Spring 5-2014

Mental Visualization of Three-Dimensional Space: New Tools and Challenges in Building Design Education

Breshawn C. McNeal
University of Southern Mississippi

The University of Southern Mississippi

Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education

by

Breshawn C. McNeal

A Thesis
Submitted to the Honors College of
The University of Southern Mississippi
in Partial Fulfillment
of the Requirements for the Degree of
Bachelor of Science
in the School of Construction

May 2014

Approved by

Desmond Fletcher, M.A., Thesis Adviser
Associate Professor of Architectural
Engineering Technology

John Hannon, M.S., Chair
School of Construction

David R. Davies, Ph.D., Dean
Honors College

Abstract

As a future building design professional, a student's ability to mentally "picture" second and third dimensional concepts is important. Learning the fundamentals of mental visualization is tantamount to laying the foundation for a building. Sketching, one of the skills required to bring a building concept to life, helps the student rapidly record their first brilliant thought. Though modern CAD software has the capability to auto-develop a three-dimensional structure, the user constructs a two-dimensional floor plan first, so the program output is based on the user's initial input. Therefore, the quality of the three-dimensional design is linked to the student's ability to visualize the final product prior to development. The purpose of this study is to assess the visualization skills of School of Construction students at the University of Southern Mississippi, as well as concept development instruction by SoC faculty. The researcher was interested in the question: are fundamental visualization skills adequately exercised as students advance in their educational career, allowing them to recall the valuable skills? The researcher developed tools to assess student skills and faculty instruction, and uncover correlations between current educational levels and visualization fundamentals. Data collected from the faculty survey were interpreted as professional advice in architectural and architectural-related fields. Ultimately, data obtained through the student tests showed that students in all educational levels had similar visualization capabilities and exposed the importance of exercising fundamental skills to avoid diminishing the accuracy of the two-dimensional and three-dimensional drawings.

Key Words: Mental visualization, two-dimensional, three-dimensional, architectural, hand drafting, sketching, technology

Dedication

Arlisha Bell, Kyliah Windham, Kamron Morgan, Joseph J. Morgan, Kim Brown, Jean Armstrong Bradley, and Polly Mayes

Thank you for motivating me to strive for more and supporting me throughout my educational journey.

Acknowledgements

I would like to thank my thesis advisor, Desmond Fletcher, for working with me throughout this process. I would also like to thank him for challenging me and encouraging me to break through barriers. Thank you for your support and encouragement.

I would also like to thank my previous thesis advisor, Miranda Grieder, for supporting and assisting me at the beginning of the process. I am grateful I had the chance to work with her before she left The University of Southern Mississippi to pursue other ventures. Thank you for all your help.

Lastly, I would like to thank Dr. Dave Davies and Jessica Brown, faculty of The University of Southern Mississippi's Honors College, for their support during this study. This process has been very challenging with all the different changes and I could not have completed it without your guidance and assistance. This experience has shaped me into a better individual and I greatly appreciate every moment.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I: THE PROBLEM

What is three-dimensional visualization?

Three-dimensional (3D) visualization is a person's mental ability to create an image of a 3D object in their mind without having a physical example of that object for reference. This type of visualization is commonly associated with, although not limited to, the non-computer aided creation process of 3D structures such as buildings. When an individual looks at a floor plan, for example, the building is sliced four feet above the floor plane and observed from the top view. Building features are represented differently according to the location relative to this cut line, above or below. Therefore, to produce an accurate two-dimensional (2D) representation of a floor plan, all aspects of the building, and how they fit together three-dimensionally, requires mental visualization by the person producing the drawing. The 2D drawing of the floor plan will create a starting point and help determine how the shape and the details of the structure will appear in the elevations. The elevations of the structure are known as the North, South, East, and West façades (the outward appearance) of the building. Being able to mentally place different materials on the structure will assist the designer in rapidly adding their choices of materials on the outside of the building, resulting in more time to work on other aspects of the building. Floor plans and exterior elevations, however, represent only two of many drawing types required in a set of construction drawings. These drawings provide necessary instructions for builders to construct buildings. Other common drawing types that demand these same visualization skills are interior elevations, sections, and building details. If students are equipped with visualization skills early in their education and are able to produce drawings more rapidly due to the increase of skills, then what is the value of this visual ability to the quality of designs?

Value of three-dimensional visualization skills to present-day building design professionals

Research has shown that design quality can be linked to an individual's 3D mental visualization ability. Nassar, Mostafa, and Rifki (2010) stated "recent research efforts have shown that perception and visualization abilities reflect the quality of a design outcome" (p.346). If this is true, 3D visualization skills must be considered valuable for building design professionals—a term used here to include architects, architect engineering technologists, interior designers, computer-aided drafting technicians, architectural historians, building contractors, construction project managers, carpenters, and many more. In light of the major advances in 3D software technology of the last several decades, the days of exclusively hand-drafting architectural drawings are over. Most firms use computer-aided drawing software with the capability of generating 3D views containing height, width, and depth data input in a variety of ways. Subsequently, today's college-level building design courses expect students to produce 3D images, more than students of previous generations. Does new 3D software technology reduce the need for students to learn foundational visualization skills? If software will generate the 3D image, do students still need to learn how to produce the image on their own?

CHAPTER II: LITERATURE REVIEW

Foundation skills

Many scholars believe that learning the foundational skills of architecture is not only important for a student's individual creative development, but it is essential in helping them to understand drawings and models created by others. The first method for teaching architectural design skills was developed by Josef Albers and Laszlo Moholy-Nagy at the Bauhaus. They designed a teaching technique called the Bauhaus Method, which help teach students the principals of the architectural design process. This method requires students to construct a particular full-scale design by hand, which help them learn to execute their ideas. This method of handcraft eventually turned to a visual language (Ellis, 1997). This visual language, however, still needed a way to be presented to someone else and one of the methods to use is sketching.

Ideation sketching

According to Ellis (1997), "The best way to learn how to read drawings is to learn how to make drawings. It is through the construction of a drawing that our visualization skills are honed to razor-sharp edge" (p.43). Sketching is closely related with imagination and can be perceived as an instantaneous invention. The word sketch originates from the word "esquisse" and is considered the first thought drawn on paper allowing the drafter to capture "the quickness of a brilliant thought" (Ellis, 1997). The sense of touch connects the body and the mind together. This allows the student to have a direct connection of their thought to construct on the paper. When the student already has the understanding of how to use this particular drawing tool, it prevents hindrance of the thought process. It also allows them to preserve their thought and eventually draft what they visualize. Therefore, the pencil would be the ideal drawing tool to equip a student with; thus aiding them in immediately getting their thoughts on paper (Ellis, 1997). In the article "Engineering and the Mind's Eye," Eugene S. Ferguson identifies three types of sketches: thinking, prescriptive, and talking (Ellis, 1997). When the "thinking sketch" is developed by the designer, he or she is able to think through their design and observers are able to get a glimpse of the designer's vision. The "prescriptive sketch" illustrates detailed information, like construction specifications and procedures, and aids in the development of construction documents. Finally, "talking sketches" are developed instantaneously with colleagues when they are discussing the design while passing a pencil around to one another as they talk to demonstrate their ideas. The sketch is developed by everyone in this case. Talking sketches are considered the easiest because the mental images are of a common picture. This type of sketch illustrates how limited the communication of thoughts are without drawings (Ellis, 1997).

Visualization

Ellis stated (1997), "Architectural design is a highly eidetic discipline that requires a vivid recall of visual images" (p.43). Sketching a design should be done before using any technical programs because it offers more benefits to the development of the designer's spatial skills (Dillon et al., 2003). The spatial mapping that happens when thinking through the design process is related to the performance process of visualizing (Ellis, 1997). To have the ability to interpret, the person must be able to create a three-dimensional image in the mind's eye. "The eye travels across the surface of a drawing, and the mind imagines both what is literally shown in the drawing and what is implied by those areas of the drawing that are transparent, indicated as beyond, or entirely hidden" (Ellis, 1997).

Visualization and verbalization can be viewed as the same desirable goal in the design process. At each stage of the design process, the student will be asked to verbalize and visualize their design. This could be done by asking the student to explain the structure and the future ideas by using only words (Tsow & Beamer, 1987). Architectural drafting is a transition of an image held in the architect's mind and a similar creation will be made in the computer software's mind. This will eventually become a structure (Ellis, 1997). According to Dillon, Kapur, and Horlin, however, if a designer has little visualization skills they are still not able to benefit by using computer-aided-design (CAD) software (Dillon et al., 2003). CAD does not teach the designer how to visualize nor does it help the designer understand how the structure fits together. The user should already be equipped with these skills before learning how to operate the program.

Technology

According to Nassar, Mostafa, and Rifki, technology is becoming so dominant that the fundamentals seem to be fading from some academic programs. They believe, something should be done to ensure that learning and teaching does not veer away from the foundation skills (Nassar et al., 2010). It is essential to be creative when producing architectural work as well as understand how the structure will function in reality. When different virtual designs are developed, students explore the process of creating different elements, however, they may not fully understand what they are producing (Nassar et al., 2010). Computers enable designers to produce more complex structures and site plans due to making a more efficient design process (Nassar et al., 2010). When a student designs a floor plan on the computer, their minds are given space to design anything they imagine. After the floor plan is drawn, however, the computer automatically takes control of what they are imagining and translates it into a three dimensional figure. What was once the brilliant idea of that student is no longer evident, because the student is now thinking about how the computer has generated their 3D model (Ellis, 1997). An image that was once visualized in the mind's eye (mental visualization) is now lost by drafting it on the computer and letting the computer design according to its data knowledge (Ellis, 1997).

Nassar, Mostafa, and Rifki's (2010) article, "Visualization Skills for the New Architectural Forms" aims to assess the understanding of the fundamentals within virtual design and the student's understanding of how it all fits together (p.349). If the fundamentals of creating a space through freehand sketching are not taught first, then it could perhaps become harder to understand the fundamentals of technical software. The student is not only learning how to operate the program, but also the foundational skills of architecture through virtual design. When designing using an architectural drafting program, the designer has no full understanding of how the different steps are performed. All measuring skills and other techniques are done by the computer program; consequently, diminishing the opportunity for the designer to make free independent decisions. This allows space for the designer to forget how to make a rational decision and become overly dependent on the technical software they use to design (Ellis, 1997). In the 1997 Journal of Architectural Education Ellis stated in her article, "For it is through the habitual experience of both visual and haptic systems of perception that an idea of space is formed" (p.40). Ellis (1997) also stated, "In educating future architects, we can only hope that they will learn to experience the world and not just the machine" (p.44).

