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Mixed Reality Tools in Engineering Drawing Course

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Mixed Reality Tools in an Engineering Drawing Course

Abstract

Some students have trouble visualizing the objects that they are trying to sketch during the orthographic projection and descriptive geometry lessons in Engineering Drawing courses. Geometry visualization is an essential skill for prospective engineers to have when entering the profession. Engineering students need to be able to visualize objects in technical problems on a regular basis, but some students have difficulty imagining objects as a three dimensional mental image from two dimensional orthographic views. They need more time and help to improve their visualization skills. Engineering drawing courses help students gain this missing skillset by providing the necessary training for object visualization, spatial cognition of problems, geometric reasoning, and graphic representation of ideas. However, lecture time tends to be limited in such courses and some students struggle in figuring out how to generate three dimensional objects or other necessary projection views in order to solve the problem while analyzing projection views. Many students with the missing visualization skills cannot comprehend the engineering problems assigned to them. Students develop these visualization skills better with mixed reality (MR) applications since it enables them to augment the virtual model in real surroundings by observing and touching the real model at the same time. MR technology projects the model in front of the students' eyes, allowing them to see the three dimensional representation of the objects while also allowing them to imagine, analyze, and sketch the necessary views. The stereographic model views are displayed in MR by using the Moverio see-through glasses or the Google Cardboard. This MR supported learning material in an engineering drawing course is reported and student success is studied by using pre- and post-mental rotation tests.

1. Introduction

Geometry visualization is an essential skill for prospective engineers to possess when entering the field. All engineering technology students are required to take the engineering drawing course in their freshmen year in order to learn principals of drawing and 2D/3D CAD modeling techniques. This course also provides object visualization, spatial cognition of problems, geometric reasoning, and graphic representation of ideas.

It is a challenge for some of the students to solve an engineering problem since they struggle in transforming views between 2D and 3D views of objects [1,2]. Students with profound understanding of geometry and spatial skills have no difficulties grasping concepts and can successfully solve engineering problems. It is reported by many researchers that the spatial ability can be taught through carefully constructed exercises[3,4]. There are educational studies that show these skills can be improved with practice[5-8] .

Augmented reality (AR) technology currently has been used to improve design and visualization skills, aid in scientific simulations and serve as a tool for education. AR technology typically provides visualization aids that bridge the gap between physical prototypes and digital computer models. AR technology offers solutions and benefits in numerous application areas such as space training [9], medical education [10], design and manufacturing [11-13], visualization training in early child education [14], assembly and maintenance training [15], entertainment [16], and military training [17]. An MR experience is one where the user is placed in an interactive setting that is either real with virtual component augmentation (AR), or virtual settings with real-world augmentation (augmented virtuality-AV). Mixed reality is the experience of a blend of the virtual and the real world, usually through one of the five senses, most often using visual displays and auditory devices[18].

MR supported learning material as a head mounted device (HMD)-based AR system, incorporating optical see-through is created for the Epson Moverio see-through glasses to use in an engineering drawing course. The same application with minor changes is also used in a large class with the Google Cardboard as a cost-effective and practical alternative to the well-known virtual reality equipment that had been used for decades to augment the virtual reality. The correlation between the academic success in the Technical Drawing course and visual ability improvement with the MR technology are studied. Students were pre- and post-tested using a standard mental rotation test to gauge spatial visualization ability.

2. Enhancing spatial skills in Engineering Drawing Course

Engineering Drawing ET0011 is a required course at the University of Pittsburgh at Johnstown for all engineering technology students in all four majors – Civil Engineering Technology, Electrical Engineering Technology, Computer Engineering Technology, and Mechanical Engineering Technology and is a prerequisite to the fundamental engineering courses. This course is typically taken during the freshmen year by students. The objectives of ET0011 include:

(1) Interpret and communicate with technical drawings and sketches,

(2) Use current computer aided graphics software,

(3) Understand and apply standard graphical principles.

These objectives recognize that in the field of engineering, much information is used in graphical form, because successful design is often accomplished in a graphical settings, and practical design skills are required for many engineering jobs.

