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A Conceptual Framework on the Development of Augmented Reality Engineering Drawing Learning Framework based on Augmented Reality Environment

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Abstract

The utilisation of augmented reality for teaching and learning has become increasingly prevalent within the context of education. Augmented reality has been incorporated into the educational landscape across several disciplines, including engineering, for both primary and tertiary education settings. Nevertheless, there is a lack of research that has delineated the guidelines in the form of a framework for using augmented reality in the context of engineering drawing disciplines. This article presents a suggested conceptual framework for the development of an augmented reality engineering drawing learning framework. The aim is to enhance the efficacy and enjoyment of learning engineering drawing. The researcher intends to demonstrate the association between the necessary components for the development of a successful augmented reality engineering drawing learning framework, using the given conceptual framework by highlighting related theories and models.

Keywords: Conceptual Framework, Augmented Reality, Engineering Drawing, Environment, Framework

Introduction

According to Afolalu *et al* (2021) the fourth industrial revolution or also known as industrial revolution 4.0 was defined as the application of cyber-physical systems to the industrial production systems. This revolution generally implemented the use of internet technologies into industry. Recently, it has become a top priority for various research centers and universities Mian et al (2020) In the future, there will be more jobs created due to the impact of the revolution that will emphasize more on the automation of the production process. With the introduction of the fourth industrial revolution in Malaysia, there will be changes to our daily lives, including our education systems. There will be more transformations made related to the integration of technology, especially in higher education as a result of this revolution in order to create technological awareness and readiness among all future engineering graduates.

Today, education plays an important role to help a country in realizing their vision as well as promoting their economic growth. Among all fields, engineering field is one of the critical fields to ensure the growth of a country. Recently, progressive changes have occurred within the engineering field, especially involving technologies specialties Nahm (2021) Based on that, technologies have been predicted to transform engineering education in the next 50 years (Froyd et al., 2012). This transformation is due to the rapid development of technologies in recent years that witnesses many new inventions in technology devices and information technology. Furthermore, engineering education has been facing numerous challenges where various researcher claimed that there should be a reform in terms of its curricula and teaching methods. According to Tri et al (2021) educational reform should be implemented to establish a new learning standard with the incorporation of technology as an integral part of the learning process.

For the past 100 years, there have been few significant shifts in engineering education, including an emphasis on the engineering design course, application of research in education and transforming education with technologies. According to Qadir *et al* (2020), ability to design is crucial for engineers, including their teamwork and communication skills. To master engineering design, students need to grasp the basic of the design itself, which is the drawing. Good design ideas without its proper respective drawing will lead to the failure of the idea deliveries. Therefore, during the first year of engineering studies, students will have to enroll in an engineering drawing course which is made compulsory for almost all engineering courses. Engineering drawing course aims to provide basic engineering knowledge to first-year students in engineering faculty. This course will help students understand the complex content of other engineering subjects by introducing the basics of engineering content (Ricaurte & Viloria, 2020) during their early years in engineering studies.

According to Marunic and Glazar (2013), there have been various efforts done by authorities 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 topics such as 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. Visualization skills can be defined as the ability to create images, diagrams, or animation to deliver messages (Borner et al., 2019). Learning engineering drawing requires students to create 2-dimensional images from its respective 3-dimensional shapes and vice versa. This process is to ensure the development of their ability to transfer ideas in forms of drawings which are commonly used as a mean of communication in technical and engineering field.

Nowadays, augmented reality technology has been used in almost all field due to its possibility to bridge the gap that exists between the physical world and the digital world (Turner, 2022). Many other potential benefits have been identified from implementing augmented reality, especially in education. However, research by Alzahrani (2020) found that augmented reality has enormous potential to support the improvements of students' visualization skills or spatial abilities as well as promotes problem-solving skills by allowing the students to view, touch and manipulates the objects or design. Other than augmented reality, many technologies have been identified and used in an educational setting, which supports students' learning and skills enhancement compared to conventional methods. Thus, it is crucial for the current researcher to continuously search for the best technology-based teaching method and approaches to match the current trends today.

Literature Review

Engineering Drawing

Several initiatives have been undertaken to outline plans for reforming engineering education. This is due to the role of academic institutions in the development of professional engineers' identities and abilities (Collins, 2018). Among all the major shifts in engineering education, one of the ongoing major shifts, which are the emphasis on engineering design course plays a huge role to ensure the success of future engineers. This is because engineering design has been proven to be a predictor for success as an engineer. History proves that drawing or also known as "universal language" have existed since a long time ago. According to Fan *et al* (2023), drawing is considered as a method for humans to communicate the visual images mentally in a natural way graphically.

