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Stereoscopic Visualization as a Tool For Learning Astronomy Concepts

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STEREOSCOPIC VISUALIZATION AS A TOOL FOR LEARNING ASTRONOMY CONCEPTS

A Thesis

Submitted to the Faculty

of

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by

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This thesis is dedicated to my parents, Mr. Moses Rafael Joseph and Mrs. Rosy Moses Joseph, without whose love and support I would have never been where I am today and who have always encouraged me to work towards my dreams and aspiration no matter how difficult they might be. I would also like to dedicate this thesis to my brother, Mr. Noel Moses Joseph, for providing me support throughout my life. I would like to thanks all my loved ones and my friends who would be happy to know that I have written my own thesis.

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ABSTRACT

Joseph, Norman. M.S., Purdue University, May 2011. Stereoscopic Visualization as a Tool for Teaching Astronomy Concepts. Major Professor: David M. Whittinghill.

Three-dimensional (3D) visualization is becoming an extensively used educational tool. 3D visualization tends to be most useful when demonstrating concepts involving the very large – such as astronomy, or the very small – such as nanotechnology. Stereo visualization allows students to familiarize and immerse themselves in worlds which are difficult or impossible to experience in real life. This study will evaluate the educational benefit of teaching lessons involving a highly spatially-oriented topic (astronomy) using stereoscopic visualization technology.

We have used a stereoscopic visualization system, installed in a classroom, to deploy 3D simulation packages for use in classroom instruction. This educational tool is currently being used for two descriptive astronomy courses in the Physics department, which involve visualization of the galaxies and the Solar System. These courses are taken by students from various departments.

This study used a 3D simulation software developed to view the local universe containing visualizations of the Local Group of galaxies and our Solar System, which was presented using stereographic projection. This interactive software allows the user to navigate through a simulation of the Local Group of galaxies, looking at various galaxies in the Group, navigating from one galaxy to another and measuring the distance between galaxies. The software also allows the user to navigate in a simulation of our Solar System and view the planets that revolve around the sun. The objects in this simulation are kept in relative scale to one another so that students can understand the large variation in sizes of objects found in the universe. The relative scale also allows students to increase their perception of the velocity required to travel the distance between two objects, two planets or even two galaxies.

After conducting the study with 153 students, the data analysis revealed that both the simulation software presented using a two-dimensional perspective and the simulation software presented using the stereoscopic projection system while wearing 3D glasses helped the students learn more compared to the traditionally used PowerPoint presentation. For the current classroom setting, however, the simulation software that was presented using a two-dimensional perspective and the simulation software that was presented using the stereoscopic projection system while wearing 3D glasses were not found to have a significant difference in the amount of information learnt by the students.

CHAPTER 1. INTRODUCTION

3D visualization is becoming a more extensively used educational tool. We propose to use a stereoscopic visualization system installed in a classroom to deploy 3D simulation packages for use in classroom instruction. This educational tool is currently being used for two descriptive astronomy courses in the Physics department and involves a visualization of the galaxies and the Solar System. This interactive simulation allows the user to navigate through the Local Group of galaxies, looking at individual galaxies within the Group, navigating from one galaxy to another, and measuring the distance between the galaxies. The system also allows the user to navigate in a simulation of our Solar System viewing the planets revolving around the sun. The objects in this system are kept in relative scale with one another so that the students can understand the large variation in the sizes of objects found in the universe and allow them to gain a better perception of the velocity required to travel the distance between two objects, two planets or even two galaxies.

1.1. Research Question

The current study will investigate the following research questions

1. Does using Dynamic Spatial Simulation for instruction result in greater understanding and retention of concepts, taught in an Introduction to Astronomy course, when compared to using a Static Information Presentation for instruction?
2. Does using Dynamic Spatial Simulation - Stereo for instruction result in greater understanding and retention of concepts, taught in an Introduction to Astronomy course, when compared to using a Static Information Presentation for instruction?
3. Does using Dynamic Spatial Simulation - Stereo for instruction result in greater understanding and retention of concepts, taught in an Introduction to Astronomy course, when compared to using Dynamic Spatial Simulation for instruction?

1.2. Statement of Purpose

At the scales of galaxies and in particular when talking about the Milky Way, it is not clear how students or a general audience make the connection between the Solar System and its position within our Galaxy. As we move into larger and larger scales, it becomes harder to imagine how billions of galaxies populate the universe. Two-dimensional (2D) graphics have been extensively exploited to address some of these issues, from diagrams to animations. However, much in the same way as it is easier for all of us to comprehend our local environment in 3D, 3D visualization techniques have the potential of becoming a standard educational (and possibly research) tool in astronomy / astrophysics instruction because stereoscopic visualization allows students to familiarize and immerse themselves in worlds in which hands-on experience is otherwise difficult or impossible.

The objective of this study is to evaluate the educational benefit of teaching lessons involving a highly spatially-oriented topic (astronomy) using stereoscopic visualization technology. This study used a 3D visualization tool developed to view a simulation of the universe containing visualizations of the Local Group of galaxies and our Solar System and is presented using a stereographic projection system. The study will investigate whether the higher degree of spatial perception in stereoscopic displays results in an improvement in understanding and retention of concepts, taught in an Introduction to Astronomy course.

1.3. Scope

This study will investigate if the use of a simulation software for instruction has a significant effect on student understanding, when compared to the usage of traditional PowerPoint presentation, and also to check if adding stereoscopic effects to the simulation improves student understanding further.

The study only considered participants as a subset of the students enrolled in the class ASTR264 at the West Lafayette academic campus of Purdue University who attend the laboratory session. The study will be conducted only in a particular classroom which has been setup with a stereoscopic projector so as to display stereoscopic content.

The implementation of the visualization is done using the Vizard Virtual Reality Toolkit and Python scripting. The models used in the simulation software were created using 3D Studio MAX.

1.4. Significance

The main goal of familiarizing students with the local universe (the group of galaxies gravitationally tied to our own, the Local Group) relies on the power of the stereo projection to guide and improve their understanding and knowledge. Additional goals to be achieved by implementation of the 3D visualization of the local universe are to increase motivation and confidence of students towards understanding and learning about astronomy.

As mentioned by Gates B. (2002), “Finding effective ways to use technology to enhance learning is a challenge that educators, academics, policymakers and the technology industry must work together to solve” (p. i). Thus this study is a collaborative initiative from the College of Technology, Envision Center and the Physics department at Purdue University.

The results of this study can also serve as a model showing how to effectively upgrade classroom technology to support stereo projection for classroom instruction.

The results of the evaluation will create feedback as to how well the new stereoscopic system is working and information about participant knowledge gains and attitude towards the system. This will assist in assessing the quality and value of this initiative.

1.5. Assumptions

The study is conducted while considering the following assumptions:

- Even though the teaching assistant will be using different means of instructions for each group of students, the teaching assistant will convey the same information to each group while teaching at the laboratory sessions.
- The student participants will pay attention at the presentation when the teaching assistant is conducting the laboratory sessions so that they will be able to understand the concepts taught.
- The student participants will wear the 3D glasses when the simulation is presented using the stereoscopic projection system.
- The participants will solve the questionnaires before and after the laboratory session with sincerity.

- The data collected during this study can safely be assumed to follow a normal distribution so that the statistical measures can be applied to the data collected.

1.6. Delimitations

The delimitations related to this study are as follows:

- The participants are a subset of the students enrolled in the class ASTR264 at the West Lafayette academic campus of Purdue University who attend the laboratory session.
- The majority of students belonging to these courses are full time students.
- The study solely depends on the score of the students on the questionnaires given to them at each laboratory session.
- The study was conducted for duration of one week in the middle of the spring semester of 2011.

1.7. Limitations

The following are the limitations of this study:

- The projector used in the classroom does not have a very powerful stereo effect as a result of stereo bleeding. The researcher cannot control the quality of the equipment used in the study.

- Student understanding of the concepts does depend on how comfortable the teaching assistant is while using the software and thus the teaching assistant will need to review the software and should have practiced well so as to deliver the presentation in a good manner.
- Since a large number of students enroll for these classes, each student is allowed to attend the laboratory session only once throughout the entire course. Thus each group of students will undergo the laboratory session using the presentation for duration of just one hour.

1.8. Definitions

3D Visualization: For this thesis we will consider the definition, 3D Visualization is the use of computer graphics to create a three-dimensional simulation to help explain a particular concept.

Dynamic Spatial Simulation (DSS): For this thesis we will consider the definition, the Dynamic Spatial Simulation represents the three-dimensional scientific visualization of the local group of galaxies and the Solar System used in this study which provides information about objects, and the spatial relationships between these objects, in space, which is projected onto a two-dimensional screen using perspective projection while using this visualization for instruction.

Dynamic Spatial Simulation - Stereo (DSS-S): For this thesis we will consider the definition, the Dynamic Spatial Simulation - Stereo represents the three-dimensional scientific visualization of the local group of galaxies and the Solar System used in this study which provides information about objects, and the spatial relationships between these objects, in space, which is projected using a stereoscopic projection system while using this visualization for instruction.

Immersive visualization environment: “Immersive visualization environments are virtual reality systems where users can view, navigate and/or modify three-dimensional models with a first-person perspective” (Olanda, Pérez, Morillo, Fernández, and Casas, 2006, p.123).

Scientific visualization: “Scientific visualization is the use of computer graphics to create visual images that aid in the understanding of complex (often massive) numerical representations of scientific concepts or results” (Bryson, 1996, p. 64).

Stereoscopic projection system: “Another element of realism in virtual reality is mimicking stereoscopic vision. To achieve stereoscopic vision the brain calculates the difference between the input it receives from both eyes in order to determine depth. This occurs because in the real world an object is slightly different distances away from each eye. In virtual reality, there are two separate images projected at alternating times, and shutter glasses are synced to the projectors such that each eye sees the appropriate image at the correct time. This arrangement leads the brain to interpret a single image with 3D depth.” (Dohse, 2007, p. 6).

Static Information Presentation (SIP): For this thesis we will consider the definition, the Static Information Presentation represents the traditional presentation medium (generally a PowerPoint presentation) used for instruction in a classroom. This presentation could contain static pictures of concepts to be explained on the topic.

Virtual Reality: “Virtual reality is the use of computers and human-computer interfaces to create the effect of a three-dimensional world containing interactive objects with a strong sense of three-dimensional presence” (Bryson, 1996, p. 62).

1.9. Summary

This chapter has given an introduction to the research study including the research question, statement of purpose, scope, significance, assumptions, delimitations, limitations and definitions. The next chapter provides a review of previous work done in the field which includes the use of virtual reality and scientific simulations in education and also previous research conducted in astronomy education.

CHAPTER 2. REVIEW OF LITERATURE

The literature review will aim to examine previous work done in the field of scientific visualization, Virtual reality and research in Astronomy education. With work done in the above areas; a literature review will be helpful not only to provide guidance but also to point out discrepancies in previous work which should be avoided in this study. Various books, journals and conference proceedings like the Journal of Computers in Mathematics and Science Teaching, Journal of Research in Science Teaching, and ACM symposium on Virtual reality software and technology were used. Sources like the Purdue library, ACM Digital Library and Google Scholar have been helpful to find articles related to this study.

2.1. Scientific visualization and Virtual reality

Scientific Visualization has been defined by Bryson (1996) as, “Scientific visualization is the use of computer graphics to create visual images that aid in the understanding of complex (often massive) numerical representations of scientific concepts or results” (p. 64).

Examples of such scientific visualization would be representations of nano particles, of astronomical applications, liquid visualizations, and ecosystem visualizations among many others. Scientific visualization has been mentioned a lot in literature as being used as an education tool to explain hard to understand concepts, like algebra (Bricken, 1992), the greenhouse effect (Jackson, 1999), science of color (Stone, Meier, Miller, & Simpson, 2000), and cultural heritage (Terashima, 1999).

Scientific visualizations are certainly popular in teaching physics concepts (Kim, Park, Lee, Yuk, & Lee, 2001), where tools have been developed to help explain concepts like behavior of weather cells (Hay, Marlino, & Holschuh, 2000), and allow interactive development of ecosystem (Benes, Andrysco, & Stava, 2009; Deussen, Hanrahan, Lintermann, Mech, Pharr, & Prusinkiewicz, 1998). Simulations for specific models have also been developed. Weeks and Comfort (1983) show a simulation for tropical trees while Costes, Smith, Renton, Guédon, Prusinkiewicz and Godin (2008) show a simulation for apple trees.

These examples are only a small set of all the visual representations that are used to present scientific information. These presentations can certainly help communicate science concepts to students and general public. As mentioned by Yair, Y., Mintz, R., and Litvak, S. (2001),

> Educators are building a new visual language that builds the gap between the concrete world of nature and the abstract world of concepts and models... Scientific visualization provides a way of observing natural phenomena that, perhaps due to their size, duration, or location, are difficult or impossible to observe directly (p. 295).

It has also been seen that the development of the plant architecture studies in horticulture has led to a better understanding of fruit tree development and improvement of tree management at the orchard level (Costes, Smith, Renton, Guédon, Prusinkiewicz, & Godin, 2008).

It is clear, from this review, that computer visualizations using 3D technologies have been widely used to successfully help students understand concepts in science.

Considering the success of using scientific visualization, using immersive virtual reality environments to present these visualizations could be considered as another means of improving the benefits of scientific visualization. Virtual reality has been defined by Bryson (1996) as, “Virtual reality is the use of computers and human-computer interfaces to create the effect of a three-dimensional world containing interactive objects with a strong sense of three-dimensional presence” (p. 62). Immersive visualization environment has been defined by Olanda, Pérez, Morillo, Fernández, and Casas (2006), “Immersive visualization environments are virtual reality systems where users can view, navigate and/or modify three-dimensional models with a first-person perspective” (p.123).

Immersive virtual reality systems have allowed the users to behave in a similar manner as they would behave in a real environment (Olanda, Pérez, Morillo, Fernández, and Casas 2006) and due to this it has been used as a valuable tool in education. There is convincing evidence that one can learn from educational VR systems (Winn, 1997). Examples of such applications include the

GeoWall, a stereoscopic visualization used for geosciences (Johnson, Leigh, Morin, Keken, 2006), immersive visualization used to improve construction education (Messner and Horman, 2003; Messner, Yerrapathruni, Baratta, & Whisker, 2003), virtual reality simulation for coal mining operations (Stothard, Galvin, & Fowler 2004), virtual reality used for traffic simulation (Chun, Ge, Yanyan, & Horne, 2008) and in architecture and build environment education (Horne and Thompson, 2007).

Virtual reality is seen to be useful in education since it enhances the students learning experience by extending the traditional forms of knowledge representations by providing interactivity and immersiveness in simulations (Horne and Thompson, 2007). A similar point is mentioned by Lee, Park, Kim, and Lee (2005), "Virtual reality (VR) techniques offer immersive environments in which the user has great possibilities of interaction" (p. 1). This is especially useful when students have to visualize a three-dimensional structure by looking at a two-dimensional representation which students usually find difficult to do. Using virtual reality for visualizing the third dimension helps students understand the spatial relationships among various sections of the model. Also virtual reality is considered to allow teaching of complex topics without the need to simplify the explanations (Furness, Winn, & Yu, 1997). Since astronomy is a very spatial topic where students need to understand the positions of objects in space relative to each other, this benefit of using virtual reality is of high importance.

Thus using virtual reality with scientific visualization is very useful since by using virtual reality, students can be given experiences which would not otherwise be possible in the real world. Even researchers can conduct investigations which would not be possible in the real world (Bryson, 1996).

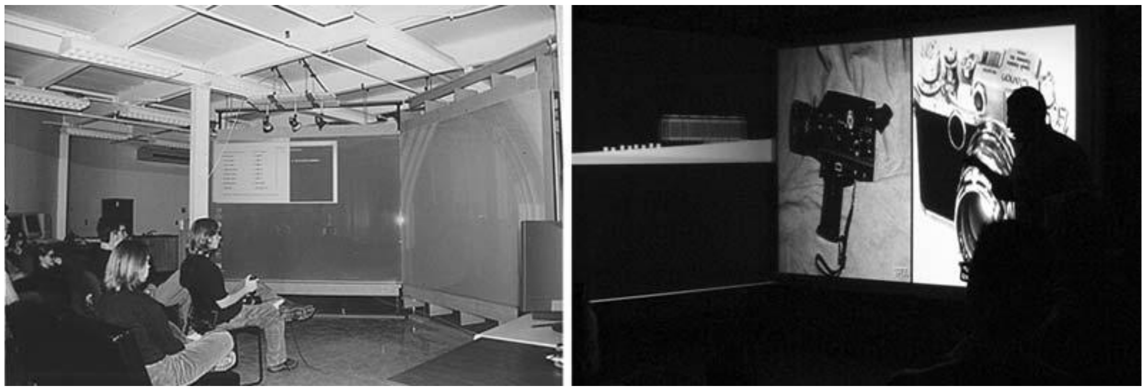

Figure 2.1. Virtual reality system used in design education (Kalisperis, Otto, Muramoto, Gundrum, Masters, and Orland, 2002).

Another study (Kalisperis, Otto, Muramoto, Gundrum, Masters, and Orland, 2002), conducted to use virtual reality in architectural education arrived at the following conclusions,

> Preliminary observations indicate that within the architectural context, virtual reality techniques involving depth perception can convey relevant information to students more efficiently and with less misrepresentation than traditional techniques. This paper suggests that full field of view, motion, stereoscopic vision, and interactivity are possible components of the 3D visualization techniques that are necessary to enhance architectural education (p. 64).

Figure 2.1 gives the system used for the above study.

Thus as said by Bryson (1996), “scientific visualization is potentially a very fruitful application area for virtual reality and should be pursued aggressively” (p. 70). I would like to pursue the current study to see if there is any improvement in student understanding by using the stereoscopic projection system alone to see if there is a need to implement a virtual reality projection system for classroom instruction. As in the above studies this projection system will further be used in various other departments and classes due to the benefits gained in education by using such a system.