Previous related research method

Testing has been performed on student participants' ability to understand spatial manipulation of an object. For example, in one study, a test administrator's goal was to get the students to manipulate a digital model to look the same as a physical model. The students were timed to see at what speed they completed the task (Nassar et al., 2010). This test was performed on students so the researchers could evaluate the new generation of architects' ability to visualize free form architecture. The researchers wanted to see if there was an adequate amount of projection and spatial manipulation skills (Nassar et al., 2010). The test was deemed difficult because of the number of holes within the object to orient the shape, which makes the inside and the outside of the model indistinctive. The high number of handles on the object also made the object even more complex (Nassar et al., 2010). The student was allowed to manipulate this object because the test was completed on a computer. While the students worked the program records the sequence of moves made by the students, the time in which the moves occurred, and when the goal was accomplished (Nassar et al., 2010). The result of the experiment found that for the new generation of architects (current college student who will later become registered architects), the successful completion of the test decreased and the failure rate increased (Nassar et al., 2010).

CHAPTER III: RESEARCH STUDY

CAD programs are dependent upon the user's input, which is limited by the user's knowledge and abilities. Many students in building design majors today are learning powerful CAD software programs before achieving proficiency in foundation skills. Foundation skills are important for developing visualization skills. For example, research has shown that sketching allows students to express their visual thoughts. In turn, it exercises their ability to mentally visualize space (Ellis, 1997, p.43). Foundation courses are courses that teach students how to visualize using the traditional method for producing a drawing by hand. If a student had efficient visualization skills, their design quality would also be efficient. In turn, they are able to produce drawings in CAD at proficient levels. Therefore, a college level curriculum lacking in foundation courses may result in more students graduating with both inferior design skills and lower CAD proficiency levels in comparison to curriculums that do not lack in these courses (Nassar et al., 2010; Dillon et al., 2003). Furthermore, the career success of these graduating students would likely be affected.

The purpose of this study is to assess if the School of Construction (SoC) students at the University of Southern Mississippi (USM) have the necessary fundamental visualization skills to accurately answer test questions. In addition, this test was also designed to assess the possible correlations that may exist between the different educational levels. Freshmen, sophomore, junior, and senior are the terms that define a student's higher education knowledge level that is determined by their institution, also known as educational levels. The researcher made hypotheses based on the courses taken that requires the students to exercise their fundamental visualization skills in relation to their educational level. These hypotheses are: (1) freshmen would score low; (2) sophomores and juniors would score average; (3) seniors would score high; and (4) juniors and seniors would finish the test faster with fewer incorrect answers. The researcher's hypotheses regarding the faculty surveys were: (1) faculty would agree that more courses should integrate fundamental skills; and (2) a small number of faculty members would teach fundamental visualization skills in their course or courses.

CHAPTER IV: METHODOLOGY

Overview

This study is based on research findings demonstrating that fundamental visualization skills indeed aid students in producing better quality design work (Nassar et al., 2010; Dillon et al., 2003). Therefore, the researcher was interested in the question: are fundamental visualization skills adequately exercised as students advance in their educational career allowing them to recall the valuable skills? The participants for this study were undergraduate SoC students and current faculty members (instructors, visiting instructors, assistant professors, visiting assistant professors, and professors) employed by USM. Students of all levels were tested to assess their ability to mentally visualize in the third dimension. The faculty was given a survey consisting of a set of semi–structured questions and one open-ended question that allowed them to leave additional comments. The researcher created the provided testing document and survey that the participants completed; consequently, allowing the researcher to collect appropriate data for the study (Appendix E).

Data collection: Student Testing

The SoC consists of four different educational majors: Interior Design (ID), Construction Engineering Technology (BCT), Architectural Engineering Technology (ACT), and Industrial Engineering Technology (IET). A total number of 410 students chose an educational career path in the SoC. There are a total of 50 ID students, 238 BCT students, 70 ACT students, and 52 IET students in each program. Each student participant was briefed about the study before signing the consent form or testing document.

All student participants signed a consent form that assured them that the results of the test would be confidential and would only be viewed by the researcher. The consent form also asked them in return to keep the questions on the test confidential; therefore, allowing each participant to have an equal opportunity in completing the testing document. Each student was required to provide an ID number (assigned by USM) on the consent form to ensure that his or her score was incorporated into the study one time only. Each testing document contained an assortment of orthographic projections [a method of projecting each side of a 3D object onto a 2D surface (Figure 1)]. It also contained isometric drawings [a 3D view of an object that eliminates the distortion of the object caused by perception (Figure 2)]. The researcher designed the test with six different question types that progressed in difficulty. The level of difficulty was determined by how much information the question provided the participant, in comparison to, how much information they had to provide to accurately answer the question.

The first question type (Figure 3) required the students to choose a multiple choice answer; in addition, it encompassed an isometric drawing and an orthographic view. It asked the student participants to identify the orientation of the orthographic projection in relation to the isometric drawing. The answer choices were front view, right side view, left side view, top view, bottom view, or back view. Seven different questions were asked of this type. The difficulty level for this question was classified as beginner because it only required them to choose one of the given answer choices.

The second question type (Figure 3) provided the students with an isometric drawing and three orthographic projections (top, front, and right views). Letters were placed on the isometric drawing and asked the students to write the correct letter in the circle located on the corresponding orthographic view. This question type was designed to understand how the students visualize the isometric drawing and how it corresponds to the orthographic projection in their mind. A total number of six different questions were asked of this type. The difficulty level was classified as beginner to intermediate because the students only had to provide letters to answer the question.

In the third question type (Figure 3), the students were provided an isometric drawing. The front view of the drawing was identified with an arrow and labeled "front". They were also given the words top, front, and right to sketch the appropriate orthographic view in its designated area. This question type was designed to determine if the students have the ability to correctly sketch an orthographic projection from an isometric drawing that is at an angle. In order to correctly sketch the orthographic projection, the students had to rotate the isometric object in their mind and mentally view it from one side. A total of seven different questions were asked of this type. The difficulty level was classified as intermediate because the questions required the student to sketch three orthographic projections. In addition, the students also had to mentally manipulate the provided objects to answer the questions correctly.

The fourth question type provided the students with three orthographic views (top, front, and right views) and asked them to sketch an isometric drawing. This question type was designed to get the students to manipulate the orthographic projections in their mind. In turn, the researcher could observe and maybe understand how the students mentally view the object. A total number of three different questions were in this question type. The difficulty level for this question type was classified as intermediate to hard because it requires the students to mentally construct and manipulate three orthographic views in their mind and produce an accurate isometric drawing. A large number of this type was not incorporated into the testing document because it takes more time to finish these questions.

The fifth question type (Figure 3) provided the students with a translucent isometric drawing which allowed them to identify all six sides (top, front, right, left, back, and bottom) of the object. The words top, front, right, left, back, and bottom were also provided which required the students to sketch the orthographic projection in its designated area. This question type had the same intentions as question type 3, but it required a slightly different answer. The students had to produce all six orthographic projections in order to get the question correct. This question type only consisted of one question and the difficulty level was classified as intermediate to hard. The difficulty level increased because this question type required the student to produce all six sides, which required more time to complete.

The sixth and final question type (Figure 3) provided students with six orthographic projections and asked the students to produce an isometric drawing. This question type had the same intention as question type 4. The only difference was that the student had three additional objects that they had to mentally manipulate. There was only one question in this question type and the difficulty level was classified as hard.

All students were provided with identical testing documents and consent forms. In efforts of keeping the test confidential, all students had an equal opportunity in completing the test. No one besides the researcher could view the completed test. Each test was composed of 25 questions and contained a variety of orthographic projection and isometric drawing questions. The allotted time for the students to complete the test was 25 minutes. They were not required to complete the entire test; yet, they were asked to complete as much of the test as possible, to the best of their ability.

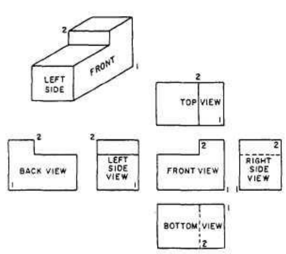


Figure 1: Orthographic Projection

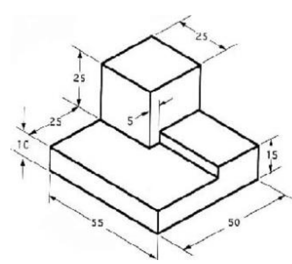


Figure 2: Isometric drawing

Figure 3: Examples of Test Question Types

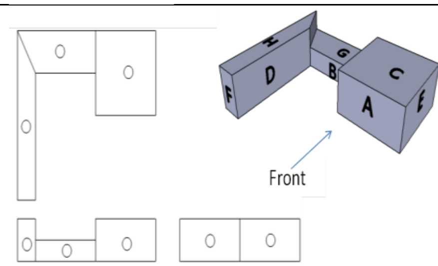
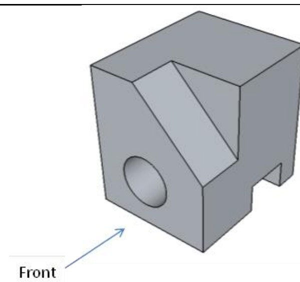
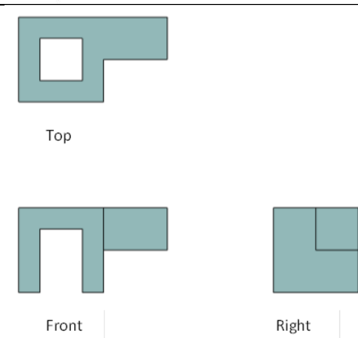
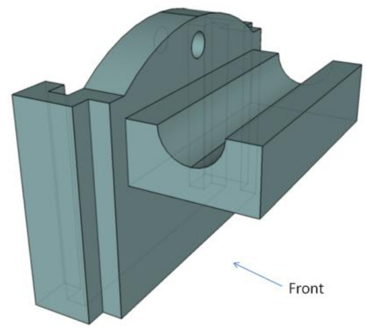
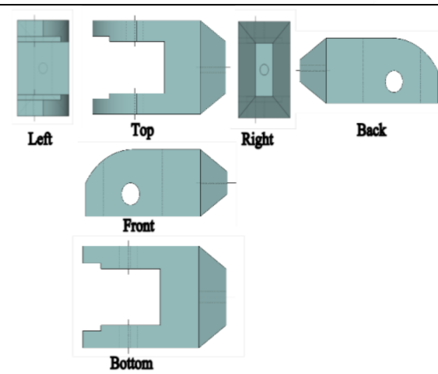
Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education Student Participant Test	
Question Types	*Example of Questions*
Type 1: Level of Difficulty | Beginner | Intermediate | Hard These questions encompassed a 3D and 2D drawing which asked the student to identify the orientation of the provided 2D view	
Type 2: Level of Difficulty | Beginner | Intermediate | Hard These questions provide the students with an isometric drawing and three orthographic projections (top view, front view and right view). Letters were placed on the isometric view; consequently, asking the student to write the correct letter in the correct circle located on the corresponding orthographic view.	
Type 3: Level of Difficulty | Beginner | Intermediate | Hard These questions provided students an isometric view. The front view of the object was identified with an arrow; in addition, they were also given the words top, front, and right to draw the appropriate orthographic view in its designated area.	
Type 4: Level of Difficulty | Beginner | Intermediate | Hard These questions provided the students with three orthographic views (top, front, and right) and asked them to sketch the isometric figure.	

