AREDAPPS: Mobile Augmented Reality Development and Learning Framework Based on Augmented Reality Technology for Engineering Drawing Course

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Abstract. Technology in teaching and learning is crucial as we are now focusing on 21st Century Learning. Moreover, the Covid-19 pandemic has affected many sectors, including education sectors, where most educators are continuously looking for approach and tools to enhance their teaching deliveries to ensure students can still learn effectively even though most of the classes are currently conducted online. Other than that, students also have problems with their visualization skills when learning engineering drawing, which caused a lack of understanding of the content, thus making it even harder for them to learn in this situation. Technology such as augmented reality is a well-received technology application due to its benefit in enhancing users' learning experiences, enhancing visualization skills, and supplementing materials more effectively. Thus, this paper aims to describe Augmented Reality Engineering Drawing Apps (AREDApps) development process, a mobile augmented reality apps for orthographic projection topic in engineering drawing subject, highlight the students' perception when using AREDApps during learning and introduce the engineering drawing learning framework based on AREDApps implementation in the classroom. The result indicates that students were mostly satisfied with augmented reality technology to learn orthographic projection. This is because AREDApps helps them supplement the information that cannot be delivered by using modules or PowerPoint presentation such as the three-dimensional representations of the task given to them. The findings of this paper strengthen the facts that augmented reality is a suitable technology to teach complex technical subjects, which requires supplementary materials that can help students to be able to visualize the task effectively.

Keywords: AREDApps · Visualization · Orthographic projection · Engineering drawing · Perception · Framework

1 Introduction

Engineering drawing is known as a universal language for people working in the technical field. It contains complete detail and specification for any design or product, which can

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help the production department understand the exact details of a product they need to produce. Even though there are various draughting software available nowadays which provide convenience for people who work in technical fields to produce technical drawings in a shorter time compared to manual drawings, they still need to master the basic of producing technical drawings and able to visualize the design given to them [1]. Insufficient visualization skills are why students face difficulties in producing the representations of an orthographic projection in engineering drawing subject [2]. According to Marunic and Glazar [3], authorities have made various efforts to redesign engineering drawing curricula for undergraduate engineering students where contents addressing visualization skills were included in the curricula. The efforts include introducing a freehand sketching activity involving isometric, orthographic, rotation of objects, and cross-sections of solids. Emphasis on visualization skills is essential because this course requires students to deal with the construction of 2-dimensional and 3-dimensional geometry and the creation of multi-view and pictorial representations.

Mastering technical drawing, primarily through an engineering drawing course, is essential among engineering students. Mastering technical drawing is essential because technical drawings play an essential role in engineering careers. The accuracy of technical drawing in the designing and production process is crucial for any engineering practitioners and the ability to read and interpret the drawings precisely. Failure in reading or interpreting technical drawing might cause a more significant impact on the whole designing and production process [4]. Sorby *et al.* [5] also mentioned in their research that it is essential to represent the problems pictorially before beginning any processes to avoid more complicated problems arises later. Thus, learning how to produce a high-quality technical drawing with a detailed specification can help reduce the errors when interpreting the technical drawings [6]. Proper training on producing, reading, and interpreting technical drawing among students in engineering and technical fields should be further emphasized to avoid misinterpretation and failure to read the drawings throughout their engineering career.

According to Sorby *et al.* [7], students have some issues when learning engineering drawing. Some students have difficulties with understanding and mastering the concept of orthographic applications such as projections, orthographic to isometric transformation and dimensioning [2]. Students also claimed to have problems with their ability to view or visualize objects mentally. These problems are closely related to the issues with lack of visualization skills [2]. Another problem identified in this study is the difficulties in understanding projection views due to the lack of ability to imagine images in three-dimensional scenarios [6]. They tend to have difficulties switching between two-dimensional and three-dimensional scenarios [8], which disrupt the process of producing, reading, and interpreting the drawing. Students lacking in visualization skills tend to use trial and error methods due to the lack of proficiency in solving the problems [9].

