MEMORIZATION STRATEGIES FOR ANATOMY AND PHYSIOLOGY

by

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ABSTRACT

The ability for students to have a deep understanding of the material in anatomy and physiology stems from having a solid foundation of lower-level learning skills of the material at hand. One of the key lower-learning skills that allows students the ability to tap into the higher-level thinking is memorization. This does not refer to basic rote memorization, but memorization that can actually help to link neural connections and bring a greater depth of knowledge into the anatomy classroom. This study will investigate whether detailed instruction on three memorization techniques targeting multimodal learners impacts students' short-term and long-term memory, ultimately impacting depth of understanding in the anatomy/physiology classroom. The study will also explore student attitudes, mainly in reference to their confidence and stress levels, in regards to the memorization strategies taught.

INTRODUCTION AND BACKGROUND

Meeker RE-1 is rural school district nestled in the mountains of western Colorado. Meeker is one the few communities left, it seems, where you know everyone and the students oftentimes come from a long lineage of "Meeker-ites." Meeker High School has 200 students, with our entire district consisting of approximately 700 students. As teachers, we watch many of our students walk into Meeker Elementary School and encourage them as they graduate from MHS. For such a small school there are still a great deal of opportunities for our students, including the AP and concurrent enrollment classes offered. The district has had a 100% graduation rate over the past two years, being "Accredited with Distinction" for the past three years. The concurrent enrollment anatomy/physiology course taught is composed of 18 junior and senior students, with 15 girls and 3 boys. The students who take anatomy and physiology at Meeker High School are college-bound students with the average GPA being above 3.5.

I have had the opportunity to teach a wide variety of subjects since receiving my teaching degree in 1997, ranging from seventh grade science to college level chemistry, anatomy, and physics courses. Oftentimes I found myself teaching subjects that required more abstract knowledge and minimal memorization, such as chemistry, physics, and physical science. It was not until I moved to Meeker four years ago that I had to teach biology courses, such as anatomy and general biology, that required at least a minimum amount of memorization in order to master some of the material.

Since I started teaching anatomy and physiology, in particular, I was amazed at how challenging it is for students to memorize material, especially material that is

foundational for anatomy and physiology. Even though the students taking this course are reasonably high achievers, they struggle immensely with having to memorize information, particularly the amount of information required to be memorized in anatomy. At first, I equated it to students having poor study skills, but the realization hit that they were genuinely trying their hardest, they just did not know how to memorize information.

It seems as if this generation of learners has been taught how to analyze and critically think, but they seem to have lost the art of memorization. Ultimately, we want students to have a greater depth of knowledge and want them to think at higher levels. Nonetheless, students need to have a foundational knowledge of which to build upon in order to get to these high levels of thinking. Simply put, there are basic facts that they must memorize before we spend valuable class time pushing them to the higher levels of learning.

The purpose of this research project was to identify the most effective memorization techniques in order to enlighten my students with learning strategies they will be able to take with them into either college or the workforce. I feel it is imperative that students learn how to learn and take ownership of this learning. By equipping them with strategies that will trigger multiple parts of their brain, I investigated the impact it has on their understanding of the material, their confidence levels, and stress levels. The strategies were then compared to each other in order to determine if any seem to make a greater impact than others as well as compared to a control where students get to choose their own methods to study. There were also comparisons made between the males and

females, as well as juniors and seniors in the class to see if particular groups of students were impacted differently by the memorization strategies.

CONCEPTUAL FRAMEWORK

Anatomy and physiology is a very demanding course that inevitably requires individuals to memorize information for the anatomical terminology, yet have a deeper understanding of material for physiological understanding. Although memorization tends to be viewed as a somewhat tortuous, tedious component of anatomy courses, it is a lower-level learning strategy that is foundational to understanding the more complex material needed in the course. If students are taught to memorize effectively, this may allow cherished class time to be more focused in on activities that engage the higher order thinking skills, such as critical thinking and problem solving (Brahler & Walker, 2008). Klemm (2007) states that although our ultimate goal as teachers is to get our students to be able to think at higher levels, it is imperative that they are able to remember things. The more information an individual has stored (memory), the more intellectual aptitudes they are able to draw from when performing higher order thinking tasks. According to Baddely (2000), working memory is how people think. This working memory is the small bursts of information that people tap into over short amounts of time in order to learn and think.

In order for students to memorize facts, and actually remember them, certain physiological aspects must occur for those connections to take place. It is important that educators stimulate as much of the brain as possible. There are two main categories of memory which include implicit memory and explicit memory. When students must

consciously recall information, making connections from their short-term to long-term memory, this is explicit memory. There are multiple parts of the brain that are responsible for the different types of memory and recall of these memories. For example, the short-term memories are stored in the prefrontal cortex and areas of the medial terminal gyrus, whereas long term memories are in the hippocampus and adjacent cortical areas. It is important that the connections can be sent from the short-term to the long-term memory, particularly when we want our students to have lasting recall of information. Robertson (2002) found that what seemed to improve memory function the most in their test subjects (from a psychology perspective), was when they were presented with information with dual-mode presentations. An example of a dual-mode presentation would be when a teacher presents material with a power point for the visual learners, a video clip for visual learners, and a kinesthetic activity for the hands-on learners. These presentations allow different part of the student's brains to be triggered, and optimal learning to occur.

In the brain, memories are not stored completely and they tend to be somewhat scattered. This means that synthesizing the information is very important in order to activate the memories. It is also important to recognize the other factors that influence the recall, such as hormones, neurotransmissions, the times at which the neurotransmitters are at their peak, etc. (Jensen, 2005). The networking of the neural connections and what makes the neurons fire is also a key to memory. Neural connections are similar to a map with connecting streets and dead ends. When connections can be made, there will be more successful memory retrieval/retention. If

certain neurons are not fired enough, those connections can be completely lost, much like a dead end (Quiroga, 2017).

There was also a study done on world-class memorizers to see if there is a physiological difference in their brains versus those of individuals who were not world-class memory performers. According to Ericsson (2003), when they looked at MRI images of the brains, there is not an anatomical difference in the brains, but it came down to how they chose to connect the information, whether it was through mnemonics or loci.

When students enter anatomy and physiology, there is already a perception that the course is a never-ending exercise in daunting, tedious memorization antics. Whether this perception comes from ignorance on the content, previous experiences, or based on gossip, these perceptions must be taken into account when planning ways to effectively teach the students (Miller, Perrotti, Silverthorn, Dalley & Rarey, 2002). According to Notebaert (2009), students in multiple anatomy courses at the University of Iowa overwhelmingly left the classroom with the perception that anatomy is all about memorization, whether it is all the structures they needed to memorize or terminology. When compared to other classes, these students felt that memorization is the technique they lean most heavily on in anatomy, but also suggested that they relied heavily on memorization in the majority of their other courses.

Perceptions regarding memorization in anatomy may be attributed to lack of guided instruction on how to learn anatomy and physiology concepts with memorization techniques combined with application. More valuable long-term lessons for students in anatomy are how to learn how to learn, then use that knowledge to fully understand,

explain, and make connections. If anatomy is presented in a progressive way where students can apply, problem solve, and relate the anatomical concepts to real life, particularly in the health field, then learning will be maximized (Miller, Perrotti, Silverthorn, Dalley & Rarey, 2002). Klemm (2007) suggests that students do not know how to memorize. They often memorize by rote memorization, which is extremely inefficient and takes away the "thinking" aspect of memorization. Using more effective, engaging ways to help students memorize material helps students retain that information in their long-term memories.

Integrating multiple learning techniques seems to be the most effective strategy in order to help students truly learn and remember information. When studies were done on the activity or passivity of students, it was determined that, ultimately, the ways students process the learning dictated how well they performed. When looking at multiple types of study methods, it was found that not one single method seemed to lead to more successful students, but students who integrated multiple techniques and had deep processing not only were more successful in the classroom, but also had better recall (Ward & Walker, 2008). The Dean Vaughn Medical Terminology 350 Total Retention System is a learning system that integrates mnemonics while making connections to the student's lifelong knowledge. By looking at roots of words and then linking it to a sound-alike word and a visual image which has absolutely nothing to do with medical terminology, students learn different meanings of word parts used in medical terminology. Groups of high school students in anatomy/physiology classes were divided into groups that included: rote memorization, Medical Terminology 350, and a

combination of both rote and Medical Terminology 350. After these students were given pre- and post-tests of word recall; the students in the Medical Terminology 350 had significantly greater improvement in word recall (Brahler & Walker, 2008).

A group of students who historically had difficulty understanding the human nervous system showed significant gains in their test scores when material was taught with multiple learning strategies instead of only rote memorization to memorize material. It was shown that each type of learning strategy had a significant role in how the students learned the material, leading to a greater depth of understanding. For example, using manipulatives enhanced the analytical skills assessed and doing practice problems in groups seemed to help improve collaborative skills and the knowledge of content. When giving students practice problem sets, students were given an opportunity to practice the skills learned and investigate the topic in greater depth (Krontiris-Litowitz, 2008).

In general, there have been multiple techniques assessed to determine what may benefit students the most when it comes to memorization. With very elaborate surveys and multiple reviews summarized, ten different learning techniques that are widely used by students to help them memorize information were reviewed for their overall effectiveness. It was found that techniques that students often turn to, such as highlighting and rereading material, were deemed “relatively low utility” (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). The techniques that seemed to have the highest effectiveness ratings in this research were practice testing, mnemonics, and imagery, with practice testing being the highest.

Research done by Brown (1992) found reciprocal teaching to be a very effective strategy to help students memorize information. This reciprocal teaching included having groups of students lead a discussion on a specific text, then they would divide into learning leaders and listeners where the leader would ask a question and summarize what was read. Next, they would reread and help clarify any misconceptions, summarize the discussion, and predict what they will be reading later. Not only did students learn effectively from reciprocal teaching, but they actually chose to use this method when allowed to study independently.

Another memorization strategy that was proven to be effective for students was using pictures versus words when trying to memorize information. When 144 second graders were given 40 words, along with some simple drawing representing the words, Pilan and Sullivan (1980) concluded that the student's memory was much better when shown pictures, not just words. However, they also discovered that one of the techniques used called "think picture," essentially using mental imagery, was not deemed effective.

