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ASSESSMENT OF SPATIAL SKILLS IN
HUMAN ANATOMY AND PHYSIOLOGY STUDENTS

By
Abigail Livingston Carroll

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of
the requirements of the Sally McDonnell Barksdale Honors College.

Oxford
May 2022

Approved by

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Reader: Dr. Carla Carr

Reader: Dr. Gregg Roman

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ABSTRACT

ABIGAIL L. CARROLL: Assessment of Spatial Skills in Human Anatomy and
Physiology Students

(Under the direction of Dr. Carol Britson)

Visual spatial skills are an individual's ability to mentally and manipulate the shapes, forms and positions of objects. Spatial skills are necessary for adequate learning in many settings. Few studies have assessed spatial skills compared to success in Anatomy and Physiology in undergraduate students. Most students in this course are on a health profession track. Due to the increasing health care demands and need for competent health care professionals, this study assesses the innate spatial skill ability in students and acquired additional learned spatial skills. This study tests 17 students with the paper-folding test, blank page test, and two surveys regarding each test. There was a total of three trials which had a different blank page test each trial. Paper-folding mean scores increased across trials and blank page mean scores decreased across trials. There was a significant interaction effect between initial scores of each test (score 1) and the trial and test that was given. ($F = 26.68$; $df = 2$; $P < 0.001$). Mean difference blank page scores also improved overtime and showed a significant effect across trials ($F = 5.4$; $df = 2$; $P = 0.009$). Since there is a necessity for competent health professionals, it is important to assess the spatial skills of undergraduate students and compare these skills to their success in A&P.

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INTRODUCTION

Human Anatomy and Physiology I is an introductory course at the University of Mississippi that educates students about cells, tissues, and the muscular, skeletal, and nervous system of the human body. To succeed in this course, it is imperative that students have adequate spatial skills. Spatial skills are necessary to understand the 3-dimensional structures and processes taught throughout the course and to comprehend complex cellular structures and molecules (Milner-Bolotin & Nashon, 2011). Many of the students in the A&P course have an interest in health care. Students in this course include those who are pre-physical therapy, pre-nursing, pre-physician's assistants, and those studying nutrition and dietetics. Health care demands have increased significantly due to the rise in population, the prevalence of chronic diseases, and the advancement of technology. Because of this demand, it is necessary to have competent health professionals (Dowsett et al., 2014). After consulting graduates and students, it is evident that full knowledge and understanding of human anatomy is necessary in the health care field (Moxham & Plaisant, 2007; Davis et al., 2013; Gonzales et al., 2020). Complete knowledge of anatomy considers several components: position, form, shape, and a spatial awareness of structures in the human body (Gonzales et al., 2020). For example, the ability to visualize an organ in a 3-dimensional view requires the use of spatial skills (Naug et al., 2016). For this reason, possession of spatial skills in students crucial for competence in human A&P and to aid in their future healthcare professions.

Spatial ability or spatial skills is generally defined as an individual's ability to comprehend the shapes, forms and positions of objects, along with creating an internal representation that can be mentally manipulated (Carroll, 1993; Höffler, 2010). There are people who naturally have a stronger ability to do these tasks. These people would be known to have strong innate spatial skills. For those who do not possess these strong natural spatial abilities, because these skills fall under cognitive developmental skills, they are able to be learned and improved. Visuo-spatial abilities depend on the context, meaning if students are to visualize complex structures and processes, for example in A&P, there needs to be circumstances to develop and further these skills (Milner-Bolotin & Nashon, 2011). If these skills are not further developed through cognitive processes and exercises, many individuals may develop a false sense of knowing. Without active and experimental learning, students believe they have learned something, but they have not practiced using deep cognitive processes in which they are able to apply and interact what they have learned to their surroundings (Naug, et al, 2016). Students must further develop visual skills, especially those in human A&P, to fully know and understand the information they are being taught (Milner-Bolotin and Nashon, 2011).

One test that has been used to test spatial visualization skills is the Paper-folding Test (Ekstrom et al., 1976). The Paper-folding test has been used along with other tests to assess individuals' innate spatial skills. Other tests include the Paper Form Board (MPFB), the Mental Cutting Test (MCT), the Differential Aptitude Test: Space Relations (DAT:SR), and the Purdue Spatial Visualization Test: Rotations (PSVT:R) (Sorby, 1999).