The significance of teaching and learning strategies during the teaching and learning process is undeniably essential to securing effective learning. However, the strategies used may vary depending on the course requirements. Failure to adopt appropriate teaching and learning strategies could make it difficult for learners to understand the learning subjects' ideas. Recent educational approaches require educators to integrate real-world situations into the learning process to nurture students' interests through technology-enhanced learning [11]. Among all the technologies used in teaching and learning, augmented reality has been receiving tremendous interests among researchers worldwide.

It is proven to effectively reduce cognitive load and help increases students' learning interests [10, 11]. The advantages that this technology offered are why people in various fields have recently seen this technology as one of the emergent technologies. Other than the education field, augmented reality also has been used in clothing, automobile, and biomedical industry [12]. The idea of this technology had exceeded the needs of different areas, providing a more engaging and efficient environment to compare how it used to be before implementing this technology. The results from all of these studies showed that the application of this technology could elevate students understanding when learning complicated concepts. Other than that, it can also improve students' visualization skills in various course and areas. Other than that, augmented reality also fosters self-directed learning skills.

Researchers in the visualization field claimed that students with excellent visualization skills would do well to visualize three-dimensional objects and better understand the concept of visual representation than those lacking visualization skills [13]. Thus, with the utilization of augmented reality technology that can help to enhance visualization skills as proven by various researchers in various field, this study aims to describe the development of Augmented Reality Engineering Drawing Apps (AREDApps), a mobile augmented reality developed with a purpose to enhance students' visualization skills when learning engineering drawing course, identify students' perception on using AREDApps during the learning process and introduce the engineering drawing learning framework based on the implementation of AREDApps in the classroom.

2 Development of AREDApps

2.1 3D Model Development

During the first stage, which is designing 3D virtual models, the program involved is Autodesk 3D Studio Max. Autodesk 3D Studio Max is a professional program designed to allow users to create 3-dimensional animations, models and images. This program was developed by Autodesk Media and Entertainment, where it is mainly used for games development purposes. This program has modelling and animation capabilities which has been used by various commercial studios as well as visualization studios. The 3D modelling process for all the 3D virtual models was done based on the included exercises in the augmented learning module. In this application, only exercises related to the orthographic projection topics are included. Figure 1 shows the Autodesk 3D Studio Max interface, and Fig. 2 shows the example of 3D modelling produced using the software.

The models are designed using Autodesk 3D Studio Max will then be rendered based on the materials that will allow the models to look more apparent and more attractive. In this study, the researcher chooses to use an ocean blue colour as the material for all the 3D models. Many experts approved that the blue colour can help students learn an intensely challenging topic and improve concentration during the teaching and learning process. Furthermore, the models were then export into.fbx file format to allow the importing process in Unity3D later on during the development of the augmented reality environment.

