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Semi-Immersive Virtual Reality for Improving the Mental Rotation Skill for Engineering Students: An Experimental Study

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Abstract

Engineering students need to have a high Mental Rotation Skill (MRS) to improve their Spatial Visualization Skills (SVS). MRS classified as a type of SVS. Having a high MRS, enhanced students to understand the engineering graphics course and pass it without difficulties. Instructors in engineering educations indicated that first-year students faced difficulties when visualizing models in engineering graphic course. Traditional tools such as textbooks and modeling techniques are not enough for enhancing the SVS of engineering students. This paper presents Virtual Mental Rotation Training (VMRT) system using semi-immersive virtual reality technology based on Purdue Spatial Visualization Skills: Rotation (PSVT:R) and on both analytical and combined mental rotation strategy to improve MRS for females' engineering students. VMRT is an adapting system according to the student's level of MRS. Moreover, we report the results of the experimental study using VMRT system and PSVT:R with axes and without axes. The results of pre-test and post-test results of the experimental study using (PSVT:R), indicate that the students have a probability of over 99% of improving their mental rotation skills. Also, results show 63% of improvement in the difference percentage between pre-test and post-test for engineering students who were training using VMRT. Moreover, the results indicate the students prefer to use analytical mental rotation strategy to improve their mental rotation skill.

Keywords

Virtual reality; Spatial visualization skills; Mental rotation skill; Engineering graphics; Adaptation systems

Introduction

The SVS is an essential skill in engineering education [1]. SVS defined as "the ability to generate, retain, retrieve and transform well-structured visual images" [2]. There will be no overloaded in the cognitive load of human memory if engineering person enhances this spatial skill [3].

We need to support MRS to enhance SVS [4]. MRS is the ability to mentally transform 3D objects and virtual images by rotating it in the virtual space (in mind). Most of the studies conclude that the spatial skills are important for the engineering students. Such as, Tseng and Yang [5] conclude that the spatial visualization is related to the engineering fields, MRS is related to SVS to build 3D models, and the spatial skill is required for the computer graphics in engineering [6].

Instructors in engineering colleges looking for solving the difficulties faced the first-year students in studying engineering graphics course when they tried to visualize the models [6]. Traditional tools are not enough to graduate engineering students with high SVS, and they fail to pass the graphic courses with high grade [6].

There are differences in SVS especially MRS between females' and males' skills. Many studies by Li et al. [6,7] and Maeda and Yoon [8] concluded that males outperform females in a most of spatial tasks, particularly when they involve mental rotation tests. "Males tend to outperform females on spatial reasoning tests significantly. Differences have been attributed to a multitude of factors including biological, social and cultural, and educational factors and are believed to contribute to the fact that males outnumber females in science and mathematics fields" [9].

The first-year females'engineering students need to have high MRS and skill to mentally visualize the 3D models like it in reality [10]. The MRS enhanced by training students to use virtual models and interacting with it by using their eyes and hands [11]. The training before studying the courses will allow students to improve their MRS and then study better with a little of difficulties. Engineering students also need to enhance their SVS, and hence increasing the working of the memory of human brain.

The next section discusses Virtual reality and its types, followed by cognitive learning strategies for MRS. Then, PSVT:R. and latter adaptation systems in learning is discussed. Later part produces the architecture of proposed system with more details. Then a brief experimental study is provided followed by results and discussions. The paper's conclusion and recommendations presented in the last.

System Types of Virtual Reality

According to Maeda and Yoon [8], the Virtual Reality (VR) is " technology that allows us to create environments where we can interact with any object in real time, and that has been widely used for training and learning purposes." Integration some of the technologies, such as computer and graphics, can generate the technology of the VR.

The VR system has different types according to the technology used. These various types represented in different displayed hardware and interaction devices [8].

There are three types of VR systems. The types are fully-immersive, semi-immersive and non-immersive VR system. More details about theses system types in the following sub-sections:

Fully-immersive

The immersion type of the VR systems requires the user to wear a data glove and head-mounted display (HMD) that tracks the user's head movements that then changes the view [10,12]. Cave Automated Virtual Environment (CAVE) is an example of fully immersion technology.

Semi-immersive

The semi-immersive is a development the desktop VR and

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include additional devices such as a mouse. It keeps the simplicity of the desktop virtual reality system, but with a high level of immersion and using physical models [13]. The semi-immersive system consists of the VR and real world attributes by embodying objects of computer graphic into the scene of the reality. The input to this type of system entered and controlled by the users such as a mouse, keyboard, interaction styles, glasses and joystick [14]. It allows the user to interact by using the hands and sometimes wear glasses or Data Gloves.

Non-immersive

The non-immersive system often called desktop virtual reality (without any input devices). It is based on the monitor screens as it is a window to the virtual world without additional devices such as HMD [15]. The most widely used VR system is the desktop system that consists of a classical computer monitor to display the virtual world. Examples of the desktop VR systems are video games and augmented reality (AR).