2.2. Research in Astronomy education

It has been observed that students generally have a poor understanding of astronomy concepts which usually do not comply with the explanations that are accepted by the scientific community. Such misunderstandings or misconceptions arise at an early age where it is seen that children develop their own explanations (Piaget, 1966). The article by Lanciano (1999) mentions that as the children are growing up these misconceptions are probably caused by incorrect information portrayed in media like films and television serials. As mentioned by Yair, Mintz, & Litvak (2001), “The private cosmological ideas become deeply rooted beliefs, that are often inconsistent with the accepted scientific view” (p. 294). These misconceptions have often seen to persist when they grow old enough to become university students (Broughton, 1999).

One of the popular examples of the above observations is the film, A Private Universe (1988), where it is shown that out of 23 recent Harvard graduates and alumni selected at random, only 2 were able to give a correct explanation of the cause of Earth's seasons. This certainly shows that the level of understanding of astronomical concepts among students is very low. Another study done by Sadler (1992) is a multiple-choice instrument which addresses misconceptions related to astronomy concepts. Sadler reported a mean score of 34% correct when the test was given to over 1,400 high school students.

Astronomical phenomena have always been considered to be difficult for students to understand and this has also been documented in literature (Sneider & Ohadi, 1998; Stahly, Krockover, & Shepardson, 1999). Parker & Heywood (1998) mention the issues in understanding astronomy concepts could be due to the fact that the students need to develop spatial awareness of the three-dimensional objects in space and also considers the movements of these objects from various perspectives. Other studies (Lee, Park, Kim, & Lee, 2005; Yair, Mintz, & Litvak, 2001; Barnett, Yamagatah-Lynch, Keating, Barab & Hay, 2005) also mention that the ability of viewing the Solar System in different 3D perspectives is essential to understand basic astronomical concepts. Presenting their results, Lee, Park, Kim, & Lee (2005) mention, "This study demonstrates that interacting with a dynamic representation such as Solar System might help students to understand spatiotemporal concepts easily without detail explanation" (p. 1).

The study by Barnett, Yamagatah-Lynch, Keating, Barab & Hay (2005) uses Virtual Reality Markup Language (VRML) to actually place the camera on different objects, like the Earth and Moon, to give different perspectives to their students. In the results of their study the authors infer that using the 3D modeling activities does help students solve their misconceptions and also mention that,

> 3-D computational models allow students to construct a realistic model that they can "step into" and shift their frame of reference from one perspective to another. This affords them multiple opportunities to examine their understanding from multiple perspectives (Barnett, Yamagatah-Lynch, Keating, Barab & Hay, 2005, p. 352).

Although these studies consider only the Solar System in their model the same conclusion can be given for the galaxy visualizations used in our system.

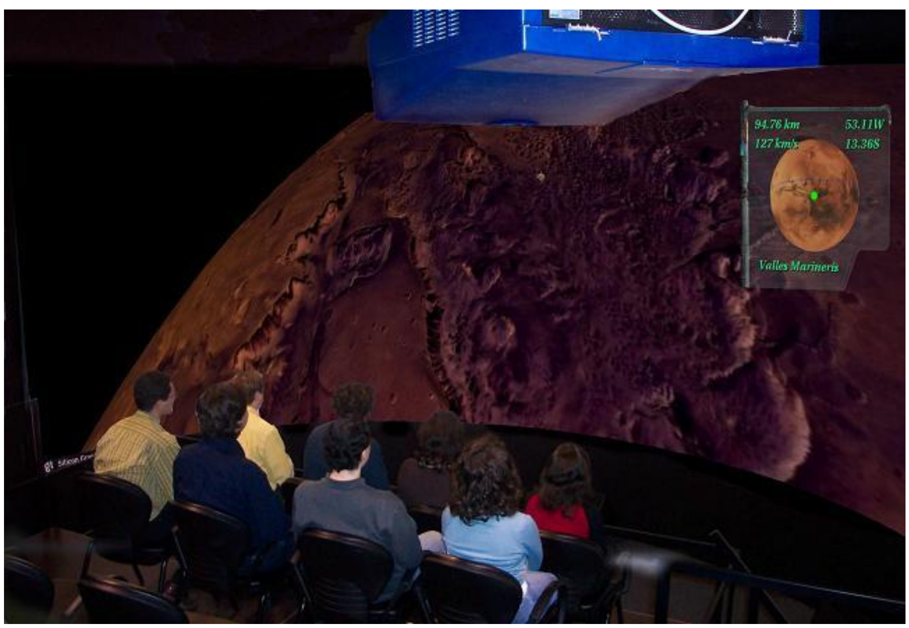

Figure 2.2. Virtual Reality System for Simulation of Mars Surface (Olanda, Pérez, Morillo, Fernández, and Casas, 2006).

Considering these issues with the understanding of astronomy concepts, it is evident that we would need to modify the instruction methods used in classroom using new technologies like scientific visualization and immersive virtual reality. One advantage of virtual reality in astronomy education would be that it allows for exploration of the three-dimensional structure of the universe (Olanda, Pérez, Morillo, Fernández, and Casas, 2006). There have been a few studies where immersive virtual reality systems have been used to teach astronomy concepts (Lee, Park, Kim, & Lee, 2005). The study demonstrates a use of such an immersive virtual reality system to teach students about the Solar System's planetary objects. The results of their study imply that students were content while using the virtual reality system and the students also thought that it helped them understand the content better. Lee, Park, Kim, & Lee (2005) mention,

> From the assessment we can infer the IVRS (immersive virtual reality systems) are very useful as teaching materials especially in case of highly interactive visualization of spatiotemporal concepts such as astronomic definitions (p. 4).

We have certainly considered the above point when developing our system which is also an interactive immersive virtual reality system. But in the above study the comparison is done between software used in an immersive environment and the traditional instruction material thus it is difficult to say if it was the use of the software that increase student understanding or was it the use of the immersive environment that made the difference. I will be attempting to check for this difference while conducting this study.

Many studies do mention that virtual reality systems should be interactive in order to be useful to convey a concept of astronomy to students (Lee, Park, Kim, & Lee, 2005; Yair, Mintz, & Litvak, 2001). This does support the idea we followed to make the system interactive for the current study so that it will promote self learning by user navigation and discovery. There have also been studies showing that students have been more interested in class while using the immersive virtual reality system rather than the usual instruction material (Lee, Park, Kim, & Lee, 2005). This is an aspect I also hope to see in to see in our study.

Olanda, Pérez, Morillo, Fernández, and Casas (2006) report a virtual reality system for space flights over the surface of Mars as an entertainment and informative system, mentioning, “virtual reality had become the most common and viable option for many different scientists” (p. 123). A desktop virtual reality earth motion system (DVREMS) was implemented in a classroom by Chen, Yang, Shen, & Jeng (2007) to teach elementary school students about concepts in astronomy. The authors did see significant results for improvement in test scores while using the virtual reality system in classroom. This study is a good example of implementation and usage of a virtual reality system in a classroom as they were able to prove using a quantitative study that the virtual reality system was effective in helping students understand astronomy concepts. Even when motion related to the Earth was only considered, this can certainly be expanded to include the local group of galaxies.

Looking at studies which mention the positive results of using a virtual reality system to explain astronomy concepts, the study by Gazit, Chen and Yair (2004) provide a few pitfalls of using the virtual reality system for instruction. They mention that using the virtual reality system did create misconceptions of the Sun-Earth-Moon system which Gazit, Chen and Yair (2004) mention were a result of,

> (1) Cognitive difficulty in coordinating visual information emanating from different frames of references; (2) Misinterpreting salient features of the VSS visual representation; (3) Ignoring the 3D nature of the Moon's relative motion, together with incorrect perception of the relative sizes and distances of the Moon and the Earth, and (4) The inability to mentally shift away from the Earth's frame of reference (p. 4346).

In conclusion the authors' advice that using of virtual reality systems in classroom should be accompanied by guided instructions. Similar recommendations have been given by Yair, Schur, and Mintz, (2003) where they mention that providing mentoring while using the virtual reality system is important and leads to improvements in student understanding since the systems do have a weakness where they could be complex to use.

2.3. Summary

This chapter has provided an overview of the previous work that has been done in the field related to virtual reality and scientific simulation used in education and also considered the various research done in astronomy education.

Thus this review provides a confirmation on the importance of usage of virtual reality and scientific simulation in education and how these technologies have been successful in astronomy education. Most of the literature does point towards positive results of the research questions implying that using virtual reality applications might improve student understanding and thus I would like to conduct a study to see if the stereoscopic projection system does affect student learning in astronomy in a positive manner.

CHAPTER 3. FRAMEWORK AND METHODOLOGY

The objective of this study is to see if the use of interactive visualization software has a significant effect on student understanding and also to check if adding stereographic effects to the visualizations improves student understanding further. This chapter outlines the project in greater detail and also provides a detailed explanation of the methodology used for this study. At the end of the chapter a review of the data analysis method is presented.

3.1. Framework

The project has been part of an initiative to introduce the use of stereoscopic visualization in a classroom setting. The project involves the use of a scientific visualization of the Local Group of galaxies and the Solar System which is displayed on the screen using a stereoscopic projection system so that students would see the effect of depth while wearing the 3D glasses.

The visualization software can be divided into four sections. The first section contains the visualization of the Local Group of galaxies which is the group of galaxies near our galaxy, the Milky Way. The user can navigate around the Local Group while taking a look at the different types of galaxies.

Figure 3.1. Section one of the software

The Galaxies are placed to scale in size and location according to the galactic co-ordinates of these galaxies and thus the user has the capability to measure the distance between any two galaxies in the Local Group as shown in figure 3.1. The user can also travel at different speeds ranging from 10,000 meters per second to 500,000 light years per second in the simulation software. The user can navigate in any direction and also can travel from one galaxy to another using a simple command. The user can also display an information screen which displays all the information about the selected galaxy.

Figure 3.2. Section two of the software

On command the user can fly inside the Milky Way, entering the second section of the software, toward the position of the Solar System. This allows the user to gain familiarity with the surroundings, distances and sizes involved within our own Galaxy. Here the user can see the planets, modeled to scale in distance and size, revolving around our Sun in their respective orbits as shown in figure 3.2.

The third section of the software involves the representation of the planets of the Solar System and our Sun to scale in size but not in distance so that it would be easier for the students to view the great size differences between the different planets and the sun as shown in figure 3.3. Here also the user could view the information about any planet on command.

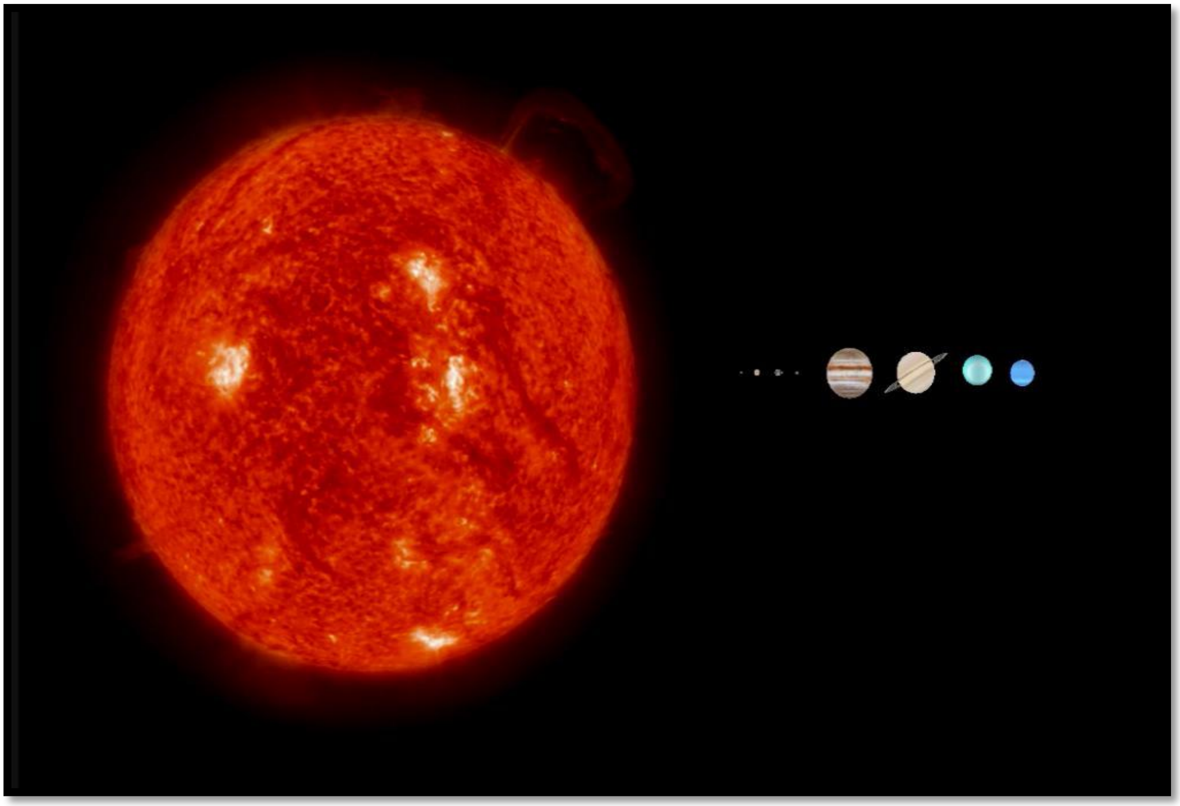

Figure 3.3. Section three of the software

The fourth and final section of the software involves the Earth and our Moon to show the students about the symmetric orbital pattern of our moon as seen in figure 3.4. The user could rotate the Moon and Earth in this section as well as move on to the Earth as well as the Moon to see how it would look if we could sit on the Moon and observe the Earth. This simulation is done to show the students that the same face of the Moon always faces the Earth. Appendix A gives the detailed commands manual for the software.

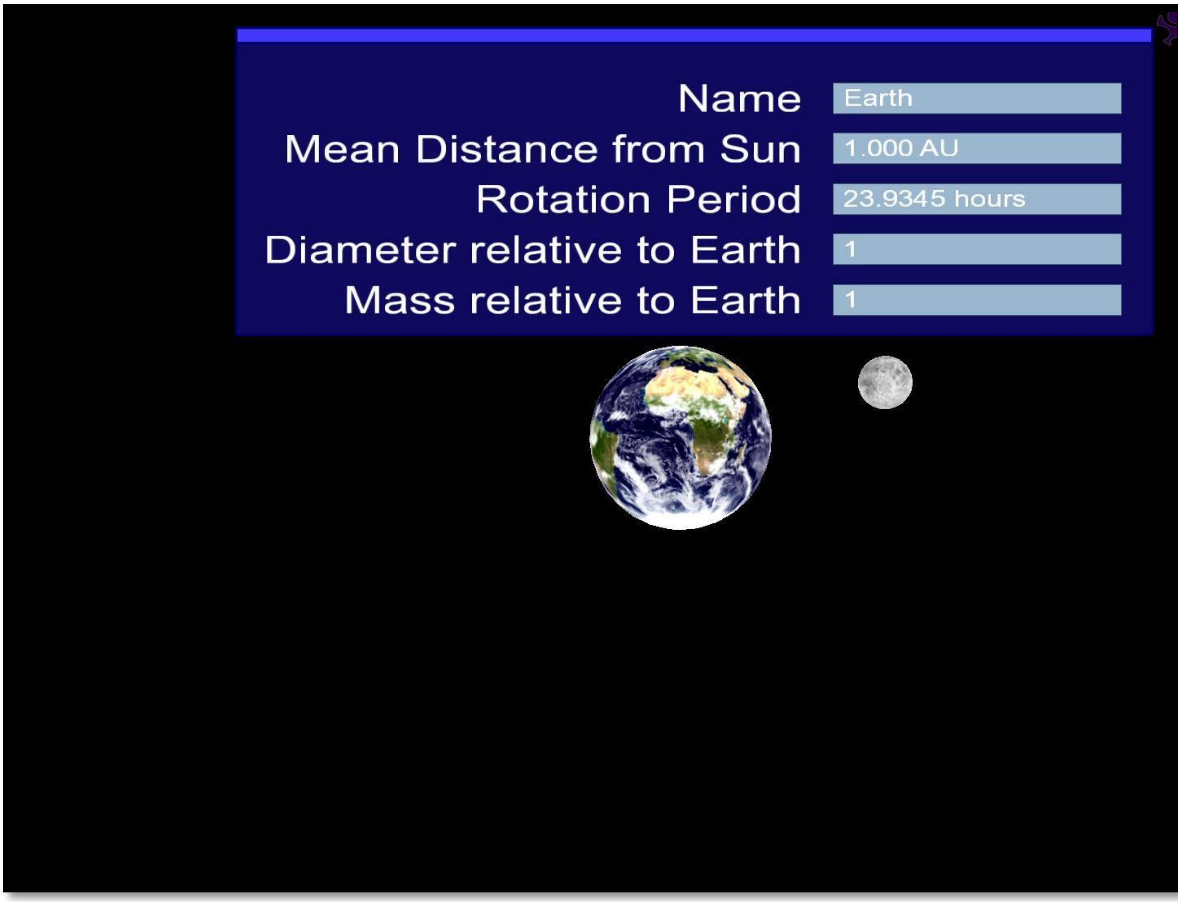

Figure 3.4. Section four of the software

The software can be used on any system that includes a stereoscopic projector system, stereoscopic computer monitor, a normal computer or even a four wall cave environment while using a wand and a head tracker system as shown in figure 3.5 and figure 3.6.