Fowler (2018) claimed that engineering drawing is particularly a language for engineers. Furthermore, engineering drawing is offered as a compulsory course for engineering students in almost all engineering faculties. Engineering drawing course aims to give students the ability to apply the spatial and graphic representations such as multi-views and pictorial projections (Marwa et al., 2021). Other than that, learning engineering drawing helps provides knowledge on descriptive and metric geometry.

The ability to accurately read and comprehend technical drawings is essential for every engineering practitioner, as is the preciseness of technical drawings used in the planning and production process. According to Shreeshail and Koti (2016), an inability to understand or interpret a technical drawing might have a more substantial influence on the entire process of developing and producing the product. In their study, Adams et al (2022) also emphasised that it is vital to portray the difficulties pictorially before initiating any operations in order to avoid more intricate problems that may occur later. According to Azodo (2017), one way to cut down on the number of mistakes made while reading technical drawings is to acquire the skills necessary to make high-quality technical drawings that include comprehensive specifications.

According to Siminialayi and Fomsi (2018) students need to know the basics of "technical" drawing before exposure to the CAD environment. This is because students are not exposed to a drawing board and set squares when learning CAD. Exposing the students directly with the CAD environment hinder their understanding of the basics of technical drawing, thus affect their performance negatively. Other than that, they also stated in their study that the majority of CAD experts have weak spatial intuition and reasoning. Zorn and Gericke (2020) identified in their study that CAD experts that have been exposed to the basic technical drafting foundations have improved their visualization skills. The study proved that hands-on drawing helps improve visualization skills significantly compared to learning CAD solely.

Some students have trouble understanding and learning the idea of orthographic applications such as projections, orthographic to isometric transformation, dimensioning, and a few more (Ali *et al.,* 2021). Some students have difficulty understanding and mastering the notion of orthographic applications. Students also reported having difficulties with their capacity to mentally view or visualize the objects, which was closely related to the difficulties associated with a lack of visualization skills (Baronio et al., 2016).

Understanding orthographic projection concepts require students to be able to visualize the spatial representations of the objects. Students with weak visualization skills will have difficulties performing this action. According to Alzahrani (2020), students often faced difficulties while visualizing complex phenomena, which is challenging to be viewed neither in the real-world or complex concept. This issue occurs due to the students' inability to relate the concepts with the real world or situation where many educators mostly will utilize the cardboard models built in order to relate the real world with the concepts.

Another problem identified related to this study is the difficulties to understand projection views due to the lack of ability to imagine images in three- dimensional scenarios (Azodo, 2016). Students who are lacking in visualization skills tend to use trial and error method due to the lack of proficiency in solving the problems (Song, 2020). The use of trial and error method when solving the tasks should be a concern among educators considering that difficulties in learning engineering drawing are likely to be reflected on students' performance (Cole, 2014). Students' engagement in teaching and learning process should involve their skills development too rather than solely focusing on training the students to perform well on the exam questions. Thus, educators should emphasize more practical implementation approaches to improve students' skills and knowledge rather than concentrating on the concept alone.

Teaching Method

In engineering drawing, the most common strategies used in the classroom are the use of conventional marker and board where the educator utilizes demonstration methods to show the steps to create technical drawing at the front (Sutton et al., 2016). Other than that, most of the educators also use real cardboard to construct three-dimensional models to reinforce the three-dimensional concepts. With the lack of emphasis to train visualization skills in engineering drawing classroom, educators often rely on the students to improve themselves in terms of visualizing three-dimensional objects skills. (Mavinkurve & Verma, 2016). These approaches does not promote active learning thus hindering the students from fully understanding the concepts. Students will easily forget what they have learned in the class and failed to implement the concepts accurately (Liono *et al.,* 2021).

Learning three-dimensional concepts through sketching which is the most common method used in engineering drawing classroom is one form of passive learning. This method caused a heavy cognitive load among students during the learning process (Knuckles *et al.,* 2020). By letting students indirectly figure out spatial information using two-dimensional format and imagining three-dimensional patterns based on a two-dimensional display, educators are forcing a great deal of energy to be used during the learning process. This is because, instructions of three-dimensional geometry concepts using two-dimensional space does not present an accurate distance and volume of the objects (Kench & Cooper, 2021).