In our proposed VMRT system for the experimental system, we chose semi-immersive VR system because of it is cheap; allow all students to interact with computers using their personal computer, and it most appropriate type of education [16]. Moreover, semi-immersive VR system lets users use their hands as in real for scanning, to rotate and to zoom the 3D models [17].

Cognitive Strategies for Engineering Graphics Course

There are three cognitive styles (strategies) for learning MRS in engineering education. The three cognitive styles are a holistic mental rotation, analytical mental rotation, and the combination of two previous styles that called combined style [17-21]. Table 1 shows more information about each mental rotation style.

Another study by Sorby et al. [22] and studies by Maeda and Yoon [2,8], concluded that there is a significant gender difference in MRS and when they solve mental rotation tasks. Males outperform females on mental rotation tasks due to the differentiation in using mental rotation strategy that males using holistic strategy while females using analytical strategy. Other researchers [4,5] conclude that the females SVS needed to be improved according to their strategy (analytical style) to overcome the difference between them and males' score of MRS.

For the gender differences and low of MRS of females, we chose analytical and combined mental rotation strategies to build our proposed system VMRT. So, the engineering females are targeted population in this research.

PSVT:R

A standard test of MRS is needed for each student before and after applying proposed techniques to measure improvement of their SVS and MRS [8].

PSVT:R developed in 1977 by Islam with more facilities. PSVT:R consists of 30 questions with solving examples, and the students have to answer it during 20 min by Islam [9]. The PSVT:R available in the ETS test collection and has since been widely used by researchers in engineering and technology fields.

In 2009, before release the Revised PSVT:R, Smith [10] suggests adding the axes of coordinates to the questions of PSVT:R. Adding the axes is to represent the orientation of objects in space to minimize the effect of spatial visualization in the exam.

Moreover, adding the coordinates because the students take twenty minutes to solve twenty question whether it thirty questions as Branoff concluded in his research. Barnoff suggests the MRS of students will improve if they are training using axes and do PSVT:R with axes [11].

The PSVT:R revised and rearranged by Maeda and Yoon [8]. The 30 models arranged according to its rotation difficulty by Yoon. So, we selected 15 models out of 30 models of PSVT:R. The model's selected from PSVT:R models because this test is a standard test and specific for engineering students especially in the educational area [8]. Moreover, in our experimental study, we selected PSVT:R as standard test. Moreover, we add axes based on Branoff recommendation [11], to used axes in PSVT:R test and in training.

Adaptive hypermedia system for education

Each learner has different abilities and skills in education. Some of the learners get the information and understand it in short time based on its prior knowledge, abilities, and learning skills. However, some students learn with a long time to process the received information based on many factors such as age, prior knowledge, abilities and learning skills. According to that differentiation in getting and processing information, there is an electronic system can change according to the level of each learner. It can be adapted based on each student level of training and learning. The system is called Adaptive Hypermedia System (AHS) [15]. The AHS offers more attention for the individual learning [20].

The AHS is based on some Artificial Intelligence (AI) technologies [21].The AHS is an electronic system to support adaptive (dynamic) content for each learner [15]. The AHS used in the educational area to offer appropriate content and information for each student, allow each learner to train based on his level, increase the satisfaction of learner, and improve the efficiency (learn in a short time) and effectiveness (assessment results) of learning [16].

The AHS used on the web and in the educational area. This system "build a model of the individual user and use it to adapt the content or/and the hyper-structure of the pages in a hypermedia environment" [17]. The AHS used in learning environments has three basic models [17].

Table 1: Cognitive styles of mental rotation skill.

Analytical Mental Rotation	Holistic Mental Rotation	Combined mental rotation
The analytical strategy based on rotating the object mentally step by step. The features of objects are considered to rotate the object mentally. The analytical mental rotation is used by females to solve the spatial visualization tests and tend to use the left hemisphere which is responsible for the analytical mental rotation [8].	The holistic mental rotation is rotating a 3D object mentally without considering for any features of the object such as color, coordinate axes, shadow, and size [8]. The males are tending to use the holistic mental rotation and solving the mental rotation tests using this style by using the right hemisphere which is responsible for the holistic mental rotation [8].	The third type of mental rotation cognitive styles is a combined of holistic and analytic styles. The combined style allows learners to rotate a 3D object mentally by both the left and right hemispheres when rotating the object mentally. In this style, the user can mentally rotate the object with holistic processing and analytical processing based on some features of the object. The later studies by Li [8,9] noticed and concluded that the females are tending and preferring to use the combined strategy or analytical strategy.

We chose AHS to make the proposed VMRT system adaptive for each user's level. AHS was chosen because it used in the educational area and the author can but rules by himself [17].

Related works

In this section, we represent the previous studies used to facilitate the education of engineering students and enhance MRS.

Luo and Xia-Mei [18] aimed to develop educational material based on AR formats and several virtual. The authors also proposed to recognize how students behave while using educational material based on AR formats and several virtual, and checking if they are useful materials to improve their spatial skills and capabilities.