Because of its easy access and free cost, the Paper-folding Test was chosen to evaluate the student's spatial skills in A&P I. The Paper-folding test has twenty questions that ask an individual to look at a folded piece of paper that has been hole-punched. The individual then must mentally unfold the piece of paper and identify where the resulting holes will be. As proposed in a study by Cooper and Shepherd (1973), completing the Paper-folding test requires four stages of processing. The first stage that the test requires is the process of encoding stimuli, which is the ability to make a depiction of the stimuli and also store the depiction in working memory. The second stage requires the transformation of the stimuli, mentally folding the paper, visualizing the paper with a hole punch, and mentally unfolding the paper, while visualizing where the hole will be with every unfold. The third stage includes comparing the mental image that has been created with the answer choices, and the fourth stage is selecting an answer choice (Jaeger, 2015).

The Blank Page activity is an exercise which is used to further develop spatial skills. Through active learning, on their first attempt, students must draw anatomical structures without any resources, starting with a 'blank page' (Naug et al., 2016; Quillin, 2015). This activity gives students the ability to construct their own knowledge. After the first attempt, students are able to study resources pertaining to the figure for 5-10 minutes and then try to draw and label the figure again. This activity requires the student to take responsibility for his or her drawing. By creating a figure from visual memory and depending on mental images to complete this activity, the activity focuses on spatial skills. For example, actively reconstructing structures works to further develop skills (Naug et al., 2016).

By learning through an experiential way, metacognitive skills are also developed, and students are able to see and then correct their mistakes (Naug, et al 2016). Students being required to draw and create their own model also motivates the student (Quillin and Thomas 2015). They are required to connect the concepts that they have in their mind into a big picture on the piece of paper. This technique also lets students learn through visual and kinesthetic approaches rather than reading or writing. Students often rely on an image from a textbook but are not able to form a correct image of the structure mentally. Through the use of drawing, students have the opportunity to re-construct their knowledge. The blank page technique steers the students toward visualizing images in their minds, resulting in a stronger confidence of knowledge and understanding (Naug et al., 2016).

Throughout the semester, students in the A&P I course will come into lab and participate in the Paperfolding test and Blank Page activity. For my research, I hypothesize that (1) students' spatial skills at the beginning of the course will be positively correlated with their course performance, (2) spatial skills will improve over the duration of the course, and (3) the magnitude of the improvement will positively correlate with their course performance.

METHODS

A&P I is a main pre-requisite for pre-physical therapy, pre-nursing, and pre-physician's assistant. In the fall semester of 2021, there were 276 students enrolled in the course. A lab is required for the course, and students were divided among 10 lab sections. Students attend a lecture 3 times a week for 50 minutes and attend a lab once a week for 2 hours and 50 minutes. A&P I, being the first of two courses, is an introductory anatomy and physiology course which focuses on the integumentary, skeletal, muscular, and nervous systems of the human body.

Participants in this experiment included 17 students, 12 female and 5 male. The students were currently enrolled in A&P I at the University of Mississippi, and each student's age ranged from 18-21. The typical majors for these students include Exercise Science, Allied Health Studies, and Dietetics and Nutrition, with most students preparing to apply to nursing or physical therapy schools. To schedule participants, an email was sent out to every student in A&P. The email included basic information about the experiment and the opportunity to earn bonus points by volunteering. Each student interested in participating received an email including a scheduling time. Students signed up for a 30-minute slot in the lab on Friday afternoon. Students had the opportunity to sign up for a total of 3 testing times. This research was approved as exempt by the Institutional Review Board exempt number 21x-263.

When students arrived for research, the project was described to them and they were given the opportunity to give informed consent. The study was divided into three

different testing trials, and each one focused on a different A&P subject. Trial 1 consisted of 3-4 meetings, each Friday in September 2021; trial 2, each Friday in October; and trial 3, each Friday in November. Each student's testing time was approximately a month apart. This timing was important for observing the student's progression through the course and the improvement of his or her spatial skills. During each trial, a student performed a paperfolding test, a paper-folding survey, a blank page test activity, and a post blank-page survey.

The first activity for this research included a pre-testing called the paper-folding test (Ekstrom et al., 1976). The paper-folding test asked students to imagine how a piece of paper that was folded up and hole-punched should look once unfolded (Figure 1). This test is intended to assess the innate spatial skills of the volunteers. The test included 20 of these problems, and students attempted to pick the image of paper with holes located in the correct position. There is one correct answer for each question and the students were graded by how many they answered correctly out of the 20 problems. Each student had 3 minutes to complete each page which had 10 problems on each side. After completing this test, students completed the post survey (Appendix A), which asked about the student about their thoughts on the paper-folding test.

