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The Impact of AR Environment in Enhancing Visualization of Petroleum Refinery Process

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Abstract
Petroleum refinery is an industrial process plant where crude oil is being transformed and refined into most useful products. In the industrial process, it involves a lot of complicated physical and chemical processes that are sequentially applied for various refinery processes. Some employees are facing a difficulty to understand the training module because the tools being used limits the ability to learn and understand the abstract complex process and face the challenges to visualize the content as it is viewed via a two-dimensional (2D) method. Therefore, this paper tries to focus the attention on the practical use of AR in the crude oil refinery process, describing the potential and the effectiveness of this technology to enhance their visualization skill. The study used quasi-experimental research design on the technical employees that were trained on the basic refinery process of crude oil. Two groups of samples consist of an experimental group who were exposed to the AR environment and a control group that was taught using conventional training methods. The result demonstrated there is a significant difference between the scores obtained by the technical employees in the experimental group, thus the application of AR was able to enhance technical employees' visualization skills as a training approach.
Keywords: Augmented Reality, Visualization Skills, Visualization Ability Test, Crude Oil Refinery Process.

Introduction

The crude oil refinery process is the important aspect to be learned as technical employees before entering the plant operation, studies were conducted to investigate the difficulties facing by the technical employees. One of the reasons highlighted in learning and training activities involved difficulty in the representation or in seeing and viewing of a three-dimensional (3D) object known as poor visualization skills (Esparragoza, 2015). Visualization skills is a process that construct visual images from physical world to people's mind or it can be reflect the knowledge to the physical world (Jansen and Dragicevic, 2013). Current research findings have proved that the visualization of 3D elements plays an important role in education to identify the complex concept of the elements to enable users to have better understanding of the concepts (Han et al., 2021; Atabekova, 2017). Through visualization, the features that create an object, body, behavior, action, process, or activity looks visible. To enhance visualization skills, it means to improve the ability to process and interpret visual information, thus it can be generated ideas and transformed it into concrete image and objects.

Visualization in the oil and gas industry is generally considered as a proven tool for characterizing and understanding surface and subsurface phenomena (Ivson et al., 2019) particularly in the exploration and refining of crude oil. However, many researchers found that visualization skills are significant issues that lead to low performance in carrying out the task in oil and industry. A study also found that the employees have issues in visualizing and representation of the physical asset in its real-world context, mainly representation of the equipment in the plant operation at the workplace. This is probably caused by the failure to identify and does not have a visualization technique in imaging a 3D object of plant operation. Therefore, technical employees need to master visualization skills to fulfill the task at the operation.

However, the training module that is currently used does not support the enhancement of technical employees' visualization skills. Many of the technical employees are facing the problem in processing and understanding the visual information or developing mental images at workplace. Technical employees are facing difficulty to understand well or better on the current training module because the current approach and tools being used limit the ability to understand the detailed complex process, as it is viewed in conventional 2D and not using latest technology approaches such as Augmented Reality or Virtual Reality in the teaching and learning approach. Meanwhile, the training module is an instructional guide, a specific module that is created and designed which is used for teaching and learning activities. According to Cheng and Bakar (2020), the module is a book or workbook of reference that has been developed to fulfill the needs and interests of the learners. It also contains directions for users to perform tasks, as a means of practicing the learning and to assess the learner's comprehension. Using a module in learning activities is meant to increase active learning and improve critical thinking. Critical thinking is essential to overcome various complex issues in our life where this skill is associated with thinking activities to evaluate the ideas without judgment (Andriani and Suparman, 2019). Study has found that creative learning speeds up the learning process and enhances students' performance (Kowang et al., 2020). Furthermore, understanding the student engagement in the learning activities encourages more than just active learning is the first step toward innovative teaching (Phan et al., 2021). However, when the trainers are too focused on their content delivering in a traditional way, it will be impotent to build conceptual understanding while neglecting to apply visualizations skills among the technical employees. According to Mun et al. (2019), learners should be able to apply what they are learning to daily lives and relate based on their experience. To obtain understanding in the learning of crude oil refinery process, it requires them to see objects, images of what it looks like from different perspectives and different views. Fig. 1 below shows the visual thinking model that consists of three types of visual imagery that are the way people see, the way people imagine, and the way people draw.