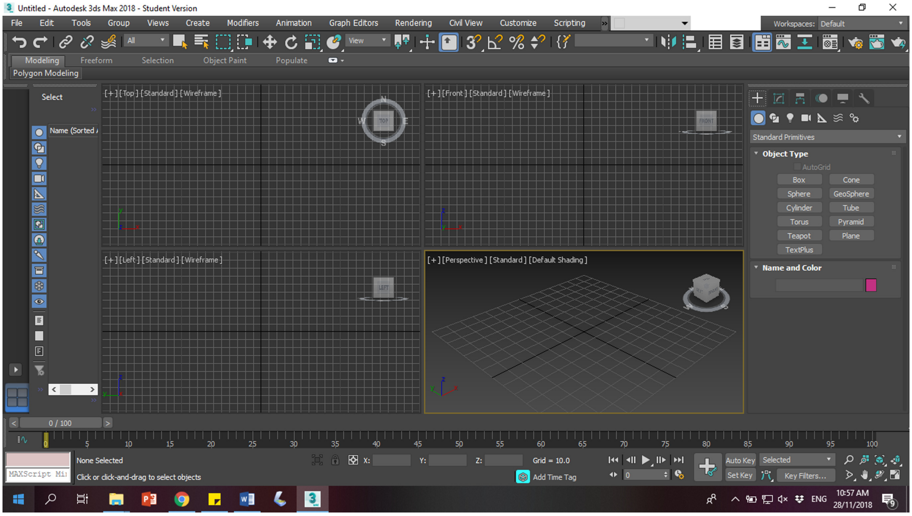

Fig. 1. The interface of Autodesk 3D Studio Max

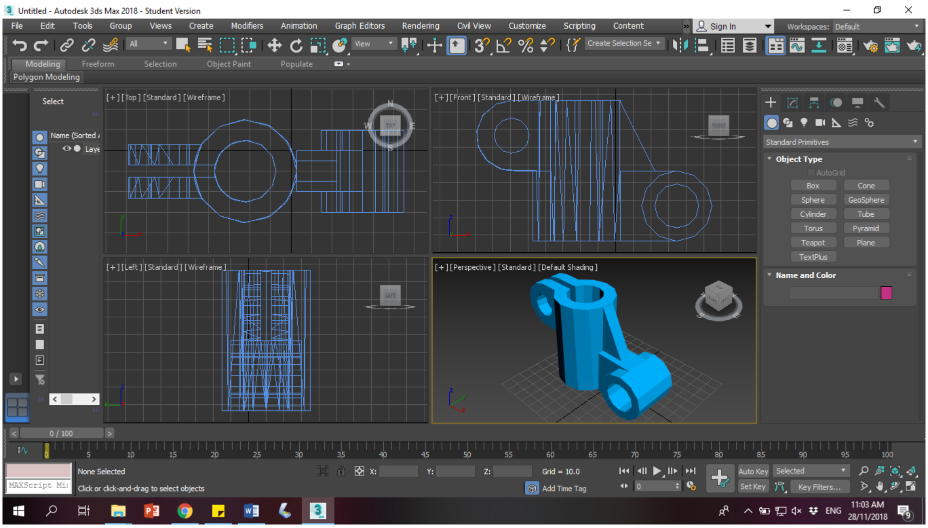

Fig. 2. The example of 3D modeling produced using the software

2.2 Mobile Augmented Reality Development

Once the first stage is completed, the next stage will be developing AREDApps using Unity3D software. Unity3D software is chosen due to the researcher's familiarity with the programming language used in the software, which is the C# programming language. Apart from its use to develop an augmented reality content, it is also widely used to develop games content. Unity3D can develop contents that can be used in various devices such as computer and mobile devices that use Android and iOS operating systems. For AREDApps, the researcher has chosen the Android operating system option as the medium to run mobile apps since most students use Android devices instead of iOS devices. Figure 3 shows the options that the developer can consider when developing using Unity3D.