One of the greatest factors influencing memory recall is whether or not test subjects are actually paying attention and engaged. In order for neural connections to occur, students must first be focused in on what is being presented. (Robertson, 2002) The engagement level of students desiring to learn may be linked to how exciting the activity associated with memorization is. When a group of first graders were tested to see what strategies most effectively helped them memorize math facts, Fife (2003) found that there was not a significant difference in active learning (students bouncing a ball while learning math facts) versus students who sat down and studied the same flashcards.

However, she did find that, when surveyed, students were much more enthusiastic to engage in the learning process when the activity allowed them to be more active. D'Ettorre (2009) determined flashcards to be the most effective memorization tool when compared to memorization games and songs for his fifth-grade students memorizing multiplication facts. The surveys he sent out to students; however, revealed that students were most enthusiastic about the games which led to maximizing participation in the memorization process.

There has been an enormous transition in education over the past 10-15 years to push higher-order thinking skills, such as critical thinking and problem solving. Research has actually steered educators away from having students memorize information, and instead focus very heavily on critical thinking skills and how to effectively teach these skills. The *American Institute of Research* (2018) shows that, when surveyed, groups of students tested in both New York and California who attended institutions that focused on deeper learning performed significantly better on standardized tests, were more successful in college, had better collaborative skills, etc. In addition, research done by Qasim, Helmut, Fattah, & Alshaya (2016) found that a particular school in Saudi Arabia that tested lower than schools similar to it, had teachers that focused primarily on memorization instead of scientific inquiry in their instruction. They also found several other contributing factors to the lower scores, such as lack of time committed to science, lack of knowledge of formative assessments, etcetera. Ben Orlin (2013), a teacher, states, "What separates memorization from learning is a sense of meaning. When you memorize a fact, it's arbitrary, interchangeable--it makes no difference to you whether sine of $\pi/2$ is

one, zero, or a million. But when you *learn* a fact, it's bound to others by a web of logic. It could be no other way" (para. 20). Students need to be able to make connections with the material they are asked to memorize otherwise true learning will not occur.

Despite all of the research out there that gives very compelling evidence that critical thinking and analytical skills lead to deeper levels of learning, memorization is a necessary, foundational component to these deep levels of learning. Because of the large focus on teaching students how to conceptualize material at deeper levels, many of the memorization techniques that have been proven to be effective are not being utilized in classes where memorization is a necessity. Students are simply not learning how to learn this foundational skill anymore. Because of the many perceptions out there that anatomy and physiology is just a daunting exercise in rote memorization, the more effective, fun, engaging memorization techniques are being overlooked. The best teaching strategies in order to help students memorize information better seem to incorporate multiple "triggers" for the brain. When looking at the complexity of the human brain and how multiple neural connections must be made in order for short term memory to become long term, it is imperative that presentations fire multiple parts of the brain. That being said, it is ideal to expose students to multiple techniques in order to help them memorize information and allow that information to be stored.

METHODOLOGY

Purpose

The intent of this study is to determine how the implementation of multiple memorization strategies may impact student understanding in anatomy and physiology, along with their

confidence and stress levels in the content area. 18 high school juniors and seniors taking dual-enrollment anatomy and physiology participated in the study, 15 girls and three boys. The treatment period began at the beginning of student's second quarter (mid-fall) with clear instruction on each type of memorization strategy that would be implemented. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

Research Questions

The research questions being addressed were as follows: 1) Will the intentional teaching and implementation of different memorization techniques impact student's long-term and short-term memorization in a high school anatomy/physiology classroom when students are assessed on anatomical terminology? 2) Will the implementation of these techniques impact student's confidence and perceptions of the material when it comes to memorization in anatomy?

Treatment

Prior to starting the implementation of the memorization strategies, students were given a survey which addressed the time they generally spend studying and how it impacts their test scores, their perceptions of stress, factors they felt affected their testing performance, and the study methods they generally resort to in order to memorize and conceptualize information (Appendix B). Student test averages on certain sections of an exam were also compared and related to the time spent studying the material. This information was used to identify the types of strategies that should be implemented and to

get a sense as to how students perceived stress and approached studying. Table 1 shows the research questions and data collection instruments used.

Table 1
Data Triangulation Matrix

	Data Collection Instruments		
Research SQ. 1:	Growth Indicator Short-Term: Quantitative data obtained will be from pre-test and post-test growth data. A t-test will be used for analysis.	Unit Test Averages Comparisons Long-term: Comparing class mean averages on specific sections of a unit test.	Analysis of strategies: T-test test to analyze the different teaching strategies used.
	Survey on memorization techniques students are already utilizing.		
Research SQ. 2:	Pre-memorization survey: https://www.surveymonkey.com/r/W5XRCC5 Post-memorization survey: https://www.surveymonkey.com/r/CT77WLL	Student perceptions individual interviews: Individual student interviews Charts will be used identifying themes in interviews.	Students perceptions on usefulness: Class Interviews/ Discussions
	Surveys on perceptions of stress and factors that may influence test performance.	Class interview on material they find to be most challenging.	

After analyzing this preliminary data and having researched some of the best strategies for memorization, a total of three memorization strategies were chosen: modelling, reciprocal teaching, and mnemonics. Each memorization strategy was implemented for one group of bones and their locations and one group of muscles and locations that students were required to memorize, each having approximately 30 items to memorize. Modelling was the strategy implemented for skull bones and arm muscles, reciprocal teaching was used for upper limb bones and lower limb muscles, and a story using mnemonics was used with the bones up the lower limbs and the thoracic muscles. During class, students were instructed as to how to utilize the chosen memorization technique and implemented that specific technique when studying for the group of bones or muscles. Outside of class, students were expected to draw out the specific system and do a labelling worksheet for every section in addition to the memorization strategy.

Students were given pre-tests over a specific list of anatomical terms (including locations) that they had not been exposed to pertaining to the skeletal or muscular systems. Immediately following the pre-test, students were given a Likert-type pre-memorization survey asking questions regarding their perceptions of the material prior to learning the new memorization technique, their stress levels, and confidence levels (Appendix C). These surveys were analyzed with charts comparing themes discovered throughout the surveys.

Students were then taught one of the researched memorization techniques for that particular group of terms and locations. Again, the techniques used included reciprocal teaching (targeting auditory and visual learners), creating models and presenting to peers

(targeting kinesthetic, auditory, and visual learners), and using mnemonic devices while creating a story about the bones or muscles and sharing it with their peers (targeting visual, auditory, and kinesthetic learners). Reciprocal teaching required each student to be assigned the task of designing a lesson to teach their peers for each section of the material (the material was broken down into two sections). Students then taught their lesson to one of their peers and then their peer had to "reciprocal teach", meaning they retaught what they had just learned. Students were then asked to switch and the student that was the teacher became the learner and reciprocator. Students rotated through at least three different peers in the class period in order to hear multiple individuals teach the material. The next day students taught a different section than what they taught the night before and reciprocal teaching ensued once again. For modelling, students were given clay or materials of their choice and they created the specific bones or muscles as they discussed the models with their peers. They then took a day to present their models to multiple peers using a technique similar to reciprocal teaching. Finally, the mnemonic story required students to write a fun, creative story using all of the bones or muscles for that upcoming quiz. The key was they had to try to use a name for each bone that starts with the first letter of the bone. For example, "Tina the tibia fell in love with Fred the Fibula". They will also be expected to connect the story to where the muscles or bones actually articulate or attach.

Following the teaching and implementation of the particular technique, the students had two nights to study the material as they normally would and they were given a post-memorization survey with similar questions to the pre-memorization survey in

order to identify if their confidence levels, stress levels, and perceptions were altered once they implemented the memorization strategy (Appendix D). Immediately after taking the survey, students took a quiz over the material studied which showed growth for short-term memorization (Appendix E). Each technique was tested twice, once in the skeletal system and once in the muscular. A paired t-test was used for statistical analysis on the pre- and post-test scores. Finally, a control group was established where students were not intentionally taught a specific memorization tool to use for that given material. The mean average from the control group was compared to the mean averages from the tests using specific memorization techniques to see if there was a difference on the test averages. A t-test was also run in order to determine validity of data.

In order to assess student's long-term memorization, they were given a unit test approximately two weeks after the material was taught (Appendix F). The mean class averages on each section of material previously taught was compared in order to assess whether or not the memorization techniques used on those sections seemed to make a difference. Again, there was a control group established for this unit test. It was important that students' grades were not influenced by these unit tests as they would try to study for the particular section prior to be tested, ultimately testing short-term memory rather than long-term. I was purely assessing what they could remember having used that memorization technique without any further memorization.

T-tests were also run in order to determine if there was a significant difference between the data obtained on the juniors in the class verses the seniors. The males versus

females were also analyzed with t-tests in order to determine if certain memorization tools had a different impact on the two sexes.

In order to obtain some qualitative data for research question two, I spent time walking around talking to students individually to assess how they felt as they were implementing the memorization technique and their perceptions of how that technique influenced their learning. Students were chosen at random, with an effort to have half of the students as juniors and half seniors. They were also asked questions regarding the potential use of that technique in other classes using a survey (Appendix G). This data was analyzed by looking at key words and key themes on charts that had the responses on them. The number of students that eluded to these key themes were then tallied.

Some more qualitative data was obtained through class discussions when I asked the entire class a series of questions regarding the memorization technique taught and how useful/not useful the students feel that technique may be in all of their classrooms. This interview was administered immediately after the students took their post-tests, with another interview after their unit test in order to identify what techniques they felt made the greatest impact on their learning. Again, this data was analyzed by looking through the key words/themes and tallying student responses.

DATA AND ANALYSIS

Preliminary data was obtained in order to determine the memorization techniques students were already familiar with and seemed to naturally gravitate toward. One of the questions posed after sorting through data was, “What types of techniques or tools are students already using in order to study for material that requires memorization and

material that requires conceptualization?" The data showed a vast majority of students are relying heavily on repetition in order to study for material that requires memorization and material that requires more of a conceptual understanding. These repetitive methods included rereading notes, rewriting notes, saying things over and over, rereading material in the book, etc. As far as memorization tools are concerned, 94.4% of the students relied on repetition (Figure 1). One student who maintains a 4.0 GPA commented in the class interview, "The only way I know how to memorize is through repetition and I am bad at that." Mnemonic techniques and use of auditory techniques were the next most popular techniques, with 16.7% indicating they used these techniques to study. This data helped omit the use of repetition and a couple of mnemonic devices students were already utilizing, such as rhyming and acronyms. Another student commented at the end of the implementation of the memorization tools, "I figured out that there is more than one way to studying besides repetition that helped me. It was very impactful, something I would use again.