The work presented three different technologies that are AR, VR and PDF three-dimensional (PDF3D). The three techniques applied to three groups of students in the same classroom and the same level. There is a fourth group (control group) that will not use any of three technologies. They will use the traditional methodology of teaching and learn the concepts and models in engineering graphics that based on the textbook and real models only.

The AR technology uses either direct or indirect view of a physical environment of the real world and uses a set of devices to combine virtual information and material information that already exists. This study uses distinct AR from VR. The exercise in this material based on AR constructed using BuildAR Pro augmented reality application. BuildAR Pro augmented reality allows to create scenes consists of the set of images or marks that modify a 3D object. After creating the scene, a webcam on the computer recognizes an image that related to the 3D model and showed it integrated into the real world.

The portable document format included in PRO-X version. This material has many features that are an open standard, multiplatform, extendable, reliable and secure, sophistication for information integrity, search capability, accessibility and interactive.

However, the students made inappropriate use of the strategies of the proposed technologies. They still need to the existence of instructor to guide them.

Cole presented the study using VR and one strategy of mental rotation cognitive styles. This study used holistic mental rotation for both genders. That is, there is no any features for the 3D models. The rotation of 3D models was based on choosing a number of angels. It was Web Application (WebApp) training contained many levels.

The software and tools used for building the WebApp were HTML, SQL database, Amazon server and JavaScript. The hardware were laptops and desktop computers.

The evaluation of this study used Revised PSVT:R test. The outcomes of this study were improving in students score of PSVT:R test. The "increase for males in the experimental group was 1.72 times greater than that of the comparison group (experimental group (N=75) and the comparison group (N=134))" and "The increase for females in the experimental group was 2.45 times greater than that of the comparison group. (experimental group (N=19) and the comparison group (N=29))".

On the other hand, the strategy of this training is supporting for the males more than females. The 3D models rotated in axes directions only and based on precise angles degree. The researcher used all models of PSVT:R in training. It should be two sets of models (training sets and testing sets).

Another prominent researcher is Sorby [22]. She has been doing many types of research since 1999 till 2016 to improve the SVS of engineering students and comparing between the females' and males' skills when they are doing the mental rotation tests. In her researches [1,23] she was trying to change the content of engineering courses. Also, changing the methods of teaching and using the modeling programs such as CAD programs to improve the SVS of students. The researcher did not yet introduce a training system specific for improving the MRS and independent of the contents of the course. However, the researcher concluded that there is a difference in MRS depends on the gender.

Proposed VMRT System architecture

Our proposed VMRT system aims to improve the MRS for engineering females' students. The VMRT system architecture is composed of three components: VR, analytical and combined cognitive strategies, and AHS as shown in Figures 1 and 2. These components explained more details in the following sub-sections:

Virtual reality: We applied the semi-immersive VR system by allowing selecting, rotating, zooming, and navigating over the 3D models. This interaction made by implementing the navigation with Six Degrees of Freedom (6DoF) in virtual space. 6DoF allow to see the object from six sides that are (up-down, left-right, forward-back, pitch, yaw and roll and enable users to navigate and manipulate the objects in the virtual reality environments [14].

For building VMRT, we used many tools and software. For constructing 3D models, we used AutoCAD 2015. HTML5, CSS3, PHP, JavaScript Library (three.js) are used to build the WebApp of

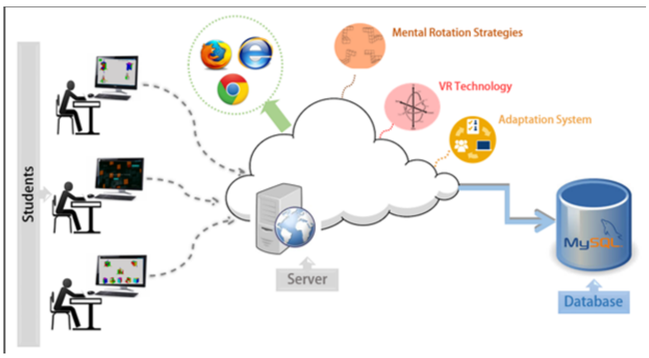

Figure 1: VMRT architecture.

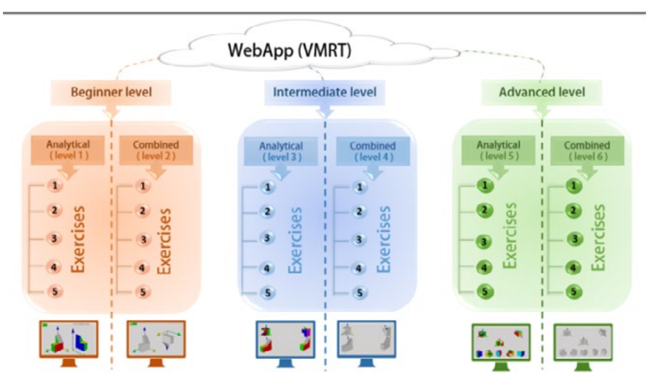

Figure 2: Levels of training in VMRT.