The course content of ET0011 is delivered in three formats – hand drawing and sketching, 2-D CADD, and 3-D CADD. The class meets three times a week, twice in a computer lab and once in a classroom equipped with drawing boards. In the computer lab, AutoCAD is taught for the first half of the semester, and Autodesk Inventor for the second half. In the classroom the main emphasis is on theory and problem-solving, and exercises are done in the form of sketches rather than mechanical drawing.

Spatial visualization and graphical representation skills are essential for engineering students to allow them to express ideas in the course of solving problems. Different students with different learning needs should use different representations in the classroom. Therefore, different approaches are used to improve the spatial visualization skills. The simplest and oldest of these approaches are concrete representations such as wooden blocks to be depicted graphically by the student that can be observed, touched, and measured (Figure 1). During this activity, they observe the model inside the glass box and generate three principle orthographic projection views. The glass box is used to show the projection views of an object. This is very effective for tactile learners who learn by touching and manipulating objects[19,20].

Figure 1 Glass box approach

Another approach is creating simple foam models. Students build foam models starting from isometric sketches during the class in ET0011 (Figure 2).

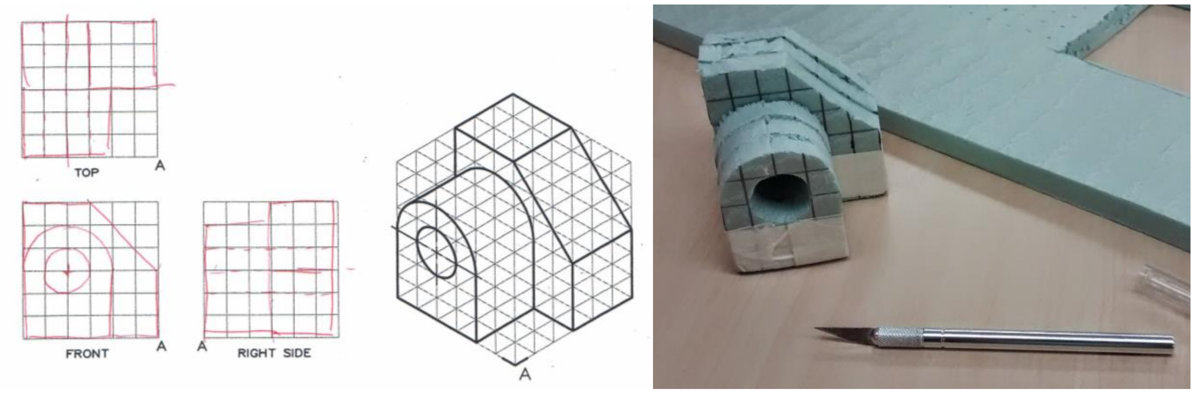

Figure 2 Foam model built by student

Dynamic representations of three dimensional models on a computer screen is another form of representation that can help students see the object from different perspectives (Figure 3). Inventor CAD system is used to visualize and inspect the geometry from different point of views. A mixed reality (MR) mobile app was created and virtual models are used mixed with the paper form exercises to enhance the learning experience in the Fall 2015 term.

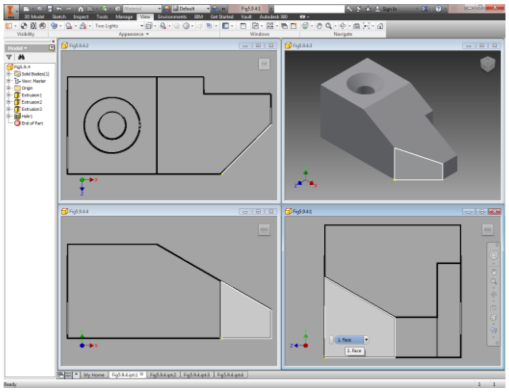

Figure 3 Projection views in CAD

3. Why Mixed Reality Tools are used in the Engineering Drawing Course

Traditionally engineering students are expected to read 2D projection views of technical objects and visualize them or start with an isometric view and create principle orthographic views. Some students struggle in figuring out how to generate 3D objects or other necessary projection views in order to solve the problem while analyzing projection views in 2D. Many students with the missing visualization skills cannot comprehend the engineering problems assigned to them. Visualization requires the ability to form a 3-D mental image of a part based on limited or incomplete information. For some students, this comes naturally and without much analysis. For others, the given information must be analyzed and synthesized in a logical manner.