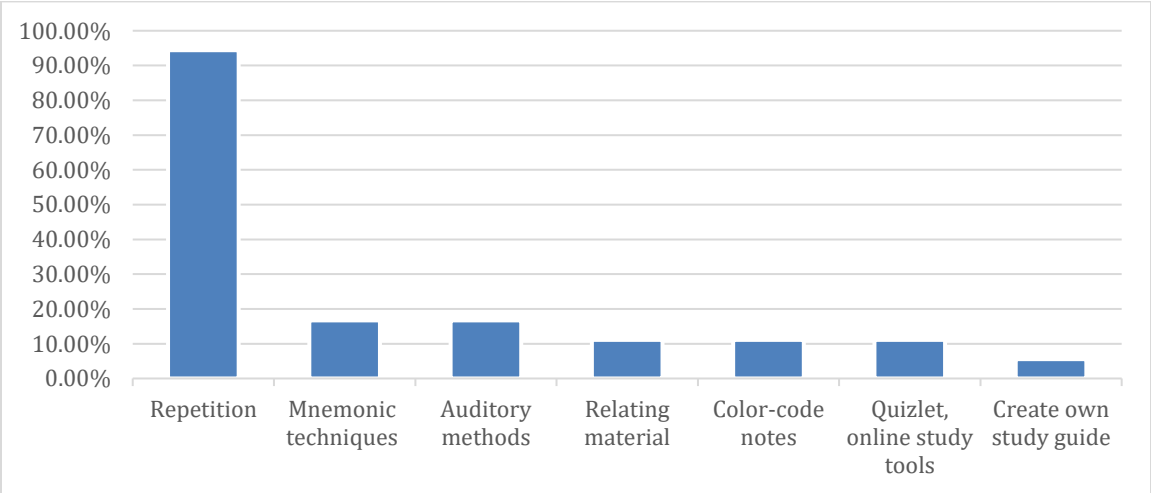

Figure 1. Student responses for preliminary survey on study techniques already being used, (*N*=17).

The first set of data analyzed compared the pre- and post-test scores of the short-term memorization tests given using the three testing strategies: modelling, reciprocal teaching, and mnemonics, as well as comparing the mean averages of these tests to a control group. The pre- and post-test data obtained for the material tested after modeling was implemented showed a normalized gain of 87.8% with a mean average of 85.7% (N=18). With a p value less than 0.0001 after t-tests were run and a t-value of 35.34, this showed significant improvement. When compared to the control group, which had a mean average of 72.02%, standard deviation of 0.21, there was a significant difference in averages considering the p-value was 0.001546, less than 0.05. Similar data trends can be seen for the tests taken when reciprocal teaching and mnemonics was implemented (Figure 2). The pre- and post-test data for the tests in which reciprocal teaching was implemented showed a normalized gain of 91.9% and a mean average of 91.37%. After data from the tests given after a story using mnemonics was analyzed, it showed a normalized gain of 87.1% and a mean average of 88.53%. T-tests did not show a significant difference between the test scores of the three different memorization strategies implemented. However, there was a significant difference in the test scores of all of the strategies compared to the control group with p values < 0.05 (Figure 3). In addition to this quantitative data, it was safe to say that these are the highest averages by 5-10% that I have had teaching anatomy the past three years. According to one of my students, she summarized the impact of the implementation of these memorization techniques quite well, “With the many memorization tools implemented throughout this unit, I have gained a better tool set for studying. I have seen my test average grow

tremendously from what it was last semester and I am finding that it is easier for me to memorize the material in a short amount of time."

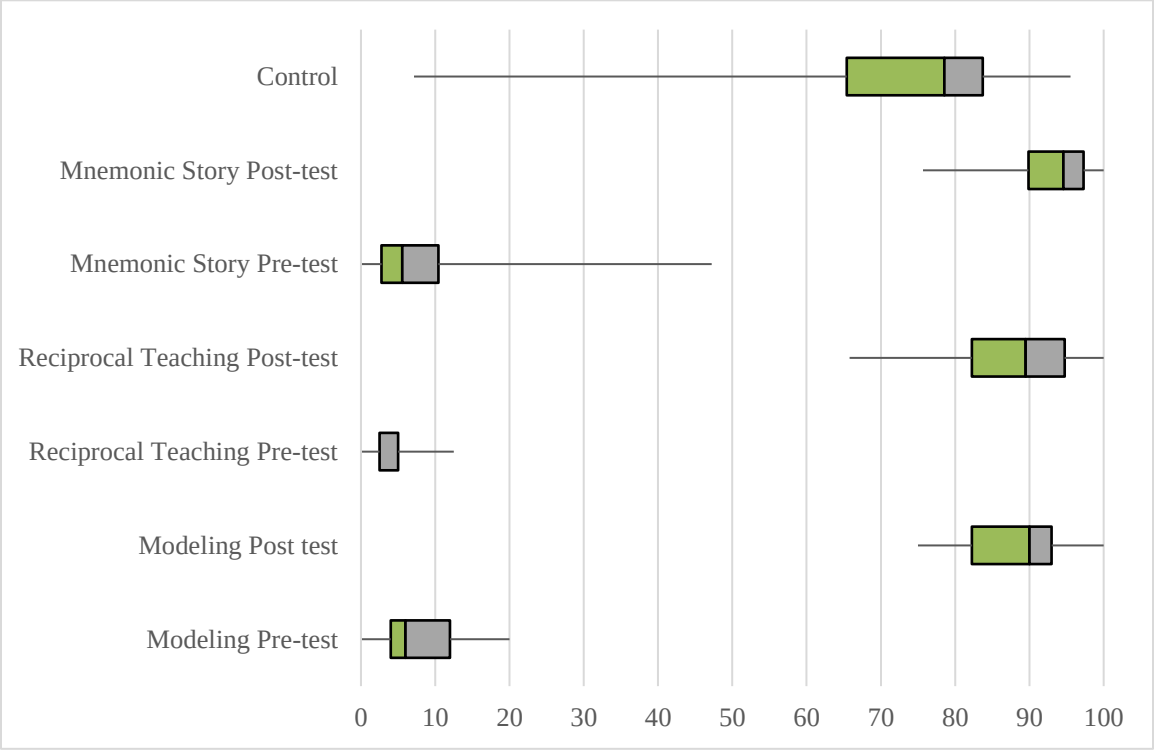

Figure 2. Pre-test and post-test scores for each type of memorization strategy, (*N*=17).

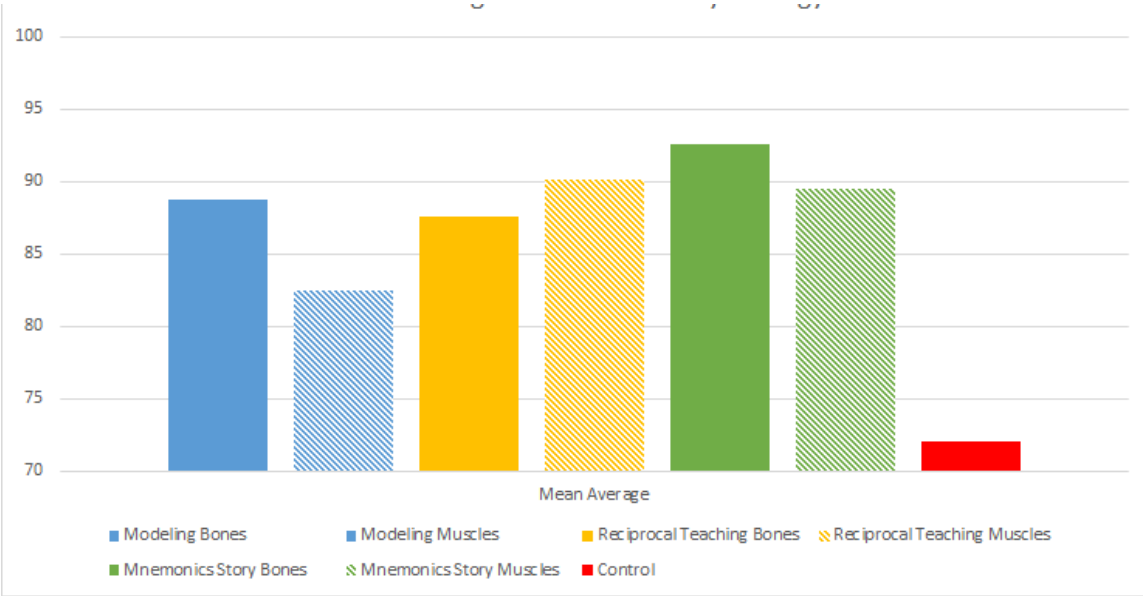

Figure 3. Mean averages of tests with memorization techniques vs. control.

In analyzing data for the long-term memorization unit test given, the mean average for the material in which reciprocal teaching was used was a 46.69% with a standard deviation of 16.70 (*N*=17). The mean average on the questions pertaining to material in which reciprocal teaching was taught was a 39.24% with a standard deviation of 10.45. The questions covering material which used mnemonics had an average of 44.52% with a standard deviation of 19.91. Finally, the control group had a mean average of 48.24% with a standard deviation of 23.51. This data did not show a significant difference between the material in which the memorization techniques were implemented versus the control, nor did it show a significant difference in the mean averages between the material with different strategies implemented. When t-tests were run, all p values were above 0.05.