The next activity performed by the students was the blank page exercise (Biggs, 1989). This activity related to topics students were learning in the A&P lecture. The blank page exercise first asked students to draw and label an A&P figure to the best of their ability without looking at any resources. The students were given a sheet of paper

with a list of structures to label. After completing the figure and labeling its structures, students were allowed to study resources from their textbook, lab manual, or the internet for five minutes. Next, the students put away all resources and attempted to draw and label the figure for a second time. Students completed this activity each trial, with a different figure to draw each time. The figures drawn each trial included a cell (Trial 1), a femur (Trial 2), and a muscle fiber and sarcomere (Trial 3), respectively (Table 1). The cell was based on Figure 3.15, the femur on Figure 7.37, and the muscle fiber and sarcomere were on 10.4, 10.5, and 10.8 in Amerman (2018). Each structure included in the figure was worth 3 points. The grading criteria was based on 3 requirements: did they draw the structures correctly, did they place the structures in the right place, and did they include the structure at all. After students completed the blank page activity, they took a survey (Appendix B) where they were asked questions based on their experience and performance of the activity.

Descriptive statistics were obtained for all variables. A two-way analysis of variance, with tests and testing period as the independent variables, was used to analyze for significant effects on the response variables. Correlation analyses were used to test for relationships between response variables and student exam or lab practical scores. The level of significance was set at $\alpha = .05$ for all statistical tests. All tests were performed using SPSS V2 software licensed to the University of Mississippi.

RESULTS

Results with Score 1:

Of the 17 students that participated in the study, 16 students participated in period 1, 15 students in period 2, and 10 in period 3. Score 1, the mean score of the paper-folding test and first attempt of the blank page test, was taken for each student. There was a significant interaction effect between score 1 and the trial and test that was given. ($F = 26.68$; $df = 2$; $P < 0.001$). The paper-folding mean scores showed to increase from period 1 to period 3 (60.625 in period 1 to 69.5 in period 3), while the student's blank page mean scores decreased significantly from period 1 to period 3. There was a significant effect between score 1 with how students answered question 1, "How confident did you feel in your ability to complete this task?" ($F = 8.1$; $df = 1$; $P = 0.006$). There was no significant effect between score 1 and how students answered question 2, "Did you feel this exercise assisted your learning?" ($F = 2.03$; $df = 1$; $P = 0.159$). There was no significant effect between score 1 and how students answered question 3 in the blank page survey, "After looking over your notes, did you feel more confident forming the structure?" and question 3 in the paper-folding survey, "Were you confused why we should do this?" ($F = 2.03$; $df = 1$; $P = 0.159$). There was no significant effect between score 1 and how students answered question 4 in the blank page survey, "Were you confused why we should do this?" ($F = 1.15$; $df = 1$; $P = 0.290$).

Results from Blank Page Mean Difference Scores:

The mean difference between score 1 and score 2 was also taken for the initial blank page test and the test taken after the student's studied for five minutes. The mean difference scores were shown to increase from period 1 to period 3 (Figure 2). There is a statistically significant increase in the difference between score 2 and score 1 from period 1 to 3 on the blank page test ($F = 5.4$; $df = 2$; $P = 0.009$).

Results with both surveys:

Overall, students answered question 1, "How confident did you feel in your ability to complete this task?" in the paper-folding survey and blank page survey. The question 1 survey scores did not show a significant effect across tests ($F = 0.660$; $df = 1$; $P = 0.419$) or across periods ($F = 1.39$; $df = 2$; $P = 0.256$). The paper-folding survey scores increased slightly from period 1 to period 3 (fig. 3). The student's answered the question with a mean score of 6.31 in period 1 which increased to a mean score of 6.51 in period 3 (1 = strongly disagree and 10 = strongly agree). Students answered question 2, "Did you feel this exercise assisted your learning?" in the paper-folding and blank page survey. Question 2 showed a significant effect across tests ($F = 43.482$; $df = 1$; $P < 0.001$), but not from period to periods ($F = 1.853$; $df = 2$; $P = 0.164$). The mean score on the paper-folding test was 6.05, while the mean score on the blank page test was 8.68 (1 = strongly disagree and 10 = strongly agree).