VMRT. Three.js is a library of JavaScript for WebGL [19]. Three.js used to make the interaction between the students and 3D models. The 3D models visualized by using Three.js which is represented 3D graphics JavaScript library in WebGL [19].

Mental rotation cognitive strategies: We constructed the 3D models and adding some features to it such as color, axes, and shadow.

The 3D models are standard models that are selected from PSVT models, and then, we construct it as virtual models. The 30 models arranged according to its rotation difficulty by Maeda and Yoon in 2013 [8]. We selected 15 models out of 30 models of PSVT:R. The model's chosen from PSVT:R models because this test is a standard test and specific for engineering students especially in the educational area [8]. The 15 models subdivided into three levels (beginner, intermediate, and advanced) as shown in Figure 2. There are five models in each level.

Beginner level: Beginner level has two level (1 and 2). The first level designed based on analytical strategy. The second level designed based combined strategy. Both intermediate and advanced levels have the same division of designing and strategies. This division for levels and strategies shows in Figure 3.

In level 1, each exercise has two shapes as shown in Figure 4. The student has to rotate the right shape to become like the same position of left shape. The student can use the roll of the mouse to zoom in and zoom out the 3D models. These features of models (color, axes, shadow) applied as it is analytical mental rotation strategy.

The combined cognitive style implemented in beginner level, but after analytical strategy. Combined style has only axes with gray color as shown in Figure 4.

The goal of beginner level is to educate the student how to rotate the 3D models step by step and allow them to see the 3D models as it in the real world and interact with it.

Intermediate level: The second level is intermediate level. It has four 3D models. The type of exercises of this level, for example, analytical exercise, showed in Figure 5. In this level, the student asked to rotate the models in the second row using the same rotation of the first row.

The combined style of this level shows in Figure 6. The goal of the intermediate level is to train the student to know how to rotate a model based on the rotation of another model.

Advanced level: Advanced level has eight 3D models as shown in Figure 7 (using analytical style). The students asked to rotate the second model (mentally) and imagine how its position will be if we are using the same rotation of the first row. The student will choose only one answer.

The combined style of this level has the same type of questions but without color. Its gray color with axes as combined style in two previous levels. The goal of the advanced level is to train the student to mentally rotate the 3D models after they learned how to rotate step by step in previous levels.

AHS: In our VMRT system, we applied AHS by creating many rules according to the content and log file of each student. Also, we made the logic of WebApp based on the sequential style of learning. We have done it sequentially to make the WebApp more appropriate for training and to be like the analytical mental rotation as it in combined mental rotation styles.

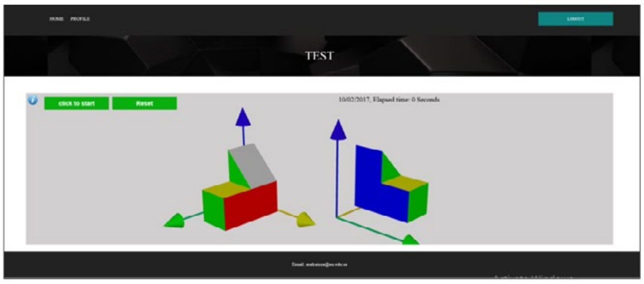

Figure 3: Beginner level (analytic).

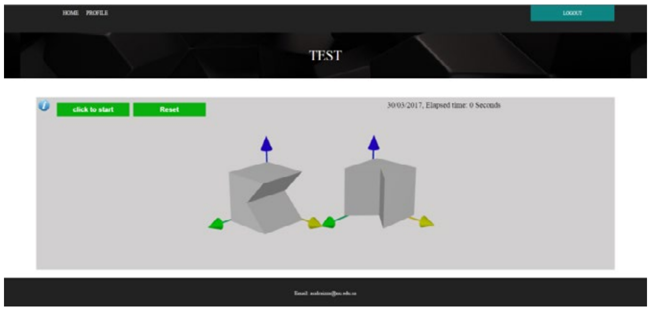

Figure 4: Beginner level (combined).

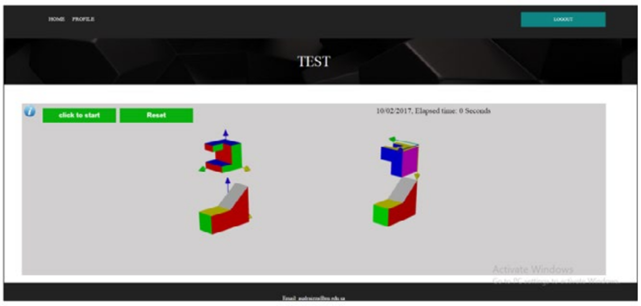

Figure 5: Intermediate level (analytic).