Figure 3: Examples of Test Question Types continued

Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education Student Participant Test	
Question Types	*Example of Questions*
Type 5: Level of Difficulty | Beginner | Intermediate | Hard This question type provided the students with a translucent isometric view allowing the student to identify all six views (top, front, right, left, back, and bottom) of the object.	
Type 6: Level of Difficulty | Beginner | Intermediate | Hard This question provided the students with six orthographic views and asked the student to sketch an isometric drawing of the object.	

Data collection: Faculty Survey

The other participants in this study were the faculty members who are employed by USM's SoC. The term faculty includes instructors, visiting instructors, assistant professors, visiting assistant professors, and professors, but not adjunct faculty. Deemed experts in their disciplines and initiators of curriculum development, their insights were valuable to this study. Each faculty member was sent an email (Appendix A) briefing them on the study and asked them to: (1) complete a survey about their judgment on how their courses aim to enhance the students mental visualization skills; and (2) whether or not they would agree to participate in administering the test to their students during one of their class sessions. Also in this email was a link to the faculty survey that was conducted on a website entitled surveymonkey.com. If faculty agreed to participate in the study, a follow up email was sent to the member. This email informed them about the amount of time that would be needed to conduct the student test. To avoid conflicting scheduled times and dates, a spreadsheet of classes within the SoC and their meeting times was created in advance. This was produced in efforts to set up times that the researcher could meet with each class. There was an option on the spreadsheet for the faculty to agree to the scheduled time the researcher wanted to test their students. The faculty also had the option of providing an alternate time and/or day. Also attached to the follow up email was a consent form that the faculty had to sign before participating in the study.

The faculty survey consisted of semi-structured questions and a general open-ended question that allowed them the freedom to provide any additional comments. The survey also incorporated specific questions only for faculty who teach courses that require students to mentally visualize. These additional questions asked the faculty to explain how they incorporated fundamental visualization skills into their course. Each faculty member was asked to sign a consent form and send a PDF copy to the researcher through email or the researcher would pick up a signed hard copy from their office. The consent form ensured the faculty that the survey was confidential. It notified them that it would only be used for research purposes and would only be observed by the researcher. The consent form also asked them to keep the survey confidential in efforts to eliminate the change of response based on another faculty member's comment.

Data analysis

While analyzing data collected during the spring semester, student participants were placed into different groups to compare their testing achievements. For example, the students' achievement levels will be compared according to education level and level of mental visualization in relation to their test results. The difficulty of the questions will also be analyzed which is identified by how many students correctly or incorrectly answered the questions. A visual of these comparisons are shown in various types of graphs to demonstrate the differences between the student group categories.

The data collected from the faculty, being a set of responses from a survey, were used in a descriptive manner. Because identical surveys were provided to each faculty member, there was a percentage given in cases when teachers had a common response. The response was stated and the percentage of faculty with the same response was provided. The responses were mentioned as advice from a set of experts within his or her field.

CHAPTER V: RESULTS

Overview

Only two out of four programs within the SoC participated in the student test. The 63 student participants consisted of 11 freshmen, 12 sophomores, 24 juniors, and 16 seniors. Each educational level was analyzed individually and as an entire group.

Out of 15 faculty members, only 4 participated in the faculty survey and agreed to allow student testing to take place during a scheduled class session. One faculty member only agreed to participate in the faculty survey. After analyzing the faculty survey, they all had similar responses to the provided questions.

SOC Student Results

The level of difficulty was analyzed individually and collectively among the educational levels. As previously stated, each question type on the testing document was assigned a level of difficulty, which was hypothesized by the researcher. The questions on the test were designed to progress in difficulty as participants took the test. Each question number was placed into a spreadsheet horizontally; furthermore, the test questions were grouped according to their question type. To foster the comparison, each student test was vertically grouped according to their educational level. The spreadsheet noted which questions each student answered correctly and incorrectly (Figure 4). A table was created to condense the results and show the most frequent incorrectly answered test question; in addition to, how many of the students incorrectly answered these questions throughout the test (Figure 6).

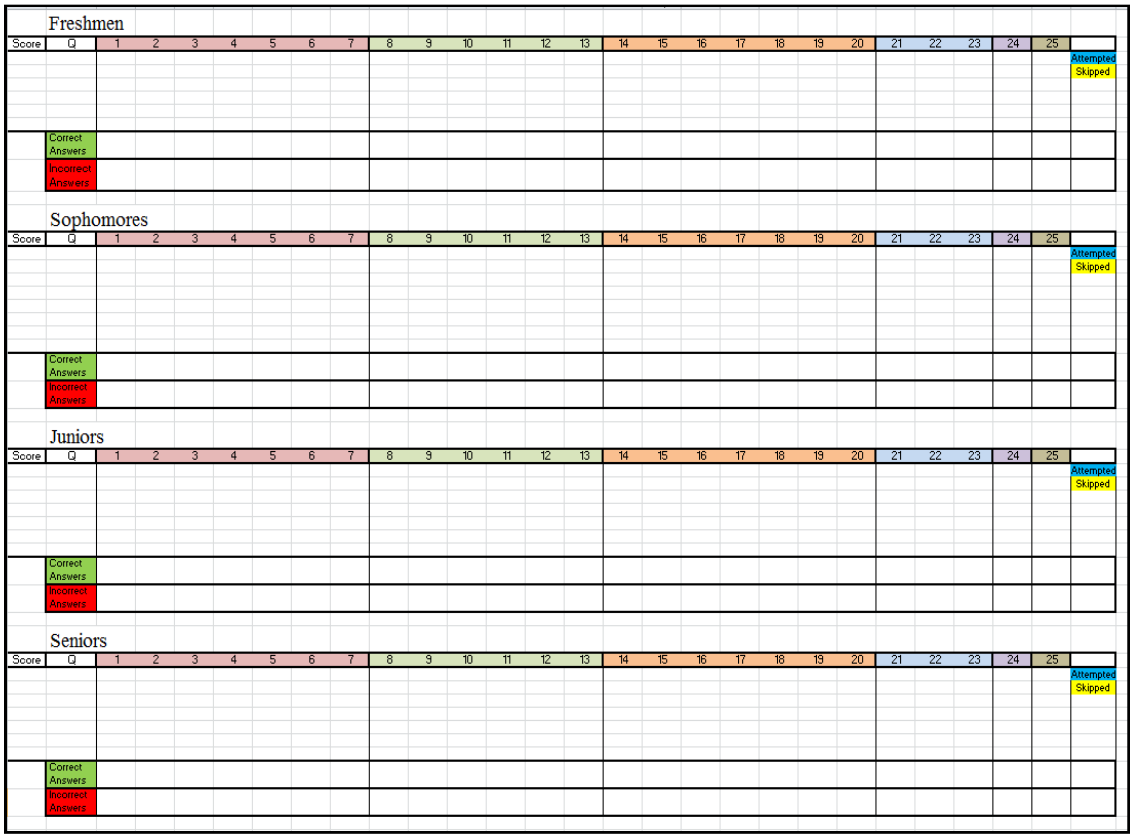


Figure 4: Students' Correct and Incorrect Answer Spreadsheet

In the first question type, the most frequently missed question by freshmen students was number one. Seven students answered this question incorrectly. Similarly, sophomore students also frequently missed question 1. Nine of the students incorrectly answered the question. The junior education level had the same difficulty with the first question type as the freshmen and sophomores. Twelve students incorrectly answered question 1. Seniors most frequently missed question was number 3. A total of 10 students answered this question incorrectly. Collectively, a total of 38 students incorrectly answered questions in the first question type. Figure 5 depicts the number of students who incorrectly answered questions in each question type for all the educational levels individually.

In question type 2, freshmen students answered two questions incorrectly the most. A total of six students answered questions 9 and 11 incorrectly. The sophomore students had the most trouble with answering question 13 correctly. There were 10 students who incorrectly answered the question. Juniors also incorrectly answered question 9. A total of 14 juniors missed this question. The senior educational level missed question numbers 9 and 11 just as the freshmen level. A total of 12 seniors missed both questions. Collectively, a total of 42 students missed questions in the second question type.

In the third question type, both freshmen and sophomore students missed two questions. A total of five freshmen students missed question numbers 19 and 20. Four students in the sophomore education level missed question numbers 15 and 20. The juniors frequently missed question 20. A total of nine students missed this question. A total of six senior students missed question 17. Collectively, a total of 24 students missed questions in the third question type.

Question type 4 was designed to be one of the hardest question types. For this type, a total of eleven freshmen students missed both question numbers 22 and 23. Likewise, 11 sophomore students missed question numbers 22 and 23. Juniors had the most trouble with question 22. All juniors incorrectly answered this question. Fifteen senior students also missed question numbers 22 and 23. Collectively, a total of 61 students incorrectly answered questions in the fourth question type.

The last two question types only consist of one because of their high level of difficulty. In question type 5, freshmen students answered question 24 incorrectly. Ten freshmen students missed the question. Similarly, ten sophomore students answered question 24 incorrectly. Juniors had 22 out of 24 students who also incorrectly answered question 24. Seniors had 14 out of 16 students incorrectly answer question type 5. All education levels had 1-2 students to correctly answer question 24. Collectively, a total of 56 students incorrectly answered question type 5.

In the last question type, sophomore and junior students had the most success with question 25. Eleven sophomore students missed question 25. Twenty-three of the junior students incorrectly answered question 25. All freshmen and senior students answered question 25 incorrectly. Collectively, a total of 61 students incorrectly answered question type 6.

