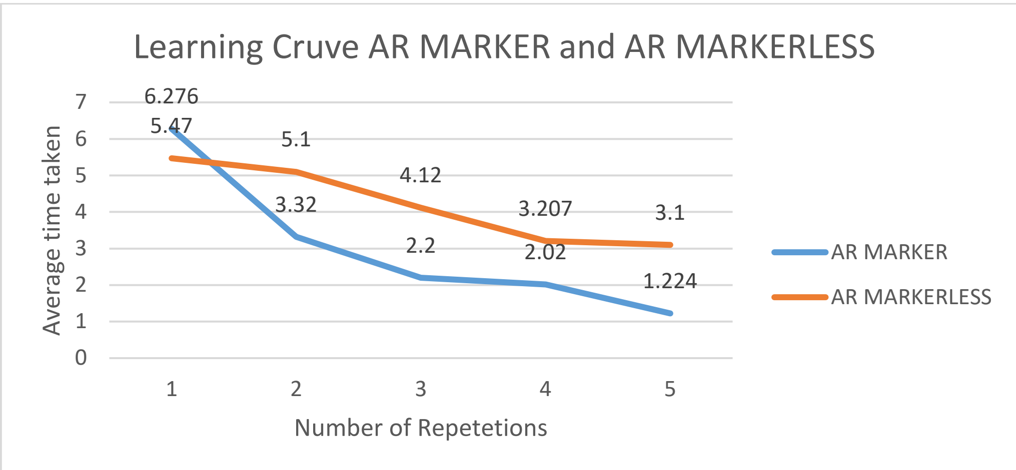

Figure 12: Learning curve AR marker vs markerless

3.4 Technical Test

Figure 13 shows that participants for both types of AR apps were able to answer the technical test question most correctly and got an average score of 9. This finding proved

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that both AR apps had a positive impact on the participants. It is shown that AR training app manage to deliver information clearly to the user.

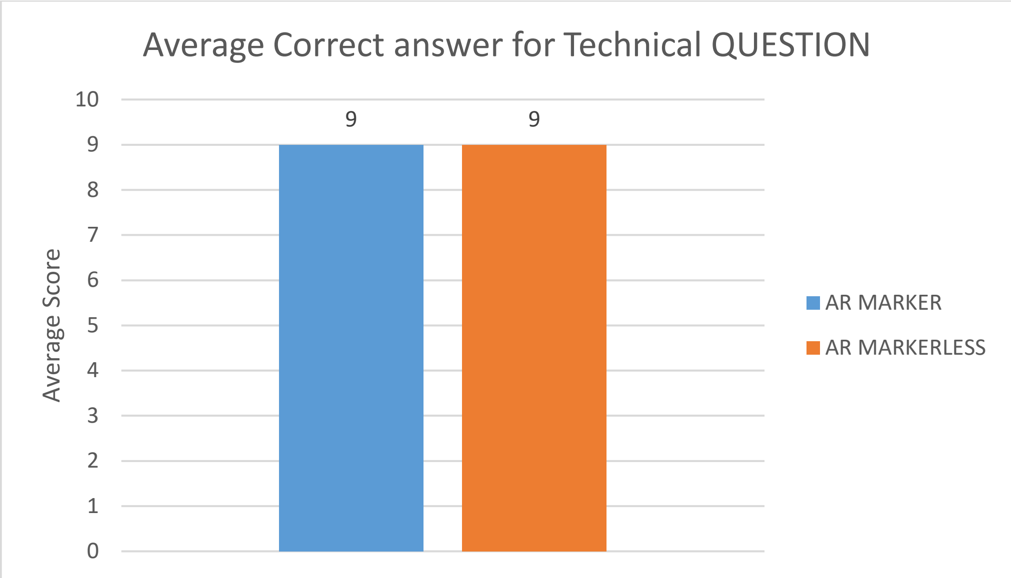

Figure 13: Technical test

3.5 Post Questionnaire

Overall, Figure 14 shows the result of the User Experience Questionnaire (UEQ). AR Marker group scores slightly higher compared to the AR Markeless group. Under section Efficiency: AR Marker scores 80 % (4 scores) over 66% (3.3scores), Perspicuity 94% (4.7 scores) over 74% (3.7 scores), Dependability: 80% (4 scores) compared to 66% (3.3 scores) and Stimulation: 88% (4.4 scores) compared to 76% (3.8 scores). This might be due to the AR Marker providing a more visible and clear simulation that increases their understanding very well.