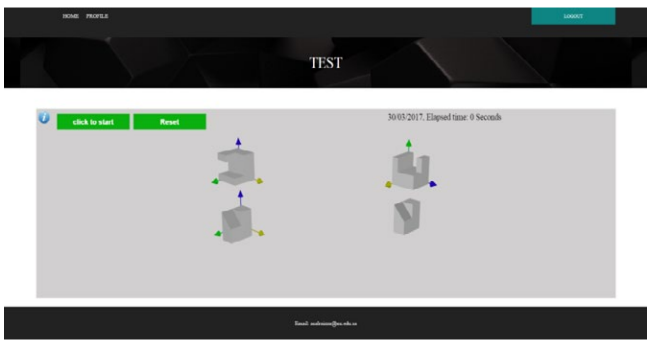

Figure 6: Intermediate level (combined).

Each level does not appear and activated till the student training on it completely. When the student finished solving any exercise, the feedback appears for a student on a popup window. The feedback notifies the student whereas rotation is correct or incorrect. If the answer correct, then the second exercise automatically appear on the window. On the other hand, if the feedback is incorrect, the same

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exercise appears to be solved by the student. The students cannot move to the second exercise till she answered it correctly.

If the third exercise of any level, for example, beginner level (analytical), answered correctly at the first trying, then the system understand that the student was training correctly and she got the idea of the first level. After that, the system jumps to the first exercise of the second level, for example (combined) of beginner level.

On the other hand, if the third exercise of beginner solved incorrectly at the first trying, then the system understand that the student did not get the idea of the first level. The system then appears the fourth exercise after the student solved the third exercise correctly. These rules are the adaptation part in VMRT. The same rules applied for the fourth exercise and fifth one. If the fifth exercise of beginner level solved incorrectly, then the system return to the first exercise of the same level till the student understand very well how to rotate the 3D models using analytical mental rotation strategy. The same rules of AHS applied for all levels.

AHS rules are working based on the information of student's performance. For recording information of each student, a web service used. It is a program used on web pages to allow the application to communicate with another application [24]. The web service allows requesting information from other software [25]. That is, the web service has two participants. The first participant is a provider (service producer) that provides a service such as a server. The second one is requester (service consumer) that request of service such as PHP [25].

The recorded information are the following: login and logout times, feedback of each exercise that is either (pass, fail or jump). Also, the number of tries to solve each exercise, date and time consumer to solve each exercise (each trying), the number of training for all six levels, and the number of rotating and moving the 3D models.

An example of user information shown in Figures 8 and 9. It has more details about tries for one training to solve one exercise with time, some moving (rotating object), and feedback. Each training calculated as one train if the student passes all levels.

Each student can log out any time then come back and complete the last step she solved it. All previously solved tests are displayed and activated.

Experminetal Study

The experiment of this research did on four groups. The groups were females engineering students from the faculty of an engineering college at King Abdulaziz University in Saudi Arabia. The plan of the experiment shows in Figure 10. We have two main groups (control group and experimental group (VMRT)). Control group has 19 students (9 non-freshmen students, and ten freshmen students). The nine non-freshmen students, was studying the engineering graphics course last semester, but they did not pass the course. Another VMRT group has 19 students, they all freshmen students. We did the experiments as the following steps and as it shows in Figure 10.

Step 1: The pre-test (PSVT:R) introduced online for two main groups (VMRT and control groups). Each group has two sub-groups that are (without-axes) and (with-axes) groups according to the type of test. The tests are (with-axes PSVT:R) and (without-axes PSVT:R). (the test is in one a day).

Step 2: Only VMRT groups are training on the VMRT system (intervention system). The control group (comparison group) did not train on the VMRT. (The training on VMRT system is one week at the first week of the semester).

Step 3: Post-test for VMRT group introduced online. Each group has the same previous pre-tests. (The test is in one a day).

Step 4: Both groups (control and VMRT) are studying SolidWorks in engineering graphics course (for one month). The SoildWorks is Computer-Aided Design (DAD) software used for modeling which helps to create 2D and 3D solid objects. Students study it by learning how to draw 2D objects, then how to construct the 3D models [26].

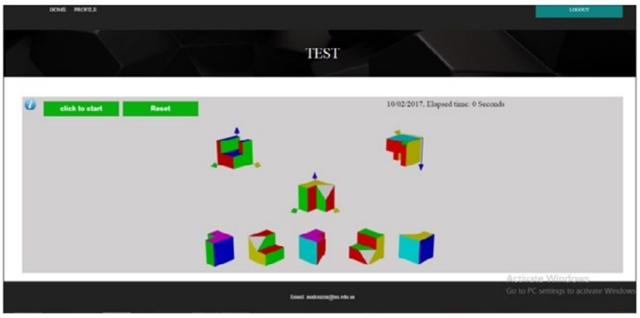

Figure 7: Advanced level (analytic).