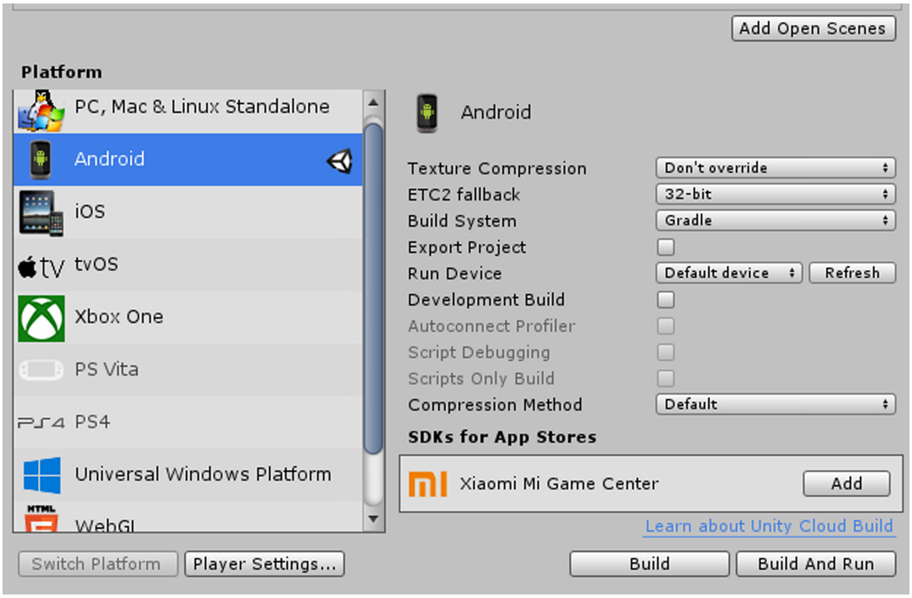

Fig. 3. Options when developing using Unity3D

On the main menu of AREDApps, several buttons are available to navigate the main menu to the content of AREDApps. The simplicity of the interface is the primary key of the development for users to be able to use it comfortably. Other than that, bright colours provide an attractive learning environment to the users, significantly to help maintain their interests in the teaching and learning process. Figure 4 shows the interface of AREDApps.

In the tutorial video menu interface, several buttons are available where each of the buttons will navigate users to the tutorial video of each type of surface. Apart from that, an animation video is placed at the top of the interface to explain the basic information on orthographic projection. The video explains the meaning of orthographic projection, types of orthographic drawings and their labelling. Users will choose the tutorial video that they want to learn according to their interests and move to the other tutorial video based on their own learning pace. The tutorial video in the app allows users to fast forward, stop and pause according to their interest.

The second button in the main menu will navigate users to the AR camera when they are ready to answer the task for orthographic projection. The questions that users need to solve is designed with the AR Marker. The marker consists of two sides, where the front side is where the AR marker is. Users can scan the marker using the AR camera to view

Fig. 4. Interface of AREDApps

the virtual objects. Meanwhile, the backside of the AR marker is the two-dimensional images of the virtual objects complete with the dimensions. The format of the two-dimensional images is designed according to the content of the orthographic projection syllabus. Users can view and manipulate the three-dimensional virtual objects to help them see the hidden views and draw their respective orthographic projection drawing accurately. Figure 5 shows the example of a marker for AREDApps, and Fig. 6 shows the example of the augmented reality interface of AREDApps.

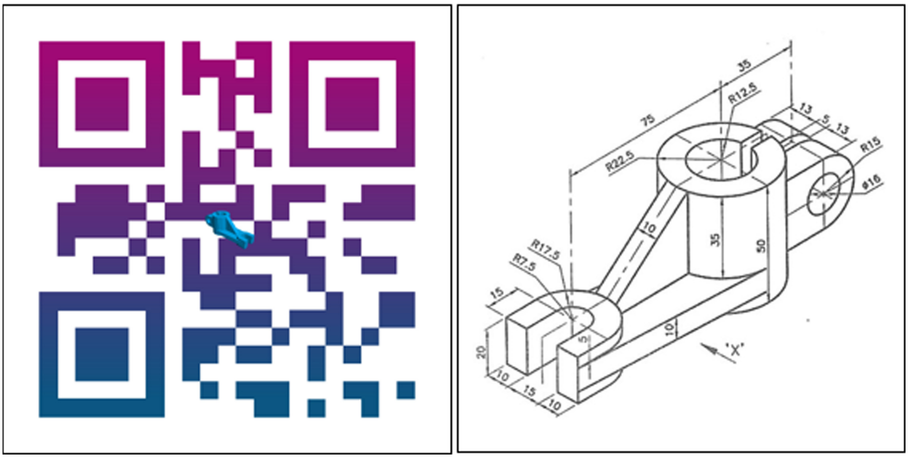

Fig. 5. Marker for Augmented Reality

Fig. 6. Example of Augmented Reality interface of AREDApps

Augmented reality will show the three-dimensional virtual objects for each two-dimensional image that they need to solve, and users will be able to freely manipulate the object as if they are holding the actual object and view the cross-section views of the objects. According to Chen [14], students tend to treat virtual objects in an augmented reality environment as holding an actual object. This approach will encourage them to learn independently while educators will act as their facilitators. This feature is also known as one of the appropriate strategies for effective learning. The development process followed the ADDIE Model to ensure the quality of the developed end-product, which is AREDApps. Other than that, the development process also incorporated some theories and models that are useful in ensuring the quality of the AREDApps to enhance user's visualization skills and learning comprehension.