The next set of categorical data obtained was intended to compare males and females, junior and seniors, in order to determine if the different types of strategies had a greater impact on one group over the other. After t-tests were run for all short-term memorization data comparing the both the males versus females and juniors versus seniors, all p scores were significantly above 0.05 showing the differences were not statistically significant. The only group that showed any statistically significant data was the control group with the females having a 70.95% average and males a 77.38%, and juniors with a mean average of 68.34% and seniors with a 77.81% average. As far as long-term memory is concerned, the only statistically significant trends to note were the males vs. females on all material except the modeling. The males had significantly higher mean averages on the material that used reciprocal teaching, mnemonics, and the

control group. The males' average was 14% higher for reciprocal teaching, 26% higher for mnemonics, and 31% higher for the control group. The only category where there seemed to be a notable difference between juniors and seniors was in the reciprocal teaching material. With a t-value of 2.86 and p-value of 0.00602, the mean average for juniors on the reciprocal teaching material was 12% higher than seniors (Figure 4).

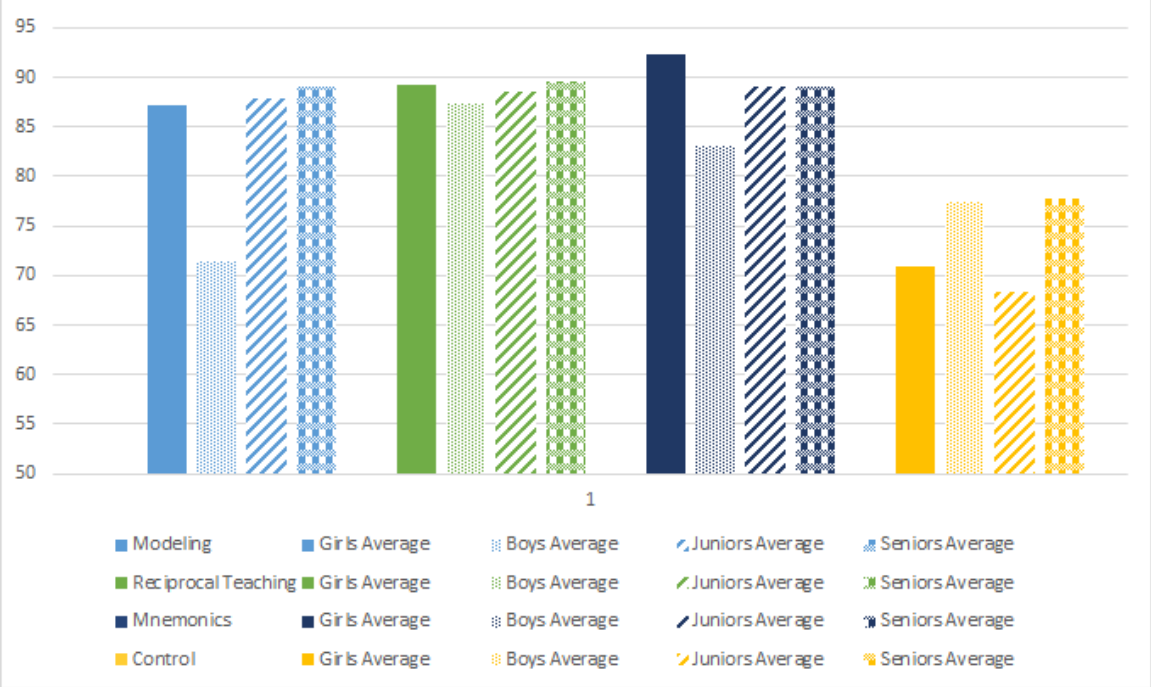

Figure 4. Mean averages broken down by sex and year in school.

When analyzing the qualitative data that looked at students' confidence levels, stress levels, and perceptions of the material and study techniques to be taught before and after the implementation of the technique, it showed a significant increase in confidence (Figure 5), less stress, and improved perceptions of the material at hand. Survey question one (Appendices B, C) which asked about their confidence levels before and after the memorization technique was presented showed a 61.91% increase in the number of students who felt either completely confident or somewhat confident in modelling, a

93.75% increase for reciprocal teaching, and an 82.36% increase for the mnemonics story.

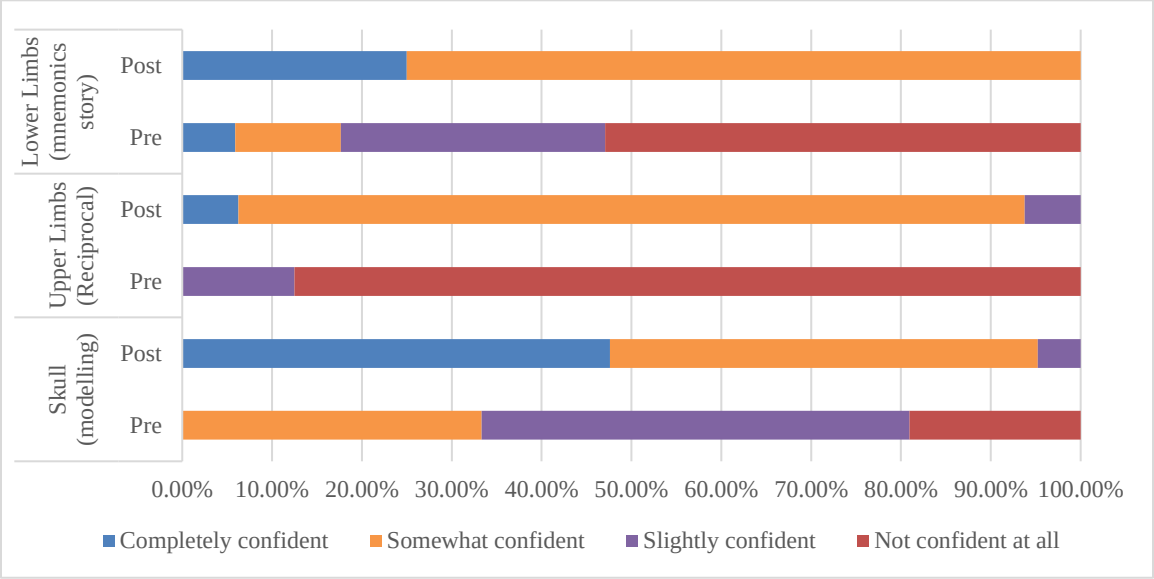

Figure 5. Responses to survey question: "What is your level of confidence on the material at hand?"

For survey question number two which asked about the students' familiarity of the material before and after the implementation of the strategies showed that 100% of the time students were either not so familiar or not at all familiar with the material before the tool was presented and 100% were either somewhat familiar or very familiar with the material after they used the given memorization strategy to study with. Both the modelling and mnemonics story showed nearly 70% of the students being very familiar with the material, but reciprocal teaching only showed 50% of the students being very familiar with the material after having studied it.

When looking at data pertaining to student stress levels (question three on surveys), not one student at any point in time experienced extreme levels of stress. Before the modelling was implemented, 19.05% of the students felt high stress and only

23.81% were slightly stressed. After they were able to implement modelling only 9.50% felt a high level of stress before their test and 42.90% were slightly stressed. After reciprocal teaching was applied the high levels of stress decreased by 31.25%, however, 43.75% of the students still felt an average level of stress before this test with only 18.75% slightly stressed. This was 23.25% less students in the slightly stressed category compared to modelling. When students practiced mnemonics with their stories, the number of students that were slightly stressed when they first saw the material actually decreased after the story was done by 4.4%. The high levels of stress still decreased by 19.79%, but 50% of the students felt an average level of stress prior to taking to their test (Figure 6). Question six actually looked at stress symptoms before and after the strategies were implemented in order to identify the symptoms students associated with stress (Figure 7). Students seemed to demonstrate fewer stress symptoms after they practiced modelling. After studying the lower limbs material using mnemonics and upper limbs using reciprocal teaching more students seemed to have slightly more stress symptoms than before they studied the material.

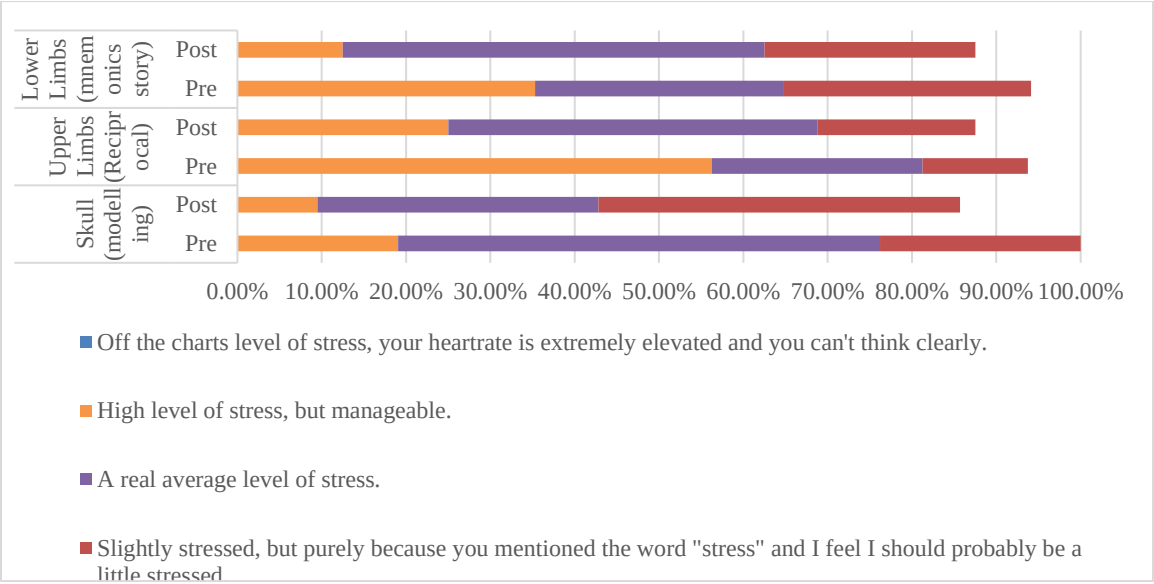

Figure 6. Student responses to survey question: "What is your stress level as you look at this list of anatomical terms and locations?"