Student Name :
University Name : King AbdulAziz University. **University ID :**
Finished Levels : 6.
Last update: 2017-02-19 13:54:09

Question Number	Result	Result Status	Number of tries	Duration(sec)	Tries
11	✔	Passed	3	4	see tries details
12	✔	Passed	13	4	see tries details
13	✔	Passed	2	4	see tries details
14	✔	Passed	9	6	see tries details
15	✔	Passed	1	4	see tries details
16	✔	Passed	8	3	see tries details
17	✔	Passed	1	2	see tries details
18	✔	Passed	1	3	see tries details
19	✖	Jumped	0	0	see tries details
20	✖	Jumped	0	0	see tries details

Figure 8: Part of detail about tries for one exercise.

Step 5: Post-test introduced online for all groups after studying SolidWorks. (The test is in one a day).

We select to build the test on the web using Moodle because of it free and allow the instructor to have full permission for creating the courses and tests. By using the Moodle, we can also change themes and build a complete course with multimedia materials.

An example of PSVT:R with axes in Moodle shows in Figure 11. The same thing for the PSVT:R without axes but it is holistic test, without adding that axes. The test navigation on the left side allows the student to navigate through questions. Under the navigation, there is a time counter which is not available on the paper test. When students using Moodle, the time elapsed of the test will show in front, each user and any students can interrupt her solving and complete it lately without losing the time of the test.

In this experiment study, the goal is to investigate the effectiveness of VMRT on first-year students engineering students. Based on the review of literature and hypotheses of related researches by Branoff [11] and others [27-29], we developed the hypotheses according to our study and concluded the following hypotheses:

1. Training on VMRT system has a positive effect on the MRS of students.
2. Studying SolidWorks does not affect the students' MRS.

The SolidWorks is software used for modeling 3D objects. Students study it by learning how to draw 2D objects, then visualizing the 3D models. However, our proposed system aimed to help students to understand what the 3D models are and how to imagine it and rotate it mentally.

#	Answer	Movements counter	Duration	Date/Time
1	Failed	2	3	2017-02-17 14:09:56
2	Failed	2	6	2017-02-17 14:10:48
3	Failed	3	3	2017-02-17 14:12:41
4	Failed	2	3	2017-02-17 14:13:13
5	Failed	4	7	2017-02-17 14:15:20
6	Failed	2	5	2017-02-17 14:15:39
7	Failed	2	5	2017-02-17 14:15:51
8	Passed	2	3	2017-02-17 14:18:29

Figure 9: Page of students information about login and logout details.

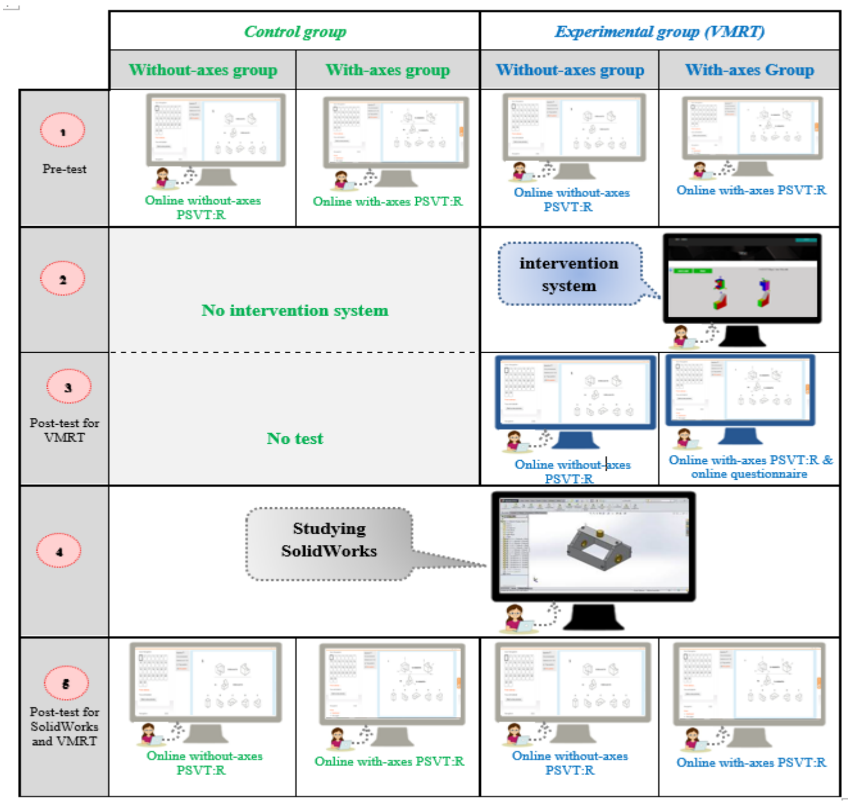

Figure 10: PSVT:R with axes in Moodle.

Results and Discussion

In this section, we analysis and discusses the result of students before and after training on VMRT. ANOVA used to compare results between VMRT and control groups. Independent two-sample t-test used for pre-test and post-test between groups. Moreover, paired t-test used to compare results between pre-test and post-test.