Analyzing and understanding complicated three dimensional (3D) problems using a two-dimensional paper space or a desktop computer screen has always been a challenge for engineering students. They need to interact with complex 3D CAD drawings using two-dimensional devices like a mouse and a keyboard while viewing the models using a flat computer screen. In other words, they cannot view models with natural stereoscopic vision while working with engineering problems. Even though powerful computers and software are available today to generate very realistic 3D vision, they are too expensive to use in a large classroom settings. It is not realistic to expect schools to be able to afford extensive installations of expensive equipment for large classes[21]. However, as mobile devices such as cellphones, smart phones, laptop computers and tablets are becoming an increasing part of daily activities, most of the students have smartphones and therefore mobile applications have entered the world of education. Mobile applications are good enough to generate realistic virtual models.

A mixed reality (MR) mobile app was created and alpha tested by using the Moverio see-through glasses as an instructional tool that enables students to visualize geometry problems and enhance their spatial visualization skills (Figure 4-A). This mobile app, called Geometry Visual Learning System (GeoVIS), augments 3-dimensional digital models of existing, assigned, paper-based engineering graphics problems. Students solve paper based problems while being able to see and "touch" the model with the MR application that is compiled for the Moverio see-through glasses. The Mobile App projects the model in front of the students' eyes, allowing them to see the three dimensional (3D) representation of the objects in the problems right in front of them. This is a similar experience to giving a real model of the problem to their hands which is not always possible in large classes. Moverio has a mobile touchpad unit that is used to control the model and move the user in a game-alike application.

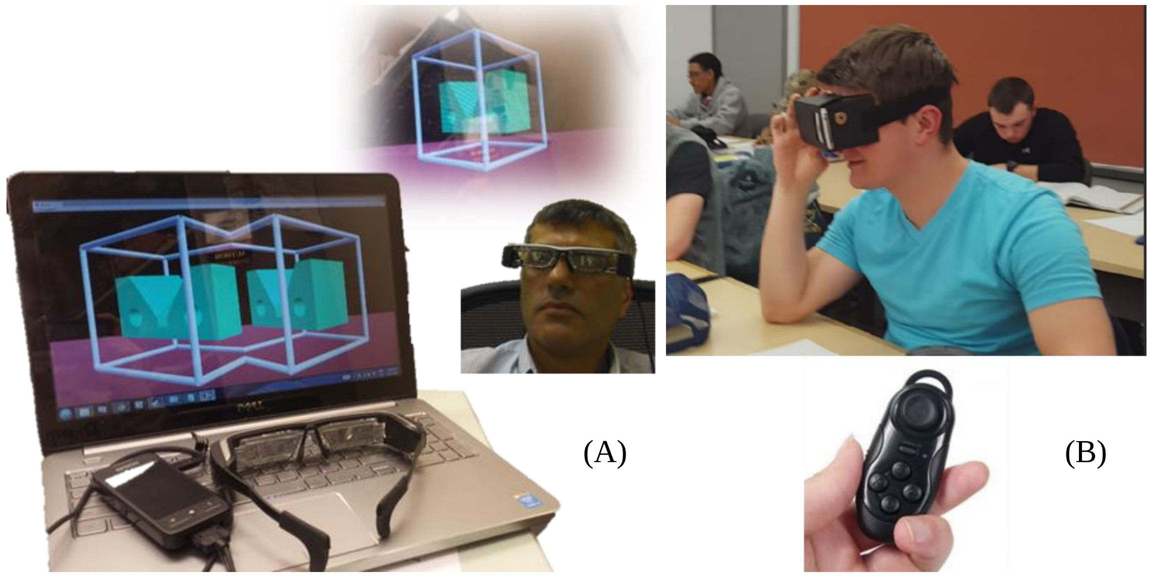

Figure 4 (A) Moverio see-through glasses (B) Google Cardboard display digital model of the auxiliary view problem augmented into the real environment.