Figure 3.5. Four wall cave with walls closed

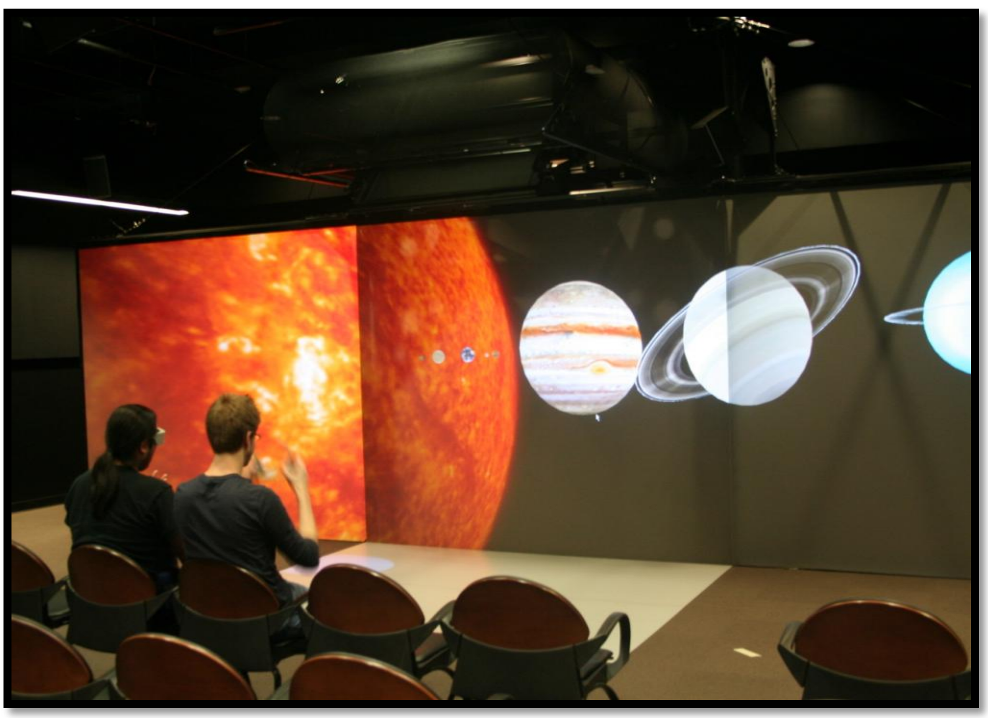

Figure 3.6. Four wall cave with walls open

3.2. Methology

The objective of this study was to evaluate if the use of the simulation software and stereoscopic technology would increase retention of information in students. Content questionnaires were used which had questions that were related to the topic taught in the laboratory session. The score on these questionnaires were then evaluated to see if the students undergoing instruction using the simulation software scored higher than the students undergoing instruction using a static information presentation (SIP).

3.3. Permissions

This section mentions about the permissions that were taken as part of this study. Permissions included course instructor permission for execution of the study in his class and Institutional Review Board approval to conduct this study at Purdue University.

3.3.1. Course Instructor Permission

The instructor was informed about the study and the instructor had given permission to conduct the study using the students of course ASTR 264 as subjects for the study. Information regarding the statement of purpose, research question and methodology of the study was shared with the instructor of the course. Appendix B mentions the email permission given by the course instructor of the course ASTR 264 during the spring semester of 2011.

3.3.2. Institutional Review Board Approval

Institutional Review Board approval from the Human Research Protection Program at Purdue University was requested during the spring 2011 semester. After one round of revision the permission was granted to conduct the study in ASTR 264 during the spring 2011 semester. As the study was deemed to be exempt, a consent form was not required to be signed by the participants to take part in the study. The important point about this request was that participation in the study did not involve risk to the participants beyond that faced in daily life; participation in the study was voluntary, data collected during the research study was not linked with the participant’s name, and only participants above the age of 18 were allowed to be part of this research.

Appendix C provides the letter of approval by the Institutional Review Board at the Human Research Protection Program at Purdue University for this study.

3.4. Experimental Setup

Each seat in the classroom was numbered and a recruitment script was placed on each seat before the students entered the class as can be seen in Figure 3.7.

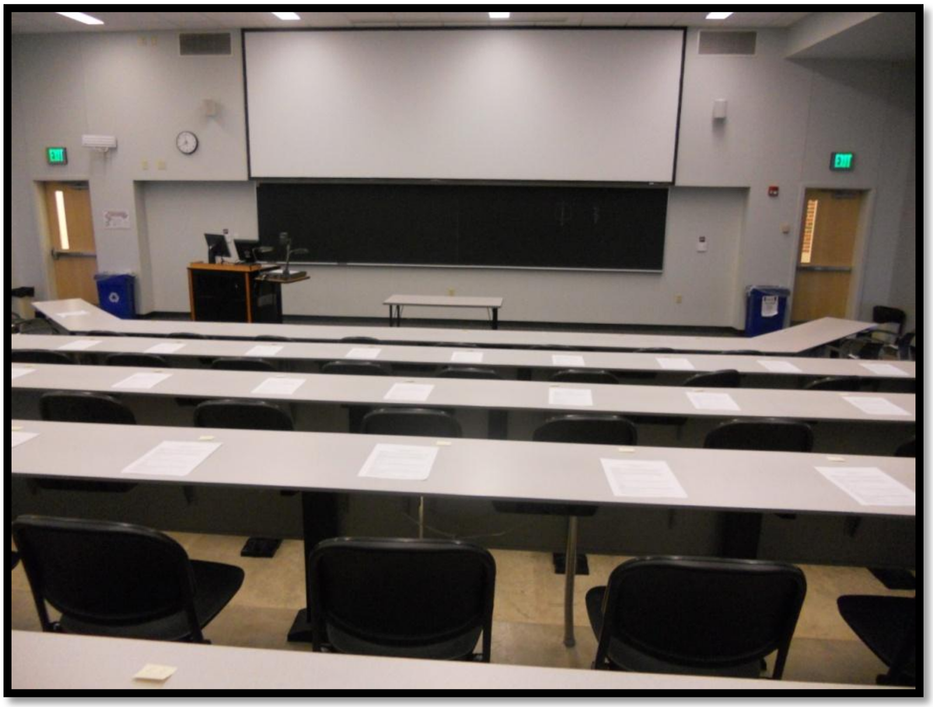

Figure 3.7. Experimental setup

The Recruitment script can be found in Appendix D attached with this document.

3.5. Participants

The software is currently being used as a laboratory session of the classes ASTR 263 and ASTR 264. The students in these classes are divided into sections and a student is assigned to a section at random depending on the time they register for the course and the day they select to attend the laboratory session according to their convenience. The laboratory session would take place on Monday, Tuesday, Wednesday, and Thursday of the week and a student could attend this laboratory session only once. The students of the class of

Spring 2011 for course ASTR 264 were selected for the research study. This course had ten sections which were put together in three different groups. The first group is the control group who received classroom instruction using SIP. Three sections with a total of 54 students attending the laboratory session and were part of Group 1 and underwent instruction on the first day of the research testing. The second group received classroom instruction using the dynamic spatial simulation (DSS). Next three sections with a total of 34 students attending the laboratory session and were part of Group 2 and underwent instruction on the second day of the research testing. The third group received classroom instruction using the Dynamic Spatial Simulation - Stereo (DSS-S). The remaining four sections with a total of 65 students attended the laboratory session on the third and fourth day of the research testing, two sections on each day. All students in the course ASTR 264 who attended the laboratory session (on 21st March 2011, 22nd March 2011, 23rd March 2011 and 24th March 2011) had the opportunity to participate in this study regardless of age, gender or ethnicity.

3.6. Procedure

The participants were first introduced to the research study by informing them about the details included in the recruitment script (present in Appendix D). Then they were asked to take a pretest before the class began. The students then underwent the classroom instruction using the respective medium. A teaching assistant (TA) conducted the class for the students. The same TA conducted the class for all the groups and thus not causing any TA effect. After instruction, the students were asked to take a posttest. After completion of the posttest the students who had not been exposed to the stereoscopic presentation during class instruction (Group 1 and Group 2) were shown the stereoscopic presentation at this time. The students who had seen the stereoscopic presentation (Group 3) were shown the PowerPoint presentation at this time. After this presentation the students were asked to fill out a Post-3D questionnaire which allowed students to provide open-ended comments about the stereoscopic presentation.

3.6.1. Pretest

A pretest was given to the all the students in the start of each laboratory session. The pretest included question involving student background including education level and major. The pretest also had questions related to the course to assess the level of prior knowledge the student has about the principles to be taught in the course.   Bibliographic information was also asked at this time to learn about the background of the students. The students also reported the seat number that they will be sitting on so that we could judge which seating provided the best possible immersive effect for the current classroom.

3.6.2. Class Instruction

The courses ASTR 263 and ASTR 264 provide an introduction to astronomy and are non-mathematical courses that cater to non-physics majors. Thus, students from various majors can be expected to attend this course. To conduct the laboratory session, the students are divided into sections and each section of students undergoes the laboratory session just once during the semester. The students were given a questionnaire after the laboratory session which needed to be completed in class.

The objective of this study was to see the effects of the different configurations of the presentation on student learning which would then be measured by student scores on the questionnaires after each class. Using different means of instructions for each group of students, helped compare the effects of each medium on student understanding.

Thus Group 1 and Group 2 conducted instructions in a classroom without using the stereo capability of the classroom. Group 3 underwent instructions on using the stereographic capabilities of the classroom while wearing 3D glass.

3.6.3. Posttest

A posttest was conducted after the completion of the laboratory session to assess the knowledge gained by the student. The score gained on this test will be compared with the pretest scores to check for any difference in score. The post test will also contain questions related to motivation aspects of the student to know the students opinion and attitude towards this initiative.

3.6.4. Post 3D Opinion Questionnaire

After completion of the Posttest questionnaire, Group 1 and Group 2 were shown the visualization using the stereo capability of the classroom and were then asked to fill the Post 3D Opinion Questionnaire. Students in Group 3 had undergone instructions while using the stereographic capabilities of the classroom while wearing the 3D glasses and thus were now shown the PowerPoint presentation and were then asked to fill the Post 3D Opinion Questionnaire. The Post 3D Opinion Questionnaire contained questions asking the students how they felt about the stereographic presentation and also asked the students to mention any comments they had about the stereographic presentation including things that they would like to see improved.

3.7. Hypothesis

This study involved the following hypotheses:

$H1_0$: There is no difference in the change of scores, between pretest and posttest, taken by students who received class instruction using a Static Information Presentation and students who received class instruction using the Dynamic Spatial Simulation.

$H1_{\alpha}$: There is a difference in the change of scores, between pretest and posttest, taken by students who received class instruction using a Static Information Presentation and students who received class instruction using the Dynamic Spatial Simulation.

$H2_{0}$: There is no difference in the change of scores, between pretest and posttest, taken by students who received class instruction using a Static Information Presentation and students who received class instruction using the Dynamic Spatial Simulation - Stereo.

$H2_{\alpha}$: There is a difference in the change of scores, between pretest and posttest, taken by students who received class instruction using a Static Information Presentation and students who received class instruction using the Dynamic Spatial Simulation - Stereo.

$H3_{0}$: There is no difference in the change of scores, between pretest and posttest, taken by students who received class instruction using the Dynamic Spatial Simulation and students who received class instruction using the Dynamic Spatial Simulation - Stereo.

$H3_{\alpha}$: There is a difference in the change of scores, between pretest and posttest, taken by students who received class instruction using the Dynamic Spatial Simulation and students who received class instruction using the Dynamic Spatial Simulation - Stereo.

3.8. Data Analysis

The test scores for each group underwent statistical analysis to check if each individual instruction medium has been effective in improving the knowledge level of the student. A matched pair *t*-test statistic will be used to analyze this data. A *t*-test statistic is used to provide the information as to how different two groups of measurements are, providing the capability to check if the two distributions differ or are essentially the same. As mentioned by Moore, McCabe, and Craig (2009), "in a matched pairs study, subjects are matched in pairs and the outcomes are compared within each matched pair" (p. 428). This test statistic is used when observations are taken on the same set of subjects at different conditions as in the case of this study where the two tests (pre-test and post-test) are taken by the same subjects of each group. As mentioned by Moore, McCabe, and Craig (2009), suppose a simple random sample of size n from a Normally distributed population with mean μ and sample mean $\bar{x}$ sample standard deviation s, then the *t* statistic

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}}$$

has the t distribution with n – 1 degrees of freedom. This statistical measure is a good choice because of the robustness of the *t* procedure against non-Normality of the population. We know that larger samples improve the accuracy of P-values and critical values from the *t* distributions when the population is not Normal. In statistics it is known that for large samples with number of subjects greater than or equal 40, *t* procedures can be used even for clearly skewed distributions

(Moore, McCabe, & Craig, 2009). The number of subjects in each group used for this study is near or more than 40 and thus the *t* procedure is a good choice for this analysis. The calculations for this test statistic are done using Statistical Analysis Software (SAS).

A quantitative analysis was conducted to see if there is a significant improvement in student scores across the various instruction methods used. To make a comparison among the three groups the one-way analysis of variance (ANOVA) test statistic was used. The ANOVA tests statistic is generalized from the t procedure for comparing the means of more than two groups and shares the robustness and usefulness of the *t* procedures (Moore, McCabe, & Craig, 2009).

The scores obtained on the pre and post test for each student was considered and the difference in the pre and post test scores will be compared between groups to see if the students are gaining any advantage by using the different mediums of instructions. Thus the main variables to be considered for this study would be the test score and the medium of instruction that the student undergoes during the laboratory session. One-way analysis of variance (ANOVA) tests statistic will be used to check for significance for the difference in the means (of score differences) of the three groups. A one-way ANOVA tests statistic is used since there is only one-way to classify the three groups, namely by the medium that was used for the classroom instruction. Since we are comparing the means of the difference between the pre and post test for each student the ability of a particular student can be ruled out as a factor affecting the results. As mentioned by Moore, McCabe, and Craig (2009),

> ANOVA tests the null hypothesis that the population means are all equal. The alternate is that they are not equal. This alternative could be true because of all the means are different or simply because one of them differs from the rest. This is more complex situation than comparing just two populations. If we reject the null hypothesis, we need to perform some further analysis to draw conclusions about which population means differ from which others and by how much (p. 641).

I applied the ANOVA test statistic on each pair individually to check for the hypothesis for this study and also checked for robustness of the result by applying the Tukey’s test statistic. The Tukey's test is usually used along with the ANOVA test statistic and is used to compare which means are significantly different from one another. The formula for Tuket test is given as

$$q_s = (Y_A – Y_B) / SE$$

where Y_A is the larger of the means and Y_B is the smaller of the means and SE is standard error. If the groups fall in different Tukey groupings it would imply that the means of these two groups are significantly different. The least mean square method is also use to further confirm the statistical results.

The statistical Analysis was reviewed by a statistical constant at the university.

CHAPTER 4. RESULTS

This chapter presents the data collected during the study and also presents the quantitative analysis of these data, namely the scores of the students on the pretest and posttest questionnaires. This chapter also gives an analysis of the opinion questionnaires so as to convey what the students generally thought about the simulation software and the stereoscopic effect.

4.1. Review: Statement of Problem

The objective of this study is to evaluate the educational benefit of teaching lessons involving a highly spatially-oriented topic (astronomy) using stereoscopic visualization technology.

This study used a visualization tool developed to view the local universe containing visualizations of the Local Group of galaxies and our Solar System and will use stereographic projection. The study concentrated on the content questions of the questionnaires to test to see if the students viewing the visualization had greater understanding and retention of the concepts taught in an introduction to astronomy course. Thus, content questions underwent detailed statistical analysis whereas the opinion questions are presented for informational purposes only. We look at the opinion questions at the end of this chapter to see what the students preferred the most and what students think about the presentation.

4.2. Description of Participants

Students from the ASTR 264 class were chosen as subjects for the research. The questionnaires revealed that of these subjects who took part in the research 49.67% were male and 50.33% were female (out of a total of 153 students). For each group the gender population was as mentioned in Table 4.1.

Table 4.1.

Gender distribution between groups

Group	**Percentage of Males**	**Percentage of Females**	**Total Number of students**
1	48.14814815	51.85185185	54
2	47.05882353	52.94117647	34
3	52.30769231	47.69230769	65

The subject population constituted of only undergraduate students from all four years: freshman, sophomore, junior and senior (as mentioned in Figure 4.1). The bibliography information questionnaire also revealed that there were students with several majors and minors as part of the research study. The list of Majors and Minors can be found in Table 4.2 and Table 4.3.

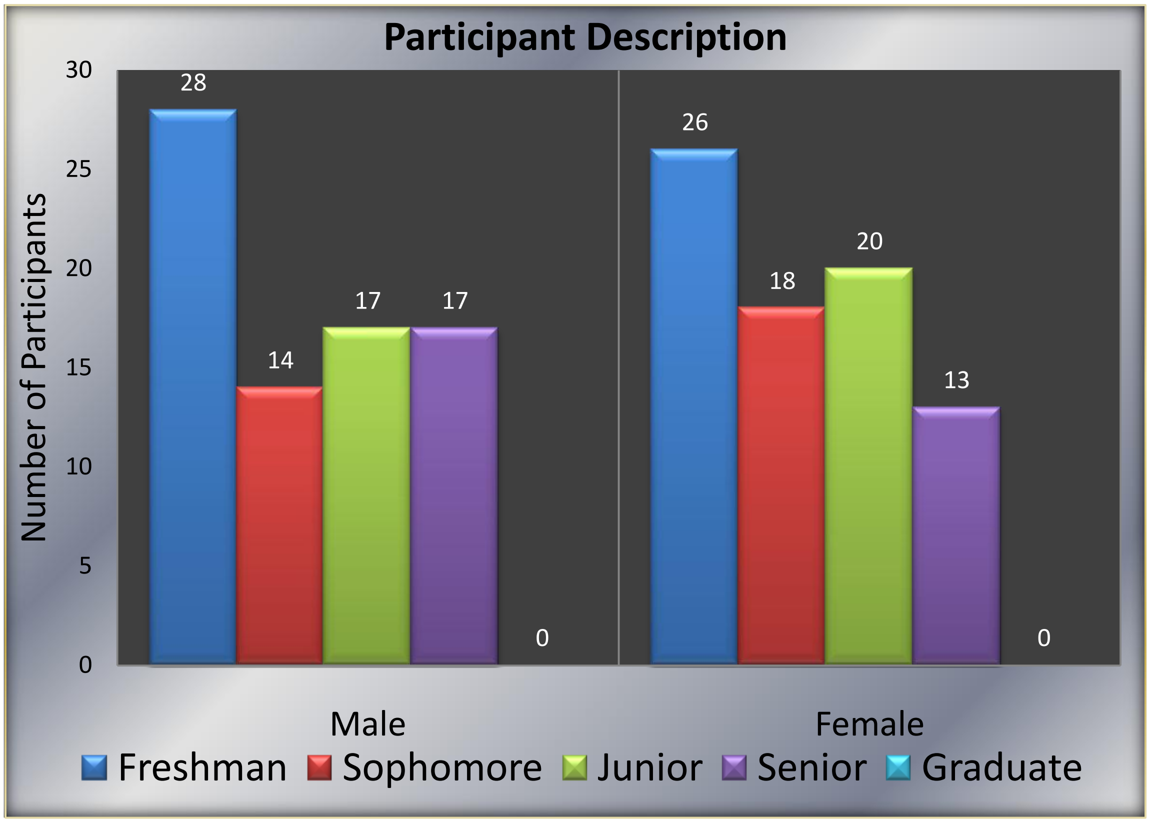

Figure 4.1. Participant Description

Table 4.2.