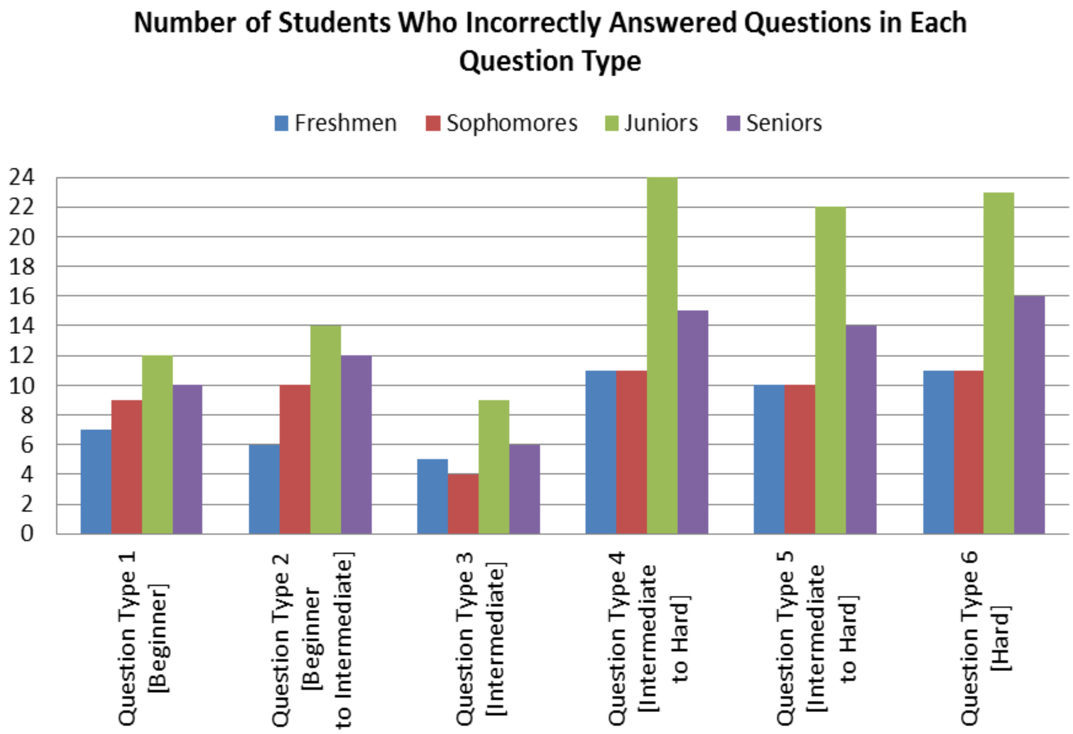


Figure 5: Number of Students Who Incorrectly Answered Questions in Each Question Type

Most Frequently Missed Question for Education Levels

	QUESTION TYPE 1	
Education Level	*Frequently Missed Question*	*Number of Incorrect Answers*
Freshmen	1	7 out of 11
Sophomores	1	9 out of 12
Juniors	1	12 out of 24
Seniors	3	10 out of 16
	QUESTION TYPE 2	
Education Level	*Frequently Missed Question*	*Number of Incorrect Answers*
Freshmen	9 and 11	6 out of 11
Sophomores	13	10 out of 12
Juniors	9	14 out of 24
Seniors	9 and 11	12 out of 16

Most Frequently Missed Question for Education Levels continued		
QUESTION TYPE 3		
Education Level	*Frequently Missed Question*	*Number of Incorrect Answers*
Freshmen	19 and 20	5 out of 11
Sophomores	15 and 20	4 out of 12
Juniors	20	9 out of 24
Seniors	17	6 out of 16
QUESTION TYPE 4		
Education Level	*Frequently Missed Question*	*Number of Incorrect Answers*
Freshmen	22 and 23	11 out of 11
Sophomores	22 and 23	11 out of 12
Juniors	22	24 out of 24
Seniors	22 and 23	15 out of 16
QUESTION TYPE 5		
Education Level	*Frequently Missed Question*	*Number of Incorrect Answers*
Freshmen	24	10 out of 11
Sophomores	24	10 out of 12
Juniors	24	22 out of 24
Seniors	24	14 out of 16
QUESTION TYPE 6		
Education Level	*Frequently Missed Question*	*Number of Incorrect Answers*
Freshmen	25	11 out of 11
Sophomores	25	11 out of 12
Juniors	25	23 out of 24
Seniors	25	16 out of 16

Figure 6: Most Frequently Missed Questions for Education Levels

While analyzing data, the researcher also noticed that some students skipped questions to complete or made an effort to complete the upcoming questions. Also, there were students who attempted to complete questions; yet, they got them incorrect because they were not able to complete them in the allotted time. Skipped questions are defined as a student advancing to complete the upcoming questions. Attempted questions are defined as questions that the student started to answer but did not finish because he or she ran out of time. Percentages for skipped questions were allocated to each educational level to compare the groups. These percentages were also placed in a pie chart to provide a visual comparison (Figure 7).

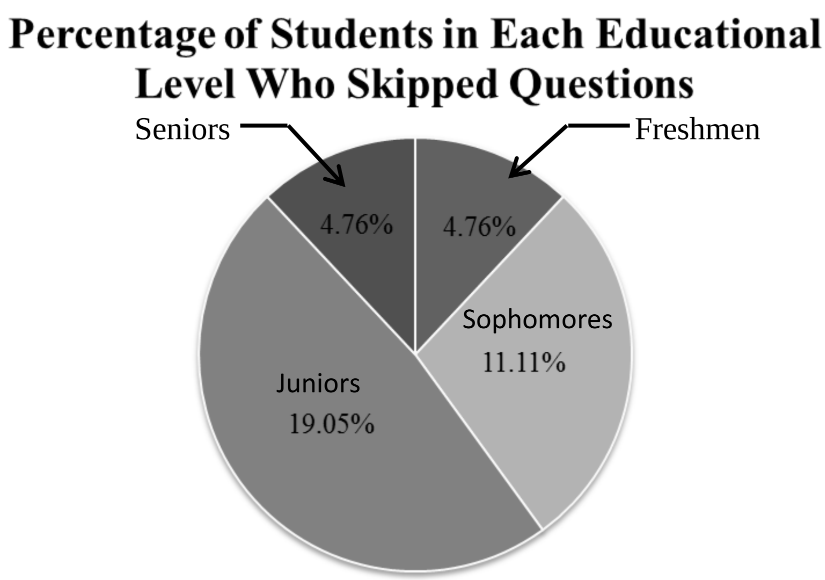


Figure 7: Percentage of Students in Each Educational Level Who Skipped

A total of three freshmen students skipped six questions, and these question numbers were 21, 22, and 23. Their most frequently skipped question was number 22. A total of seven sophomore students skipped thirteen questions, numbers 8, 20, 21, 22, and 23. Their most frequently skipped questions were 22 and 23. A total of twelve junior level students skipped 20 questions. These questions were numbers 19, 21, 22, 23. 24 and

25, with the most frequent being number 22. A total of three senior students skipped five questions, which were numbers 22 and 23. Number 23 was the most frequently skipped question. Overall, the students frequently skipped question 22. Sixteen students skipped this question in total. All values for skipped questions can be found in figure 8 and the most frequently skipped question can be found on the table in figure 6.

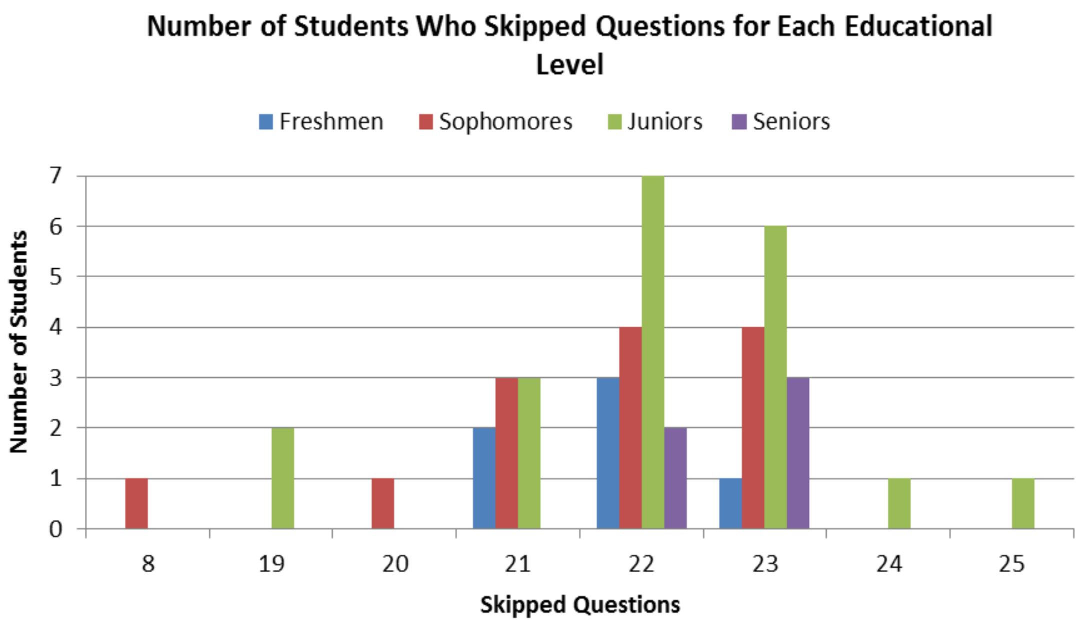


Figure 8: Number of Students Who Skipped Questions for Each Educational Level

Two freshmen students attempted to answer questions before running out of time. One student started on question 20 and the other on question 22. Five sophomore students attempted question numbers 22, 23, and 24. One did not finish number 22, one did not finish 23, and three did not finish number 24. Nine junior students attempted to answer questions 19, 21, 22, 24, and 25. With three attempts each, the junior students did not complete question numbers 21 and 24 before the allotted time expired. One junior attempted question 19, another student attempted question 22, and the last junior student attempted number 25. Four senior students attempted to answer four questions. Those questions were numbers 21, 22, 24, and 25. With one attempt each, senior students failed to complete questions number 21 and 23. Three seniors attempted question 24. All the values for attempted questions can be found in Figure 9.