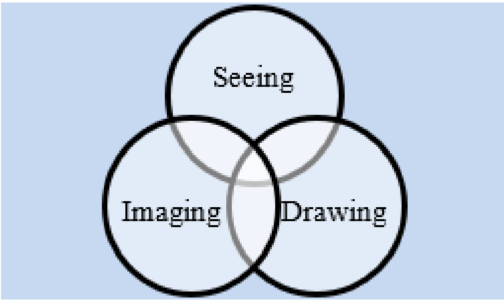

Fig. 1. Visual Thinking Model (Mc Kim's, 1980)

Based on the visual thinking model, the interactions between the three aspects that are seeing, imaging, and drawing will continue until the contents are visualized and the problem is being solved. Therefore, visual thinkers applied the elements of seeing, imaging, and drawing in a fluid and dynamic approach, thus moving from one image to another (McKim, 1980). Because of that, it is essential for the trainers to allow the technical employees to make use of all types of imagination to help them to gain an effective learning and improve their visualization skills. This approach can be done through the application of new technology to cater these issues.

In the oil and gas industry, especially in the basic refinery process, skills training and discovery-based learning are suitable to implement augmented-reality environment approaches. Basically, the implementation of augmented reality should be aligned and appropriate with the topics and content because it might not be the best approach for all educational settings and issues in the oil and gas areas. However, this new technology will let the users visualize abstract concepts and understand better about the crude oil process, as well as any issues that may occur (Ginsburg, 2013). Jabar et al (2020) stated that teaching and learning through conventional methods such as chalk-and-talk, lecture based, and teacher oriented based learning does not give an impact to the learning in this digital world. According to Diaz et al (2015), the use of augmented reality is to improve learning experiences in the classroom. Augmented reality technology has also gained an increasing interest in teaching and learning due to its interactivity (Omar et al., 2019). It is useful in engaging learners as well as to motivate them to discover knowledge and apply to the real environment, because learners can easily interact with the virtual (Martin-Gutierrez et al., 2015).

Augmented reality obviously seen as a technology that offer a particular tool in the process of making the content of teaching looks attractive as well as improving visualization (Martin-Gutierrez et al., 2013) by integrating the objects of real environment, digitally processed, and producing it through digital devices (Aldalalah et al., 2019). As mentioned by Ali et al (2012), visualization skills are important especially for engineering professionals to solve engineering problems. It also can enhance learner's conceptual understanding as they are dealing with the duplication of real objects or situations. Therefore, it is a great opportunity to prove the effectiveness of this technology in enhancing technical employees' visualization skills for crude oil refinery process topics.

Method

Theory of constructivism and ADDIE Model was implemented in development of AR training courseware to obtain better understanding among the technical employees. Generally, this model consists of five different phases which are analyze, design, develop, implementation and evaluation phase, to keep enhancing the training experience. In the analysis phase, researchers determined the needs of the technical employees. This includes the objectives to be achieved and the goals to be accomplished. In the beginning stage of analysis, systematic planning was required before the process of courseware development was conducted to ensure the learning outcomes from training courseware to be more effective to the learners. In the design stage, the storyline was developed to ensure the content and flow of the courseware followed correctly. Then, the storyboard was drawn in the PowerPoint template to describe the objects and the "story" on the screen. At this point, the design for each process of the crude oil, the equipment's of the plant operation was emphasized by the combination of text, images of the objects and audio to help the learners understand thoroughly and to see how each element combined to be transformed in the new concept.