List of Majors

Student Major	Student Major
Accounting	Industrial Design
Actuarial Science	Interior Design
Advertising	Japanese and Asian Studies
Aeronautical Engineering	Landscape Horticulture and Design
Agricultural Communications and Agricultural Economics	Law and Society
Agriculture Sales and Marketing	Liberal Arts
Animal Science	Linguistics
Anthropology	Management
Astronautical Engineering	Mass Communication
Behavioral Neuroscience	Mechanical Engineering
Biochemistry	National Resources and Environmental Science

Table 4.2. (continued)

Student Major	Student Major
Biology	Occupational Health Sciences
Business Management	Organizational Leadership and Supervision
Chemistry	Philosophy
Communications	Photography
Communications - Public Relations and Rhetorical Advocacy	Physics
Computer Engineering	Political Science
Computer Graphics technology	Professional Writing
Computer Science	Psychology
Creative Writing	Public Relations
Earth and Atmospheric Science	Retail Management
Economics	Selling and Sales Management
Electrical Engineering	Sociology
Engineering	Sociology
English	Spanish
Film and Visual Studies	Spanish Education
Financial Counseling and Planning	Speech language hearing Science
Fine Arts	Systems Management
Fisheries and Aquatic sciences	Theatre Production and Design
Film and Video Studies	Undecided
Geophysics	Undergraduate Studies Program
German	Visual Communication Design
History	Wild Life
Human Services	

Table 4.3.

List of Minors

Student Minor	Student Minor
Antropology	German
Arabic	History
Art and Design Studio	Law and Society
Astronomy	Management
Child development Family Studies	Marketing

Table 4.3. (continued)

Student Minor	**Student Minor**
Communications	Math
Creative Writing	Music
Dance and Flim and Video Studies	Organizational Leadership and Supervision
Economics	Philosophy
Education	Psychology
English	Sociology
English Literature	Spanish
Entrepreneurship	Statistics
Finance	Theatre
Flim Studios	Undecided
Forensic Science	Wild Life
French	Women's Studies

4.3. Data Analysis on Individual Groups

We will first consider each group individually to check if each instruction medium did, by itself, help students understand the topic taught in the course and also retain information about the topic after completion of the laboratory session (as evidenced by higher scores in the post test). A matched pair *t*-test statistic was carried out to compare the pretest and posttest scores for a Group with the below hypotheses

H_0: The means of the posttest and pretest scores gained by students in a particular group are equal.

H_α: The mean of the posttest scores is greater than the mean of the pretest scores gained by students in a particular group.

To analyze the performance of the students in this group the scores on the posttest and pretest were considered and analysis was done using Statistical Analysis Software (SAS). The data (the pretest scores and posttest scores) were checked for normality using the Histograms and Normal quantile plots. The distributions show a slight deviation from Normality but because the sample size of all the groups is large we can safely apply the t procedures assuming that the distributions are normal (Moore, McCabe, & Craig, 2009). The Box Plots drawn for each group show that there were no suspected outliers. A Box Plot is a graph that is used to summarize the distribution of a set of data values. The upper and lower ends of the center box indicate the 75th and 25th percentiles of the data, and the two ends of the lines indicate the maximum and minimum values in the data set. The line in the center box indicates the median, and the center **o** indicates the mean.

4.3.1. Data Analysis for Group One

Group 1 was the control group for this research study and consists of 54 students. The students in this group underwent the classroom instruction using the Static Information Presentation (SIP).

A matched pair t-test statistic was carried out to compare the pretest and posttest scores for Group 1. These scores were compared for statistical significance using the matched pair *t*-test statistic as shown in table 4.4.

Table 4.4.

Matched pair t-test statistic for test scores for Group one

Match Paired T-test Scores of students in Group 1					
Difference: Post_Test_score - Pre_Test_Score					
N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
54	3.7778	2.5229	0.3433	-1	9
Mean	95% CL Mean		Standard Deviation	95% CL Standard Deviation	
3.7778	3.0892	4.4664	2.5229	2.1208	3.1145

DF	t Value	Pr > |t|
53	11	<.0001

Figure 4.2. Students viewing the Static Information Presentation (SIP)

Figure 4.2 shows students viewing the SIP. The Matched pair *t*-test revealed that there was a significant difference between the post test and pre test scores among participants of Group 1 with *p*-value < 0.0001 which is significant at the 0.05 alpha level. We can thus reject the null hypothesis and say that the data shows evidence that the scores gained (difference between scores earned by students on posttest and pretest) by students on the posttest is significantly larger than the scores gained by students on the pretest.

Figure 4.3 gives a visual representation of the posttest and pretest scores of students in Group 1. The mean of the pretest scores for the 54 students forming Group 1 was 8.8333333 with standard deviation of 2.2716464. The mean of the posttest scores for the 54 students forming Group 1 was 12.6111111 with standard deviation of 2.2605448.

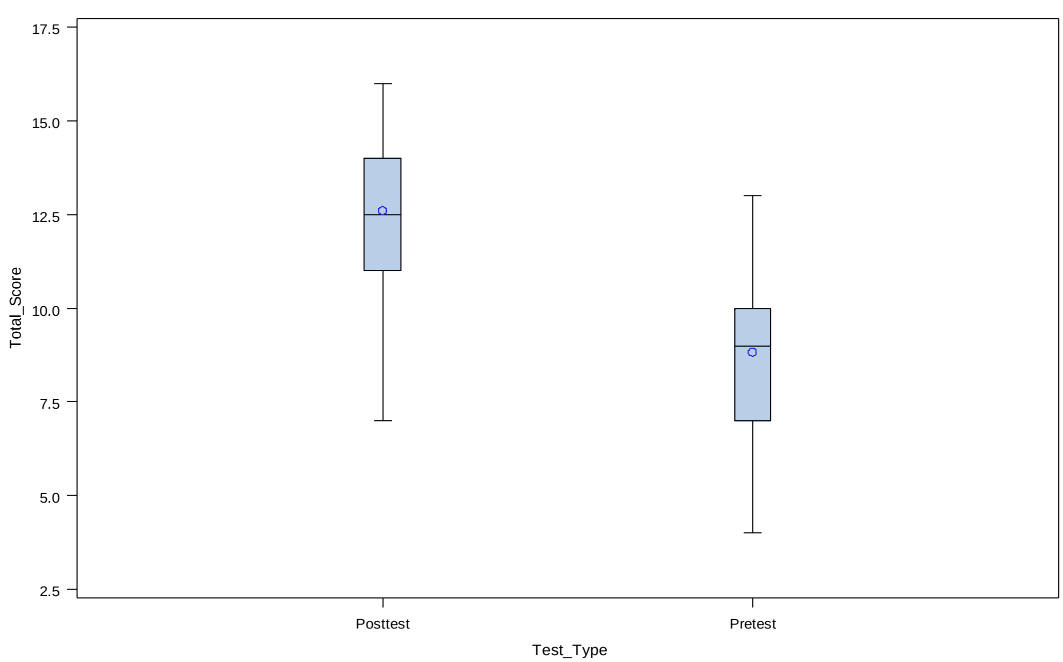

Figure 4.3. Box Plot for pretest and posttest scores of students in Group 1

4.3.2. Data Analysis for Group Two

The students in this group underwent the classroom instruction using the Dynamic Spatial Simulation (DSS). Group 2 consist of 34 students.

A matched pair *t*-test statistic was carried out to compare the pretest and posttest scores for Group 2. These scores were compared for statistical significance as shown in table 4.5.

Figure 4.4 shows students viewing the DSS. The Matched pair *t*-test revealed that there was a significant difference between the post test and pre test scores among participants of Group 2 with *p*-value < 0.0001 which is significant at the 0.05 alpha level. We can thus reject the null hypothesis and say that the data shows evidence that the scores gained by the students on the posttest is significantly larger than the scores gained by the students on the pretest.

Table 4.5.

Matched pair t-test statistic for test scores for Group two

Match Paired T-test
Scores of students in Group two

Difference: Post_Test_score - Pre_Test_Score

N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
34	5.0588	2.6622	0.4566	1	10

Mean	95% CL Mean		Standard Deviation	95% CL Standard Deviation	
5.0588	4.1299	5.9877	2.6622	2.1473	3.5042

DF	t Value	Pr > |t|
33	11.08	<.0001

Figure 4.4. Students viewing the Dynamic Spatial Simulation (DSS)

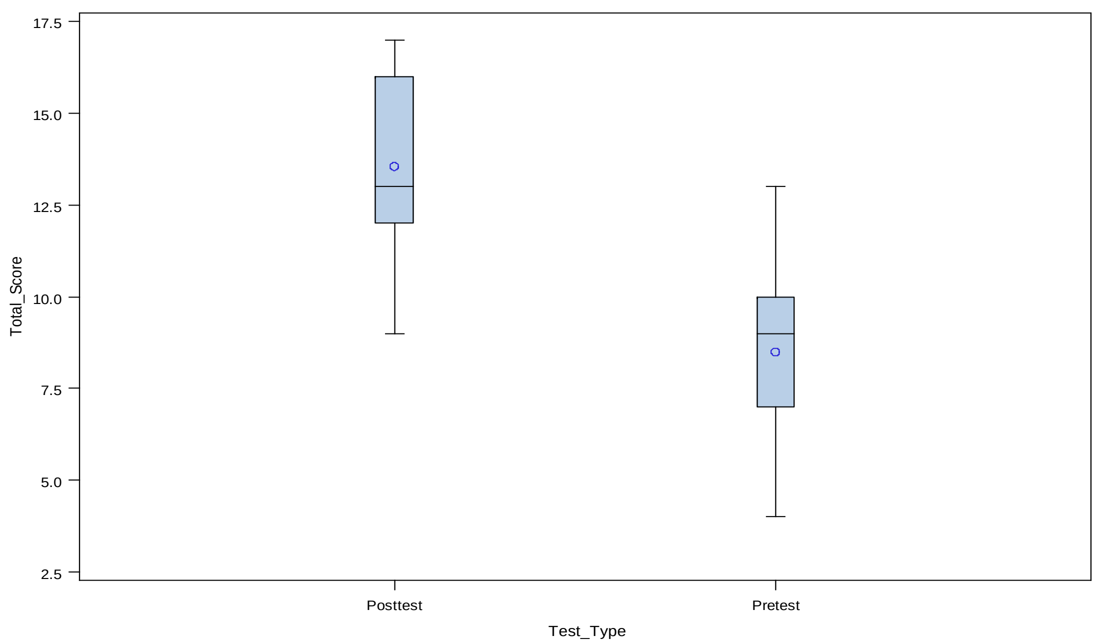

Figure 4.5. Box Plot for pretest and posttest scores of students in Group 2

Figure 4.5 gives a visual representation of the posttest and pretest scores of students in Group 2. The mean of the pretest scores for the 34 students forming Group 2 was 8.5000000 with standard deviation of 2.2863230. The mean of the posttest scores for the 34 students forming Group 2 was 13.5588235 with standard deviation of 2.2588704.

4.3.3. Data Analysis for Group Three

The students in this group underwent the classroom instruction using the Dynamic Spatial Simulation - Stereo (DSS-S). Group 3 consists of 65 students.

A matched pair *t*-test statistic was carried out to compare the pretest and posttest scores for Group 3. These scores were compared for statistical significance as shown in table 4.6.

Table 4.6.

Matched pair t-test statistic for test scores for Group three

Match Paired T-test
Scores of students in Group three

Difference: Post_Test_score - Pre_Test_Score

N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
65	4.8000	2.5630	0.3179	0	11

Mean	95% CL Mean		Standard Deviation	95% CL Standard Deviation	
4.8000	4.1649	5.4351	2.5630	2.1856	3.0989

DF	t Value	Pr > |t|
64	15.10	<.0001

Figure 4.6 shows students viewing the stereoscopic version of the simulation software. The Matched pair *t*-test revealed that there was a significant difference between the post test and pre test scores among participants of Group

3 with *p*-value < 0.0001 which is significant at the 0.05 alpha level. We can thus reject the null hypothesis and say that the data shows evidence that the scores gained by the students on the posttest is significantly larger than the scores gained by the students on the pretest.

Figure 4.6. Students viewing the Dynamic Spatial Simulation - Stereo (DSS-S)

Figure 4.7 gives a visual representation of the posttest and pretest scores of students in Group 3. The mean of the pretest scores for the 65 students forming Group 3 was 7.6615385 with standard deviation of 2.5937239. The mean of the posttest scores for the 65 students forming Group 3 was 12.4615385 with standard deviation of 2.8122329.

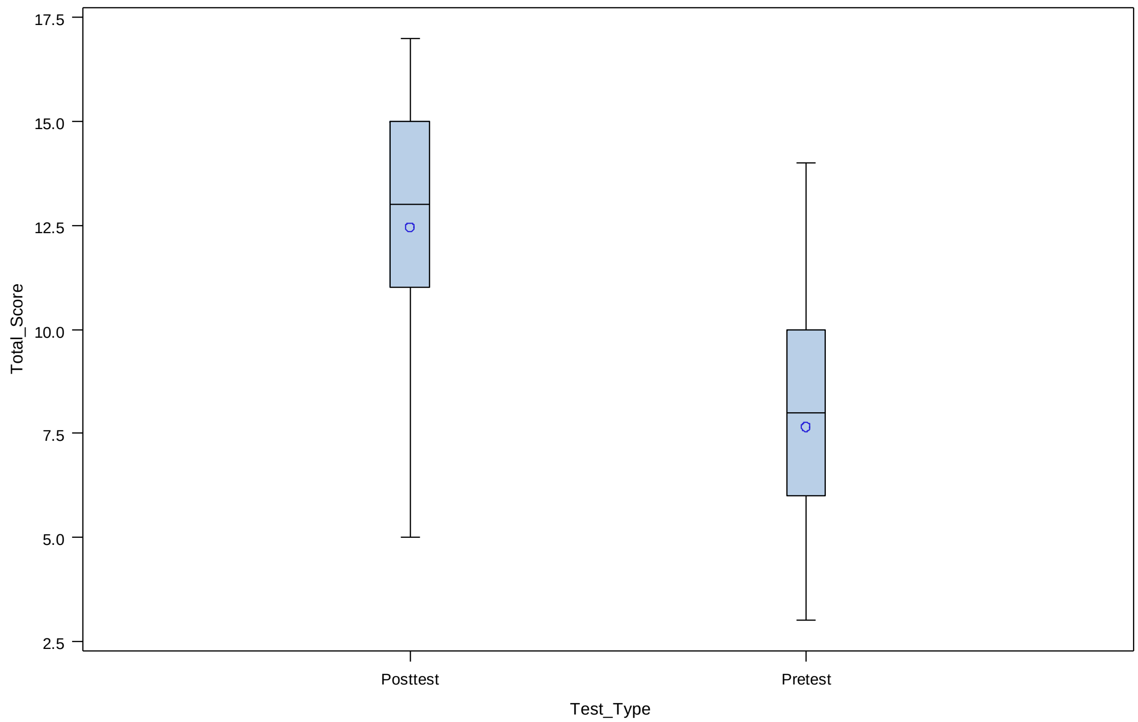

Figure 4.7. Box Plot for pretest and posttest scores of students in Group 3

4.4. Comparison Among Groups

In this section we look at the difference between the three groups to determine if students in a particular group performed better, that is, students of one group better understand the topic taught in the course and also retain more information about the topic after completion of the laboratory session than the other group so as to get a higher difference between the posttest and pretest scores.

A one-way analysis of variance (ANOVA) test statistic was carried out for the three groups of students in the study.

4.4.1. Check for Assumptions

The assumptions for ANOVA, Tukey Test and Least Squares Means test statistic were tested as below.

1. Independence of cases – The score gained by the students on the test for one group is independent of the scores gained by students in any other group. Additionally the questions on each questionnaire were different and were independent of any other questions on the questionnaire. Though the pretest and posttest questionnaires could be considered similar due to the fact that they were checking for similar concepts, for the matter of this study we could considerer the two questionnaires independent of each other since the questions were reordered in the two questionnaires and many of the questions were either reworded or changed. Also after giving the pretest the students underwent classroom instruction for duration between 45 minutes to 60 minutes before they were asked to fill in the posttest questionnaires. Thus, we could consider the two questionnaires independent of each other.
2. Normality – The distributions of the residuals were checked for normality. The distributions show a slight deviation from Normality, but because the sample size is large and the distributions show no strong skewness we can safely apply the statistical tests.
3. Equality (or "homogeneity") of variances – Because largest standard deviation (2.6622) is less than twice the smallest standard deviation

(2.5229), we may assume the standard deviation is constant among groups.

4.4.2. Comparison Among All Three Groups

The one-way ANOVA revealed that there is a significant difference in scores among the three groups, that is, not all means are equal. The analysis gives F (2,150) = 3.38, giving a *p*-value of 0.0368, which is significant at the 0.05 alpha level. Thus, the data shows that the score gain for the students for all three groups is not the same. Figure 4.8 gives a visual representation of the score gain of the students in each group.