Results with Blank Page Survey and Mean Difference Between Score 1 and 2:

Students answered question 1, "How confident did you feel in your ability to complete this task?" in the blank page survey. There was a significant effect between the mean scores of question 1 and across periods ($F = 3.6$; $df = 2$; $P = 0.038$). There was no

significant effect between the mean scores of question 1 and the mean difference between score 1 and score 2 ($F = 0.277$; $df = 1$; $P = 0.602$). Students answered question 2 “Did you feel this exercise assisted your learning?” in the blank page survey. There was not a significant effect between the mean score of question 2 and the period ($F = 2.7$; $df = 2$; $P = 0.084$) or the mean difference between score 1 and score 2 ($F = 0.951$; $df = 1$; $P = 0.336$). Students answered question 3, “After looking over your notes, did you feel more confident forming the structure?” in the blank page survey. There was no significant effect shown between mean scores of the survey question and the period for this question ($F = 2.4$; $df = 2$; $P = 0.102$) or the mean difference between score 1 and score 2 ($F = 1.164$; $df = 1$; $P = 0.288$). The results of question 4, “Were you confused why we should do this?” demonstrated no significant effect shown between the mean scores of the survey question and across periods ($F = 0.166$; $df = 2$; $P = 0.848$) or the mean difference between score 1 and score 2 ($F = 0.439$; $df = 1$; $P = 0.512$).

Lab Practical and Test Mean Scores Correlation:

There was no correlation between lab practical scores, paper-folding test scores, and blank-page tests scores (LP1: $R = .280$; $df = 16$; $P = 0.293$; LP2: $R = 0.241$; $df = 16$; $P = 0.370$). This seemed to show no association between spatial skills and anatomy and physiology.

DISCUSSION

This study analyzed innate and learned spatial skills of students in Anatomy and Physiology. The Paper-folding test and Blank Page are both used to assess and further these skills. This study used the paperfolding test to evaluate the innate spatial skills and to measure the difference of spatial skills throughout the A&P I course. The mean paper-folding scores increased slightly between each period, suggesting the improvement of spatial skills overtime. Gonzales et al., (2020) studied spatial skills in medical students using a slightly different spatial skills test called Visualization of Rotation test (ROT). Gonzales et al., (2020) tested a control group and an intervention group twice. The intervention group received spatial training in a 3-month period between testing. Similar to the increase seen in the paper-folding scores across trials, Gonzales' et al., study showed that there was a significant difference in students between the first and second time that they took the ROT. There was, however, no significant difference between the control group and intervention group. The increase of paper-folding scores did not show correlation with performance in lab practicals or an increase in blank page scores in this study. Gonzales' et al. study differed in that pre- and post-scores of the ROT test in the control group were compared to a post-training anatomy score. Though the effect size was small, results from Gonzales et al. study showed a slight association between spatial skills and learning anatomy. The results of this study differ because the blank page and lab practical scores were not shown to be associated with the paper-folding test; however, the mean difference of the blank page scores showed to increase across trials. The

decrease of mean test scores in the blank page activity across trials is most likely due to the increase in difficulty of the exercise. The increase between score 1 and score 2 in the blank page test is most likely due to the increase in possible points from exercise 1 to 3, making it easier to improve from score 1 to score 2.

This study also used the blank page test to observe learned spatial skills. These scores actually showed to decrease with each period. One factor that may have caused this was the increasing difficulty in the drawings with each period. The Blank page scores also showed to have no correlation with the students' performance on their lab practicals. In one study, students using the blank page technique demonstrated higher scores on an assessment than those who used review questions. This supports the importance of using kinesthetic approaches for learning anatomy (Naug, et al., 2016).

The paper-folding survey and blank page survey were used to assess student's responses to both tests. Because question 1 for the paper-folding survey increased slightly from each period, confidence showed to increase slightly each time the students were tested. Question 2 "Did you feel like this exercise assisted your learning," was shown to have a much higher score on the blank page survey than the paper-folding survey. This reveals that students believed the blank page exercise was much more helpful in their learning.

Although spatial ability is an extremely important skill to measure, this study had a few limitations. This study would be extremely informative on a larger sample size. Due to volunteer-based participation, only 17 students out of the 278 students in the Anatomy and Physiology course participated. Being able to test the whole class could show far more significance between the paper-folding scores and the lab practical scores.