This application is also used with minor code changes in a large class with the Google Cardboard (Figure 4-B). Changes are needed to make the semi-transparent background visible and add the wireless controller. Smartphone in the cardboard is controlled by head movements and also by using a wireless controller.

The Google Cardboard system projects two views of the CAD model on each half of the screen which when perceived by the eye through the pair of biconvex lenses creates an augmented stereoscopic model (Figure 5). It has no see-through capability like Moverio, but it is possible to combine the camera view of the user's smart phone with stereoscopic virtual model if the phone's hardware has the capability.

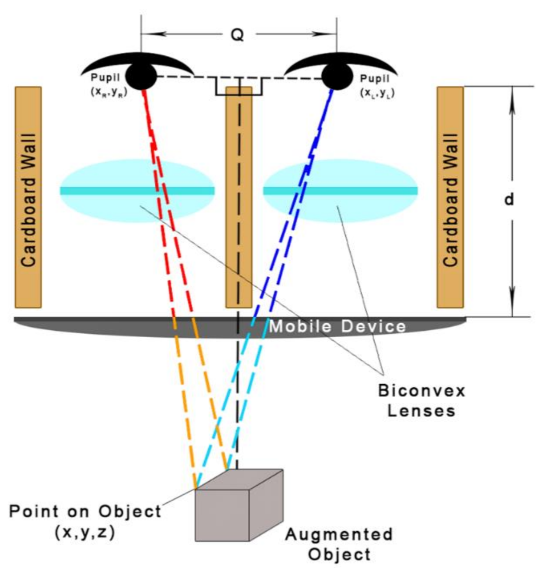

Figure 5: Stereoscopic View of Virtual Model

Visual and spatial skills require the ability to rapidly and accurately rotate two or three dimensional figures, to determine relations with respect to their orientations, and to visualize their image in mind[22, 23]. This ability is critical for engineers in order to solve geometric problems. Stereoscopic views are more realistic and help enhance the spatial skills easier. Today, more than half of the college students in the US have smartphones[24,25]. Google Cardboard is an economic alternative as a stereoscopic VR viewer if students use their own smartphones.

CourseWeb is utilized to provide the virtual models. Students were able to download different types of virtual models or run the GeoVIS on their phones (Figure 6).