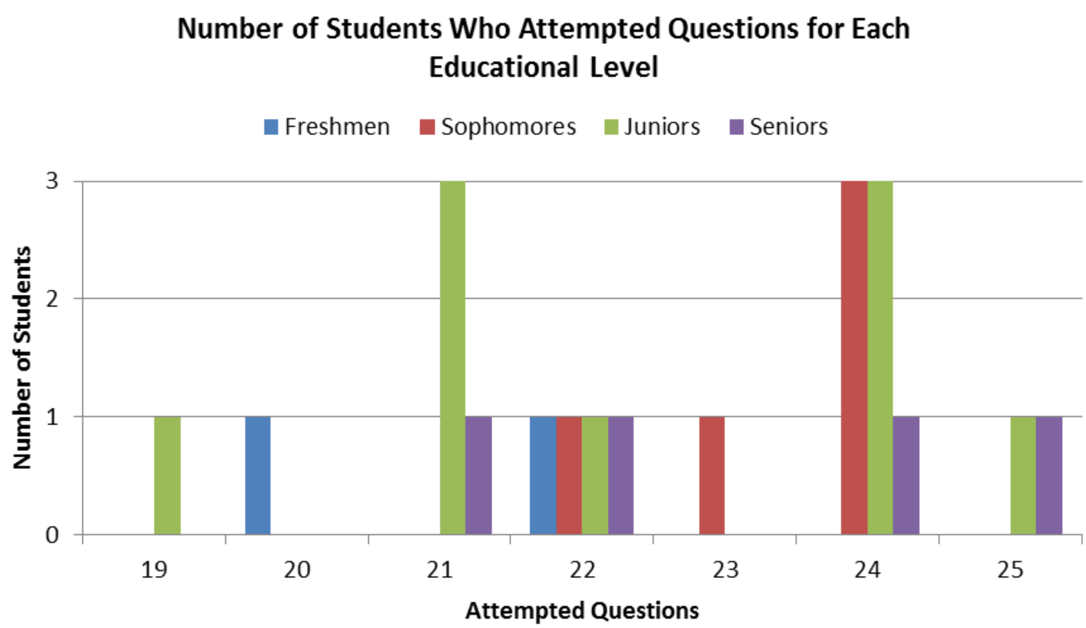


Figure 9: Number of Students Who Attempted Questions for Each Educational

SOC Faculty Results

The faculty participants were asked to participate in a survey to incorporate their field of professional expertise. The collection of responses from the surveys provided useful data to the researcher as to how the curriculum can be enhanced to improve the students' mental visualization skills. The first question ask the participants if they feel it is essential for architectural and architectural-related majors to learn the fundamentals of visualization and to the have the ability to visualize effectively. One hundred percent of faculty agreed that it is important for these students to learn and effectively use these skills. The faculty common responses were all summarized by one of the five participants, which states,

> For architectural students, visualization is important because we are creating documents for projects that will eventually be reality; however, in the beginning, these documents are simply ideas. Visualization is important for architectural students because we are drawing from our imagination; if we cannot visualize these building components as a finished product, we cannot perform basic functions required in our field.
>
> As for construction and other students, visualization is incredibly important as well. Just as architectural students are creating the documents necessary to build a structure, other professionals are utilizing those documents to build the structure. Construction and other students should be able to "see" the finished product just by looking at the plan set.

Two other faculty participants also similarly stated " It is also essential that that 3D competencies be learned and practiced in the Pre-Construction stage of project delivery in order for proper constructability review, clash detection, and other planning tasks--this has proven to reduce overall construction costs and change orders." Washington state human resources define competencies as, "the measurable or observable knowledge, skills, abilities, and behaviors (KSABs) critical to successful job performance" ("Competencies," 2012).

Question 2 asks faculty do they feel additional fundamental task should be incorporated into the SoC or if the current courses offered are effective. One hundred percent of the faculty agreed that additional task should be integrated. In question 3, the faculty participants were asked if new courses should be added to the SoC to assist with fundamental skills. If the faculty member answered yes, they were asked to explain why new courses should be added. Four participants said courses should not be added, rather, additional skills should be added to existing courses. One participant stated, "Descriptive geometry and model building may be enhanced in existing courses but does not require a new course." Question 4 asked the participants whether they have any additional ideas or comments about the importance of fundamental visualization. A faculty member stated that the skills are not only important to operate effectively in the architecture and construction fields, but could also allow students to expand into other fields such as graphic design and web development. In addition, this faculty participant also stated, "Visualization skills can translate into new approaches to design and how we address emerging concepts such as sustainability and facilities management." Eighty percent of the faculty participants teach courses that require mental visualization. Most of the classes that they instruct are computer based and the other classes combine traditional media skills and a variety of computer programs.

CHAPTER VI: DISCUSSION

Student testing and Faculty Survey

After receiving conformation emails from the faculty that were interested in allowing their class of students to participate in the survey, it took the researcher one week to complete student testing. Some students completed the whole test within the allotted time. Other students turned the test in early without completing the document or were not able to complete the test within the allotted time. A total of 10 students turned the test in before the time expired. These tests were submitted within 18 to 23 minutes of the allotted time. Two students completed the entire test in the allotted time. One of the two students completed the test within eighteen minutes and received a high score. Four students skipped questions, preceded to the last question, and failed to go back and attempt the previously skipped questions. The last four students stopped toward the end of the testing document. It can be stated that 8 of the 10 students gave up on completing the entire test because they had about 5 minutes left to complete as much as possible.

Freshmen had a lower amount of incorrect questions. This shows that they performed better on the student test. This is depicted in figure 5 bar graph. Freshmen are required to take a course in their current educational level that teaches and exercises their fundamental mental visualization skills. A faculty participant responded saying, "The students perform several in-class and AutoCAD exercises practicing their visualization skills. I also found a great website a few years ago that takes students through various "Brain Exercises" to assist with visualization." This may be the reason why they scored so high.

Students may lack knowledge of the fundamental skills of sketching the intermediate to hard figures because they have not had continual practice doing this in an educational setting. After the first year of higher-level education, students are not required to develop sketches for computer-based projects; yet, a faculty response said they are encouraged. This allows the students to slowly lose their ability to independently visualize; consequently, they totally depend on the computer programs that provide the 2D or 3D model (Ellis, 1997). All educational levels struggled with the last three question types (type 4, type 5, and type 6). This is depicted in figure 10 bar graph, which shows the percentages of students who incorrectly answered questions for all the question types in the testing document.

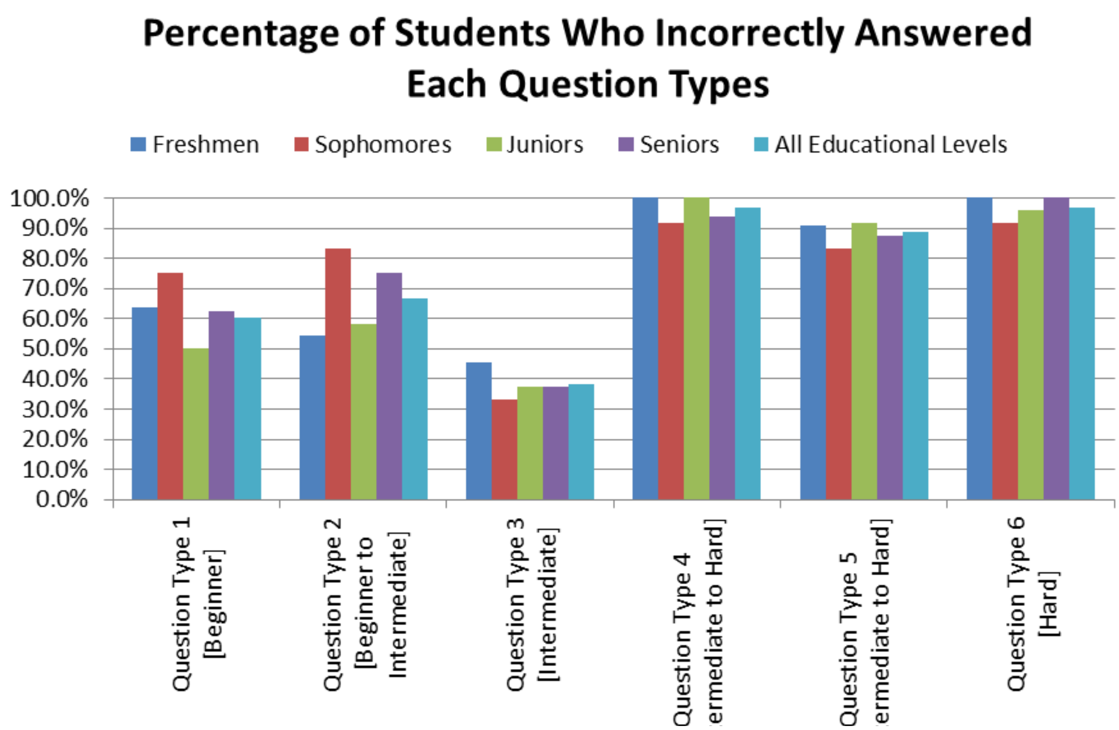


Figure 10: Percentage of students who incorrectly answered questions in each question type.

There were three questions in question type 4. These questions require the students to sketch an isometric drawing that could be produced from the three orthographic projections provided. This question type level of difficulty is intermediate to hard because it requires the students to use the provided views to configure the 3D object in their mind and then transfer the object onto the testing document. Some students may have skipped these problems because they were too challenging or they did not want to use the provided time to challenge their selves. Other students did not complete the questions; therefore, they received an incorrect mark for the incomplete questions. They were possibly working on question type 3 and ran out of time; consequently, they could not advance to the next question types (types 4, 5, and 6). All students in each educational level scored poorly for question type 4. The percentage of students who incorrectly answered questions in question type 4 ranged from 93.8 to 100 percent (Figure 10). It is important to be able to form and manipulate an object within your mind because it has a direct relationship with a building's floor plan, sections, and elevations (Ellis, 1997).

Question type 5 only consisted of one question. This question requires the students to produce six orthographic projections (front, back, right, left, top, and bottom). To correctly answer this question, the students had to manipulate the isometric drawing in their mind, which would allow them to view one side of the object. This question had a difficulty level of intermediate to hard. All students scored poorly on this question type as well. The percentage of students who incorrectly answered the question ranged from 87.5 to 91.7 percent collectively (Figure 10). A total number of 56 students incorrectly answered this question.

Question type 6 only consisted of one question that required the students to produce an isometric drawing from the six provided orthographic projections. Two students had the ability to correctly depict the isometric drawing. All isometric drawings have to be drawn at an angle in order to incorporate at least three orthographic projections to effectively construct the isometric drawing. Question 25 was last on the testing document because it was perceived by the researcher as the hardest question on the entire test. 96.83 percent of students (Figure 10) got this question incorrect because: (1) the allotted testing time expired, (2) they skipped the question by turning the test in early, or (3) they did not correctly depict the isometric drawing. To assist students with retaining the fundamental skills, a better understanding or additional exercises of the fundamental skills should be incorporated into higher education level courses. A faculty participant stated "I don't think it is necessary to create an entire course dedicated to visualization, but it would be beneficial to incorporate additional visualization exercises into the existing curriculum."