Furthermore, using blank page exercises which had similar difficulty levels could have shown very different results. For example, the increasing difficulty from a cell to a femur and muscle fiber were able to have a huge effect on the decreased scores over periods.

This study attempts to observe and further develop spatial skills for students. Spatial skills allow complete knowing, and it is essential for these students to be able to look at a specimen in two dimensions and be able to visualize it in a three-dimensional space. This is an important skill to have for Anatomy and Physiology and several other science classes that are required for students in pre healthcare majors. A&P teaches complex 3-D anatomical structures and processes that require the use of these spatial skills to fully understand them. If students plan to become competent future health care providers then ensuring they have this skill is extremely important. The increasing health care demands shows the necessity of spatial skills in reference to A&P to be further studied in the future.

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TABLES

Table 1: List of Blank Page Anatomical Structures

Blank Page Test Trial 1	Blank Page Test Trial 2	Blank Page Test Trial 3
Draw a Cell:	Draw a Femur:	Draw a Muscle Fiber and Sarcomere:
Cytosol Free Ribosomes Golgi Apparatus Mitochondrion Smooth Endoplasmic Reticulum Rough Endoplasmic Reticulum Lysosome Nucleus Nucleolus Centrioles Plasma Membrane	Articular cartilage Compact bone Distal epiphysis Endosteum Epiphyseal plate Fovea capitis Gluteal tuberosity Greater trochanter Head of the femur Intercondylar fossa Lateral condyle Lateral epicondyle Lesser trochanter Linea aspera Medial condyle Medial epicondyle Medullary cavity Neck of the femur Nutrient artery Nutrient foramen Patellar surface Periosteum Proximal epiphysis Red bone marrow Spongy bone Yellow bone marrow	Actin Endomysium Epimysium Fascia Fascicle Myofibrils Myofilaments Myomesin Myosin Opening of t-tubule Perimysium Sarcolemma Sarcoplasm Sarcoplasmic reticulum Terminal cisternae of sarcoplasmic reticulum Thick filament Thin filament Titin Triad Tropomyosin Troponin T-tubules Z-disc