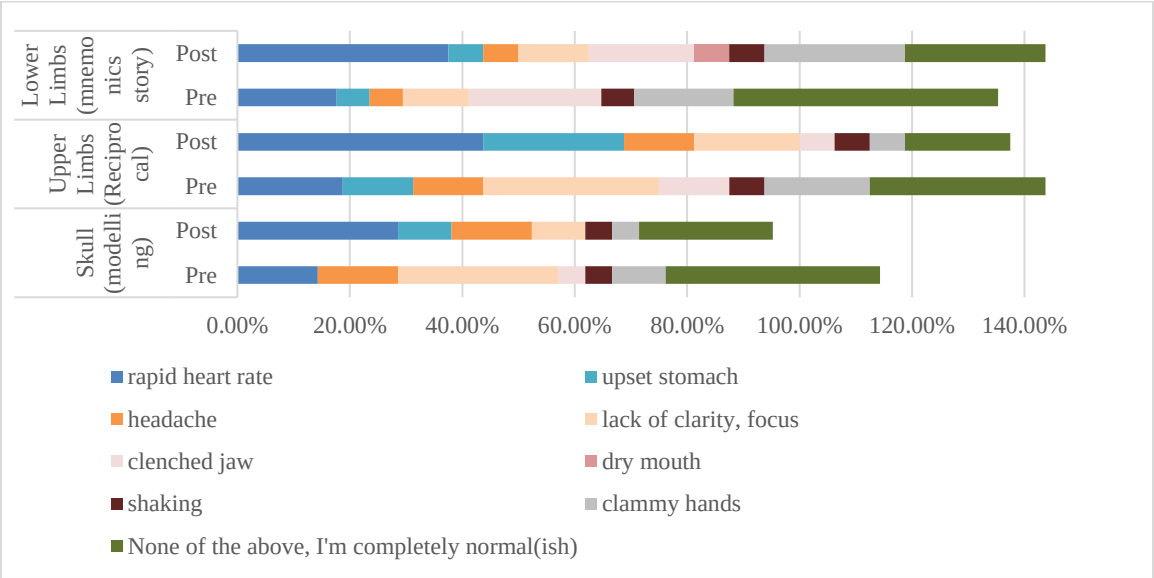

Figure 7. Stress symptoms experienced pre-memorization and post-memorization.

Question four addressed perceptions around how confident students felt in their abilities to memorize the terms at hand before they practiced the given strategy and their confidence on getting an A on that particular test. The data only showed 5.88% of the students feeling very unlikely to memorize the information for the lower limbs material

that would be supported by mnemonics and 31.25% felt very unlikely to memorize the material for the upper limbs using the reciprocal teaching method. No one felt memorizing the skull would be very unlikely using modelling, but 33.33% felt it was unlikely. For every single teaching method implemented, nearly 100% of the students felt it was either likely or highly likely that they would receive an A on their test. Only one student felt it would be unlikely for them to receive an A on both upper limbs (reciprocal) and lower limbs (mnemonics).

When analyzing the results from question five which asked about student perceptions of the memorization technique being administered before and after the implementation, the majority of the students for all techniques felt the implementations would be somewhat useful or slightly useful (80.9% for modelling, 19% very useful, 93.7% for reciprocal teaching, 6.25% very useful, and 64.7% for mnemonics, 5.88% not useful at all, and 29.41% very useful). After they were able to practice the techniques, the majority transitioned to somewhat useful and very useful, with very few considering the methods to be slightly useful or not useful at all. Both modelling and reciprocal teaching showed 93.7% of the students that felt these techniques were either very useful or somewhat useful. Mnemonics showed only 75% of the students that felt this was very useful or slightly useful, with 12.5% feeling this technique was slightly useful and 12.5% feeling that is was not useful at all.

After analyzing the patterns of comments made during the class discussions and individual interviews, it was found that students felt reciprocal teaching was not as effective of a tool as modelling and mnemonics; however, it was determined that

reciprocal teaching made the greatest impact as to how students would choose to study in the future. All three techniques contributed positively to student confidence levels. Nonetheless, two students did comment that the mnemonics story actually negatively impacted their confidence levels. In regard to modelling, students commented on the effectiveness of it, but found it to be very time consuming and somewhat distracting. A junior said, "I was too worried about getting it done, so I can't memorize." Another senior student commented, "It is effective but distracting (Figure 8). I got lost in art, not thinking through what I was supposed to be learning." On the other hand, a very kinesthetic student reflected, "It helps me more than anything else because I am actually making it." Another very artistic, kinesthetic learner mentioned, "It really helped my confidence as I am detail oriented, I knew every shape/contour of every bone." Students were extremely divided as to whether or not they felt it helped/hindered their stress levels. One student said, "It reduced my stress, it was an outlet." Another student commented, "It added stress, I learn better auditory/visually, I am not a hands-on person." There did not seem to be significant difference in comments made by boys/girls or juniors/seniors.

Figure 8. Example of student's model of the upper limb muscles.

Reciprocal teaching, although not the top choice in effectiveness, seemed to be the top choice as to what students would use in their future study endeavors. A female senior found this was particularly effective when your peer learns like you do, “It was a really good tool. Get someone who learns like you. It is good to have both, but weird when someone doesn’t learn the same way.” Another female senior said, “The teaching part was good, I tried to learn to teach. But, for the reciprocal teaching part, I had to go back and relearn the material.” Another student chose to use modelling for her reciprocal teaching lesson! Overall, this method seemed to improve confidence levels. Two junior students’ comments were very similar in saying this made them WAY more confident! “It made me a TON more confident because I studied my material and having someone teach me their way of learning and my way helped me piece things together (Figure 9).” “It made me WAY more confident. Talking to people really helps something in my brain click. I was able to put methods that help me in order to teach (Figure 10).” On the other hand, a couple of students who found modelling to be more helpful commented, “It gave me less confidence. I can’t master it as quickly as I can alone. Working with someone else made me feel less efficient.” “I was not as confident as with modelling. I learned a lot more in modelling.” Nonetheless, the majority of the comments suggested reciprocal teaching did increase their confidence and lowered stress.

Figure 9. Students engaging in reciprocal teaching activity.

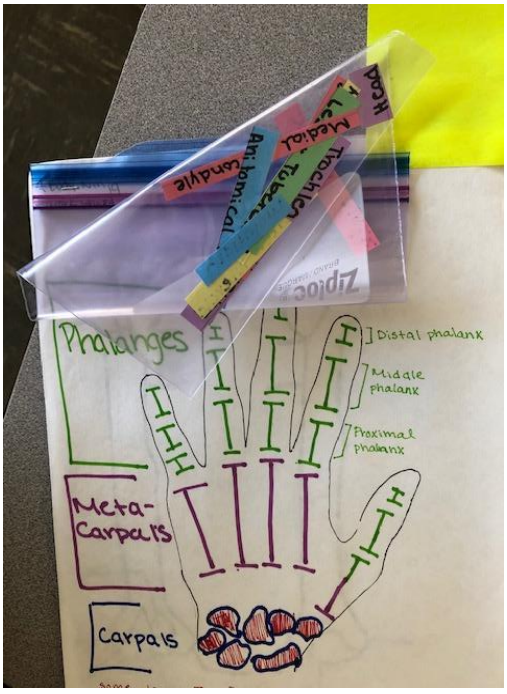

Figure 10. Students' reciprocal teaching material.

The mnemonics was very divided in regards to students either feeling that it was helpful or not helpful. The same with confidence levels, there was a split. One student who tends to color code all notes commented, “I feel the technique of pairing words with other words starting with the same letter as the vocabulary word was very helpful.” Another student reflected, “I think mnemonics helped me memorize the stuff a lot better than anything else we have done before. I feel like this will help me be a better learner for long term instead of just forgetting it tomorrow.” There were no strong comments against mnemonics, however, about 50% of the students felt this was the least helpful of the three techniques studied.

Students also noted during the interviews that there were other study methods that they somewhat relied on in addition to the memorization technique implemented. The most common methods they leaned on were repetition, coloring pages, pointing to the bones/muscles on family members, and online 3D models. Students also suggested that other factors influenced how they tested such as a head cold, not enough sleep, no sleep at all, hungry, gloomy weather, and the stress of other classes.

The final survey sent out to students (Appendix G) shows that the memorization techniques overall had positive impacts on confidence levels and their study habits for future. The first question asked students to comment on how the strategies impacted them as a learner and changed how they approached studying. 100% of the responses indicated a positive impact made. 29% of the comments made referred to not just using repetition any longer as they discovered it was not as effective. “Using these techniques has forced my brain to think in a different way and has given me more effective ways to

learn versus repetition." "Through this experiment I have found my greatest studying techniques like teaching others. When I just used repetition, it did not work as well." "I figured out that there is more than one way to studying besides repetition that helped me. It was very impactful, something that I would use again." Although there were students that preferred certain techniques over others, the data showed every single comment had a positive impact from the methods researched.

When looking at all of the techniques used and the confidence and stress levels of students, it was determined that 88.2% of the students felt that the memorization techniques improved confidence levels and decreased stress. One of the two students who did not feel they helped commented, "These study tools have made me more stressed because I feel as though it is hard for me to study material in new ways. I am used to repetition and I feel as though it gave me the same confidence as the study techniques implemented." The other negative comment said, "Yes, (they helped) when using the method I preferred, but when using the method I didn't have much luck with I had a higher stress level because I did not feel as prepared." All other comments showed positive impacts of the strategies implemented. "The in-class studying techniques on top of home memorization methods did have a positive impact on me." 29.4% of the students specifically mentioned modelling as being most helpful, 35.2% of the students gave credit to mnemonics, and 17.6% addressed reciprocal teaching as being the most helpful.

INTERPRETATION AND CONCLUSION

The goal of this research project was to see how the intentional implementation of memorization techniques that targeted multiple types of learners would impact students' ability to memorize material both short-term and long-term. It was my desire that students would be able to use the tools implemented not only in anatomy, but in other classes and, especially, in college. Another goal of the research to help improve perceptions of the material, confidence levels, and reduce stress levels when it came to having to memorize challenging anatomical parts. A variety of both quantitative and qualitative data analysis tools were administered in order to break down the data.

The quantitative data showed that there did not seem to be one memorization technique that stood out from the others as far as allowing for higher test averages. However, when compared to the control group in which there was not a strategy intentionally implemented, all three techniques showed improved test scores for the short-term memory tests. All strategies showed significant gains from the pre-test to post-test with normalized gains of 85-90%, which is not surprising when students had not been previously exposed to the material.