The process of development of the courseware involved the combination of multimedia elements. Since the technology continues to evolve, the researcher also used the interactive digital of augmented reality in the courseware with the main idea to connect users to experience the real world. This technology is used to provide facilities for users to carry out the learning process in the form of 3D animation to help them gain better understanding (Suprapto et al., 2020). In this phase, several approaches were used in the development of interactive augmented reality courseware to enhance the visualization of the employees. Therefore, support from different multimedia tools plays an important role for the training courseware. To create the interactive courseware, the researcher added multimedia elements such as videos, animations, audio files, and 3D virtual environments as the platform in making the courseware which in turn helped the technical employees to learn the contents more interesting and easier to understand. Yaacob and Ali (2021) found that through the application of 3D objects and views, imaginative media, and simulations with different varieties of interactions will connect the two isolated worlds. The elements of 3D digital objects, videos, sounds, and text generated by a digital computer will overlay on top of the real world at the right point where it is designated (Boonbrahm et al., 2019), so that the employees can see all the details in the courseware. The technical employees can learn the contents and procedure in real conditions, discover the process step by step by seeing instructions appear in real time (Elmqaddem, 2019).

The courseware content was then selected from the topics that employees have a challenge to visualize, and they have difficulty in learning, especially the process flow of the crude oil in the crude distillation unit and the internal part of the equipment. The trainees were not able to visualize the process flow of crude oil in the distillation unit and the exact internal parts of desalter for crude tower since the current module used 2D diagrams which was further improved using 3D elements and drawing concept to explain the topics through the newly developed courseware sing augmented reality environment.

The augmented reality learning environment was developed using Solidworks, Unity3D and 3D computer-aided design (CAD) software was used to design 3D virtual models and helps to create authentic design experiences. SolidWorks is a professional software design to allow users create accurate 3D models, from image to animation and with interactive content. This software is mainly used in the engineering field for industry. The augmented reality approach used in this study was marker-based augmented reality. Laptop and personal computers were used to scan the markers to augment the 3D objects. The 3D modeling process for all the 3D virtual models was done on the certain topics that were included in the augmented reality courseware. The application of virtual models was selected based on the complexity of the process and the requirement to understand the content itself. After all the 3D virtual models were completed, the models were then exported to Unity 3D by importing the models for the development of an augmented reality environment. After the first stage is completed, the development of the courseware then will continue using Unity3D software. This software is chosen for this courseware because the software has an ability to create and develop an augmented reality content and transform from 2D image to 3D objects. Figure 2 shows examples of the augmented 3D objects used in this study.

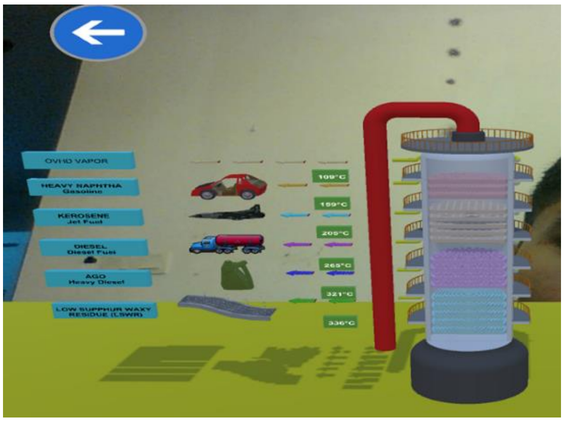

Fig. 2. Example of AR 3D objects

The study then was conducted among technical employees (trainees) at the oil and gas organization. Samples of the study were the technical employees in the engineering and operation department that were trained on the basic refinery process of crude oil, and they were involved in the control and experimental groups. The trainees in the control group experienced the learning using the current training module with traditional methods while the experimental group was taught using an augmented reality learning environment. Each group consists of 30 trainees respectively. In this study, a set of visualization test instruments were used in the pre-test and post-test to find out the level of visualization skills of the technical employees. The Visualization Ability Test (VAT) was conducted, and the data collected were analyzed using Statistical Packages for Social Sciences (SPSS) version 20.