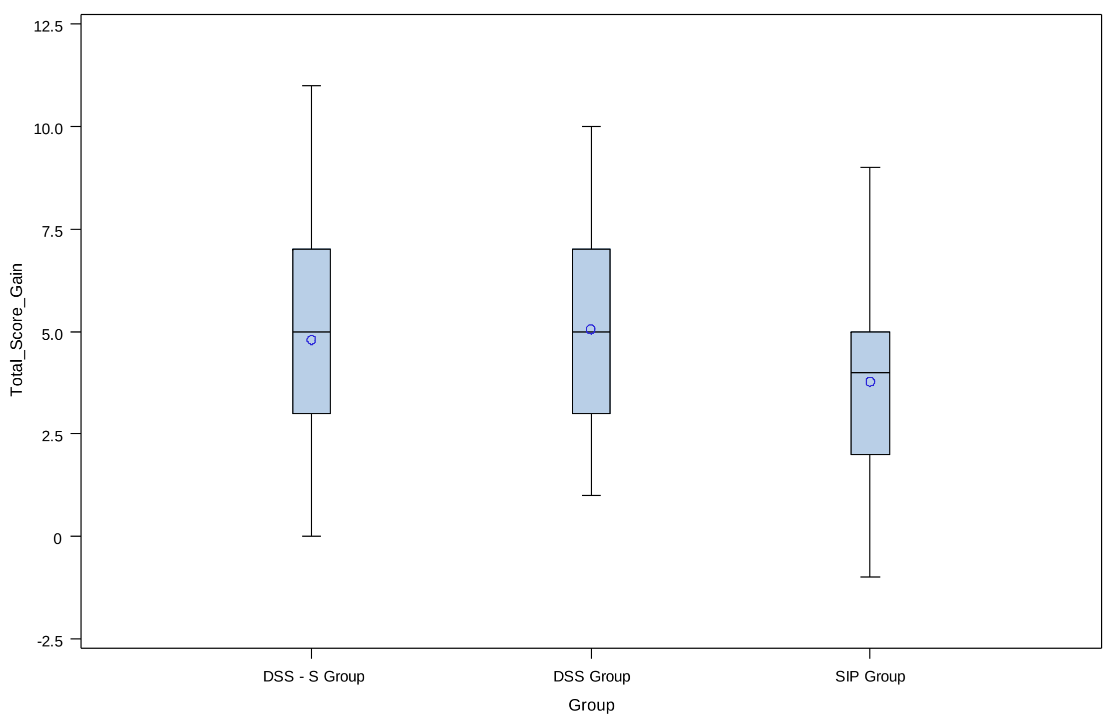

Figure 4.8. Box Plot for score gain of students in all groups

A one-way ANOVA analysis was also run considering each of the factors, Gender of the Students and their Current Year of Study (freshman, sophomore, junior or senior). Both of these factors did not show up as significant factors affecting the results at the alpha level of 0.05 in the one-way ANOVA analysis. The factor Gender of the Students had the *p*-value of 0.1255 while the factor Current Year of Study had the *p*-value of 0.3511 which failed to be significant at the 0.05 alpha level.

In the below section I will analyze each pair of groups individually to check which pair of groups differ from each other.

4.4.3. Comparison Between the Group Which Underwent Instruction Using Static Information Presentation and the Group Which Underwent Instruction Using the Dynamic Spatial Simulation

Here, I check to see if there is a significant difference in the change in pretest and posttest scores among the students who received classroom instruction using a SIP and the students who received class instruction using the DSS. To analyze the performance of the combined 88 students from these two groups, the score gains (difference between the posttest and pretest scores for each group) of the students of the two groups were considered and the analysis was done using SAS.

A one-way ANOVA test statistic was carried out to compare Group 1 (group which underwent instruction using the SIP) with Group 2 (group which underwent instruction using the DSS). The one-way ANOVA revealed that there is a significant difference in score gains between the two groups. The analysis gives F (1, 86) = 5.15, giving a *p*-value of 0.0257, which is significant at the 0.05 alpha level. Thus, the data shows that the score gain by the students who underwent classroom instruction using the DSS is not the same as the score gain by the students who underwent classroom instruction using the SIP. By comparing the means of the score gains of the group which underwent instruction using DSS (5.0588235) and the group which underwent instruction using the SIP (3.7777778) we can conclude with statistical significance, at the 0.05 alpha level, that the students who underwent classroom instruction using the DSS have a higher score gain compared to the students who underwent classroom instruction using the SIP. This result was confirmed by running the Tukey Test statistic on the data as mentioned in Table 4.7.

Table 4.7.

Tukey Test statistic for comparing Group 1 and Group 2

Tukey Grouping	Mean	N	Group
A	5.0588	34	DSS Group
B	3.7778	54	SIP Group

In table 4.7 we can see that the two groups belong to different Tukey groupings and thus we can say that the two groups have statistically significant difference at the 0.05 alpha level in their means with the group which underwent instruction using the DSS having a higher mean score gain. This result was also confirmed by running the Least Squares Means test statistic, the results of which are given in table 4.8.

Looking at the Least Squares Means test statistic results, we can conclude with statistical significance (at the alpha level of 0.05) that the mean score gain of the students in the group which underwent instruction using the DSS is larger than the mean score gain of the group which underwent instruction using SIP (*p*-value=0.0257).

Table 4.8.

Least Squares Means test statistic for comparing Group 1 and Group 2

Group	Total_Score_Gain LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
DSS Group	5.05882353	2.27	0.0257
SIP Group	3.77777778		

4.4.4. Comparison Between the Group Which Underwent Instruction Using Static Information Presentation and the Group Which Underwent Instruction Using the Dynamic Spatial Simulation - Stereo

Here, I check to see if there is a significant difference in the change in pretest and posttest scores among the students who received classroom instruction using the SIP and the students who received class instruction using the DSS-S. To analyze the performance of the combined 119 students from these two groups, the score gains (difference between the posttest and pretest scores for each group) of the students of the two groups were considered and the analysis was done using SAS.

A one-way ANOVA test statistic was carried out to compare Group 1 (group which underwent instruction using the SIP) with Group 3 (group which underwent instruction using the DSS-S). The one-way AVOVA revealed that there is a significant difference in score gains between the two groups. The analysis gives F (1, 117) = 4.76, giving a *p*-value of 0.0311, which is significant at the 0.05 alpha level. Thus, the data shows that the score gain by the students who underwent classroom instruction using the DSS-S is not the same as the score gain by the students who underwent classroom instruction using the SIP. By comparing the means of the score gains by the DSS-S group (4.8000000) and the SIP group (3.7777778) we can conclude with statistical significance at the 0.05 alpha level that the students who underwent classroom instruction using the DSS-S have a higher score gain compared to the students who underwent classroom instruction using the SIP. This result was confirmed by running the Tukey Test statistic on the data as mentioned in Table 4.9.

Table 4.9.

Tukey Test statistic for comparing Group 1 and Group 3

Tukey Grouping	Mean	N	Group
A	4.8000	65	DSS-S Group
B	3.7778	54	SIP Group

In table 4.9 we can see that the two groups belong to different Tukey groupings and thus we can say that the two groups have statistically significant difference at the 0.05 alpha level in their means with the group which underwent instruction using the DSS-S, having a higher mean score gain. This result was also confirmed by running the Least Squares Means test statistic, the results of which are given in table 4.10.

Table 4.10.

Least Squares Means test statistic for comparing Group 1 and Group 3

Group	Total_Score_Gain	H0:LSMean1=LSMean2	
	LSMEAN	t Value	Pr > |t|
SIP Group	3.77777778	-2.18	0.0311
DSS-S Group	4.8000		

Looking at the Least Squares Means test statistic results, we can conclude with statistical significance (at the alpha level of 0.05) that the mean score gain of the students in the group which underwent instruction using the DSS-S is larger than the mean score gain of the students in the group which underwent instruction using the SIP (*p*-value=0.0311).

4.4.5. Comparison Between the Group Which Underwent Instruction Using the Dynamic Spatial Simulation and the Group Which Underwent Instruction Using the Dynamic Spatial Simulation - Stereo

Here I check to see if there is a significant difference in the change in pretest and posttest scores among the students who received classroom instruction using the DSS and the students who received class instruction using the DSS-S. To analyze the performance of the combined 99 students from these two groups, the score gains (difference between the posttest and pretest scores for each group) of the students of the two groups were considered and the analysis was done using SAS.

A one-way ANOVA test statistic was carried out to compare Group 2 (group which underwent instruction using the DSS) with Group 3 (group which underwent instruction using the DSS-S). The one-way AVOVA revealed that there is no significant difference in score gains between the two groups. The analysis gives F (1, 97) = 0.22, giving a *p*-value of 0.6388, which failed to be significant at the 0.05 alpha level. Thus the data shows that any difference in the means of the score gain by the students who underwent classroom instruction using the DSS-S and the students who underwent classroom instruction using the DSS could be ascribed to chance alone. This result was confirmed by running the Tukey Test statistic on the data as mentioned in table 4.11.

Table 4.11.

Tukey Test statistic for comparing Group 2 and Group 3

Tukey Grouping	Mean	N	Group
A	5.0588	34	DSS Group
A	4.8000	65	DSS-S Group

In table 4.11 we can see that the two groups belong to the same Tukey grouping and thus we can say that the two groups do not demonstrate a statistically significant difference at the 0.05 alpha level. This result was also confirmed by running the Least Squares Means test statistic, the results of which are given in table 4.12.

Table 4.12.

Least Squares Means test statistic for comparing Group 2 and Group 3

Group	Total_Score_Gain LSMEAN	H0:LSMean1=LSMean2 t Value	Pr > |t|
DSS Group	5.05882353	0.47	0.6388
DSS-S Group	4.8000		

Looking at the Least Squares Means test statistic results reveals a *p*-value of 0.6388 which fails to be significant at the alpha level of 0.05. Thus the data does not provide enough evidence that the mean score gain of one group is larger than the other.

4.4.6. Comparison Between the Group Which Underwent Instruction Using the Dynamic Spatial Simulation and the Group Which Underwent Instruction Using the Dynamic Spatial Simulation - Stereo Considering Seat Numbers

To confirm the analysis in the previous section I wanted to analyze the data and factor in the location where the students were seated. It is usually seen that while making a stereoscopic presentation in a room the best stereoscopic effect, or depth effect, is experienced by an individual sitting near the center of the room rather than the corners or edges. An additional analysis considering this aspect of the stereoscopic presentation was also performed.

Figure 4.9 gives the layout of the classroom with seat numbers as places while conducting the study.

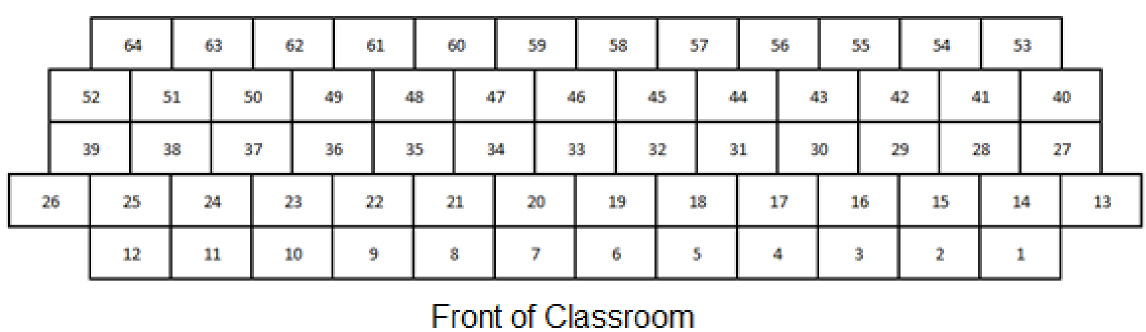

Figure 4.9. Classroom layout with seat numbers

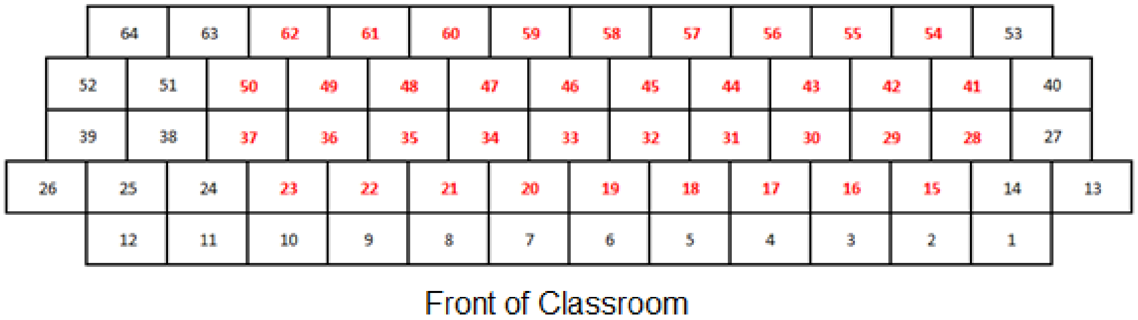

Figure 4.10. Classroom seat numbers considered for analysis

The seat numbers of the students in the DSS-S group with score gains larger than 5 were considered. It was found that these students were sitting in the section marked in red in figure 4.10.

A one-way ANOVA test statistic was carried out to compare Group 2 (group which underwent instruction using the DSS) with Group 3 (group which underwent instruction using the DSS-S) for only the students who sat in the above marked section in figure 4.10 (83 students from the two groups). The one-way AVOVA revealed that there is no significant difference in score gains between the two groups. The analysis gives F (1, 81) = 0.61, giving a *p*-value of 0.4361, which failed to be significant at the 0.05 alpha level. Thus the data shows that any difference in the means of the score gain by the students who underwent classroom instruction using the DSS-S and the students who underwent classroom instruction using the DSS could be ascribed to chance alone. This result was confirmed by running the Tukey Test statistic on the data as mentioned in table 4.13.

In table 4.13 we can see that the two groups belong to the same Tukey grouping, which indicates they do not demonstrate a statistically significant difference at the 0.05 alpha level. This result was also confirmed by running the Least Squares Means test statistic, the results of which are given in table 4.14.

Table 4.13.

Tukey Test statistic for comparing Group 2 and Group 3 considering seat numbers

Tukey Grouping	Mean	N	Group
A	5.4348	23	DSS Group
A	4.9167	60	DSS-S Group

Table 4.14.

Least Squares Means test statistic for comparing Group 2 and Group 3 considering seat numbers

Group	Total_Score_Gain	H0:LSMean1=LSMean2	
	LSMEAN	t Value	Pr > |t|
DSS Group	5.43478261	0.78	0.4361
DSS-S Group	4.91666667		

Looking at the Least Squares Means test statistic results reveals a *p*-value of 0.4361 which fails to be significant at the alpha level of 0.05. Thus the data does not provide enough evidence that the mean score gain on one group is larger than the other.

4.5. Post Opinion Questionnaire Data Analysis

The objective of this section of the questionnaire was to see what the students felt about each instruction medium. The students were asked to fill in responses to four questions regarding their opinion about the presentation medium after they had taken classroom instruction using that specific instruction medium. Figure 4.11, figure 4.12 and figure 4.13 give a summary of the responses of the students of each group on these questions.

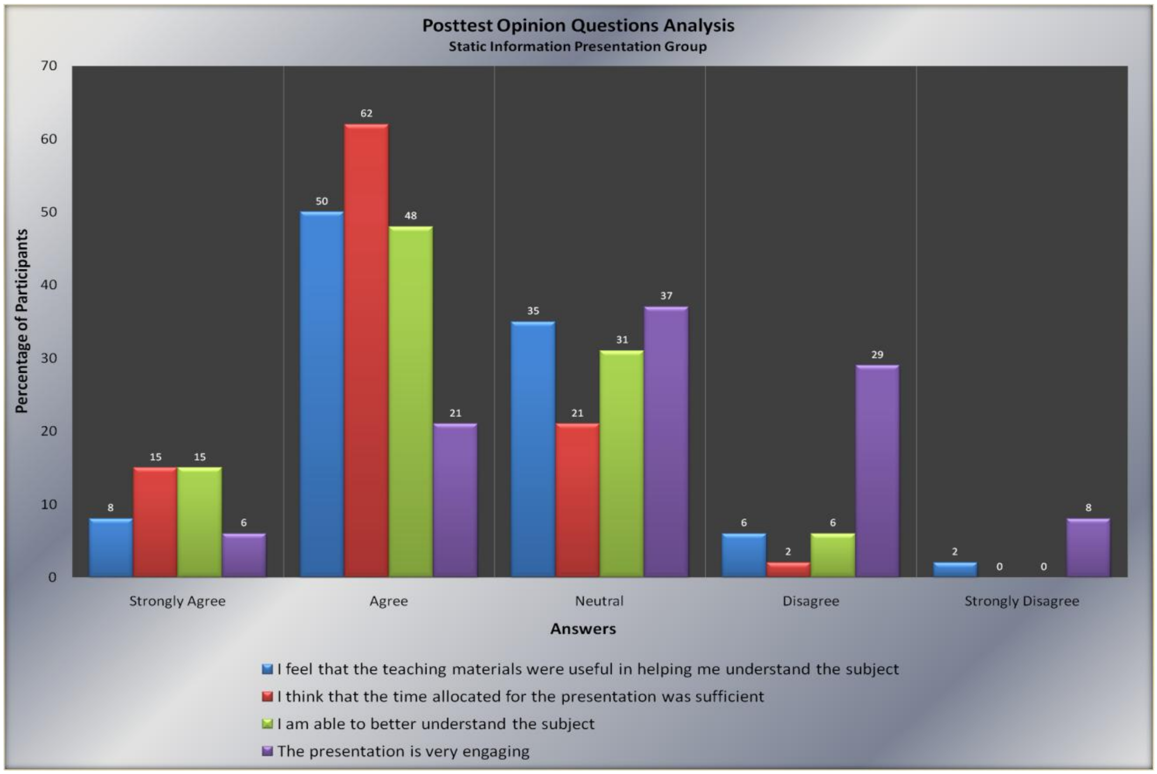

Figure 4.11. Feedback of students in Group 1 on the Static Information Presentation

As seen on the above charts, there were a larger percentage of students who had positive feedback for the use of the stereoscopic version of the simulation software.

4.6. Post3D Presentation Questionnaire Data Analysis

The objective of this questionnaire was to gauge the attitudes of the students towards the stereoscopic presentation and if they felt it helped them understand the subject matter. This questionnaire is a 6-question survey with a five-point Likert-type scale and two questions where the students could give their personal comments about what they felt about the stereoscopic presentation. The questionnaire can be found in Appendix E.