If the p-value of in t-tests is less than 0.05 (alpha value), then there is the difference between the results of pre-test and post-test is statistically significant. However, when p-value greater than alpha value then, the difference between the results of pre-test and post-test is not statistically significant [30].

Our goal of this study was to verify that the VMRT were more useful in helping students to improve their MRS.

We present results with more details according to the hypotheses.

First hypothesis

The first hypothesis was that *"Training on VMRT system has a positive effect on the MRS of students."* The paired t-test used to investigate whether VMRT groups have improved their MRS or not after training on the proposed VMRT system. Table 2 shows means, variance, and p-value between pre-tests and post-tests of VRMT after training on VMRT system.

The p-value is 0.0000 (0.0000<0.05) and other data of test was (df=19, t=-8.681437486). The p-value indicates that there is a significant difference between pre-tests and post-tests for two groups of VMRT. The p-values (0.0000) are well below the 1% statistical significance level. It indicates that the students have a probability of over 99% of improving their MRS by training on VMRT system.

The difference in performance between pre-test and post-test is 63%. For previous research [6], the number of females students was 19 students. They were training using holistic mental rotation. The percentage of improvement their MRS was only 15.8% despite they trained for three months for all 3D models of PSVT:R and did the tests many times as a type of training. The percentage of males was 12%. The percentages for pre-test and post-test for VMRT.

We did another test to ensure that students prefer to use analytical mental rotation strategy as they training, and they prefer to solve mental rotation tests using analytical or combined strategy. The t-test of two independent samples used between the groups of VMRT. The descriptive analysis shows in (Figure 11). The p-value (Table 3) was (0.003<0.05). Other results of this test was (df=13, t=3.503908). The results indicates that there is a significant difference between two groups. The reason for the difference because the students training using analytical and combined mental rotation. However the test without axes was a holistic mental rotation. For another group, the test was combined mental rotation strategy. This significant prove the recommendations of Branoff [27,31] to training using axes and then do the test of PSVT:R with axes [32]. The students thinking using analytical and combined strategies as the Li concluded in his researches [6,33].

Second hypothesis

The second hypothesis stated, "Studying SolidWorks does not affect the students' MRS." To investigate this hypothesis, we did many tests. The first test is pre-test to. To do the pre-tests, we divided all students in engineering graphics course into six groups according to the type of tests, training, and first-year students as follows:

3. (With-axes) control group
4. (Without-axes) control group.
5. (With-axes) previous experience (non-freshmen students).
6. (Without-axes) previous experience (non-freshmen students).
7. (With-axes) VMRT group.
8. (Without-axes) VMRT group.

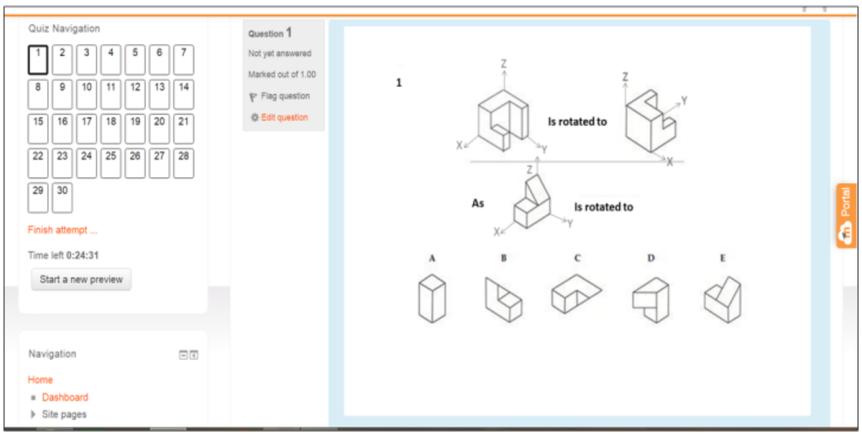

Figure 11: PSVT:R with axes in Moodle.

Table 2: Mean values with p-value for VMRT using paired T-test.

	Pre-test	Post-test #1	p-value
Mean	14.35	23.4	0.0000
Variance	11.50	21.83	

Table 3: Means and P-values of post-test for VMRT groups.

	With-axes	Without-axes	p-value
Mean	26.3	20.50	0.003
Variance	5.12	22.27	

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Figure 12 presents the averages for the six groups. The letter C indicates to control groups, pre. Exp. indicates to the students who are non-freshmen students and was studying the engineering graphics course last semester but they did not pass the course. They are now studying the engineering graphics course for the second time.

We used one-way ANOVA (Table 4) to investigate if there is a difference between non-freshmen students and first-year students. The p-value was (0.560) and other data was F=0.80, df (between groups)=5.00. the p-value is greater than the alpha value (0.05). It indicates that there is no a significant difference between all groups. So, we considered the previous experience groups as control groups. Also, the result indicate that the SolidWorks does not effect on the MRS. After that, we have only two major groups (control group and VMRT). So, The p-value also indicates that previous experience groups did not have high MRS even they study the course and training before by using SolidWorks software for modelling.