Another example of teaching engineering drawing in conventional ways is by using a wall map and model to convey the concept of projection. Besides, educators also tend to show a three-view diagram as a way to help students visualize three-dimensional objects (Guo *et al.,* 2022). This material lacks spatial information as students are generally unable to rotate and manipulate the diagram to see perspectives from the side, front and top as needed in orthographic projection topics. Students with low visualization skills might also fail to relate to the diagram.

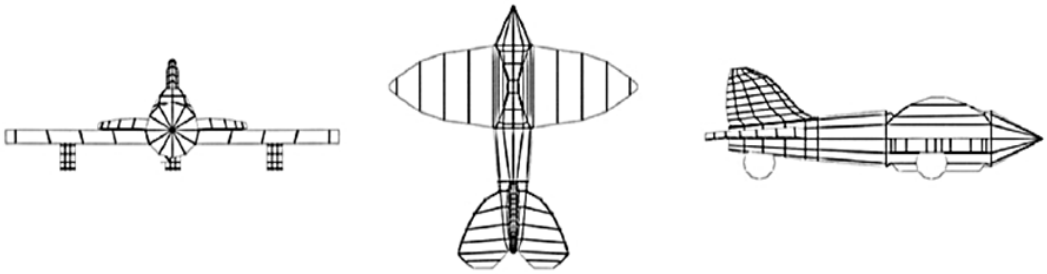

Figure 1. Three-view diagram (Khabia and Khabia, 2012)

Khabia and Khabia (2012) have identified several problems among educators while teaching engineering drawing. The problems are listed below:

1. Difficulties in explaining three-dimensional concept just by using static models or diagrams as well as giving lectures
2. Reducing the class control during drawing demonstration on the board
3. Teachers often obstruct the students' view from the board when they demonstrate drawing steps using instruments on a vertical board.

However, advancement in information technology has offered various options for teaching and learning approaches for educators to choose based on their course needs. According to Dauer *et al* (2019), computer-based materials or tools enables students to extract and process complex information which allows them to construct a high-quality mental model. In short, using suitable technology in teaching and learning process have the potential to help develop visualization skills which are much needed in the engineering drawing course. . Based on the studies conducted to study the effectiveness of each technology in teaching and learning according to different courses, augmented reality has shown a positive impact on developing visualization skills (Gonzalez, 2018). Augmented reality has proven to help students visualize the volumetric and generates representations of objects and space in real-time. Students also show a positive attitude towards the implementation of AR in the classroom (Hsu et al., 2017).

Augmented Reality

Augmented reality technology can be defined by three properties (Azuma et al., 2001) which are:

i. The system must be a combination of real and virtual objects in a real environment.
ii. Aligned the real and virtual objects together simultaneously.
iii. Runs interactively in real-time.

There is a various researcher that implements augmented reality in education fields, especially for science, anatomy, architecture, and geography course (Park *et al.,* 2016). The advantages that this technology offered are the reason why people in the various field have come to see this technology as one of the emergent technology recently. Other than the education field, augmented reality also has been used in clothing, automobile, and biomedical industry (Omar *et al.,* 2019). 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 the implementation of this technology. The results from all these studies showed that the application of this technology actually could especially elevate students understanding of complicated concepts and improve visualization skills in various course and areas.

The use of static images is already considered as obsolete among new generations (Gonzalez, 2018). The new generation prefers the integration of three-dimensional virtual objects with real-world approaches that they could interact with the virtual objects freely. Besides, the new generation today are overly exposed to digital visual space (Qi *et al.,* 2021) since they were kids. Augmented reality has been used by various researchers to study its impact on improving students' learning, motivation, performances, and visualization skills. When learning a complex concept, especially those with high spatial information, students will tend to overuse their cognitive load. According to Hsu et al (2017), there is a positive correlation between engineering and visualization skills. The correlation is due to claims that visualization skills can help reduce cognitive load during learning. This is why implementing augmented reality in the engineering classroom will help students to understand and visualize difficult objects and automatically reduces their cognitive load (Juidias et al., 2017).
Even though there has been some research on the development of augmented reality applications for engineering drawing courses, there has been lack of studies on the teaching and learning framework based on augmented reality application in an engineering drawing course. Most of the framework developed in the augmented reality field is a component-based framework that focuses on the technical aspects when developing augmented reality applications (Behzadan & Kamat, 2012; Kodeboyina & Varghese, 2016). Some of the technical aspects are the hardware platforms and applications used when developing augmented reality applications. To ensure the effectiveness of augmented reality applications towards students learning, especially to achieve the purpose of developing the application, the researcher needs to develop a framework that focuses on the learning elements.