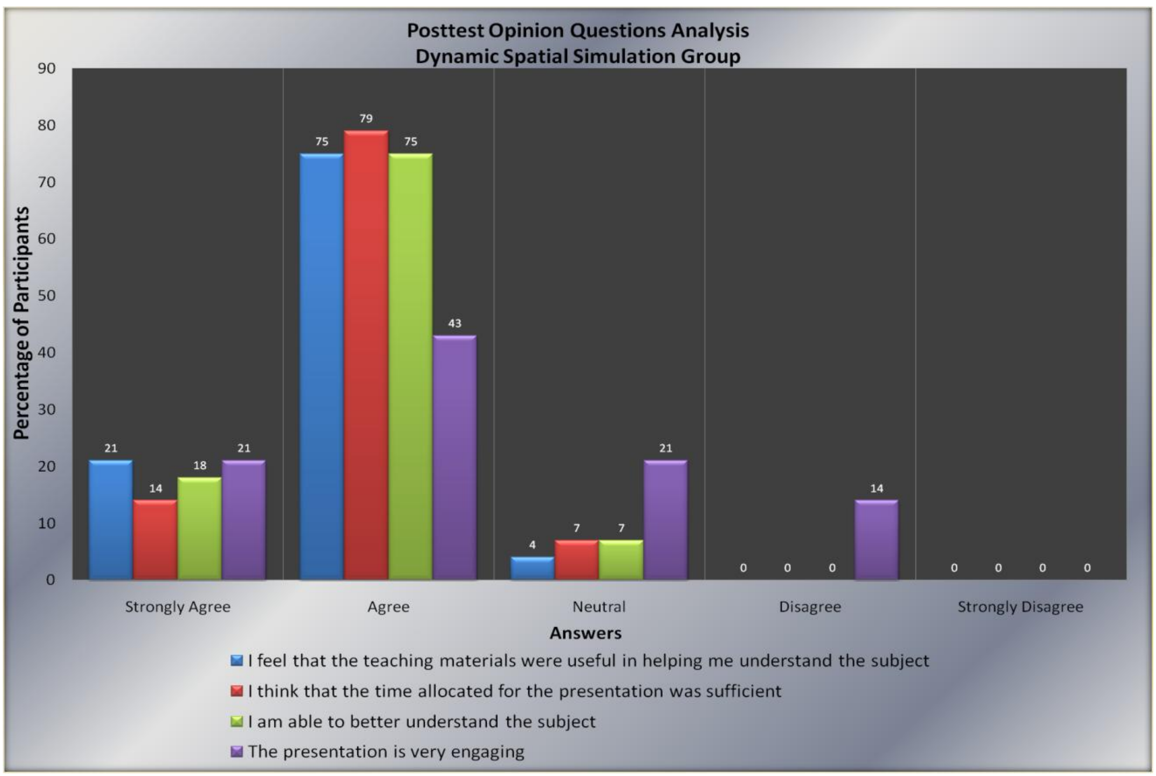

Figure 4.12. Feedback of students in Group 2 on the Dynamic Spatial Simulation

The summary of the responses on the questions on this questionnaire by all the 153 students can be seen in Figure 4.14. It can be seen from the figure that most of the students had a positive attitude towards the presentation and did like the idea of having a stereoscopic presentation to explain topics in astronomy.

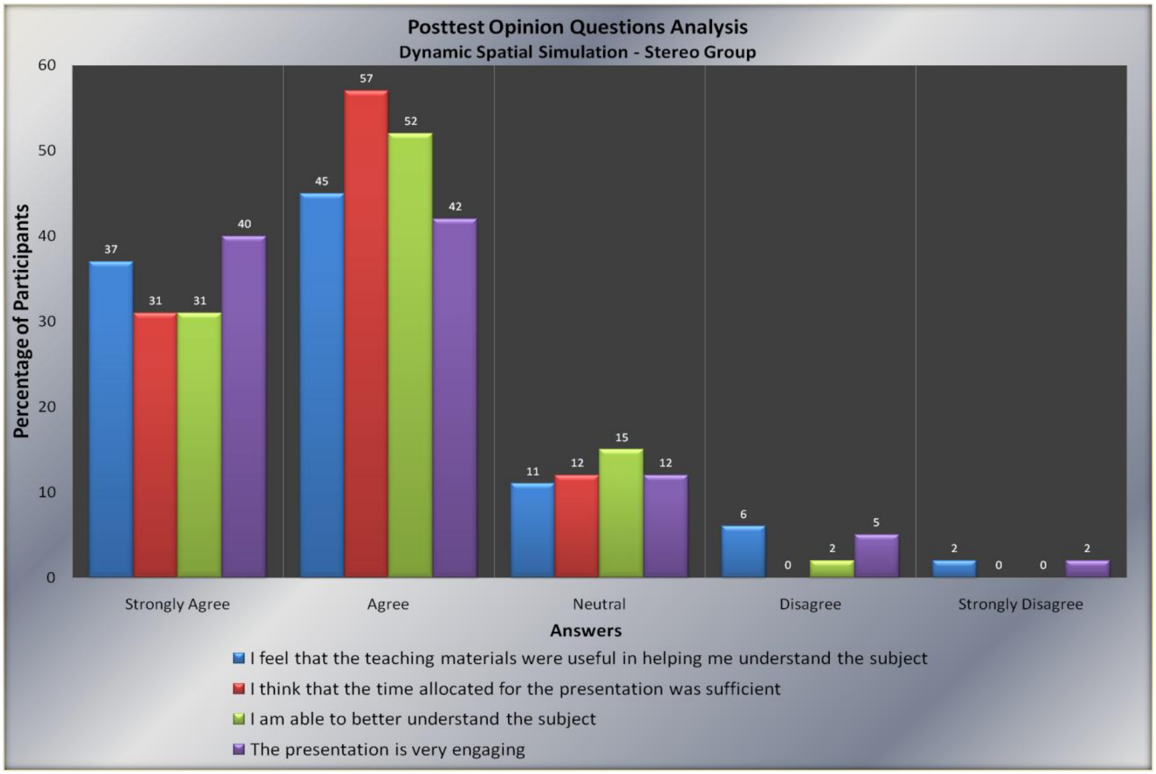

Figure 4.13. Feedback of students in Group 3 on the Dynamic Spatial Simulation - Stereo

Some of the comments on question 7 and question 8 are mentioned in table 4.15 and table 4.16. It should be noted that these questions were worded in such a way that would encourage students to find areas where the simulation software is lacking or to mention something that they did not like in the simulation software when viewed using the stereoscopic projection system. These comments will be considered while making a new version of the simulation software.

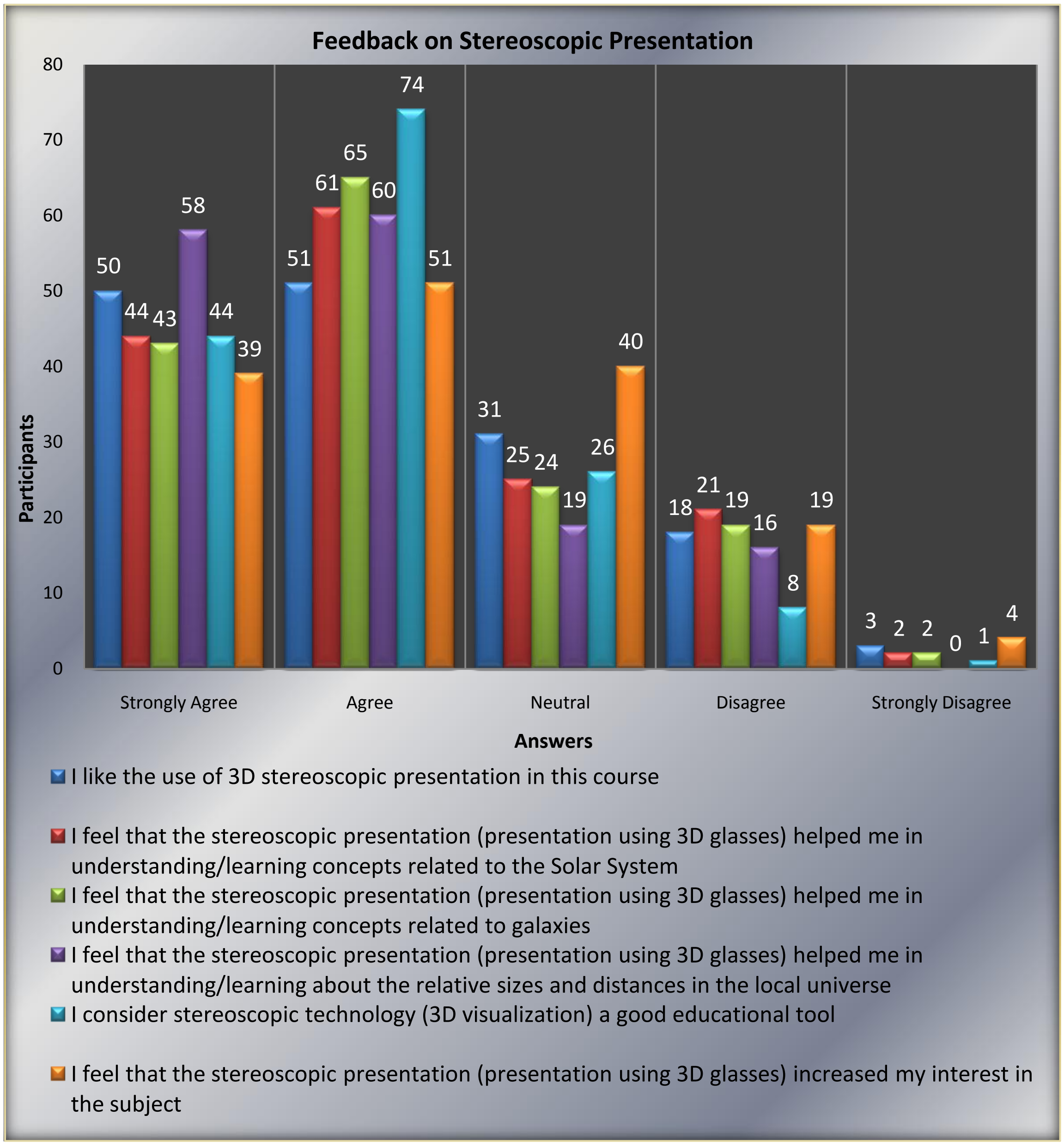

Figure 4.14. Feedback on stereoscopic presentation by all students

Table 4.15.

Student comments in response to question 7 on post3D questionnaire

Do you have any suggestions on how to improve the 3D stereoscopic presentation?
It would be good if movements would be less jerky, that made it slightly hard to watch
Bigger Screen

Table 4.15. (continued)

Do you have any suggestions on how to improve the 3D stereoscopic presentation?
It could be fun for the student if they could control the simulation
The concept of the 3D was good, but it made it difficult at times to listen to the instructor because I was trying to focus my eyes. The animation is what primarily helped
No was set up well with the seating, may be better projector
Music, pre recorded narration
I liked both ways, they each helped me to learn equally
The 3D did not do much for me, I liked the program but I feel the 3d did not do much for me
Its not that hard to visualize in 2D. 3D was just confusing
I found difficult to understand the location of the planets / stars because I was turned around so much
I just wanted it to last longer, it's very neat
Better technology with more detail
Better navigation with software. Smoother movements, less accidents
A larger screen would be nice because the smaller screen prevented us from being able to see large sections of the universe / galaxies at once
Things are too Blurry/doubled up and 1 wanted to vomit; 3D TVs are boss
Bigger screen otherwise I really liked it
Develop the software more and use larger screen in the background. More activities would make the presentation more interactive
Need bigger screen; More distinction in the third dimension (make it jut out more); the mouse was freaking me out
I don’t think if really needs 3D glasses, they're kind of distracting. A 3D animation would have been better
The rapid movement back and forth between images was a little disorienting, if that could be smoothed out it would be better. Also images were a little fuzzy
I just got bad headaches and nausea with 3D so in general I'm not really for 3D
make the 3D more extreme sometimes hard to tell which objects were 3D and which objects were 3D. Maybe use three screens for people not sitting in center of room
Nothing looked 3D for me, everything just looked like overlapped images, still flat. A 3D model while fun to look at distracts you from the material being studies because you just want to look at the pictures
Its almost like how movies are made now; almost any excuse to use 3D is taken, no matter what the context. However, I think using 3D helps, but the presentation itself didn’t utilize it to its full capabilities

Table 4.15. (continued)

Do you have any suggestions on how to improve the 3D stereoscopic presentation?
More Fluid movements
Don't use the mouse pointer to shoe what you are talking about. Its hard to focus on
I liked the stereoscopic presentation better than the PowerPoint by far, but I'm not sure it really NEEDS to be 3D. I'm sure you can make the same presentation a 2D presentation and it will still be very similar and more better than a normal PowerPoint
It’s a step in the right direction to something better Just needs more work
No I liked it

Table 4.16.

Student comments in response to question 8 on post3D questionnaire

What kind of information would you like to see added or removed from the presentation that would enhance your understanding of the subject discussed?
more information about other galaxies near us and a bigger scale model for the Solar System
Less Solar System more galactic phenomenon such as supernova explosions
more views from the planets, night sky and general views; travelling through the distances of space
I liked the presentation and it was easy to understand
I think everything presented was fine
Nothing it was perfect the way it was
The presentation was fine as is
NO real additions, the model is spectacular
More size comparisons, example, size of our sun compared with Sirus
Some more exploration of the local group or Milky Way would be nice
More fluid transitions from larger to smaller to emphasize scale
About more in depth about certain things
A better 3D experience
Divide presentation in half, 50% 3D, 50% 2D
I would prefer that both steps (3D and PowerPoint) be used to best help me understand
nothing very entertaining

Table 4.16. (continued)

What kind of information would you like to see added or removed from the presentation that would enhance your understanding of the subject discussed?
I cannot think of an improvements
No it was good

4.7. Summary

This chapter described the various data that were collected for this study. It also provided detailed data analysis using statistical measures. This chapter provided visual representation of the data analysis using the various statistical analysis methods used in this study. The next chapter discusses the findings and the proposed conclusion for the study. It also provides future recommendations for this study.

CHAPTER 5. DISCUSSIONS AND CONCLUSION

This study has looked into the effectiveness of using stereoscopic technology in a classroom setting. The objective of this study was to evaluate the educational benefit of teaching lessons involving a highly spatially-oriented topic (astronomy) using stereoscopic visualization technology. This chapter presents a discussion and conclusions based on the results of the quantitative analysis of the data collected during this study. This chapter also gives recommendations for future work on this study.

5.1. Discussion on Individual Groups

In this section we review the results of the data analysis done on each group individually.

The statistical analysis of the test scores of the group of students who underwent classroom instruction using the Static Information Presentation (SIP) shows evidence that the score gains by the students on the posttest are significantly larger than the score gains by the students on the pretest. This result suggests that the students were able to learn about the topic using the SIP alone and makes the case that the SIP is a useful medium, by itself, for instruction in teaching lessons involving a highly spatially-oriented topic (astronomy).

The statistical analysis of the test scores of the group of students who underwent classroom instruction using the Dynamic Spatial Simulation (DSS) shows evidence that the scores gained by the students on the posttest is significantly larger than the scores gained by the students on the pretest. This result suggests that the students were able to learn about the topic using the DSS alone and makes the case that the DSS is a useful medium, by itself, for instruction in teaching lessons involving a highly spatially-oriented topic (astronomy).

The statistical analysis of the test scores of the group of students who underwent classroom instruction using the Dynamic Spatial Simulation - Stereo (DSS-S) shows evidence that the scores gained by the students on the posttest is significantly larger than the scores gained by the students on the pretest. This result suggests that the students were able to learn about the topic using the DSS-S alone and makes the case that DSS-S is a useful medium, by itself, for instruction in teaching lessons involving a highly spatially-oriented topic (astronomy).

5.2. Discussion on comparison between groups

In this section we will discuss about the score gain between the three groups of students.

The ANOVA statistic run on the three groups tells us that the gain and retention of information by students of the three groups is significantly different;

that is, students of at least two of the groups have significantly different gain and retention of information by using the different instruction medium. To know which groups differ from each other, so as to test the hypothesis for this study and by how much, I did statistical analysis on each pair of groups.

Looking at the analysis performed to compare the group of students who underwent classroom instruction using the SIP and students who underwent classroom instruction using the DSS, we can certainly say that the data gives evidence that the score gain of the students in the two different groups is significantly different. The data analysis was also performed using the Tukey's test statistic and the Least Squares Means procedure which leads to similar results. Looking at these measures we can say the results are robust and that the students gained and retained more information when they are instructed using the DSS than by using the SIP to teach the same subject matter in astronomy. By the above analysis we can reject the first null hypothesis for this study which says,

$H1_0$: There is no difference in the change of scores, between pretest and posttest, taken by students who received class instruction using a Static Information Presentation and students who received class instruction using the Dynamic Spatial Simulation.

This means there is a difference between the score gain of the students in the two groups, with the group of students who underwent instruction using the DSS having the larger score gain.

Thus the first research question, “Does using Dynamic Spatial Simulation for instruction result in greater understanding and retention of concepts, taught in an Introduction to Astronomy course, when compared to using a Static Information Presentation for instruction?”, has been answered with a positive reply; using DSS for instruction does result in greater understanding and retention of concepts in astronomy when compared to using SIP.

By comparing the means we can say that there has been a 134% increase in scores with the use of the DSS. This implies that the students had increased their knowledge on topics in astronomy by 134% when compared with the use of the SIP.

Looking at the analysis performed to compare the group of students who underwent classroom instruction using the SIP and students who underwent classroom instruction using the DSS-S we can say that the observed data provides evidence that the score gain of the students in the two different groups is significantly different. The data analysis was also performed using the Tukey's test statistic and the Least Squares Means procedure which leads to similar results. Looking at all these measures we can say the results are robust and that the students gained and retained more information when they are instructed using the DSS-S than by using the traditional SIP to teach the same subject matter in astronomy. By the above analysis we can reject the second null hypothesis for this study which says,

> $H2_0$: There is no difference in the change of scores, between pretest and posttest, taken by students who received class instruction using a Static Information Presentation and students who received class instruction using the Dynamic Spatial Simulation - Stereo.