FIGURES

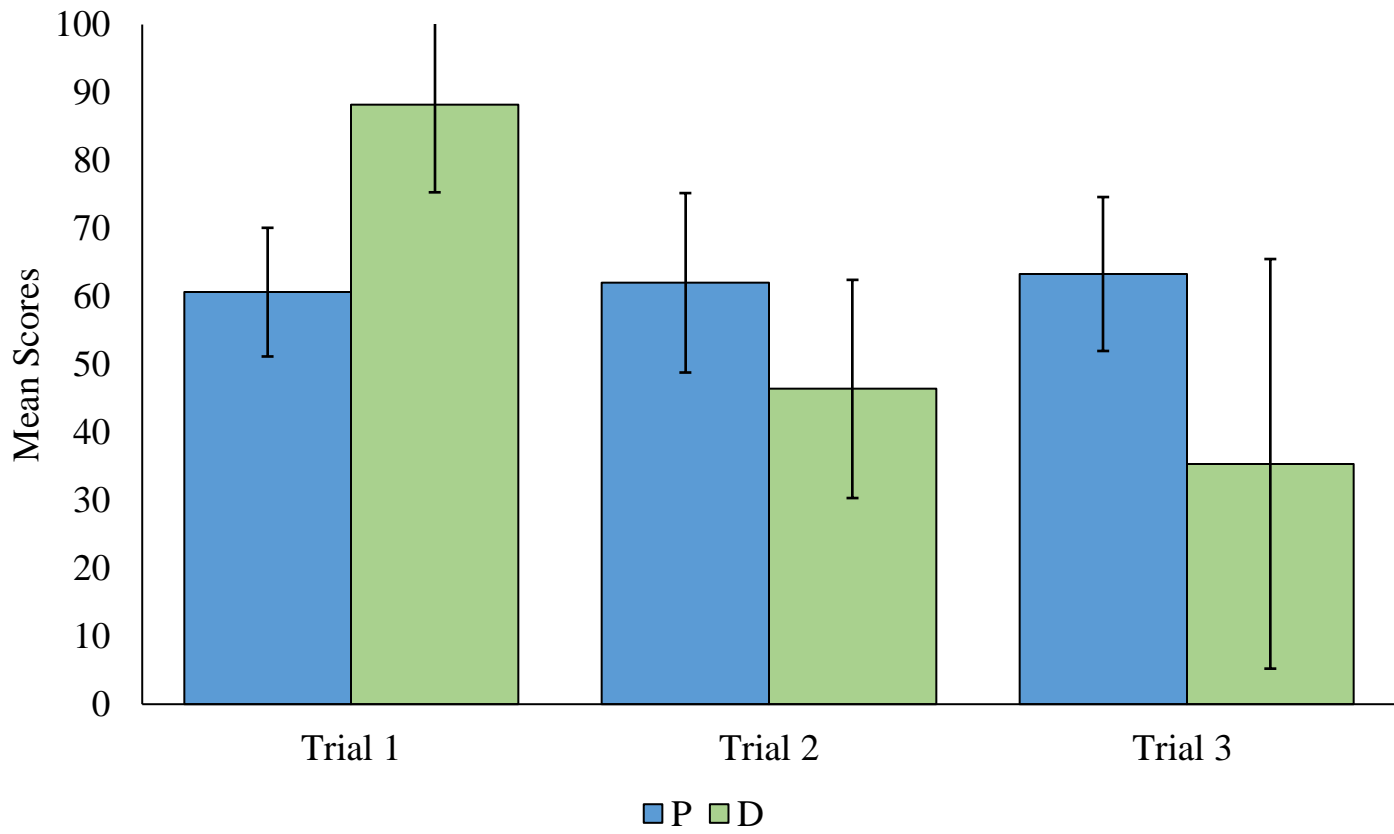


Figure 1. Mean percent correct for score 1 on drawing test (D) and paperfolding test (P). Error bars represent 1 Standard Deviation around the mean.

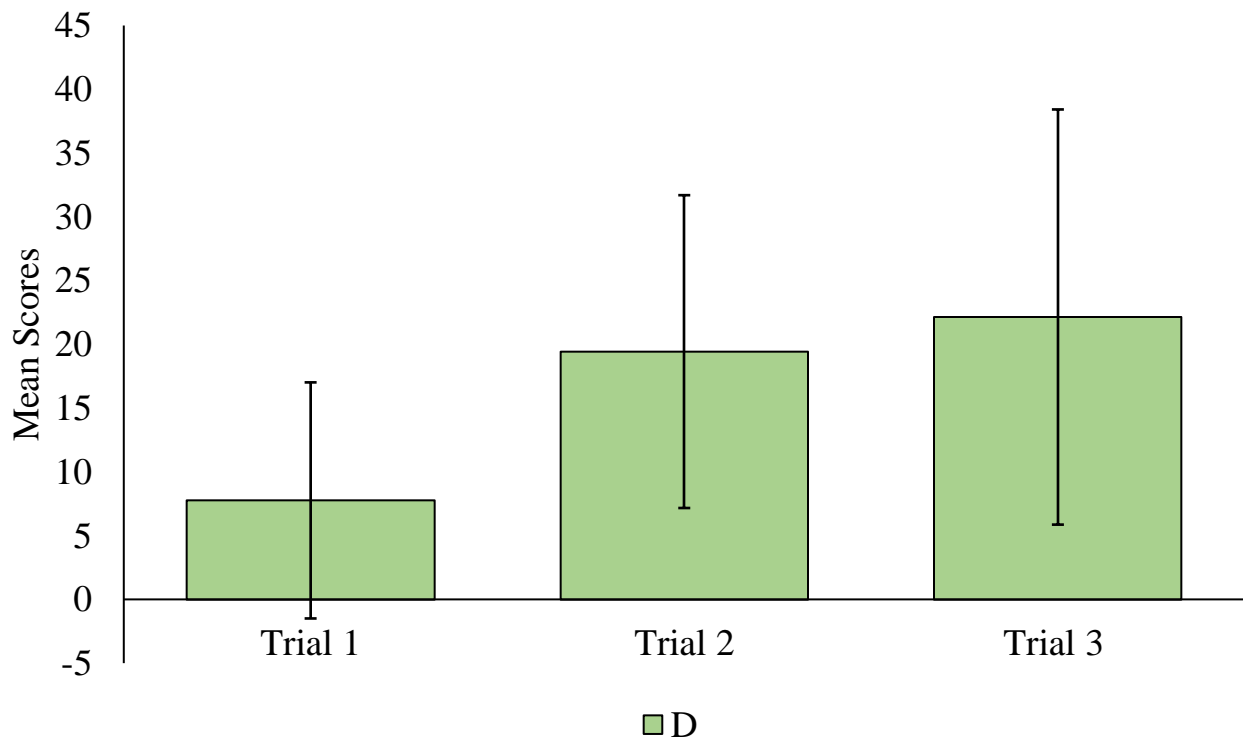


Figure 2: Student's mean differences (Score 2 minus score 1) on drawing test (Blank page). Error bars represent 1 Standard Deviation around the mean.