In the third question type, the questions required the students to produce orthographic projections (top, front, and right sides) for an isometric drawing that was provided. 20.63 percent of the participants faced multiple challenges in producing the orthographic projections from the isometric drawing. Three out of the seven questions in the third question type had isometric drawings that incorporated angles. Some of the students misrepresented the angles on the objects by: (1) not including them in the 2D sketch, (2) sketching a hidden line where it should be solid, or (3) sketching them in one of the required views and not the others. For example, the isometric drawing in question 5 in Appendix D incorporated an angle. For this question, some students drew one orthographic projection with no angled lines. They proceeded to add angled lines in other 2D views for the same question. Other isometric drawings in this question type incorporated curves. Some students sketched the curve in the 2D figure when it should only be constructed of straight lines. For example, the top view of an arched window should be constructed of only straight lines. Other students also tried to sketch the 2D figure at an angle. These students sketched the figure the way they observed it on the testing document; therefore, they did not manipulate the 3D object in their mind to only view one side of the provided isometric drawing. This provides evidence that some students need more knowledge on how to depict curves and angles in a 2D figure.

According to the faculty survey, all faculty participants feel that additional fundamental tasks should be added to the existing courses. Faculty participants also believe that fundamental skills are important for students within the other units of the SoC. A participant stated, “Just as architectural students are creating the documents necessary to build a structure, other professionals are utilizing those documents to build the structure. Construction and other students should be able to "see" the finished product just by looking at the plan set.” Another participant stated,

> There is plenty of room in our existing courses to develop 3D competencies, however there needs to be more coordination among the faculty to ensure what outcomes are required in each course; the Construction and Architecture programs need to plan together and possibly have more cross-collaboration (which may require adding or redesigning some courses).

CHAPTER VII: CONCLUSION

Ellis (1997) stated, “In educating future architects, we can only hope that they will learn to experience the world and not just the machine.” (p.44). It is important to learn different software programs because the world is evolving and starting to use a variety of technology to develop construction documents. Yet, the ability of all students to mentally visualize is just as important. A faculty participant stated, “The architecture industry as a whole is undergoing a dramatic shift in how it applies design and methodologies to construction and building science. Visualization skills can translate into new approaches to design and how we address emerging concepts such as sustainability and facilities management.”

To get an understanding of how students perceive 2D and 3D objects in their mind, the researcher created a test. After testing 63 students, the results showed that the educational levels mental visualization skills for all students were the same. Some students faced challenges when they were asked to produce an orthographic projection from the provided isometric drawing. These students produced 2D figures that were drawn at an angle. They also attempted to draw the figure without manipulating it in their mind to observe only one side of the object. Some of them neglected to incorporate angled surfaces in their 2D figures and others depicted the angle with hidden lines. These questions were located in question type 3 and had an intermediate level of difficulty.

The researcher made a hypothesis on difficulty level and placed the test problems in order so they would progressively be more challenging. Most of the students faced challenges in answering the last three question types (Figure 3 and 10). Question types 4 and 6 required them to manipulate the provided 2D figures in their mind to form a 3D object. Question 5 type required students to produce six orthographic projections from a translucent 3D object. Some students incorrectly answered the problems in the last three question types because: (1) they turned the test in early, (2) they skipped the question to advance to the next question, (3) they attempted to complete the problem before time expired but failed to finish, or (4) they were not able to complete upcoming questions because time expired. This can be a result of the students not understanding how to manipulate orthographic projections and isometric drawings in their mind. Consequently, the students faced challenges that cause them to give up on completing the questions or they did not have the fundamental knowledge to complete the questions.

After assessing the surveys, all faculty participants had about the same outlook on including additional fundamental elements within existing courses. Eighty percent of the faculty that participated in the survey instructs a course or courses that require mental visualization. Only two faculty participants require students to utilize the traditional media of sketching and one other participant encourages students to sketch. Another faculty participant mentioned through a survey response saying,

> Although computer-based modeling is the most predominant tool in our industry, it bypasses many of the fundamental skills needed to understand spatial relationships and 3D visualizations. Physical models, although dated, have proven to be the hands-on approach to visualization and spatial understanding.

This applies to not only students in the architectural programs, but also students in the architectural-related programs. Collecting data from both students and faculty was very useful for comparative purposes.

In conclusion, freshmen, sophomores, juniors, and seniors performed at the same difficulty level (beginning to intermediate). After a student's freshmen year, sketching is not required in courses; yet, sketching conceptual ideas are only encouraged. Not continuing to exercise this skill can cause students to slowly lose the ability to produce accurate isometric drawings and orthographic projections. This statement is supported by Ellis's 1997 journal and by the students testing results. Fundamental skills should be continually exercised throughout a student's educational career to assist them in remembering how to accurately depict figures and objects.

CHAPTER VIII: FUTURE RESEARCH

This research can be enhanced by creating a short answer question set to ask students about their previous background within their field of study. Some students may have fundamental education or even had an internship with a company that could have contributed to the fundamental skills they obtain. Knowing this could foster another category to compare students and derive efficient data and results. It is also recommended that students be divided into groups according to their major of study. All students in this field of study are required to visualize. Analyzing which group has a better understanding could be beneficial and possibly foster ideas on how to improve the students' fundamental visual abilities. Lastly, transfer students from community colleges should be separated from students who started their higher educational career at a university.

References

Competencies. (2012). Retrieved from http://www.hr.wa.gov/WorkforceDataAndPlanning/WorkforcePlanning/Competencies/Pages/default.aspx

Dillon, D., Kapur, A., & Horlin, C. (2003). Teaching spatial concepts in the architectural design process. 18-19.

Easton, V., & McColl, J. (n.d.). Statistics glossary. Retrieved from http://www.stats.gla.ac.uk/steps/glossary/paired_data.html

Ellis, V. (1997). Education of the architect in hyperspace. *Journal of Architectural Education*, 51(1), 37-45.

Nassar, K., Mostafa, M., & Rifki, A. (2010). Visualization skills for the new architectural forms. Special volume: Design education: Explorations and prospectus for a better build environment, 4(2-3), 346-358.

Tsow, D., & Beamer, L. (1987). Verbalization and visualization: A need in architecture education. *Journal of Architectural Education*, 40(2), 80-81.

Standard score. (2012, November 17). Retrieved from http://en.wikipedia.org/wiki/Z_scores

Appendices

Appendix A: Professor Email

Dear Professor ________________:

My name is Breshawn McNeal and I am currently a senior in the School of Construction with the major of Architectural Engineering. I am also a student of the Honors College and currently working on my senior thesis project. I am contacting you because I would like you to participate in the Professor Survey that I am conducting.

The title of my thesis is "Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education". I am currently looking for professors to volunteer some of their time to fill out the survey. It will consist of open ended questions about students visualization skills within the School of Construction. This survey will be confidential and it is also opinionated.

To participate in the survey, the link is: http://www.surveymonkey.com/s/DBGFC3Q

Also, please sign the consent form and either email me a PDF or I can come pick up the signed copy from your office.

Not only do I want to give the professors a survey, but I would also like to give the students a mini test to evaluate their mental visualization skills. It would be greatly appreciated if I could use a small amount of your class time to conduct the test. The test is timed and the students are not required to finish the whole test, but I do ask that they complete it to the best of their ability. This test will also be confidential. The scores will be evaluated and grouped according to categories; therefore, no one student will be singled out.

If you agree to allow your students to participate, I have attached an excel spreadsheet of the classes you instruct and the time I would like to test students. If you would highlight the yes box if you agree to the day and time or put a time in the "Actual Scheduled Time" box. After receiving your email, I will email you back to confirm the date.

Also attached is a copy of my IRB Approval letter.

If there are any questions I can be reach on my cell phone at _____________ or by email ____________________. My thesis advisor name is Desmond Fletcher and he can also answer any question or provide you with additional information. His email is: ____________________.

Thank you for your time and I look forward to hearing from you soon!

Thank you, Breshawn McNeal

Appendix B: Student Consent Form

Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education Student Participant Test

Foundation skills are important for developing visualization skills, Research has shown, for example, sketching allows students to express their visual thoughts and, in turn, exercise their abilities in mentally visualizing space (Ellis, 1997, p.43).

The test is designed to measure the visualization skills of current college students in the School of Construction at the University of Southern Mississippi. This test will solely be used for the thesis research topic titled Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education. Each student will only provide his or her student test number to ensure confidentiality and also to ensure that the completed test score is only counted once. This mental visualization test requires student to finish as many test questions as possible within the allotted time. It is asked that each individual complete each test question to the best of his or her ability. Data from scores will be collected and analyzed which will then be incorporated into the thesis research project.

By providing your name, date, testing number and signature you will agree:

1. to be a participant in this research.
2. to allow the researcher to analyze and use the results collected.
3. that you understand the test results are confidential and data will only be used in this research thesis.
4. to not share the content provided on the test to ensure all students have equal opportunity in completing the test.
5. That you completed each question to the best of your ability.

Please check one: ___ I am 18 years old or older ___ I am under 18 years old

____
Name

______________________________ ____________________
Signature Date

ID Number __________________

Appendix C: Professor Consent Form

Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education Professor Participant Survey

Foundation skills are important for developing visualization skills, Research has shown, for example, sketching allows students to express their visual thoughts and, in turn, exercise their abilities in mentally visualizing space (Ellis, 1997, p.43).

The survey is designed to receive a professional input of the visualization skills of current college students in the School of Construction at the University of Southern Mississippi. This survey will solely be used for the thesis research topic titled Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education. Each professor will only provide his or her name on the consent form to ensure confidentiality and also to ensure that the completed survey is only counted once. This mental visualization survey requires professors to finish the survey questions to the best of their ability based on their knowledge of the School of Construction students and from a professional outlook. Data from survey will be collected and analyzed which will then be incorporated into the thesis research project.

By providing your name, date, and signature you will agree:

1. to be a participant in this research.
2. to allow the researcher to analyze and use the results collected.
3. that you understand the survey results are confidential and data will only be used in this research thesis.
4. to not share the content provided on the survey to ensure all professors have equal opportunity in completing the survey.
5. that you completed each question to the best of your ability.