We did not train the students of previous experience for two reasons:

1. They already study the engineering graphics course, and our proposed system aimed for freshmen students.
2. To make the comparisons between post-tests of VMRT groups

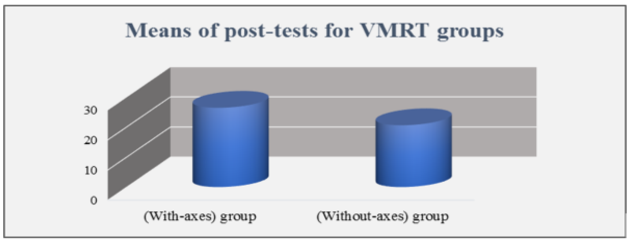

Figure 12: Differences between post-test groups (VMRT).

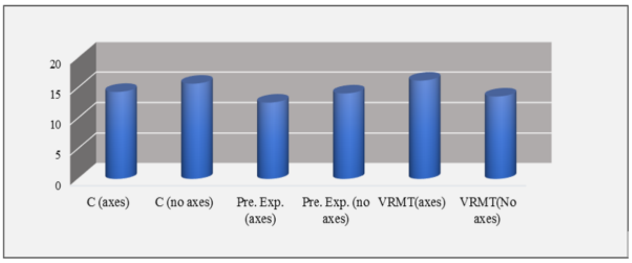

Figure 13: Differences among all groups for pre-tests.

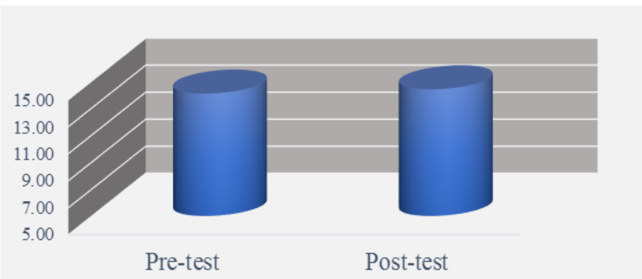

Figure 14: Average for pre and post-tests of control group.

Figure 15: Average values for both post-tests for VMRT.

Table 4: Mean square and P-value for all groups (pre-test).

	Mean Square	p-value
Between Groups	11.77	0.560
Within Groups	14.78	

Table 5: Means values and P-value for pre and post-test of control group.

	Pre-test	Post-test	p-value
Mean	14.05	14.37	0.43
Variance	15.94	18.69	

Table 6: Means values and P-value for both post-tests of VMRT group.

	Post-test after training	Post-test after raining and Solid Works	p-value
Mean	23.00	24.26	0.11
Variance	23.22	11.87	

who take the training before studying the SolidWorks, and control groups who are studying only SolidWorks before training and half of them have previous experience in SolidWorks. This comparison to investigate the second hypothesis.

Another paired t-test used to investigate the second hypothesis. The result was (df=18, t=-0.809039835) with p-value=0.43. The results Table 5 and Figure 13 indicate to that there is no difference between pre-test and post-test before and after studying SolidWorks.

Also, after training VMRT groups at the beginning of the semester and then studying SolidWorks, another test introduced to investigate the second hypothesis. We used paired t-test to compare the two post-tests of VMRT group. Figure 14 and Table 6 shows that there is no difference between the two post-tests of VMRT. The p-value was 0.11; it is a greater than 0.05. another data of this test was (df=18, t=-1.705127367). We conclude that the SolidWorks is not able to improve the MRS for students.

Conclusion and Recommendation

Engineering students need to have high MRS as it ensures the high SVS that enables students to pass and understand the engineering graphics courses. The first-year students in engineering fields are facing hardness to how to imagine any 3D model. The male outperforms females in MRS. So, the first-year women engineering students need to enhance their spatial abilities.

In this paper, we presented a brief description of VR systems and AHS. After that, we illustrated the related strategies and method for that improving. Then, we represented the related works tried to improve MRS. Moreover, the paper illustrated the proposed VMRT system to improve the MRS for women engineering students.

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Finally, we presented the results of using the VMRT. Results showed that students training using VMRT have a high MRS after training. Results showed that students training using VMRT have a high MRS after training. The difference in performance between pre-test and post-test on PSVT:R was 63%. The result of statistical analysis indicates that the students have a probability of over 99% of improving their MRS by training on VMRT system.

Also, we conclude that students prefer to user analytical or combined system than holistic. The result between two groups (test with and with axes) shows the result of using the axes higher than without axes (holistic)

For the recommendation:

- Make VMRT contains all 30 models of PSVT:R based on analytical mental rotation.
- Convert WebApp of VMRT to be an application on the desktop to overcome the delay of uploading axes if there is a bad internet connection.
- Produce VMRT training at the beginning of the semester for female engineering students.
- Using 3D mouse instead of the traditional mouse to allow students to the complete rotatation (360 degrees) if the models needed.

Adding axes on PSVT:R test.

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