When comparing the averages of the material on a unit test to look at long-term memory, there was not a significant difference between any of the averages, including the control. The teaching strategies did not appear to have a significant impact on the long-term memory storage compared to the material they chose to study on their own. They were able to remember approximately 50% of the material for each section when not given a chance to study for a unit test regardless of the how it was presented.

When looking through the categorical data, there was not a significant difference in test scores between the two sexes or the juniors and seniors in the class. Females did slightly better on the short-term test after mnemonics was taught and, in general, more females tended to prefer this method over the males. However, the long-term test did show that males had a statistically significantly higher average than the females on the material where mnemonics and reciprocal teaching was used, and the control group. This may simply indicate that the males were able to perform better on a "pop test" than the females. I did notice as soon as the females found out I was giving this unit test, even though it would not be graded, they were trying to look back at the material and study. The males were extremely laid back about it, especially considering it was not going to be graded.

From the interviews and Likert-type surveys that addressed the qualitative data, it was very obvious that the intentional teaching and implementation of the memorization techniques helped improve student confidence levels, reduced stress, made perceptions more positive, and had a positive impact on their personal study habits. The survey showed a huge shift in confidence levels from either not confident or slightly confident before their pre-tests to either completely confident or slightly confident right before their post-memorization test. That being said, students did demonstrate slightly more stress symptoms after they used mnemonics and reciprocal teaching methods versus reduced stress after modelling. Nonetheless, the pre-test was not a graded test and students were aware of this. The post-test did tend to cause a bit more stress as it was graded. Students did; however, indicate they felt less stressed after having practiced the memorization

techniques, but they experienced more symptoms. It is possible that the symptoms they felt were not necessarily related to stress.

The final survey revealed that students were ultimately positively impacted by the implementation of these memorization techniques in the anatomy classroom. Although data was very mixed as to which technique they preferred, 100% of the students felt the administration of the techniques positively impacted their study habits and were something that will help them as students in the future and in other classes. Eighty-eight percent of the students said practicing these techniques had a positive impact on their confidence levels regarding the anatomical terms and reduced stress. One of the two students who did not necessarily feel the techniques improved stress levels did indicate the techniques they were good at did help improve confidence, just not the ones they were not comfortable with. The other student simply felt stressed trying out new strategies and felt that repetition was less stressful for them. Comparing the preliminary data to the data obtained after implementing the strategies, before teaching the students new strategies, 94% of the students relied heavily on just repetition. After enlightening them with new strategies 29% of the students mentioned in their comments that they would no longer rely so heavily on repetition after being exposed to the new strategies.

VALUE

This action research project was designed to see if the intentional teaching and application of memorization techniques targeted toward multiple types of learners would have an impact on students' short term and long-term memory and on their confidence and stress levels. This research showed that it does not really matter what strategy is

implemented, but when teachers intentionally teach students how to memorize information utilizing multiple parts of their brains, it will help improve test scores and improve confidence and stress levels.

The data clearly showed with p-values less than .05 that the mean averages students achieved when teaching the different type of memorization strategies were significantly higher than when students were given the information and asked to memorize with their own methods. This research showed that students do not have a broad depth of knowledge when it comes to the different types of memorization strategies out there that can help them learn and retain the information. The intention of this research was not to teach rote memorization skills, but to tap into multiple parts of the brain when helping student memorize information. Rote memorization is not something we, as educators, should be striving for. We should be teaching students how to truly learn and retain the information. In addition to these valuable learning strategies, we need to be teaching them how to take ownership of their learning and find strategies that work best for them.

This research proved to be a very positive and valuable experience for the students in concurrent enrollment anatomy and physiology. Not only were their stress levels reduced and confidence levels increased, but they felt the implementation of these memorization strategies would be something they could take with them to other classes and onto college.

Although the research did not show a significant difference between the information tested on their long-term memory that had the memorization techniques

implemented versus the control where they could choose how to study on their own. Nonetheless, some students did comment that they chose to do a model, reciprocal teach, or use mnemonics when studying for that particular short-term memory test. On the flip side, several students also chose to go back to their "go-to" method, repetition, and a couple of students choosing not to study at all. With the diversity in methods they chose, or did not choose, this ultimately led to a lower overall class average on the short-term control, but the long-term retention on the control was not significantly different than the material where students were taught the various methods.

The *N*-value for this data was very small at *N*=18, and in some data sets 17. This low value could potentially lower the validity of the data as far as being used for all classroom. However, I can say that this data helped open my eyes as an educator as to how imperative it is that I expose my students to different, more effective, ways to memorize information. Teaching students how to learn and the type of learner they are: kinesthetic, auditory, or visual, will be something they can take with them the rest of their lives. Helping them to trigger as many parts of their brain as possible will lead to a more thorough understanding of the material at hand and, ultimately, the ability to memorize and actually learn the information.

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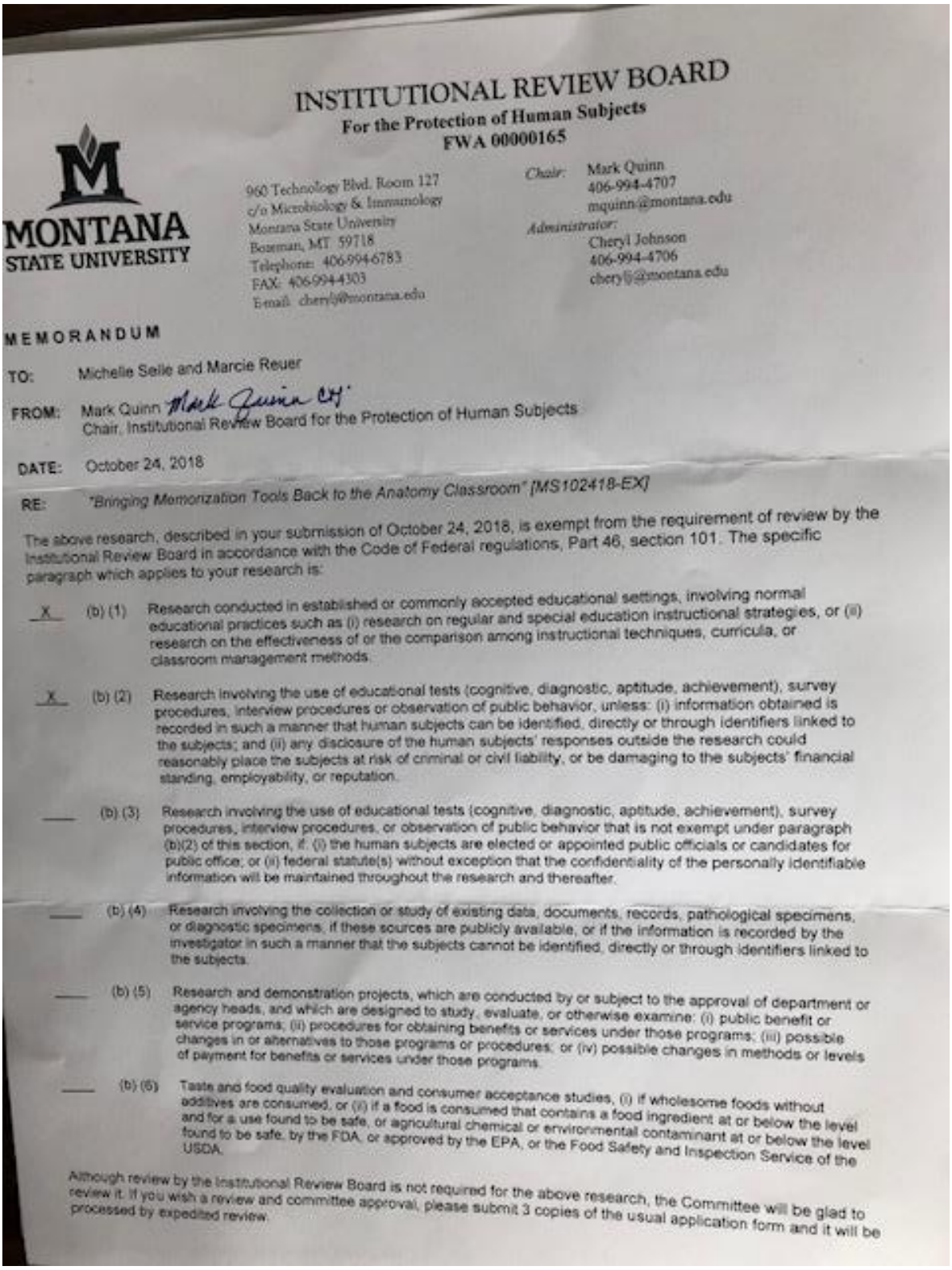
APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION



INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
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Chair: Mark Quinn
406-994-4707
mquinn@montana.edu

Administrator:
Cheryl Johnson
406-994-4706
cheryl@montana.edu

MEMORANDUM

TO: Michelle Selle and Marcie Reuer

FROM: Mark Quinn Mark Quinn CHJ
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: October 24, 2018

RE: *"Bringing Memorization Tools Back to the Anatomy Classroom" [MS102418-EX]*

The above research, described in your submission of October 24, 2018, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