Thus there is a difference between the score gain of the students in the two groups, the group of students who underwent instruction using DSS-S having the larger score gain.

Thus the second research question, “Does using Dynamic Spatial Simulation - Stereo for instruction result in greater understanding and retention of concepts, taught in an Introduction to Astronomy course, when compared to using a Static Information Presentation for instruction?”, has been answered with a positive reply; using DSS-S for instruction does result in greater understanding and retention of concepts in astronomy when compared to using SIP.

By comparing the means we can say that there has been a 127% increase in scores due to the use of DSS-S which implies that the students had increased their knowledge on topics in astronomy by 127% when compared with the use of SIP.

Looking at the analysis performed to compare the group of students who underwent classroom instruction using DSS and students who underwent classroom instruction using DSS-S, we can say that the data does not give evidence that the score gain of the students in the two different groups is significantly different. A data analysis was also performed using the Tukey's test statistic and the Least Squares Means procedure which led to similar results. Looking at these measures we can say the results are robust and that the information gained and retained by students who were instructed using DSS-S is not significantly different than the information gained and retained by the students who were instructed DSS, to teach the same subject matter in astronomy. By the above analysis we cannot reject the third null hypothesis for this study which says,

> $H3_0$: There is no difference in the change of scores, between pretest and posttest, taken by students who received class instruction using the Dynamic Spatial Simulation and students who received class instruction using the Dynamic Spatial Simulation - Stereo.

Looking at the data from this study we cannot conclude that there is a significant difference between the score gain of the students in the two groups.

Because the stereoscopic effect is usually experienced better for the students sitting in the middle section of the classroom rather than the corners or edges of the classroom, I selected the section of top scorers of the third group while considering their seating location. But even after comparing students form Group 2 and Group 3 sitting in this section, I got similar results demonstrating that the score gains between these students were not significantly different.

Thus, the third research question, “Does using Dynamic Spatial Simulation - Stereo for instruction result in greater understanding and retention of concepts, taught in an Introduction to Astronomy course, when compared to using Dynamic Spatial Simulation for instruction?”, cannot be answered with a positive reply based on the analysis of data collected during this study.

5.3. Discussion on post test opinion questions

Looking at the charts provided in section 4.5, it can be seen that the students showed preference towards the simulation software as there were more positive responses toward the simulation software (86.61% for DSS and 83.46% for DSS-S). Thus the students thought that the simulation software helped them understand the subject matter better and also that the simulation was more engaging than the traditional presentation mediums.

5.4. Discussion on post 3D opinion questionnaire

The objective of this questionnaire was to find the attitude of the students toward the stereoscopic software. Looking at the charts provided in section 4.6, it can be said that all 153 students in general had a positive attitude toward the stereoscopic presentation, where 69.72% of students gave positive responses for the questions on this questionnaire.

The objective of the remaining two questions was to encourage the student to find a fault in the software. These two questions were worded in such a way that they would lead the student to think of what they did not like about the software and how could it be improved or enhanced. The comments received for these questions were useful. A few students said that using the mouse to point at objects should be avoided (one of the comments was, “Not have the mouse showing on the screen. Use the laser to point instead. The mouse threw off the 3D effect”). This observation certainly should be considered when modifying the software for future use. Another frequently seen comment was about the screen size. Many students (30) commented that the screen size should be increased (one of the comments was, “A larger screen would be nice because the smaller screen prevented us from being able to see large sections of the universe / galaxies at once”). I do consider that the screen size might have been too small for the classroom in which the instruction took place when comparing it to screens the students might have been accustomed to when viewing in a stereo-equipped movie theater. I also think that this aspect of the system might have affected the outcome of the research because the size of the screen did seem to affect the perception of being immersed in the presentation. Many students also commented that they found the stereoscopic software to be slightly blurry. This also deals with the quality of the software simulation and the system setup compared to visualizations seen on the screens in movie theaters. The current system would benefit from improvements made to the stereoscopic effect. While there were also a few students who said they felt slight headaches due to the stereoscopic presentation there were other students who said that they liked the presentation and would have liked to see more details about other distant galaxies and stars.

5.5. Conclusion and Recommendations

The objective of this study was to evaluate the educational benefit of teaching lessons involving a highly spatially-oriented topic (astronomy) using stereoscopic visualization technology. Understanding the highly spatial information about the location and size of an object in space is very important in understanding concepts in astronomy. In various studies it has been shown that representing the concepts in 2D perspective views could reduce the cognitive load on the students due to the mental processing of spatial relationships, like location of a particular galaxy relative to another, which in turn would increase student understanding (Barnet, Ymagata-Lynch, Keating, Barab, Hay, 2005; Küçüközer, Korkusuz, Küçüközer, Yurumezoglu, 2009; Hansen, Barnett, Makinster, Keating, 2004). As mentioned by Cid, X. C., and Lopez R. E. (2010), this could be due to the fact that the students do not need to try to visualize the three-dimensional world in their mind just by using two-dimensional pictures, which are usually used in traditional presentations, and then try to understand the concept behind it.

Though this study was able to show significant difference in the learning of students taught using the DSS-S as opposed to using the SIP, it was not able to provide evidence that a significant difference exist between the score gain of students instructed using the DSS-S and students instructed using the DSS. One possible explanation of this phenomenon could be a concept explained by Cockburn, A. and McKenzie, B. (2002). They mention that important spatial clues are provided by perspective view and thus 2D perspective information, like those clues given by the simulation software presented using 2D perspective in the current study, could be providing enough information for students to understand the information the instructor would try to teach. Based on the results of this study, it could be said that the DSS effectively teaches the information, because according to the data, the DSS-S, though significant by itself, does not seem to demonstrate an advantage over the DSS. Before I conclude that the 2D perspective was enough, I however, need to consider a few possibilities as to why this occurred. First, the presentation was not completely immersive – students were not given the opportunity to interact directly with the software. Though the software is designed to be interactive, during the classroom instruction only the instructor controlled the software and presented it to the students and thus the students could not directly interact with the software. I am curious about whether the results of the study would have been different if the students had been allowed to have more interaction with the software. Second, the hardware and software system installed in the classroom was not as good in quality as systems found in a stereo-equipped movie theater. Third, the projector used in the classroom does not have a very powerful stereoscopic effect due to stereo bleeding. For example the students found the screen to be small and the stereoscopic effect was not as good as it should have been in order to provide sufficient spatial information. Groups 2 and 3 were instructed using the same simulation software. The only difference between the presentation mediums used was that for Group 2, the 3D world depicted by the simulation software was projected onto a 2D screen by providing 2D perspective information, while Group 3 used the same simulation software but the simulation was presented using the stereoscopic projection system. Simply, the extra information provided by the presentation using the stereoscopic projection system is the spatial information created by the stereoscopic effect. The quality of this stereoscopic effect is impacted by stereo bleeding, thus, the extra information that should have been provided by the stereoscopic presentation was not able to be perceived due to this drawback. I believe these factors could have had a large impact on the results of the study.

It can be concluded that for the current instruction setup, the students who were instructed using either the DSS or DSS-S demonstrated score gains greater that those students instructed using the SIP. This means the DSS and DSS-S both increase the understanding and retention of information, leading to better performance on test by students in an introduction to astronomy course. In conclusion, the results of this study support for the use of the simulation software as an educational tool to help students learn about topics in astronomy.

For this study, the DSS-S did not seem to add any advantage for this study over the DSS. Because this study was adversely affected by multiple drawbacks of the installed system, as well as the course's instructional design, however, I cannot conclude that DSS teaches as much information to the students as DSS-S. However, I do recommend that the study should be conducted again with each student being provided with a computer system which would allow them to interact with the stereoscopic presentation using computer monitors capable of showing stereoscopic content. I suspect that unless the presentation is made more immersive, and unless the stereoscopic effect is improved, DSS-S will not have a better score gain over DSS.

My study has complemented the body of knowledge in that it successfully demonstrated that the use of simulation software, whether DSS or DSS-S, increases the amount of information learned by students when compared to SIP. Essentially, using the simulation software for instruction helped students understand and learn about the topics better than using SIP, and thus, the study shows that using the simulation software for instruction could increase student grades when compared to instruction using SIP. This study also demonstrated that for the current classroom setup, in which the instructor is the only person directly interacting with the software, DSS-S does not present an advantage over

DSS. This particular finding, however, is not conclusive due to the drawbacks in the system. I believe it is likely that this finding would be different if student interaction were increased by moving from a passive to an active role in the operation of the simulation, and if the quality of the software and hardware systems were improved to create a better stereoscopic effect for the students.

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APPENDICES

Appendix A.

Commands manual for the software.

Table A.1.

Commands manual for the software.

Keys	Function	Comment
5	Speed demonstration 10000 m/s speed of fastest rocket	Work only when galaxy or Solar System active. It will move the view from which ever position in the galaxy (need not be the start location or orientation) towards Milky Way / or sun in Solar System
6	Speed demonstration 5 Light years/sec	Work only when galaxy or Solar System active. It will move the view from which ever position in the galaxy (need not be the start location or orientation) towards Milky Way / or sun in Solar System
6	Speed demonstration 500 Light years/sec	Work only when galaxy or Solar System active. It will move the view from which ever position in the galaxy (need not be the start location or orientation) towards Milky Way / or sun in Solar System
6	Speed demonstration 50000 Light years/sec	Work only when galaxy or Solar System active. It will move the view from which ever position in the galaxy (need not be the start location or orientation) towards Milky Way / or sun in Solar System
6	Speed demonstration 500000 Light years/sec	Work only when galaxy or Solar System active. It will move the view from which ever position in the galaxy (need not be the start location or orientation) towards Milky Way / or sun in Solar System
f	flight path	Work only when galaxy active. It will move the view from which ever position in the galaxy (need not be the start location or orientation) towards milkyway and then into the Solar System
+/-	Modify IPD for 3D effect	Works is all modes

Table A.1. (continued)

Keys	Function	Comment
g	get current location and orientation	Programmer debug option, no to be used by user
Space bar	start playing audio clip	Will work for all Four models
p	pause audio clip	Will work for all Four models
o	stop playing audio clip	Will work for all Four models
r	reset object orientation	Work only when galaxy active
x	Start spinning current clicked galaxy around X Axis	Work only when galaxy active and only for spiral galaxies
y	Stop spinning current clicked galaxy around Y Axis	Work only when galaxy active
z	Start spinning current clicked galaxy around Z Axis	Work only when galaxy active and only for spiral galaxies
c	Stop spinning current clicked galaxy	Work only when galaxy active
w	Move Front	Will work for all Four models
s	Move Back	Will work for all Four models
e	Increase speed of movement	Will work for all Four models
q	Decrease speed of movement	Will work for all Four models
a	Turn Camera Left	Will work for all Four models
d	Turn Camera Right	Will work for all Four models
Up Arrow	Turn Camera Up	Will work for all Four models
Down Arrow	Turn Camera Down	Will work for all Four models
Left Arrow	Turn Camera Clockwise	Will work for all Four models
Right Arrow	Turn Camera Counter Clockwise	Will work for all Four models
1	Move to galaxy model	Will work for all Four models
2	Move to Solar System Animation model	Will work for all Four models

Table A.1. (continued)

Keys	Function	Comment
3	Move to Solar System SizeCompare model	Will work for all Four models
4	Move to Earth Moon model	Will work for all Four models
j	Move to Moon surface	Will work only in EarthMoon SizeCompare model
k	Move to Earth surface	Will work only in EarthMoon SizeCompare model
b	Make Clicked planet rotate Solar System SizeCompare model	Will work only in Solar System SizeCompare model
n	Stop Clicked planet from rotating in Solar System SizeCompare model	Will work only in Solar System SizeCompare model
m	Make Moon rotate around the Earth	Will work only in Solar System SizeCompare model
Mouse click	Display Info of object clicked	Will work only in Solar System SizeCompare model and Galaxy model
F2	Toggle size of window	Will work for all Four models
l	Toggle Visibility of Line in Galaxy Model	Will work only in Galaxy model
i	Toggle Visibility of Information Box	Will work only in Solar System SizeCompare model and Galaxy model

Appendix B

Permission given by the course instructor for course ASTR 264 during the Spring semester of 2011.

From: Thomas J. Moffett [MAILTO:TMOFFETT@PURDUE.EDU]

Sent: Thursday, February 03, 2011 12:21 PM

To: NJOSEPH@PURDUE.EDU

Subject: Astr 264

It is fine with me. Just work things out with Dustin Hemphill.

T. J. Moffett

Appendix C

Letter of approval by the Institutional Review Board at the Human Research Protection Program at Purdue University for this study.

From: Berry, Erica L
Sent: Monday, March 14, 2011 10:30 AM
To: Bertoline, Gary R
Cc: Joseph, Norman
Subject: IRB Revision Approval 1102010482 "Stereoscopic Visualization as a Tool for Learning Astronomy Concepts"

Dear Dr.

Your request for revision for your protocol titled, "Stereoscopic Visualization as a Tool for Learning Astronomy Concepts" Ref.#1102010482 has been approved. A copy of the Approval Form will be forthcoming via campus mail. Good luck on your research.

Best Regards,

Erica L. Berry
Human Research Protection Program
Purdue University
Ernest C. Young Hall
10th Floor, Room 1032
155 S. Grant Street
West Lafayette, IN 47907-2114
PH: 765/494-7090
FAX: 765/494-9911
HTTP://WWW.IRB.PURDUE.EDU

From: Berry, Erica L
Sent: Tuesday, March 08, 2011 8:37 AM
To: Bertoline, Gary R
Cc: Joseph, Norman; Whittinghill, David M; Cayon, Laura
Subject: IRB Approval 1102010482 "Stereoscopic Visualization as a Tool for Learning Astronomy Concepts"

The IRB has reviewed your Research Exemption Request titled, "", Ref. #0 and deem it to be exempt. A copy of the approved letter will be forthcoming via campus mail. Good luck on your research.

We will now begin processing your revision request.

Best Regards,

Erica L. Berry
Human Research Protection Program
Purdue University
Ernest C. Young Hall
10th Floor, Room 1032
155 S. Grant Street
West Lafayette, IN 47907-2114
PH: 765/494-7090
FAX: 765/494-9911
HTTP://WWW.IRB.PURDUE.EDU

Appendix D
RESEARCH PARTICIPANT RECRUITMENT SCRIPT
Stereoscopic Visualization as a Tool for Learning Astronomy Concepts
Gary R. Bertoline
Purdue University
Computer Graphics Technology

Purpose of Research

The objective of this study is to evaluate the educational benefit of learning concepts involving a highly spatially-oriented topic (astronomy) using 3D stereoscopic visualization technology. This study will use a 3D visualization tool developed to view the local universe containing visualizations of the local group of galaxies and our solar system and will use stereographic projection along with 3D glasses.

Specific Procedures

Participants will first be asked to fill a pre test questionnaire. Participants will then undergo the classroom instruction using the respective instruction medium, either the PowerPoint presentation or the interactive scientific visualization. Participants will then be asked to fill a post test questionnaire. After seeing the 3D stereoscopic presentation the participants will be asked to fill in a Post Test Opinion Questionnaire. None of the above data collected will be used to identify the participant who has filled in the respective questionnaires.

Age Restriction

Participants above the age of 18 are only allowed to be part of this research

Duration of Participation

The questionnaire filled in should not take more than 30 minutes in total.

Risks

Risks are minimal. There is a slight possibility that the participants might feel a bit dizzy while viewing the software while wearing the 3D glasses similar to what you could feel when you watch a 3D movie in a movie theater. Thus the risks are no greater than you would encounter in daily life.

Benefits

There are no direct benefits to participants, but there are benefits to society and educational research.

Compensation

Participants will not be given any monetary compensation for this research.

Confidentiality
The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight. Data collected during the research study will not be linked with the participant's name and thus the participant scores will not be used to identify any individual. The questionnaires collected will be stored in lockers.

Voluntary Nature of Participation
You do not have to participate in this research project. If you agree to participate you can withdraw your participation at any time without penalty.

Contact Information:
If you have any questions about this research project, you can contact Norman Joseph, Tele: (765)-237-8983 (first point of contact) or Dr. Gary R. Bertoline, Tele: (765) 494-6875.

Appendix E
Questionnaires used for the study

EVALUATION STUDY FOR STEREOSCOPIC VISUALIZATION USED AS AN EDUCATIONAL TOOL IN ASTRONOMY
PRE TEST QUESTIONNAIRE

Date: ___ /___ /______

Seat No: ______ Group: ______

Please indicate the following information about yourself. The information below will not be used to identify any person in particular. For multiple choice questions, if the possible answers contain the symbol 'O', please select only one answer. If the possible answers contain the symbol '☐', please select all answers that you consider appropriate.

1. What is your Major

2. What is your Minor

3. Please select your current year of study
   - O Freshman Year
   - O Sophomore Year
   - O Junior Year
   - O Senior Year
   - O Graduate Student

4. Gender
   - O Male
   - O Female

5. Are you interested in Astronomy?
   - O Very interested
   - O Slightly interested
   - O Not interested

6. Have you had any exposure to astronomy before this class?
    - ○ Yes
    - ○ No

7. If you answered "yes" to the previous question please answer this question or skip to number 8. In what context have you learned astronomy?
    - ☐ High School
    - ☐ College
    - ☐ Popular books
    - ☐ Movies
    - ☐ Presentations
    - ☐ Planetarium

8. Are you interested in Video games?
    - ○ Very interested
    - ○ Slightly interested
    - ○ Not interested

9. How frequently do you play Video games?
    - ○ Very frequently
    - ○ Infrequently
    - ○ Not at all

10. Are you interested in watching video presentations or movies on galactic phenomenon?
    - ○ Very interested
    - ○ Slightly interested
    - ○ Not interested

Please answer the below question to the best of your capabilities. These questions will help us judge your prior knowledge of the subject to be discussed in this class.