____

Name

______________________________ ____________________

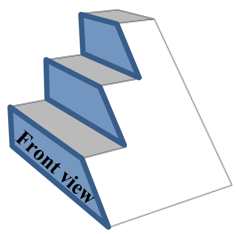
Signature Date

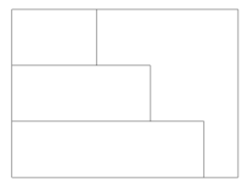
Appendix D: Sample Questions from Student Test

The questions should be completed to the best of your ability. You will have 25 minutes to take the test. Remember you are not required to complete the test; although, you should complete as much as possible within the allotted time.

Directions: Identify which view is shown in 2D by viewing the 3D object provided.

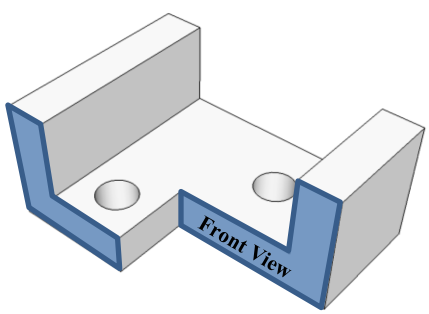
1.

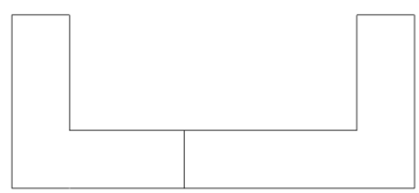




- ○ Front View
- ○ Right Side View
- ○ Left Side View
- ○ Top View
- ○ Bottom View
- ○ Back View

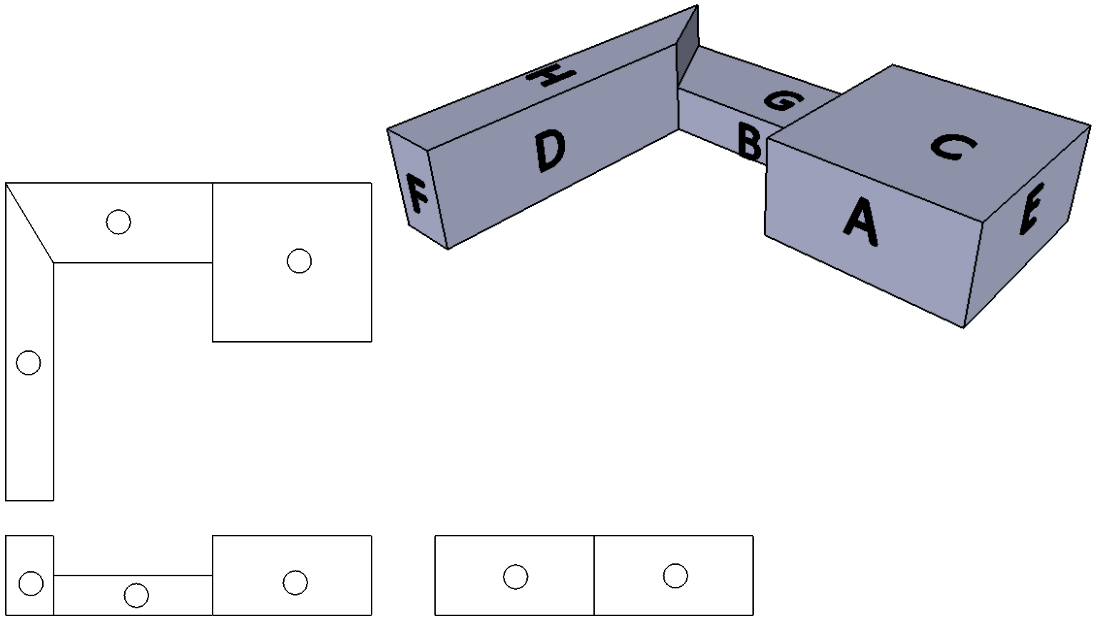
2.



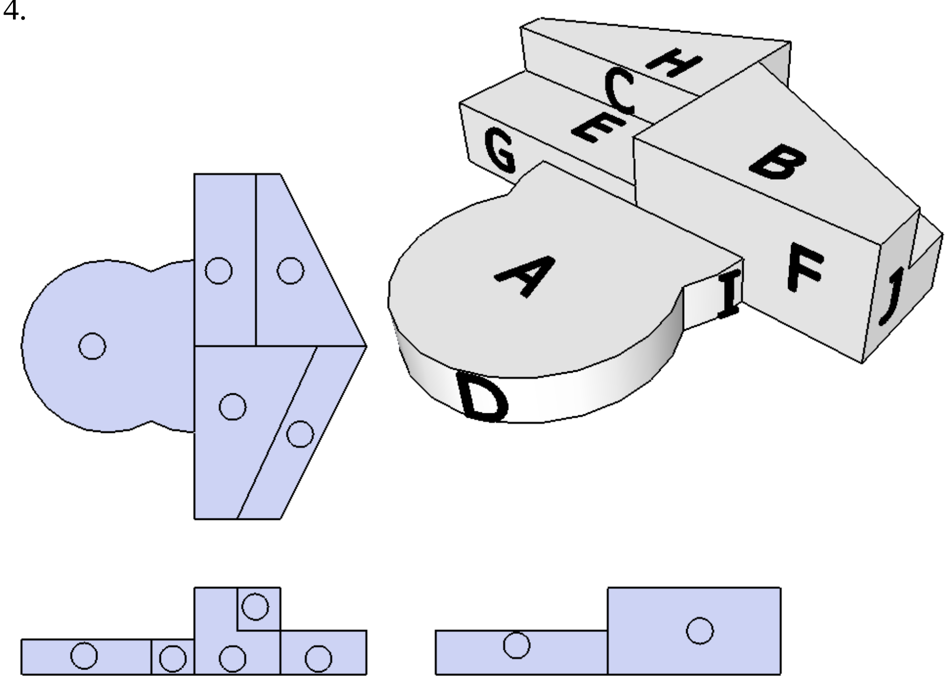


- ○ Front View
- ○ Right Side View
- ○ Left Side View
- ○ Top View
- ○ Bottom View
- ○ Back View

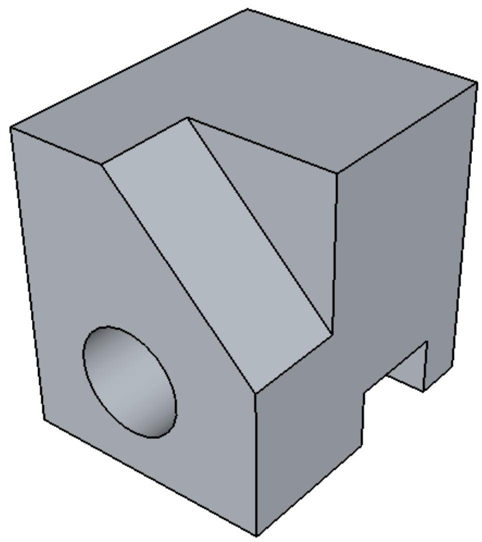
3. Use the provided isometric drawing and its letters to correctly label the orthographic views.



4.



5. Use provided isometric view to draw three orthographic views.

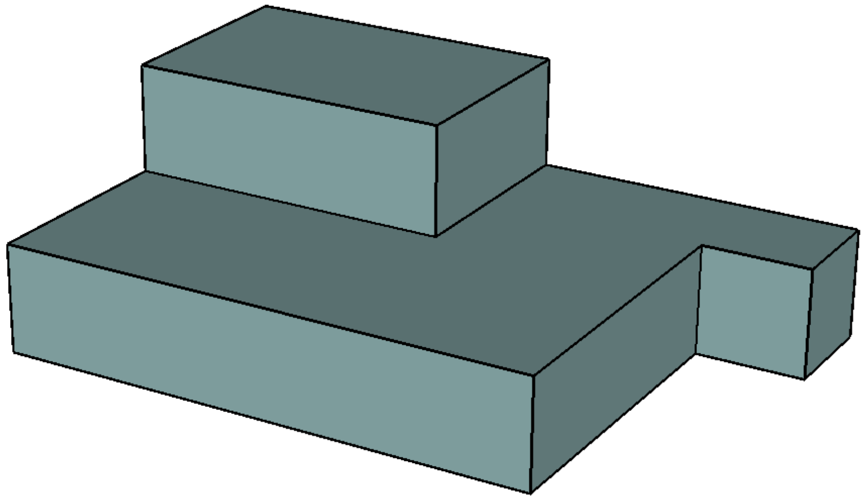


Top:

Front:

Right:

6.

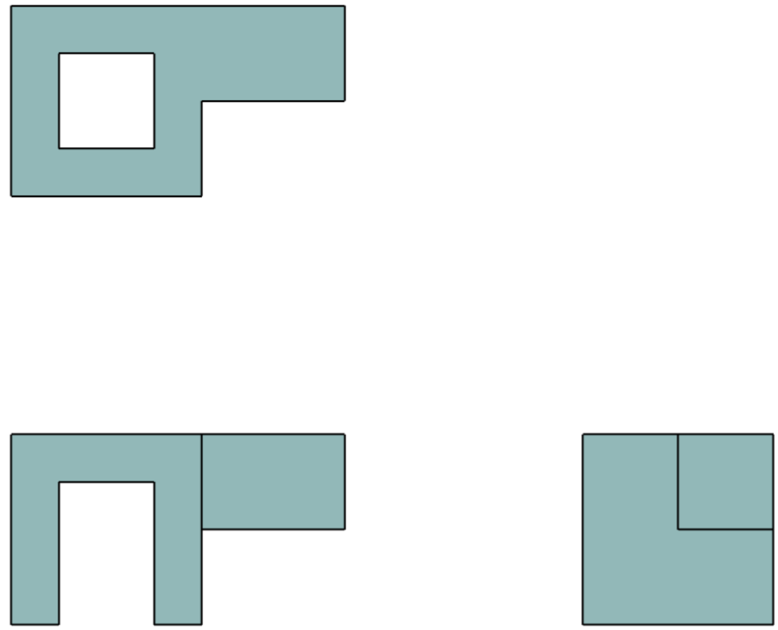


Top:

Front:

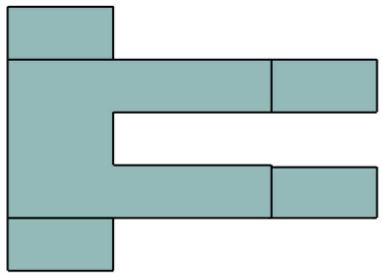
Right:

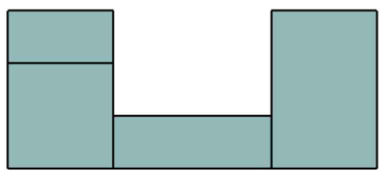
7. Use the three orthographic views provided to draw an isometric view. Be sure to include all hidden lines, visible lines, centerlines, and circles.