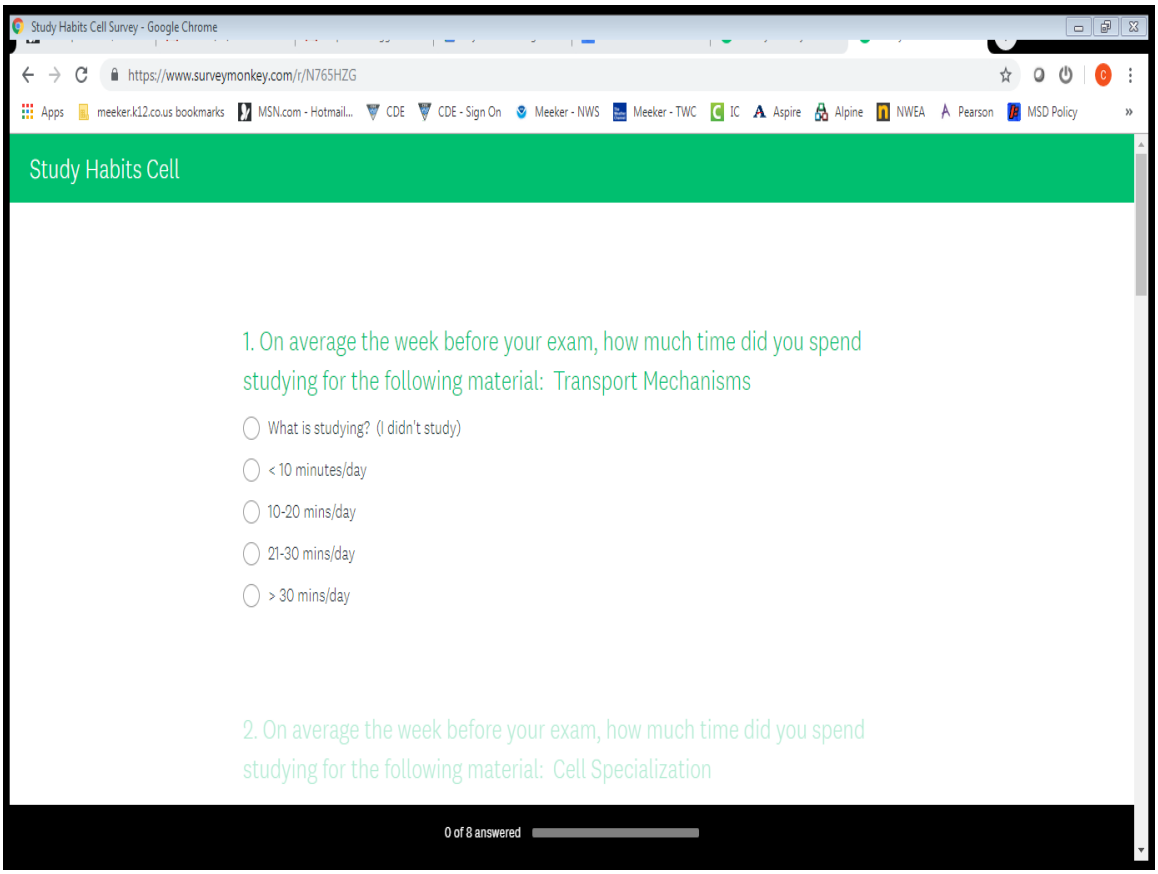
___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

PRELIMINARY DATA SURVEY

https://www.surveymonkey.com/r/N765HZG



APPENDIX C

PRE-MEMORIZATION SURVEY

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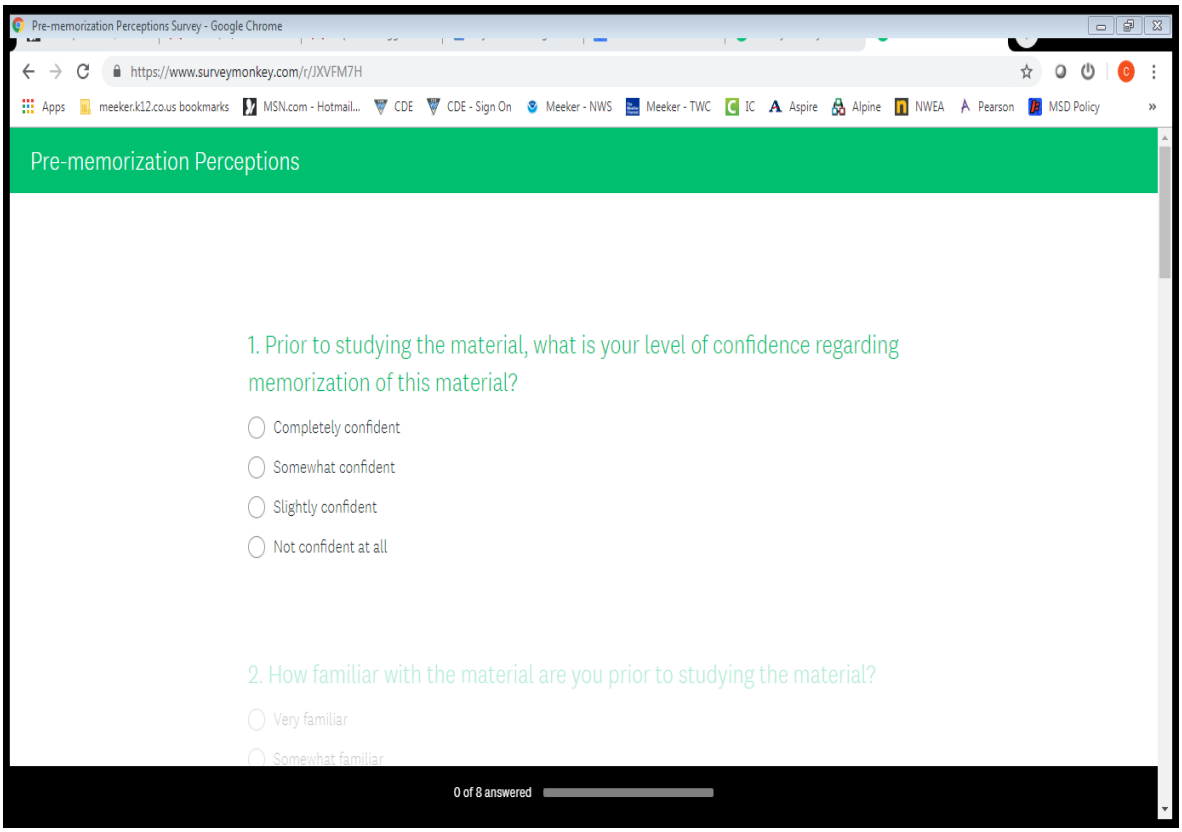

APPENDIX D

POST-MEMORIZATION SURVEY

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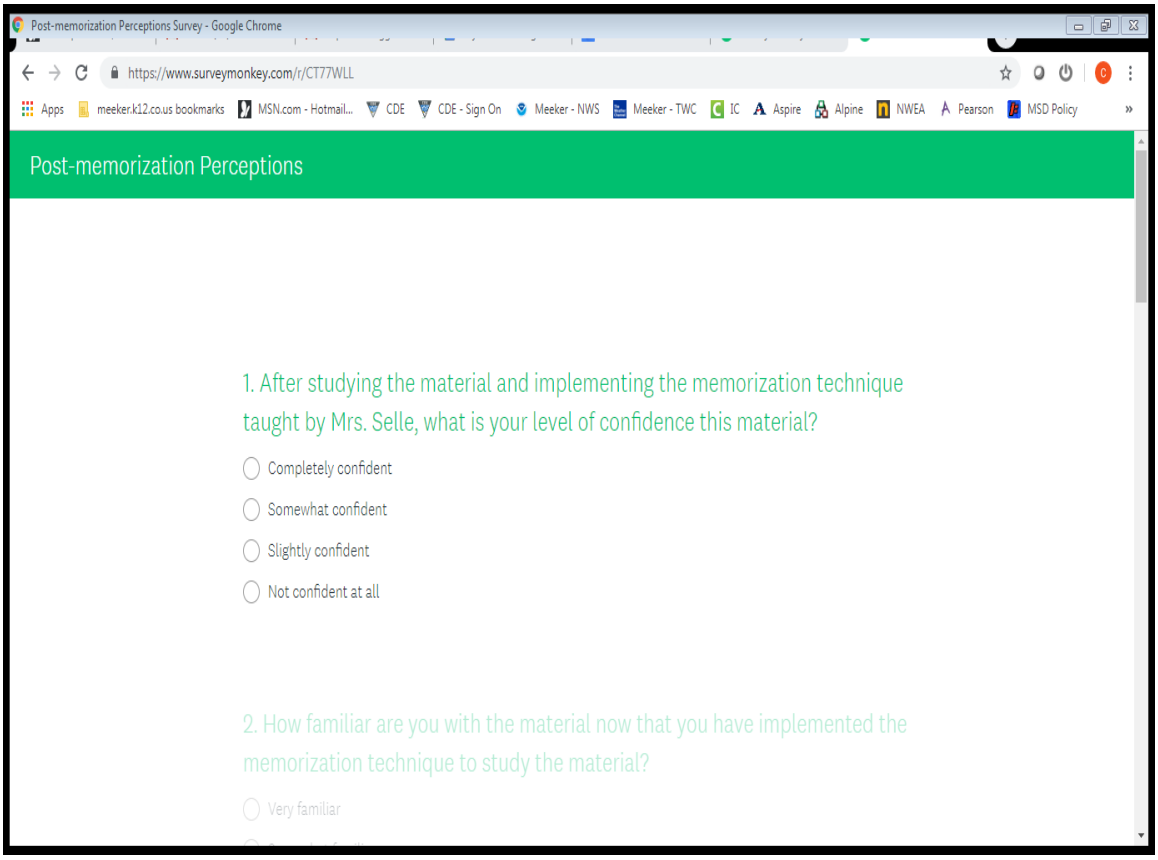
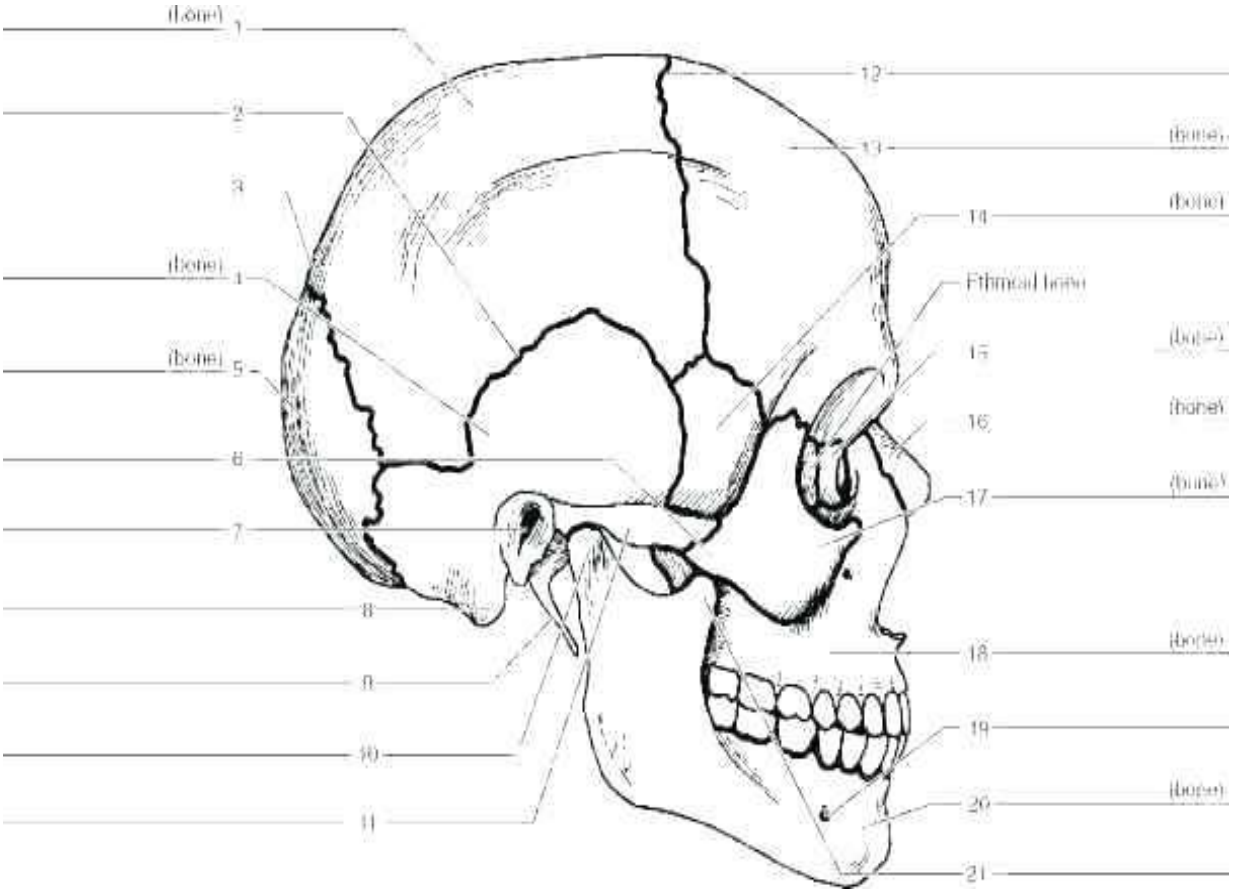