Development of Conceptual Framework
The conceptual framework in this study consists of a few theories and models used in developing AREDApps. The theories and models consist of Cognitive Theory of Multimedia derived by Mayer Mayer (2014), Information Processing Theory Atkinson & Shiffrin (1969), Constructivist Learning Theory Hein (1991), McKim's Visual Thinking Model Hester (1973) and ADDIE Instructional Design Model. All these theories and models are used in the development process of AREDApps. The selection of these theories and models is based on the previous researches that adapted these models into their research.

An efficient method for quality teaching should consist of three cognitive processes according to the Cognitive Theory of Multimedia. It consists of selecting, organizing, and integrating processes that can cause meaningful learning if the processes are appropriately utilized (Mayer & Moreno, 1998). Selecting is a process where important information such as words and images are selected to be processed in verbal working memory, organizing is a process where this selected information is organized into a verbal and pictorial model and integrating is a process of building relations between the verbal and pictorial representations along with students' previous knowledge. A good teaching and learning aids require all three processes to be properly followed as guidance throughout the development process. This is to ensure that students will be able to fully benefit from using the augmented reality learning environment during the lesson.

The conceptual framework for this study begins with identifying the effective characteristics for augmented reality learning environment based on multimedia and visualization components. Based on the effective characteristics identified in this part of this study, the characteristics is then integrated in the process of developing the augmented reality learning environment, which is the teaching and learning aid named as Augmented Reality Engineering Drawing Apps (AREDApps). Other than that, proper instructional design was also strictly followed and planned in order to produce high-quality teaching and learning aid. Other than the theories explained above, this conceptual framework also emphasizes on the importance of constructivist learning environment to be implemented in the development of this teaching and learning aid. AREDApps will be designed in a way that allows students to learn actively and become engaged with the learning process. By using constructivist learning environment, educators will act as facilitator and students can explore and manipulate the knowledge given to them which can help them to apply the knowledge within the environment Chuang (2021) This teaching and learning tools also satisfy all five components of constructivist learning environment which consist of problem-project space, related cases, information resources, cognitive tools and conversation, and collaboration tools that can provide students with the engaging task. This is by introducing the elements that promote self-learning in the tools itself which can help students to experience meaningful learning.

Cognitive theory of multimedia derived by Mayer also is used in the process of developing AREDApps. This is because AREDApps consists of a combination of images and words in it. Using pictures and words to build students mental representations are called multimedia learning, and this situation allows students to learn more deeply (Matias & Agapito, 2022). Throughout the process of developing AREDApps, three cognitive processes in this theory are followed. The first cognitive process is selecting only relevant words and images to be included in AREDApps. Next is organizing selected information properly according to the correct order and lastly integrating, which is building connections between the verbal and pictorial representations with students previous knowledge. This is to make AREDApps interesting and understandable towards the students. In addition, Mayer's principles are also used in the design of AREDApps involving multiple representation principle, contiguity principle, split-attention principle, individual differences principle and coherence principle (Moreno & Mayer, 2002).

Next, McKim's Visual Thinking Model is also used in the development of AREDApps. This model stated that effective visual thinking occurs when the learners perform three actions, which are seeing, imagine, and drawing simultaneously (Hester, 1973). The use of visual thinking will help students to view problems in different angles and allows them to imagine alternative solutions. In this study, the use of AREDApps equipped with the augmented card will ease the process of visual thinking, which will consequently help students to solve the problems in engineering drawing. Allowing students to see the real-like objects help students to see and imagine the objects better, thus allowing them to draw their respective views more easily. This model promotes the act of seeing, imagining, and drawing in which it is said to help enhance students visual thinking skills as well as visualization skills. Thus, by implementing this model in the development of AREDApps, students will be encouraged to perform these three actions throughout their learning.

Besides having theories and models in the process of developing AREDApps, the ADDIE model, or also known as systematic teaching design, is used to ensure that the objectives of teaching are accomplished based on learning outcomes. Figure 1.2 shows the ADDIE instructional design model.