Result and Discussion

A. Pre-test and post-test for Visualization Ability Test (VAT) before and after being exposed to the training module using conventional training method

Respondents in the control group were given a set of Visualization Ability Test before the learning of conventional training methods. The result has shown slight improvement among the respondents in visualization skills through a set of questionnaire Visualization Ability Test after training and learning using conventional training methods. Table 1 shows the paired sample test result of the pre-test and post-test for the control group.

Table 1
Paired Sample Test of Pre-test and Post-test for the Control Group

Paired Sample Statistics

	Mean	N	Standard Deviation	Standard Error Mean
Control Pre	41.955	30	8.296	1.515
Control Post	55.917	30	8.926	1.447

Paired Sample Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. 2-tailed
Control Pre Control Post	-13.962	8.8734	1.62	-17.275	-10.648	-8.618	29	.000

Based on Table 1, the mean score results among respondents in the Control Group for post-test (M=55.9170, SD=8.9260) was higher than the mean score result for the Control Group for pretest (M=41.9550, SD=8.2960). The results for paired sample tests between the Control Group of pre and post-test shows a significant increase in the mean score of tests after the respondents had received teaching and learning via the traditional training method. The increase was significant at t (29) =-8.61, $p < 0.05$. Hypotheses of the study are as follows:

Ho1 There is no statistically significant difference in the technical employee's visualization skills before and after being exposed using the current training module.

The findings on Table 1 indicate that the null hypothesis is rejected due to the value of p being smaller than the alpha value ($p = 0.001 < 0.05$). Thus, this result shows that there is a significant difference in the mean score of visualizing the basic refinery skills among respondents of the control group. The findings show that there was significant improvement on VAT after the use of conventional training methods in the post-test. However, the visualization skills improvement was small as the mean score of VAT increased from 41.9550 to 55.9170 (33 % improvement). The result shows that the use of conventional methods in learning the basic refinery process was not an effective method in enhancing visualization skills of the technical employees. This may be due to the irrelevance of conventional training methods in this technology advancement due to its mundane and heavy-duty teaching style by trainers which are unable to attract their attention to the topics.

B. Pre-test and Post-test after being exposed to the augmented reality learning environment

Respondents in the experimental group were given a set of Visualization Ability Test surveys before the learning of augmented reality environments. The result has shown improvement among the respondents in visualization skills through a set of questionnaire Visualization Ability Test after training and learning using augmented reality environment. Table 2 shows the mean score and standard deviation result of the pre-test and post-test for the experimental group.

Table 2
Mean and Standard Deviation of Pre-test and Post-test for the Experimental Group

Paired Sample Statistics

	Mean	N	Standard Deviation	Standard Error Mean
Experimental Pre	38.765	30	10.095	1.843
Experimental Post	81.604	30	6.187	1.129

Paired Sample Test

	Mean	Std. Deviation	Std. Error Mean	95% Interval of the Difference	Confidence	t	df	Sig. 2-tailed
				Lower	Upper			
Experimental Pre Experimental Post	-42.840	11.940	2.1804	-47.3001	-38.3815	-19.650	29	.000

Based on Table 2, the mean score results among respondents in the Experimental Group for post-test (M=81.640, SD=6.18732) was higher than the mean score result for the Experimental Group for pre-test (M=38.7650, SD=10.09518). The results for paired sample tests between the Experimental Group of pre and post-test shows a significant increase in the mean score of tests after the respondents had received training using basic refinery training courseware based on augmented reality environment. The increase was significant at t (29) =-19.650, $p < 0.05$. Hypotheses of the study are as follows:

Ho2 There is no statistically significance difference in the technical employee's visualization skills after being exposed using augmented reality environment

The findings on Table 2 indicate that the null hypothesis is rejected due to the value of p being smaller than the alpha value (p=000 < 0.05). Thus, this result shows that there is a significant difference in the mean score of visualizing the basic refinery process skills among respondents of the experimental group. The findings also show that there was significant improvement on VAT after the use of augmented reality environments in the post-test. However, the visualization skills improvement was small as the mean score of VAT increased from 38.765 to 81.604 (110 % improvement) which is much higher compared to those at the control group using conventional methods.