3 Engineering Drawing Learning Framework Based on AREDApps

Several frameworks on the use of augmented reality in the educational setting have been developed throughout the years. However, there is a lack of a framework that focuses on the learning process. Most of the framework usually focuses on the hardware and software used to develop the augmented reality application rather than from an educational perspective. This study has developed a framework that focuses on the educational perspectives of the AREDApps. In order to implement the Augmented Reality Engineering Drawing Apps (AREDApps) in the teaching and learning process, four elements in the learning process must be taken into account towards improving students' visualization skills and increase their motivation to learn the topic. The elements are visualization strategies, student's centeredness, teaching presence and meaningful learning theory. Figure 7 shows the Engineering Drawing Learning Framework based on AREDApps.

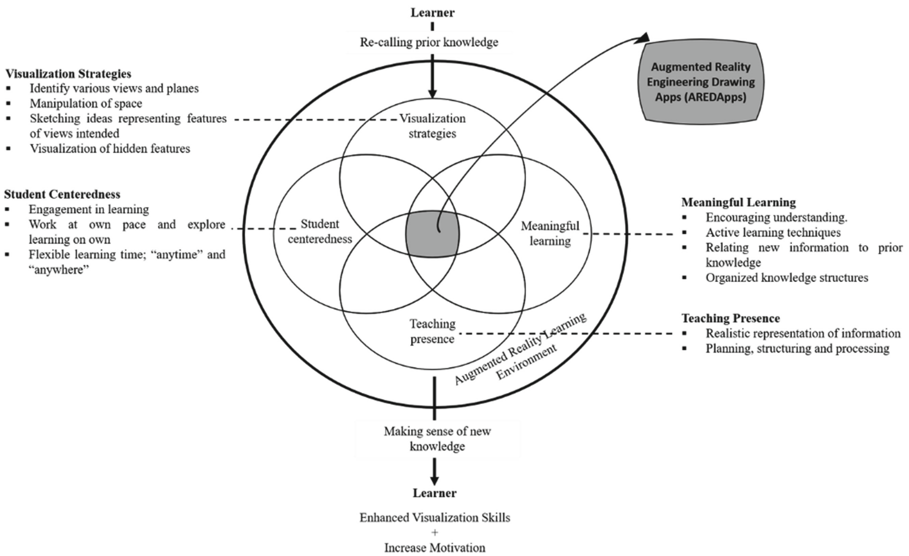

Fig. 7. Engineering Drawing Learning Framework based on the implementation of AREDApps

Educators are responsible for ensuring that all indicators are achieved to further improve teaching quality and enhance student learning. The framework in this study aims to support the learning practices of educators in engineering drawing classrooms using the augmented reality environment produced in this study, the Augmented Reality Engineering Drawing Apps (AREDApps). Using this framework alongside AREDApps as teaching and learning tools, students will be able to make sense of the new knowledge they have constructed in the classroom. Also, it helps to improve student visualization skills and motivate learners to study engineering drawing.

The first element, which is teaching presence, is crucial in the teaching and learning process. Teaching involves educators formulating an opportunity for students to learn [15]. Examples of teaching presence are giving direct instruction such as recommendations or information, facilitating students by posing questions to encourage students' further thoughts on a topic and give feedback to the students by agreeing or criticize their ideas [16]. The study also identified an indirect positive impact between teaching presence and student satisfaction as well as learning performance. There is proven to be equally great importance between teaching presence and levels of learning based on previous studies [17]. Therefore, by incorporating the elements of teaching presence in the teaching and learning process by AREDApps, students will be able to learn actively with their classmates and construct the meaning of the topic they will learn.