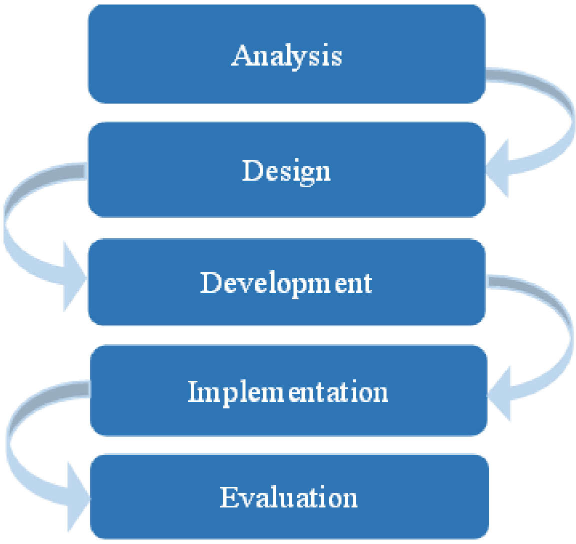

Figure 2. ADDIE Instructional design model

ADDIE instructional design model comprises of five-phase, which is analysis, design, development, implementation, and evaluation phase (Sahaat *et al.,* 2020). This model is a systematic method to promote effective learning by students Spatioti et al (2022) that can be used for various types of information. Development of instructional courses usually utilizes this model because it is based on the students rather than the teacher. This model provides students with an active setting to encourage them to solve learning problems (Wang, 2021).

The first phase of this model Is analysis, where the main focus for this phase Is the target audience. Needs of the audience, standards, and competencies should be identified to find out what the students will achieve at the end of the course. Performing task analysis is essential to identify content and specific skills related to the course Rios et al (2020), while instructional analysis is done to establish things students should learn (Rasmitadila *et al.,* 2020). In terms of designing AREDApps, this phase includes identifying students' level of visualization skills and the problems that they face while learning orthographic projection. Previous literature that highlights this issue is identified and emphasized in the background of problems. This step helps the researcher to identify the roots of the issues that students face while learning orthographic projection and allows the researcher to formulate ways to counter the issues identified. Other than that, the multimedia and visualization components obtained from the experts will also play a significant role in the development of AREDApps. The components are essential towards developing a high-quality teaching and learning aids.
The next phase Is the design phase. The Implementation of a constructivist learning environment during this phase will help emphasize the students as an active learner, learning through collaboration as well as gaining knowledge through experimentation. With the

implementation of teaching and learning tools like AREDApps, students are now able to manipulate the three-dimensional virtual object to fit their understanding. Students collaborate with classmates to address problems, and this scenario will encourage them to engage actively in the learning process, making the learning process meaningful. According to Chuang (2021), the constructivist theory emphasizes the learning environment as it is crucial for the learning process, and it plays a vital role to influence learning. Data from the previous phase is considered in this phase in determining the methods to assess the objective. A functional assessment technique with various methods will grab students' attention and can contribute to their satisfaction in learning.

In the development phase, considering the outcomes from the previous two phases, the development of the product began. In this phase, three parts are emphasized consisting of drafting, production, and evaluation where the evaluation for this phase are using a developmental approach to determine the quality of the product. In this phase, all the theories chosen in this study will be implemented to produce or develop a proper teaching tool that will benefit the students throughout their learning process. The next phase is the implementation phase where students and teachers must take an active role to contribute to the Implementation so that modification can be made in ensuring the effectiveness of the designed product. The last phase for this model is evaluation. Evaluation can occur in each phase in the model and are essential in the process. It can occur in the development phase in form or formative evaluation and at the implementations phase as summative evaluation. The purpose of the evaluation is to ensure previously identified problems have been solved and to determine the product changes needed in the future. For the development of AREDApps, the evaluation process is necessary to ensure there are no weaknesses in the AREDApps and to make improvements based on the gaps found. After the completion of the development of AREDApps, the effectiveness of AREDApps in enhancing students' visualization skills is determined. Few sets of standard short-version visualization tests are used to measure the visualization skills of students. Also, their perception of learning engineering drawing using AREDApps has been evaluated using a set of questionnaires.