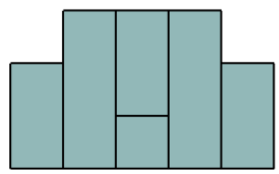


Isometric view:

8.

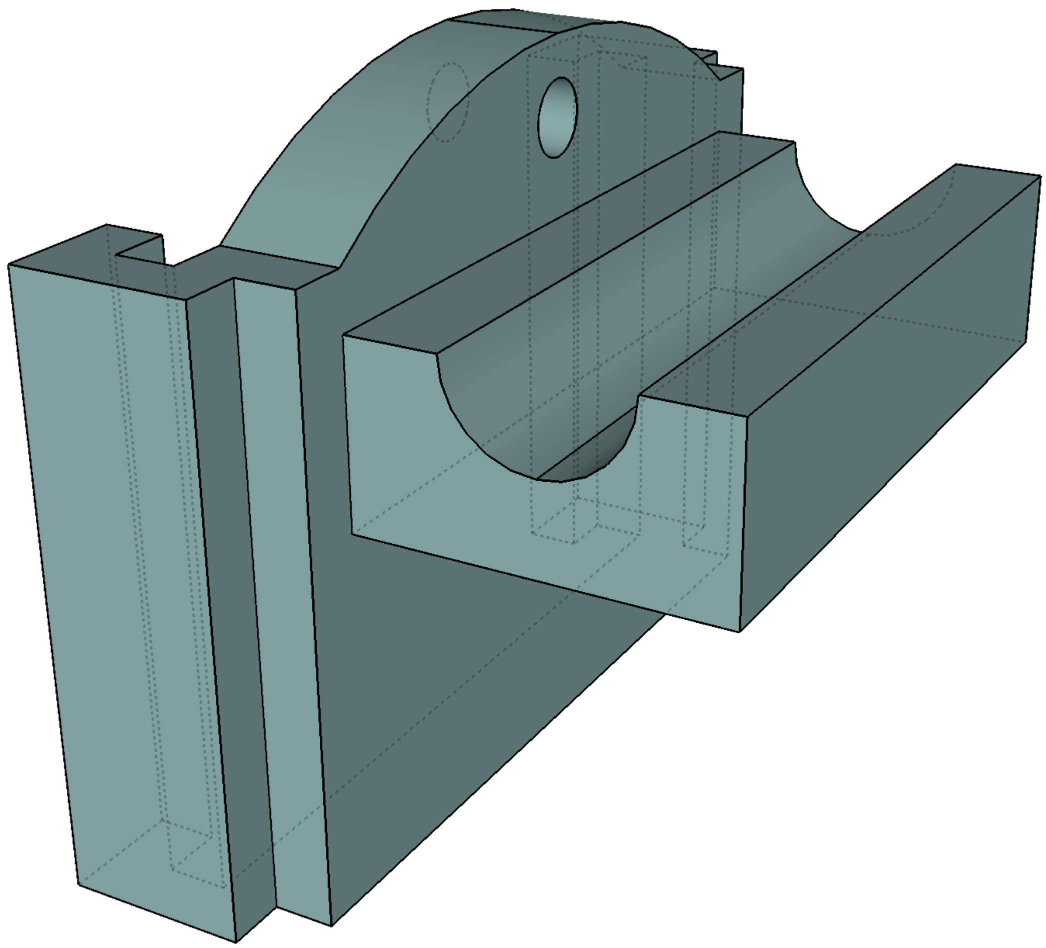






Isometric view:

9. Use the provided isometric view to draw its six orthographic views (Front, Left, Right, Top, Bottom, and Back) on the next page. Be sure to include all hidden, visible lines, centerlines, and circles.

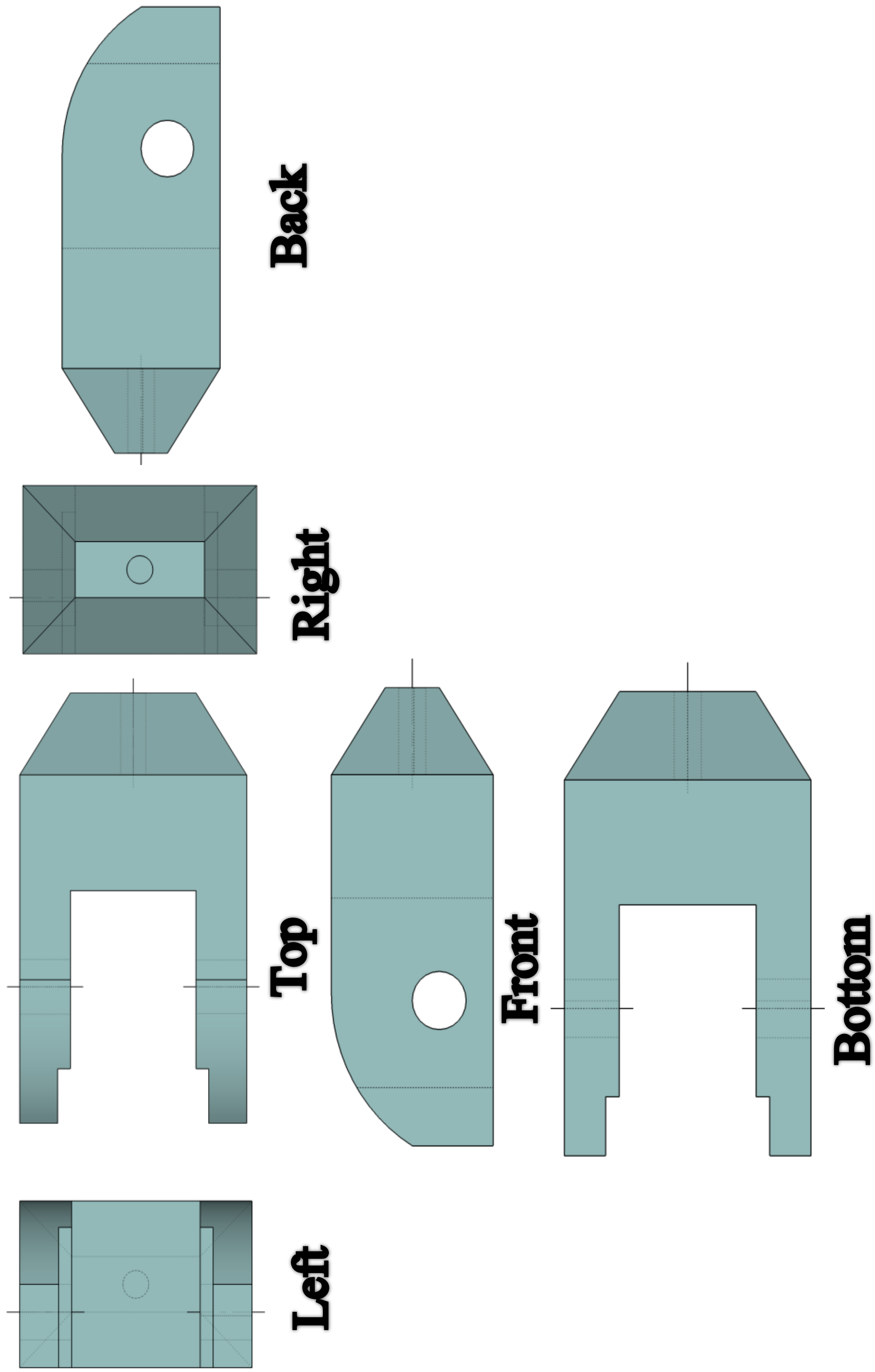


Top: Front:

Left: Back:

Right: Bottom:

10. Use the six orthographic views provided to draw an isometric view on the next page. Be sure to include all hidden lines, visible lines, centerlines, and circles.



Isometric View:

Appendix E: Professor Survey

Mental Visualization of Three-dimensional Space Professor Survey

Q1

1. Three-dimensional (3D) visualization is a person's mental ability to create an image of a 3D object in their mind without having a physical example of that object for reference.

Do you feel that it is essential for students in architectural and architectural-related majors such as Interior Design, Building Construction Technology, Architectural Engineering Technology, and Industrial Engineering Technology to learn the fundamentals of visualization and to have to ability to visualize effectively? If so why?

Q2

2. Do you feel additional fundamental tasks should be incorporated into certain courses in the Construction Program at the University of Southern Mississippi that will assist the students in effectively learning mental skill of visualization or do you feel what is currently offered is effective?

☐ Yes, I feel additional fundamental tasks should be incorporated into the Construction Program

☐ No, I do not feel additional fundamental tasks should be incorporated into the Construction Program

Q3

3. Do you think any new course(s) should be added to the Construction Program to assist with fundamental visualization? If yes, what should be incorporated in this particular course to assist the students in learning the skill of mentally visualizing?

☐ Yes

☐ No

I feel it is necessary because: [ ]

Q4

4. If you have any other ideas or comments about why fundamental visualization skills are important explain here if not place N/A in the provided box.

Q5

5. Another section of my research requires student participants who have a major in the architectural and architectural related programs. Testing will require approximately 25 to 30 minutes to complete the process. Would you allow your students to participate in the testing during class time?

- ○ Yes
- ○ No

Q6

6. Do you teach a visualization based course? If yes, please continue with this survey; if not thank you for your participation! You can stop here.

- ☐ Yes
- ☐ No

Q7

7. What is the name of your visual based course? Give a brief explanation of your course.

Q8

8. What task do you incorporate in your curriculum to help students achieve the course goal?

Appendix F: Institutional Review Board Approval Letter

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI.

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997| Fax: 601.266.4377 | www.usm.edu/research/institutional-review-board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: **14022801**
PROJECT TITLE: **Mental Visualization of Three-dimensional Space: New Tools and Challenges in Building Design Education**
PROJECT TYPE: **New Project**
RESEARCHER(S): **Breshawn McNeal**
COLLEGE/DIVISION: **College of Science and Technology**
DEPARTMENT: **School of Construction**
FUNDING AGENCY/SPONSOR: **N/A**
IRB COMMITTEE ACTION: **Expedited Review Approval**
PERIOD OF APPROVAL: **03/18/2014 to 03/17/2015**

Lawrence A. Hosman, Ph.D.
Institutional Review Board