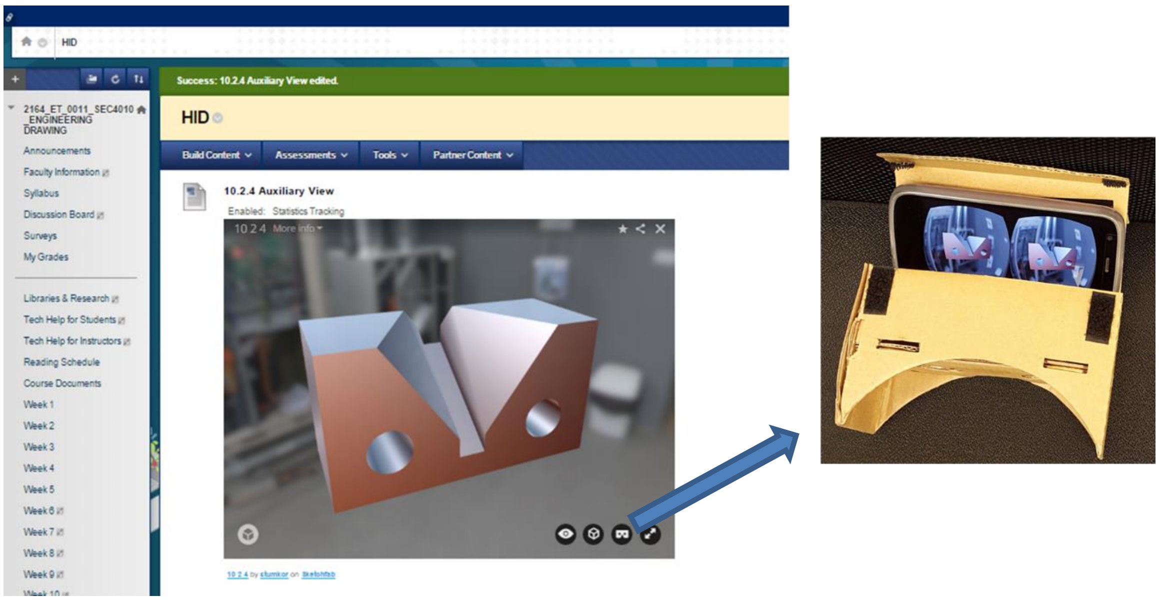

Figure 6 Virtual Models can be downloaded from CourseWeb

4. Assessment of Spatial Skills

There are several standardized tests available to measure a student's spatial skills[26-29]. In this study, Vandenberg and Kuse's[30] mental rotation test (MRT) is used to gauge students' spatial visualization improvement. This test is one of the most commonly used measures of spatial ability. Mental rotation is the process of imagining an object being rotated into a different orientation in space. The students were asked to compare objects represented as 2D images and to find the identical ones within a set of multiple choices. The only difference between the original image and the identical ones is that they are depicted at different orientations.

The MRT was given to the students at the beginning of the semester and a second time before the final exam. Test scores of the ET0011 class in Fall 2014 and 2015 terms are given in Figure 7. The correlations among student academic performance and spatial visualization ability and the effects of the spatial skill training were investigated. MR supported training was used first in the Fall 2015 term.

ET011 had two sections with 55 students in Fall 2014 and 56 students in Fall 2015. Data is filtered to include only the scores of the students that fully participated in this study. Grades were adjusted to remove components such as attendance, group assignment grades, and project participation, as well as bonus points unrelated to the hypothesis. Arithmetic means of pre- and post- MRT scores of the class of 2014 were 62% and 81% respectively which show a gain of 19 points in spatial visualization after conventional training. On the other hand, arithmetic means of pre- and post-MRT scores of the class of 2015 were 56% and 77% respectively which show an increase of 21 points after MR supported training. The author observed only two point difference between the gained skills of the class of 2015 with MR supported activities compared to the class without MR application in 2014[31]. There were more students with lower pre-MRT scores in the Fall of 2015. This is an indication that the student groups had a different level of spatial abilities. Positive effects of the learning activities has been observed while analyzing the pre- and post MRT scores in both terms. Students experienced different types of learning activities (real physical / foam model, CAD model on 2D screen, MR models) during the semester and benefited in different levels based on their preferences and abilities. Some of the students benefited more than others from MR supported learning activities.