Therefore, the finding shows that technical employees who were exposed to the augmented reality learning environment achieved higher scores in the Visualization Ability Test after the intervention compared to the technical employees before exposed to the intervention. Thus, the implementation of augmented reality in the training of crude oil refining processes contributes to the enhancement of technical employees' visualization ability. The findings also proved that visualization can be improved by using suitable intervention (Gray et al., 2022). Previous research by Rohil and Ashok (2022) found that augmented reality can support thinking and enable users to develop 3D models and scenes. While a previous study of Latif et al (2020) identified that there is improvement in learning when the students learned with 3D methods compared those who received conventional learning. The findings are proven that the implementation of augmented reality environments in the training and learning will allow technical employees to manipulate 3D models effectively to help enhance visualization skills.

C. Significant difference before and after being exposed to the conventional training method and on augmented reality environment
Table 3 shows the analysis test result from the Visualization Ability Test.

Table 3
Analysis of Test Result from the Visualization Ability Test

Intervention Group	N	Gain Scores (GS)	Standard Deviation
Experimental	30	42.840	6.1873
Control	30	13.960	7.9238

The findings for this section were obtained from the independent t test. The test was conducted in order to compare the mean scores between respondents in the experimental group and control group after receiving both training methods. Table 4 showed the gain score of the VAT test for both experimental and control groups. In this study, the experimental group is the group that received training using the courseware based on the augmented reality environment and the control group is the group that received training using the current training module.

Ho3: There is no statistically significance difference in the technical employee's visualization skills between traditional training method and augmented reality training method

Based on Table 3, the gain scores for the experimental group (GS=42.840) for VAT was higher than the gain scores for the control group (GS= 13.960). Furthermore, the table indicates that the independent sample test for VAT between experimental and control group shows a significant value of 0.179 (F= 1.85). Therefore, the null hypothesis which stated that the two population variances is accepted. Furthermore, the value of t-test with equal variance was -19.82 at degrees of freedom df equal to 58. Based on the findings, it indicates that the null hypothesis is rejected as the value of p is smaller than the alpha value (p=0.000 < 0.05). Thus, the result shows that there is significant difference in the mean score of VAT between the respondents in the experimental and control group. Thus, the conventional method is less effective in learning the basic refinery of crude oil processing since it has some limitations in enhancing the technical employees' visualization skills. Trainers faced difficulties in explaining the complex technical concepts of the basic crude refinery process by giving lectures, using slides and whiteboards. Therefore, this result shows that training courseware based on an augmented reality environment is more useful and impactful in helping technical employees to enhance their visualization skills compared to the conventional training method.

Conclusion
In conclusion, this study found that the training approach using the augmented reality learning environment showed a significant improvement in the visualization skills of the

trainees compared to the conventional training approach. The effect of augmented reality technology in learning can improve the vision and visualization ability of the users because it considers a user-friendly technology in their training oil and gas industry needs new technology such as augmented reality as one way to reduce safety concerns. For the technical employees who have unskilled experience, without entering production or endangering very expensive machinery, augmented reality is a valuable tool to be implemented at the workplace. Based on the findings it can be concluded that using augmented reality courseware based on the augmented reality environment, it helped to enhance the technical employees' visualization skills. For future study, it is suggested to add more multimedia elements such as videos, photos, and animation in all modules to assist and expedite the employees in understanding and interpreting the technical theories and the interpretations. The study also recommends having a strategic roadmap or framework for digitalizing all conventional training modules with augmented reality technology. Implementing and experimenting with the latest technologies and innovative visualization tools in the training program could be a great effort to revolutionize the training approach in the oil and gas industry.

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