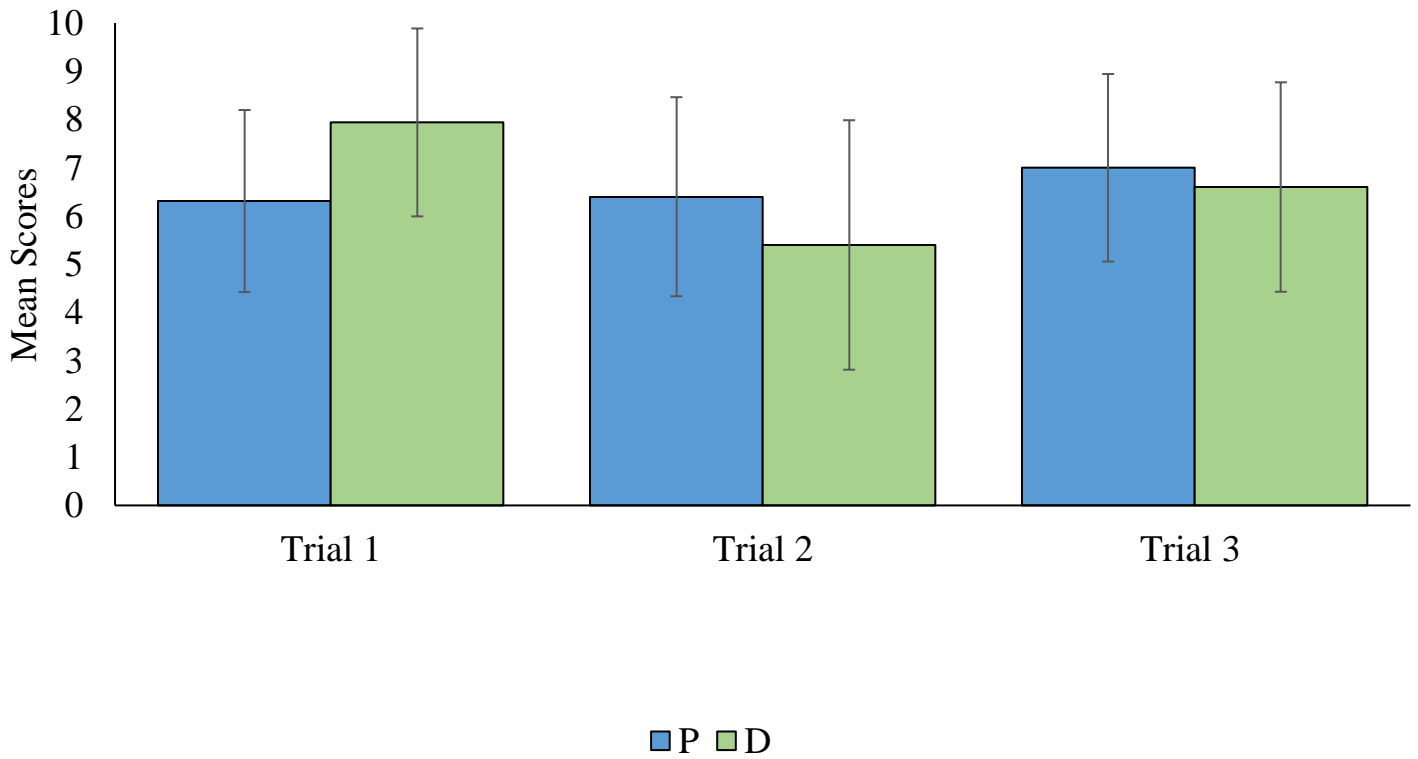


Figure 3: Student responses to paper-folding and blank page survey question 1 “How confident did you feel in your ability to complete this task?” Error bars represent 1 Standard Deviation around the mean.