The second element in the framework is student-centeredness. Among college students, various issues are being highlighted regarding their learning behaviour. Some of them are low-class attendance, lack of class participation and not conducting reading assignments [18]. This issue is sometimes due to the types of approaches in the teaching and learning process that do not encourage and motivate students to be involved in the classroom. Unattractive teaching practices and lack of sense of community with classmates are among the reasons that hinder students interests to learn [19]. However, by implementing student-centred learning, educators will be able to create a meaningful learning experience and help them actively learn, apply their skill, care for their learning and the most important thing is learn how to learn. Student-centred learning is often associated with technology-enhanced learning.

Visualization strategies are also one of the elements in the framework developed in this study. Various research has illustrated a potential for visualization skill to be developed and their effect on academic achievement. Visualization skill also becomes increasingly linked to the Science, Technology, Engineering and Mathematics (STEM) field [20]. Using AREDApps, the researcher aims to help educators collectively improve students' learning experience and visualization skills during the teaching and learning of orthographic projection topic in an engineering drawing course. By emphasizing the visualization strategies element in the framework developed from this study, students are expected to see significant improvement in their visualization skills after learning AREDApps.

According to Ausubel in Vallori [21], learning is influenced by the students' prior knowledge. Thus, making meaningful learning is a process that implies knowledge being retained much longer than memorizing. Meaningful learning occurred when learning implemented an active, constructive, and goal-oriented process involving problem-solving while strongly influencing one's prior knowledge [22]. Furthermore, this situation occurs when students can relate new knowledge with their prior knowledge. By giving students materials that they can relate to, students will contextualize what they learned [23]. Meaningful learning is much more preferred than rote learning due to the nature of this learning process that encouraged students to construct meanings from what they learned actively. When meaningful learning occurs, knowledge gained by students will be most likely be stored in the long-term memory storage.

4 Students' Perception on Using AREDApps

This section analyses the students' perception of learning engineering drawing using AREDApps. When developing an application as a tool specifically made for teaching and learning purpose, it is crucial to know the users' perception when using the tool. In this case, it is essential to know the students' feedback on using AREDApps towards improving their learning experiences and visualization skills. A total of 30 students were involved in teaching and learning of engineering drawing course using AREDApps. The students' involved are first-year engineering students in a public university in Malaysia. A questionnaire is developed to identify students' perception of using AREDApps by the researcher, where the students were asked to answer the questionnaire based on the scales provided (SA: Strongly Agree, A: Agree, D: Disagree, SD: Strongly Disagree). After the use of AREDApps, Table 1 shows the students' perceptions when learning using AREDApps.

Table 1. Mean and standard deviation score for students' perception using AREDApps

No.	Items	Mean	Standard deviation	Level
1	AREDApps helps me to memorize the content of this topic	4.20	.484	High
2	AREDApps content delivery is simple, concise and orderly which is easy to follow	3.97	.490	High
3	AREDApps help me in getting better picture (realistic) towards the content of this topic	4.10	.403	High
4	AREDApps helps me to relate the content of this topic with the real world	3.90	.712	High
5	Usage of AREDApps increase my interest towards this topic	4.47	.507	High
6	Usage of animation/graphic/3D model in AREDApps is more helpful to me compared to explanation lecture method alone in understanding the content of this topic	4.23	.626	High
7	I prefer learning through AREDApps compared to printed note	4.53	.629	High
8	By learning using AREDApps, i can reduce my study period compared to learning through printed notes	4.23	.568	High
9	AREDApps helps me to visualize the view of given object more easily	4.63	.490	High
10	AREDApps helps me to visualize side views of each object more easily	4.50	.509	High

5 Discussion

In orthographic projection, students need to master problem-solving skills. According to Frerejan et al. [24], several steps need to be followed for a practical problem-solving approach. Students must be able to explore, construct and understand the concept of this topic for them to solve the problems in this topic. Thus, educators must provide an environment that allows students to implement these steps in their learning. Providing quality teaching presence will positively impact students' learning behaviour, improve their learning motivation, and indirectly improve their learning performance [25].