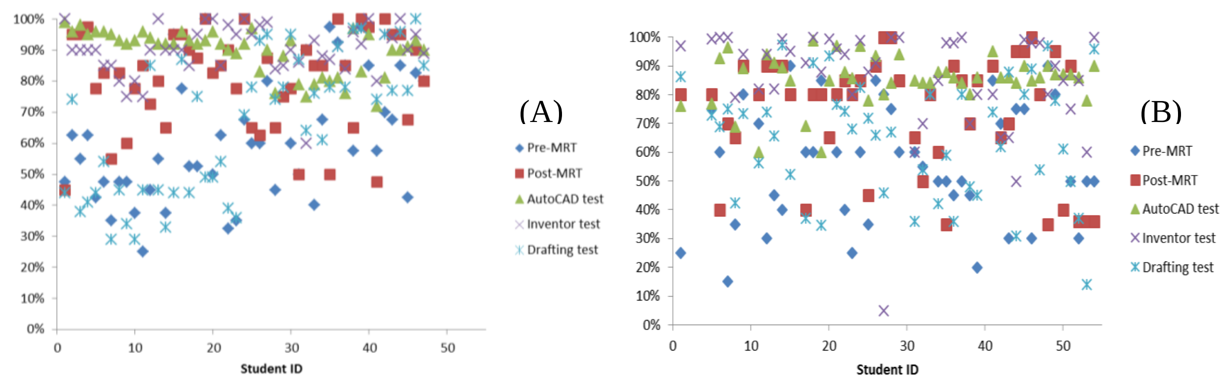

Figure 7 Test scores (A) Fall 2014 and (B) Fall 2015

In another study, auxiliary view problems (Figure 8) are assigned to students after a brief lecture including the descriptions, techniques, and methods to solve the geometry problems during the class meetings. One group of students (Group A) in Fall 2015 used the self-training mode of the GeoVIS. They went inside the virtual rooms and interacted with the virtual models before the assignment. The other group of students (Group B) in Fall 2015 completed the same exercise just after the conventional lecture without using the GeoVIS. Student success in first group was higher compared to the second group (control group). Students in both groups attempted the same questions. The overall success varies also with different topics and questions. The students who straggled on the 2D projection views benefited more from MR or VR experience, which provides them with 360 visualization of the parts that needs to be mentally pictured before drawing.

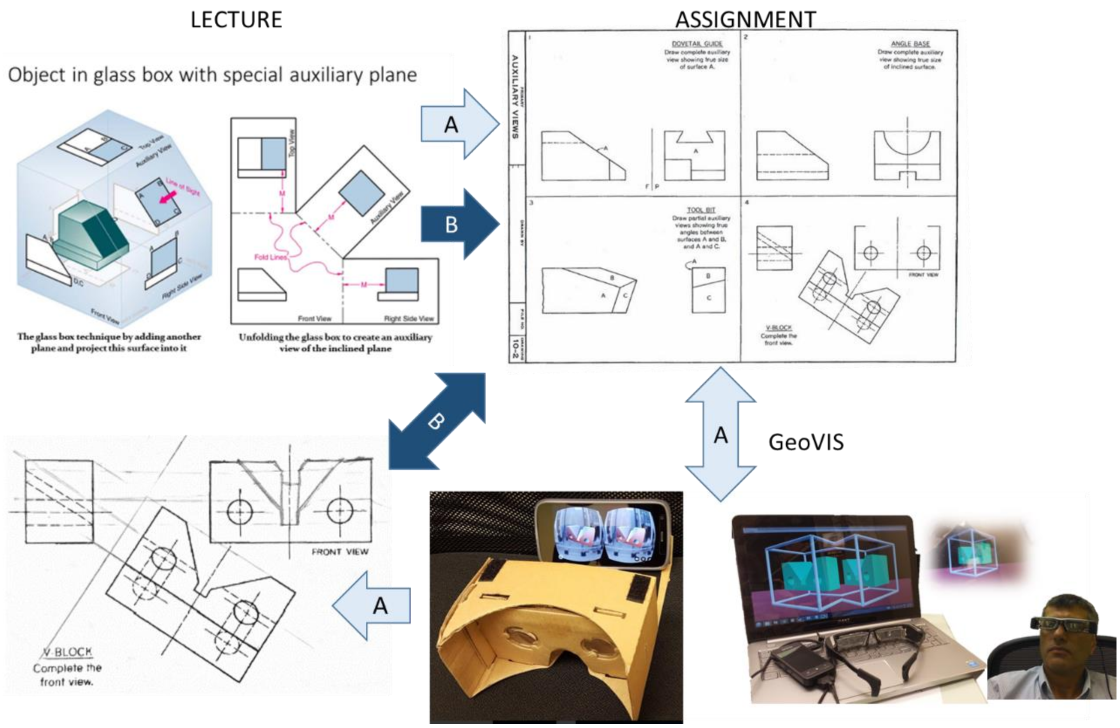

Figure 8 Auxiliary View Assignment

In the course surveys, %56 of participated students indicated that 3D augmented and mixed reality viewers allowed them to better understand the content (Figure 9).