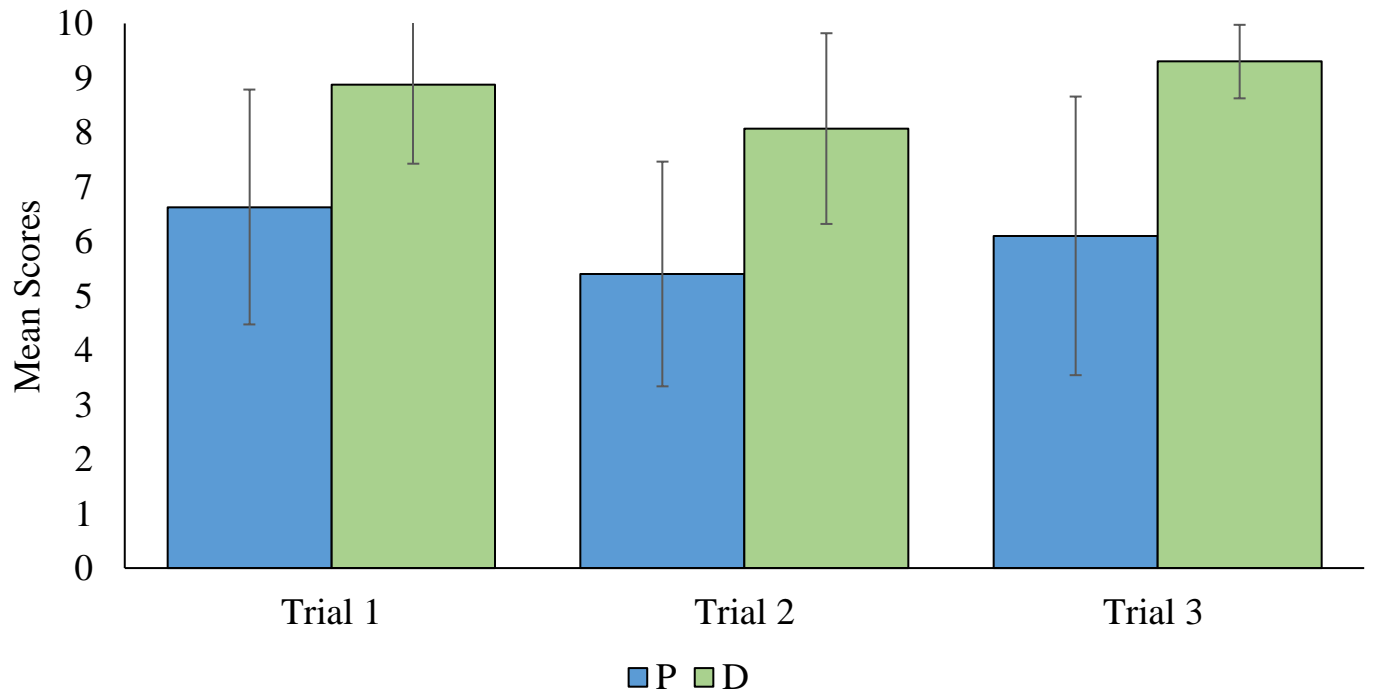


Figure 4: Student responses to paper-folding and blank page survey question 2 “Did you feel this exercise assisted your learning?”). Error bars represent 1 Standard Deviation around the mean.

APPENDIX A

Paper-folding Survey

1. How confident did you feel in your ability to complete this task?
 - a. Circle 1 2 3 4 5 6 7 8 9 10
1= strongly disagree 10= strongly agree
2. Did you feel this exercise assisted your learning?
 - a. Circle 1 2 3 4 5 6 7 8 9 10
1= strongly disagree 10= strongly agree
3. Were you confused on why we should do this?
 - a. Circle 1 2 3 4 5 6 7 8 9 10
1= strongly disagree 10= strongly agree

APPENDIX B

Blank Page Survey

1. How confident did you feel in your ability to complete this task?

a. Circle 1 2 3 4 5 6 7 8 9 10

1= strongly disagree 10= strongly agree

2. Did you feel this exercise assisted your learning?

a. Circle 1 2 3 4 5 6 7 8 9 10

1= strongly disagree 10= strongly agree

3. After looking over your notes, did you feel more confident forming the structure?

a. Circle 1 2 3 4 5 6 7 8 9 10

1= strongly disagree 10= strongly agree

4. Were you confused on why we should do this?

a. Circle 1 2 3 4 5 6 7 8 9 10

1= strongly disagree 10= strongly agree