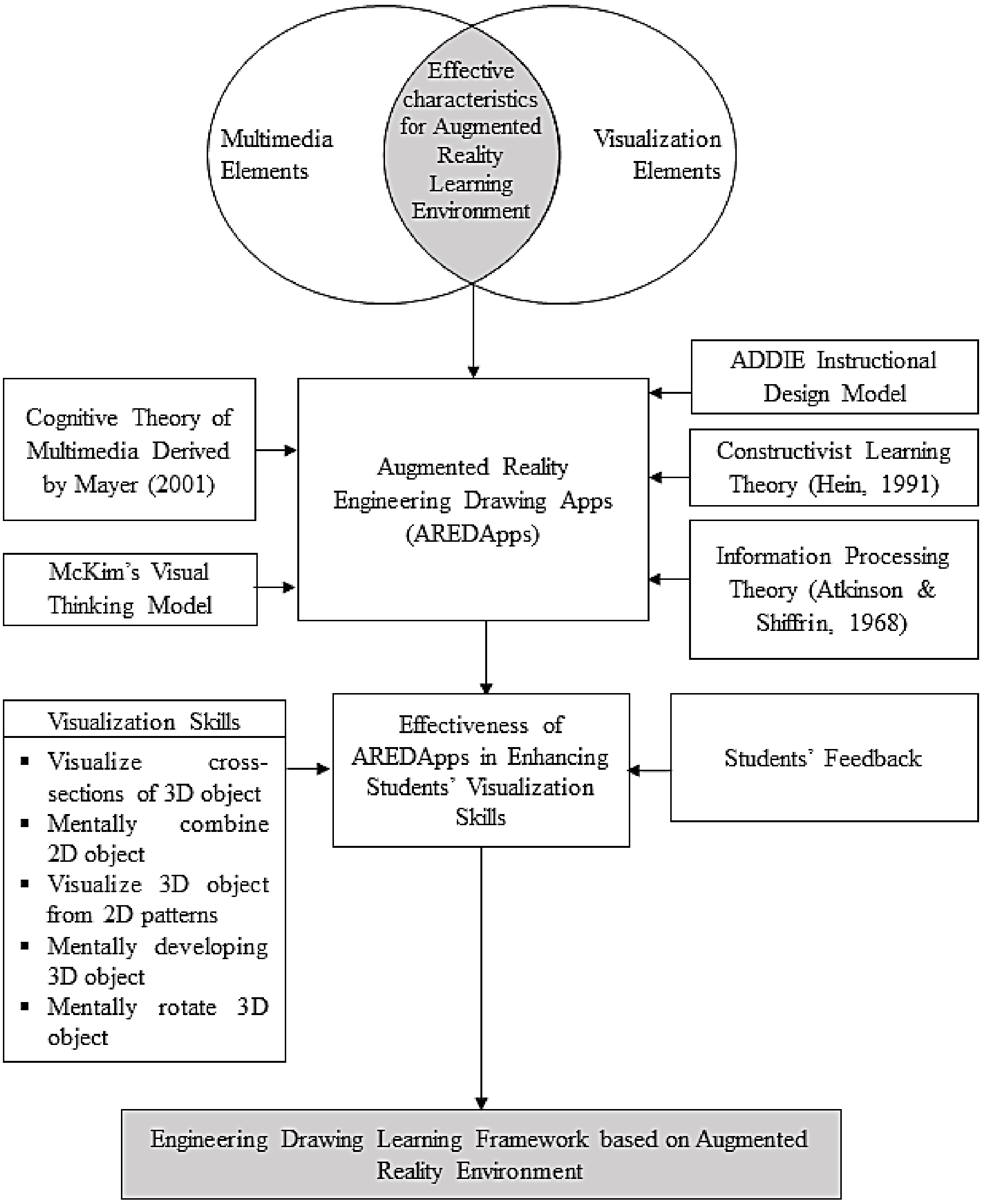

Figure 3. Conceptual Framework

Conclusion

This study emphasizes on the theories and models used to develop the Engineering Drawing Learning Framework based on Augmented Reality Environment. There are several theories and models such as Cognitive Theory of Multimedia derived by Mayer, Constructivist Learning Theory, Information Processing Theory, and Mckim's Visual Thinking Model. The conceptual framework act as a guidelines for the process of developing the framework which can give more understanding on the process from the beginning to the development of final product. To sum up, it is important to identify elements from theories and models that can contribute to the effectiveness of a teaching and learning tools as well as knowing the process involved in the development of the framework which could help the educators to teach engineering drawing more effectively. Augmented reality is a technology that has yet to be fully explored in which it holds a great potential to be used in the educational field. Implementing and experimenting with the latest technologies, especially in the engineering and technical field, could serve as a great effort to revolutionized teaching and learning in higher learning institutions in Malaysia. It is also parallel with the sustainable development goals which is to provide quality education.

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