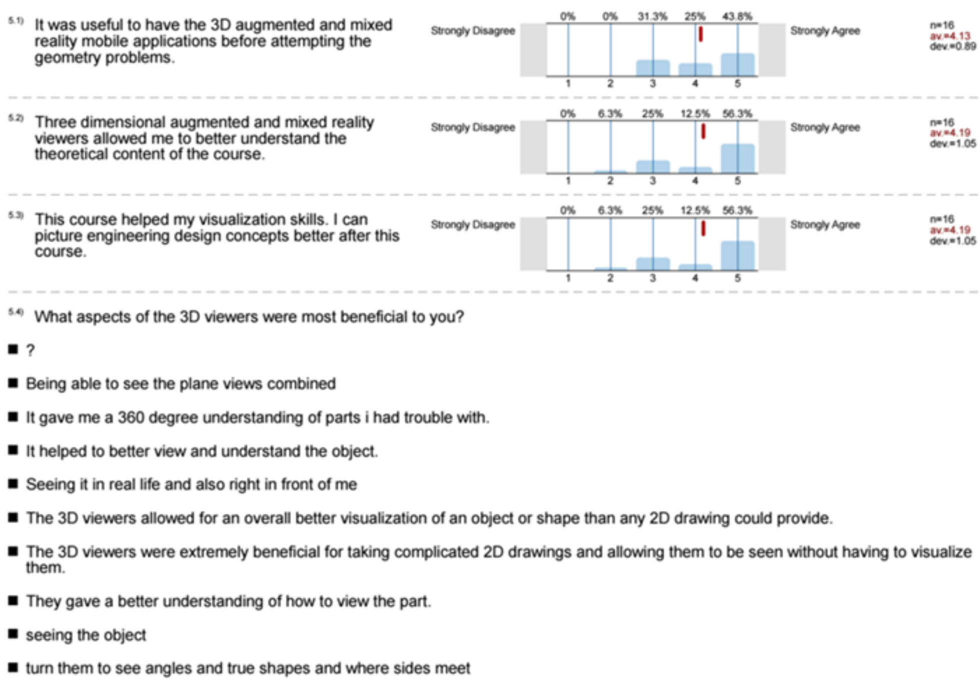

Figure 9 Student Opinion of Teaching Survey

Means of the auxiliary tests performance were calculated for all students in two classes. A paired sample t-test was conducted to evaluate whether a statistically significant difference existed between the mean achievement scores before and after use of GeoVIS with the auxiliary view assignment. The results of the paired sample t-test revealed that the results were significant, $t(34)=(-6.23)$, $p \leq 0.05$ for the first question and $t(30) =(-8.98)$, $p \leq 0.05$ for the second question. Effect size is medium to large based on Cohen's conventions[32]. Average success was improved by level of 5-23 points in different questions with 95% confidence (Table 1).

Table 1 Means of the auxiliary tests scores

	1st Question	2nd Question	3rd Question	4rd Question
Group A (used GeoVIS)	78/100	41/100	97/100	86/100
Group B (w/o GeoVIS)	60/100	35/100	92/100	82/100
Improvement %	23	14	5	5

5. Conclusion

The ability to visualize in three dimensions is a cognitive skill that is linked to success in engineering. Effects of spatial visualization ability in academic performance in engineering drawing were investigated. The MRT is used to measure spatial visualization skills. The author found that the training positively effects the MRT scores, but that there is not a noticeable difference between the two years of MRT scores. Another interesting finding is that the MR or VR experience of students increases the success in board and CAD drawing tests. Students benefited from MR and VR in different levels. The overall success varies also with different topics and questions. The students who straggled on the 2D projection views benefited more from MR or VR experience, which provides them with 360 visualization of the parts. This visualization skill needs to be learned in order to mentally picture the geometry before drawing on the board or generate projection views in a CAD system. There is not enough statistical evidence available to prove or presume any conclusion to justify this result. It will be investigated with further questions categorized based on difficulty to find the correlation in the future. Positive effects of MR and VR experience have been observed in this study based on the test scores. While enough data for a statistical analysis have not been collected yet, post-MRT scores demonstrate promising benefits with the class activities. Improvement of 20% between pre- and post- MRT scores show increasing gain of spatial visualization skill after both traditional and MR enhanced training. In addition, it was found that the MR, VR, and hands-on activities increase the students' interest and awareness in descriptive geometry.

6. Acknowledgments

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