Using AREDApps allows students to learn at their own pace by exploring all the tutorial videos and solving the exercises with the help of the augmented three-dimensional virtual objects. Other than that, the student-centred learning approach also helps increases retention and understanding of the knowledge. This is because the students apply all learning activities during the teaching and learning process, while educators facilitate the learning process by providing support when there is a complex concept that needs to be clarified.

In this study, visualization strategies consist of few activities such as identify various views and planes, space manipulation, identifying axes, sketching ideas of views, and visualizing the hidden features of the given object. The use of three-dimensional virtual objects in AREDApps provides a realistic experience that promotes visualization activity [26]. By providing means for visualization strategies in AREDApps, it enables the student to improve their visualization skills throughout their learning process. The visualization strategies incorporated in AREDApps enable students to understand the fundamentals of multi-views and allow them to see hidden views, which are difficult to explain only by using two-dimensional representations of three-dimensional objects. When using AREDApps, students can view the objects in three-dimensional views and sketch the respective image simultaneously to ensure the images that they mentally construct are precisely interpreted. Emphasizing all these visualization strategies in the framework can increase the efficiency and effectiveness of implementing AREDApps in engineering drawing classrooms.

Integrating this framework while implementing AREDApps as a teaching and learning aid for orthographic projection topic will help students make sense of new knowledge, enhance their visualization skills, and increase their motivation to learn. With the evidence from this study that proves to learn that using AREDApps positively impacts students' visualization skills, it is recommended for educators to practice using AREDApps in their classroom. Educators need to be able to provide various approaches in their teaching and learning process to help increase their teaching quality and improve students learning experience.

Based on the study results, the respondents in the experimental group are all satisfied and acknowledged that the use of AREDApps in teaching and learning orthographic projection would help them improve their learning experience and help them understand the content of the study lesson. The majority of the students are satisfied and interested in learning using AREDApps. According to the majority of the respondents, AREDApps helps students to visualize the views of the objects easily. This is based on the highest and second highest mean scores among all the items in the questionnaires. The items with the highest mean score are "AREDApps helps me visualize the views of given objects more easily" and the items with the second highest mean score are "AREDApps helps me visualize side views of each object more easily".

AREDApps provides an environment where students can manipulate, hold, and observe virtual 3D objects that then give the object's existence and location. This activity is called perceptual activities that can help improve visualization skills [27]. This statement also supports Piaget's allegations that allowing students to experience an environment involving space and object in space will help improve visualization skills [28]. With the integration of augmented reality environment in AREDApps, students can improve their visualization skills during the teaching and learning process and enable them to perceive correct views of the 3D objects accurately. With the proper design and development of AREDApps, students can experience exciting and efficient teaching and learning process. In this study, the factors that contribute to the effectiveness of AREDApps in increasing student's motivation is the types of technology integrated into

AREDApps, learning materials, and their satisfaction towards AREDApps. The findings in this study are consistent with Sungkur, Panchoo and Bhoyroo [29] that the use of mobile augmented reality helps students visualize and understand complex concepts.

6 Conclusion

In conclusion, visualization skills are essential in Science, Technology, Engineering and Mathematics (STEM) field, and it is essential to emphasize the skill during their early years of study. Furthermore, educators must improve students' visualization skills during an engineering drawing course due to their high spatial content. It is also because visualization skills are one of the predictors of success in engineering and technical career. Producing quality graduates with excellent visualization skills enables them to have good graphical communication skills and problem-solving skills. These skills will contribute to their competence as an engineer in the future. Hence, this study could be an exposure among other engineering drawing educators and other fields to encourage them to implement augmented reality technology in their classroom. With the positive findings on the use of AREDApps in this study as well as the implementation of the learning framework, it is proved that AREDApps and the implementation of the engineering drawing learning framework developed in this study can be used as visualization tool as well as able to increase students' learning motivation and interest. The researcher hopes that this study will serve as a guideline for future researchers and educators to explore further the augmented reality's potential in the educational field, especially in an engineering and technical field, to improve the quality of education in Malaysia.

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