Pretest Questions related to the Local Group

1. What is the Local Group?
    - O A group of stars near the Sun
    - O A group of extra-solar planets close to the Sun
    - O A group of galaxies near our Galaxy

2. Our Galaxy (the Milky Way) is
    - O a spiral galaxy
    - O an elliptical galaxy
    - O an irregular galaxy

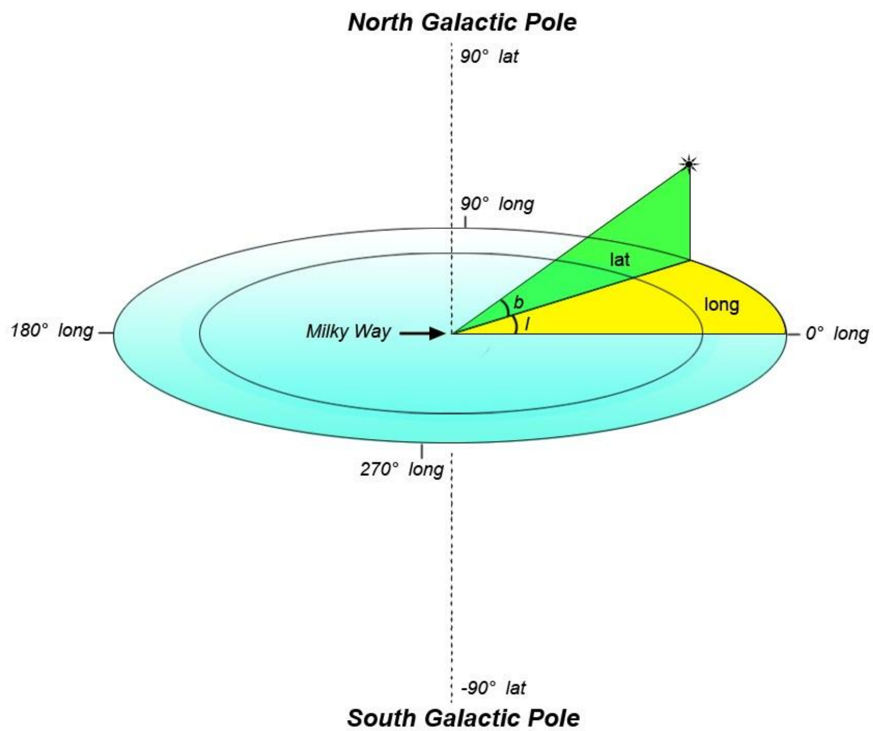
3. What are the Large and the Small Magellanic clouds?
    - O Two clouds of gas inside our Galaxy
    - O Two elliptical galaxies close to our Galaxy
    - O Two irregular galaxies close to our Galaxy

4. How many spiral galaxies are there in the Local Group?
    - O One
    - O Two
    - O Three

5. The population of stars is younger in
    - O irregular galaxies than in elliptical galaxies
    - O elliptical galaxies than in irregulars
    - O the bulge of spiral galaxies than in the spiral arms

6. Which is the largest galaxy in the Local Group?
    - O Triangulum (M33)
    - O Milky Way
    - O Andromeda (M31)

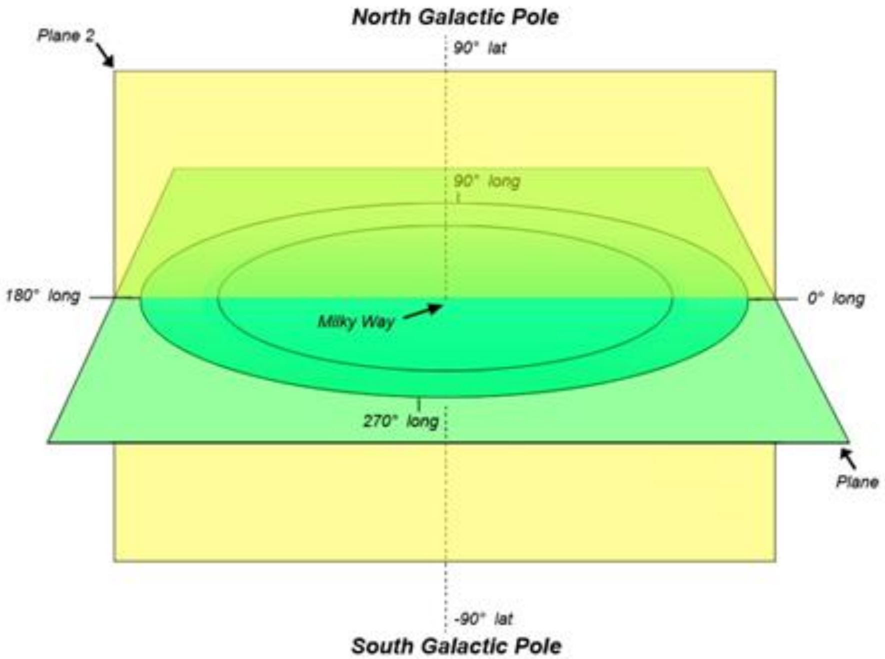
7. In a map we need two coordinates (x,y) (or a letter and a number, ex. (A,3) or (D,4)) to identify the position of a town. In the case of galaxies one refers to their position on the sky by their two "galactic coordinates" (l,b). l is the galactic longitude and b is the galactic latitude. Let's concentrate on the later. A galaxy with positive galactic latitude is a galaxy located above the plane containing the disk of the Galaxy (or Milky Way). A galaxy with negative galactic latitude is a galaxy located below the plane containing the disk of the Milky Way (see the diagram below). Taking this into account answer the following questions.



a. In the Local Group, there are more galaxies located at positive latitudes (above the plane containing the disk of the Milky Way) than at negative (below the plane containing the disk of the Milky Way) latitudes
   - O Yes
   - O No
   - O Not sure

b. Is the Andromeda galaxy located at negative galactic latitude?
   - O Yes
   - O No
   - O Not sure

8. Imagine a plane containing the disk of the Milky Way and a second one perpendicular to the first one as indicate in the diagram below.



Relative to the second plane (plane 2), Andromeda is located,

- in front of it
- behind it
- not sure

9. In a rough estimate would you say that the size of the Local Group is

- ten times the size of the Milky Way
- one hundred times the size of the Milky Way
- one thousand times the size of the Milky Way
- one million times the size of the Milky Way

Pretest Questions related to the Solar System

1. Where in our Galaxy is the Solar System located?
   - O at the very center
   - O away from the center
   - O at the edge of the Galaxy

2. In a rough estimate would you say that the size (the radius) of our Galaxy is,
   - O ten times the size of the Solar System
   - O ten thousand times the size of the Solar System
   - O more than million times the size of the Solar System

3. Our Galaxy was given the name Milky Way due to its appearance in the night sky. What part of our Galaxy are we looking at when we observe "the Milky Way" at night?
   - O the part of the Galaxy above the disk
   - O the plane of the Galaxy as we look at it edge-on
   - O the Galaxy viewed face on

4. Are the planets in the Solar System all at the same distance from one another?
   - O Yes
   - O No
   - O Don't know

5. Which is the largest planet in the Solar System?
   - O Jupiter
   - O Saturn
   - O Neptune

6. Are the larger planets in the Solar System closer to the Sun than the smaller planets (Pluto is not counted as part of the planets)?
   - O Yes
   - O No
   - O Don't know

7. Which is the smallest planet in the Solar System (Pluto is not counted as a planet)?
   - O Venus
   - O Mercury
   - O Mars

8. In a rough estimate would you say that the size of the Sun is,
    - O ten times the size of Jupiter
    - O hundred times the size of Jupiter
    - O thousand times the size of Jupiter

9. If you were standing on the moon would you observe the earth set on the moon?
    - O Yes
    - O No
    - O Don’t know

EVALUATION STUDY FOR STEREOSCOPIC VISUALIZATION USED AS AN EDUCATIONAL TOOL IN ASTRONOMY
POST TEST QUESTIONNAIRE

Date: ___ /___ /______

Seat No: ______ Group: ______

Please answer the questions below.

Posttest Questions related to the Local Group

10. What are the Large and the Small Magellanic clouds?
    - O Two clouds of gas inside our Galaxy
    - O Two elliptical galaxies close to our Galaxy
    - O Two irregular galaxies close to our Galaxy

11. In the Local Group there are
    - O More dwarf galaxies than spiral galaxies
    - O More spiral galaxies than dwarf galaxies
    - O The same number of spiral and dwarf galaxies

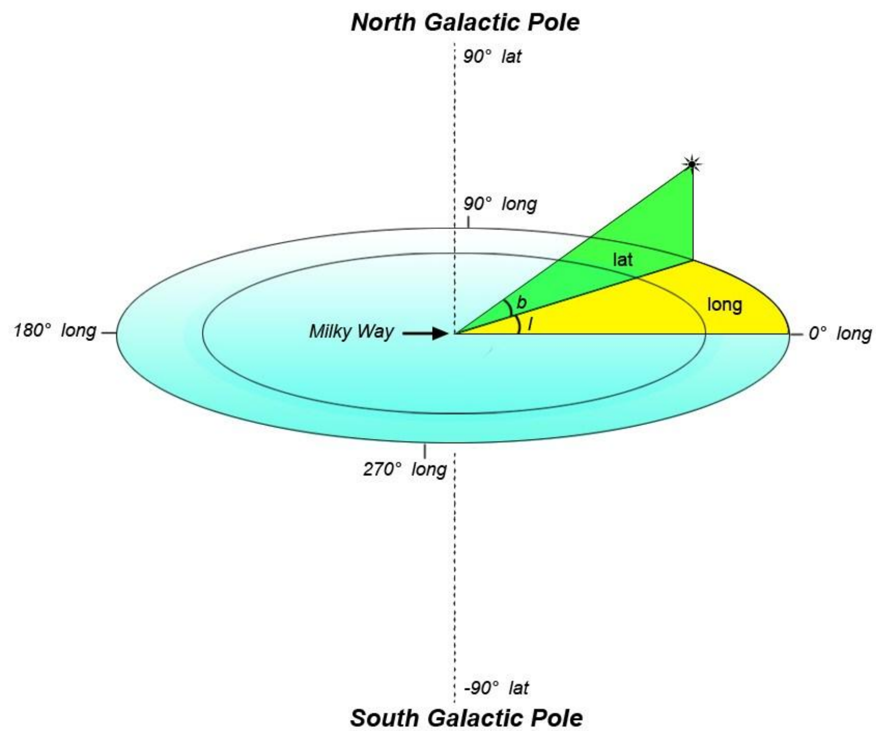
12. What is the Local Group?
    - O A group of stars near the Sun
    - O A group of extra-solar planets close to the Sun
    - O A group of galaxies near our Galaxy

13. The population of stars is older in
    - O irregular galaxies than in elliptical galaxies
    - O elliptical galaxies than in irregulars
    - O the spiral arms than in the bulge of spiral galaxies

14. Our Galaxy (the Milky Way) is
    - O an elliptical galaxy
    - O a spiral galaxy
    - O an irregular galaxy

15. The biggest galaxy in the local group is of type
    a. an elliptical galaxy
    b. a spiral galaxy
    c. an irregular galaxy

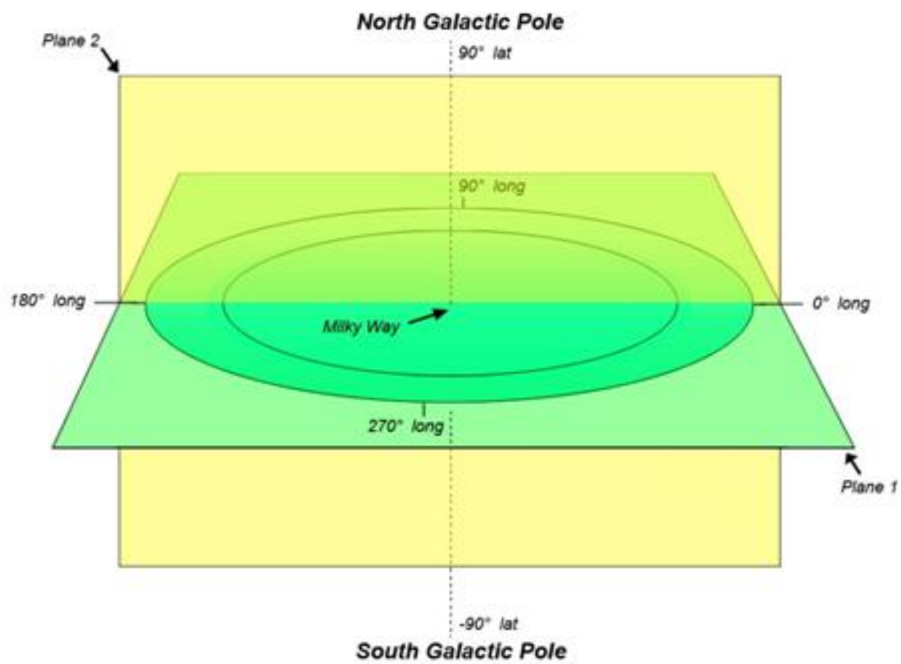
16. In a map we need two coordinates (x,y) (or a letter and a number, ex. (A,3) or (D,4)) to identify the position of a town. In the case of galaxies one refers to their position on the sky by their two "galactic coordinates" (l,b). l is the galactic longitude and b is the galactic latitude. Let's concentrate on the later. A galaxy with positive galactic latitude is a galaxy located above the plane containing the disk of the Galaxy (or Milky Way). A galaxy with negative galactic latitude is a galaxy located below the plane containing the disk of the Milky Way (see the diagram below). Taking this into account answer the following questions.



a. In the Local Group, there are more galaxies located at positive latitudes (above the plane containing the disk of the Milky Way) than at negative (below the plane containing the disk of the Milky Way) latitudes
   - O Yes
   - O No
   - O Not sure

b. Is the Andromeda galaxy located at negative galactic latitude?
   - O Yes
   - O No
   - O Not sure

2. Imagine a plane containing the disk of the Milky Way and a second one perpendicular to the first one as indicate in the diagram below.



Relative to the second plane (plane 2), Andromeda is located,

- O in front of it
- O behind it
- O not sure

3. In a rough estimate would you say that the size of the Local Group is
   - O ten times the size of the Milky Way
   - O one hundred times the size of the Milky Way
   - O one thousand times the size of the Milky Way
   - O one million times the size of the Milky Way

Posttest Questions related to the Solar System

10. Which is the largest planet in the Solar System?
    - Jupiter
    - Saturn
    - Neptune

11. Are the larger planets in the Solar System closer to the Sun than the smaller planets (Pluto is not counted as part of the planets)?
    - Yes
    - No
    - Don't know

12. Where in our Galaxy is the Solar System located?
    - at the very center
    - away from the center
    - at the edge of the Galaxy

13. In a rough estimate would you say that the size of the Solar System is
    - 1/10 times the size (the radius) of our Galaxy
    - 1/10000 times the size (the radius) of our Galaxy
    - less than 1/1000000 times the size (the radius) of our Galaxy

14. Our Galaxy was given the name Milky Way due to its appearance in the night sky. What part of our Galaxy are we looking at when we observe "the Milky Way" at night?
    - the part of the Galaxy above the disk
    - the plane of the Galaxy as we look at it edge-on
    - the Galaxy viewed face on

15. Are the planets in the Solar System all at the same distance from one another?
    - Yes
    - No
    - Don't know

16. Which is the smallest planet in the Solar System (Pluto is not counted as a planet)?
    - Venus
    - Mercury
    - Mars

17. In a rough estimate would you say that the size of the Jupiter is,
    - 1/10 times the size of the Sun
    - 1/100 times the size of the Sun
    - 1/1000 times the size of the Sun

18. If you were standing on the moon would you observe the earth set on the moon?
    - Yes
    - No
    - Don't know

Posttest Opinion Questions

Please answer the questions below.

1. I feel that the teaching materials were useful in helping me understand the subject.
    - Strongly Agree
    - Agree
    - Neutral
    - Disagree
    - Strongly Disagree

2. I think that the time allocated for the presentation was sufficient.
    - Strongly Agree
    - Agree
    - Neutral
    - Disagree
    - Strongly Disagree

3. I am able to better understand the subject.
    - Strongly Agree
    - Agree
    - Neutral
    - Disagree
    - Strongly Disagree

4. The presentation is very engaging.
    - Strongly Agree
    - Agree
    - Neutral
    - Disagree
    - Strongly Disagree

EVALUATION STUDY FOR STEREOSCOPIC VISUALIZATION USED AS AN EDUCATIONAL TOOL IN ASTRONOMY
POST TEST OPINION QUESTIONNAIRE

Date: ___ /___ /______

Seat No: ______ Group: ______

Please answer the questions below.

1. I like the use of 3D stereoscopic presentation in this course.
   - O Strongly Agree
   - O Agree
   - O Neutral
   - O Disagree
   - O Strongly Disagree

2. I feel that the stereoscopic presentation (presentation using 3D glasses) helped me in understanding/learning concepts related to the Solar System?
   - O Strongly Agree
   - O Agree
   - O Neutral
   - O Disagree
   - O Strongly Disagree

3. I feel that the stereoscopic presentation (presentation using 3D glasses) helped me in understanding/learning concepts related to galaxies?
   - O Strongly Agree
   - O Agree
   - O Neutral
   - O Disagree
   - O Strongly Disagree

4. I feel that the stereoscopic presentation (presentation using 3D glasses) helped me in understanding/learning about the relative sizes and distances in the local universe?
   - O Strongly Agree
   - O Agree
   - O Neutral
   - O Disagree
   - O Strongly Disagree

5. I consider stereoscopic technology (3D visualization) a good educational tool?
   - O Strongly Agree
   - O Agree
   - O Neutral
   - O Disagree
   - O Strongly Disagree

6. I feel that the stereoscopic presentation (presentation using 3D glasses) increased my interest in the subject?
   - O Strongly Agree
   - O Agree
   - O Neutral
   - O Disagree
   - O Strongly Disagree

7. Do you have any suggestions on how to improve the 3D stereoscopic presentation?

8. What kind of information would you like to see added or removed from the presentation that would enhance your understanding of the subject discussed?