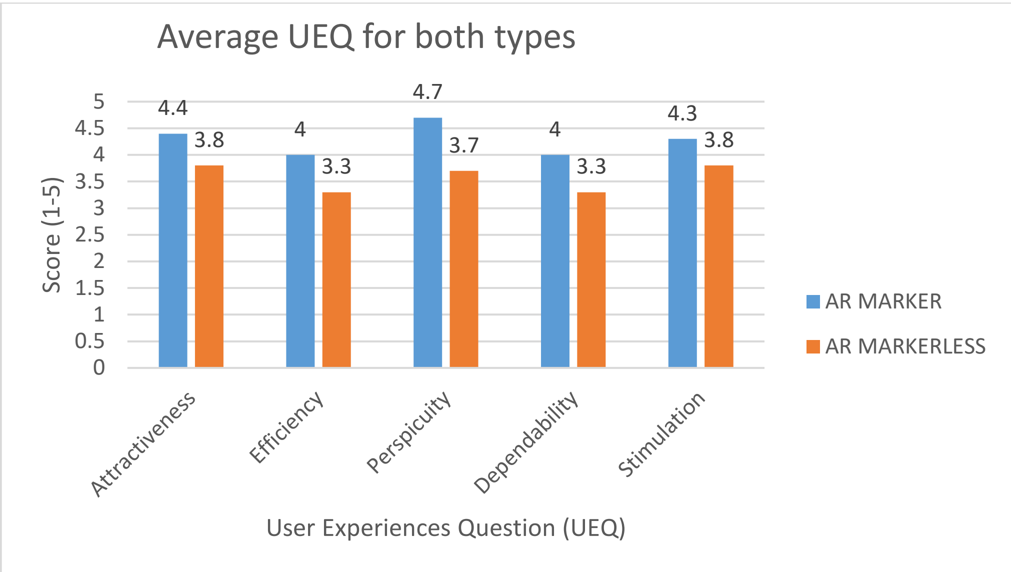

Figure 14: User Experience Questionnaire (UEQ)

3.6 Summary

Throughout this research, even though results from the pre-questionnaire, experimental work and post-questionnaire have shown great scores, especially for the AR Marker group

DOI 10.11113/jm.v48.562

compared to the AR Markeless group. In fact, the result from the technical question showed that AR apps were as effective as desired by users, especially for the fundamentals of the SMAW process, with the aid of simple animation for better understanding. This finding is similar to a previous study done by (S. Ebadi, 2022) [14]. This shows that trainee's welding knowledge towards skill can be created efficiently and more competent and qualified by using this Virtual learning and training in the welding process. Porter *et al.* (2004) through his study found that the VR welding simulator created will not replace reality welding, but it will help trainees gain basic welding skill training [15, 16]. Therefore, new users may experience and early exposure gained through the usage of these AR apps. Therefore, these AR apps might be used in future education and industry to train new users with current technologies.

4.0 CONCLUSION

In conclusion, the objective of this study was successfully achieved in designing and developing AR Marker and Markerless apps. This study also successfully evaluated the effectiveness of both AR apps for learning Shielded Metal Arc Welding (SMAW) apparatus and processes, even though AR Marker gave better results compared to AR Markeless. Overall, the implementation of digital technology with the aid of animation results effectively as desired to expose new users, especially for the new process procedure or task process for better understanding. Besides, these AR apps align with the requirement of Industry 5.0, which strives to reintegrate human, environmental, and societal factors into the equation. Moreover, this study also supports the national strategy for the implementation of digital tools in education that might be used in future education for learning and training new users with current technologies.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this paper.

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