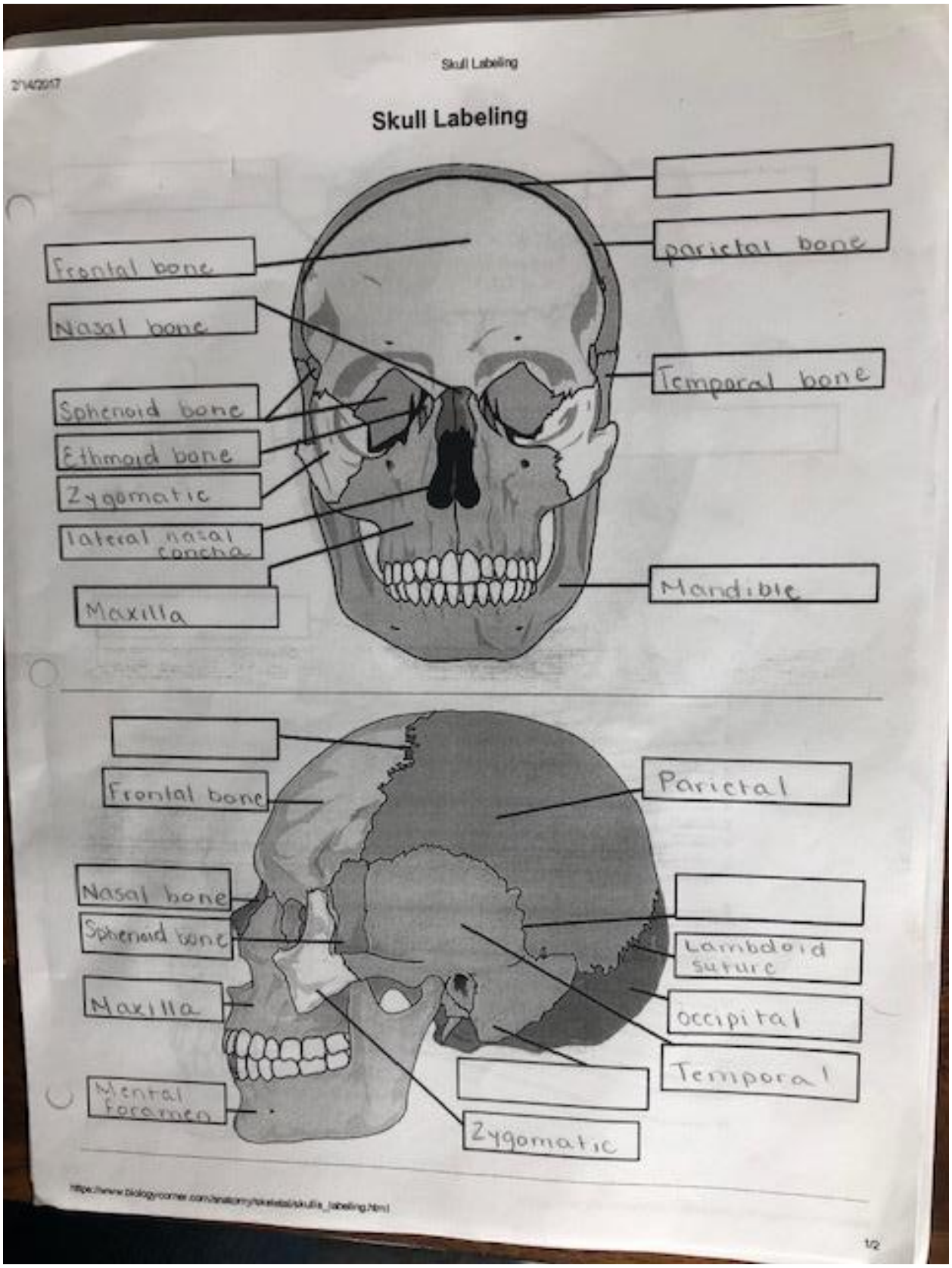
APPENDIX E

EXAMPLE OF SHORT-TERM TESTS GIVEN (SKULL)

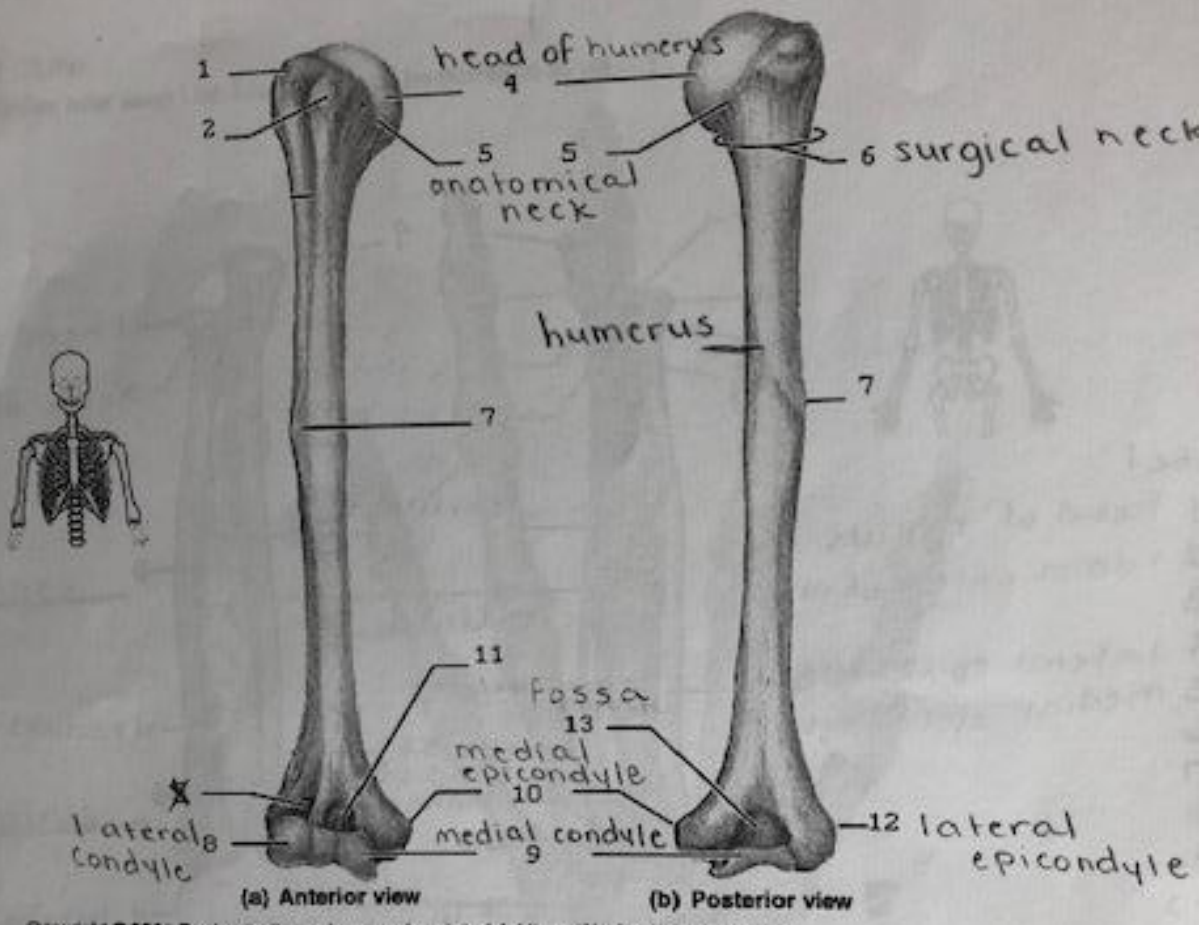

(bone)
1
2
3
(bone)
4
(bone)
5
6
7
8
9
10
11
12
13
(bone)
14
Ethmoid bone
15
16
17
18
19
20
21

APPENDIX F

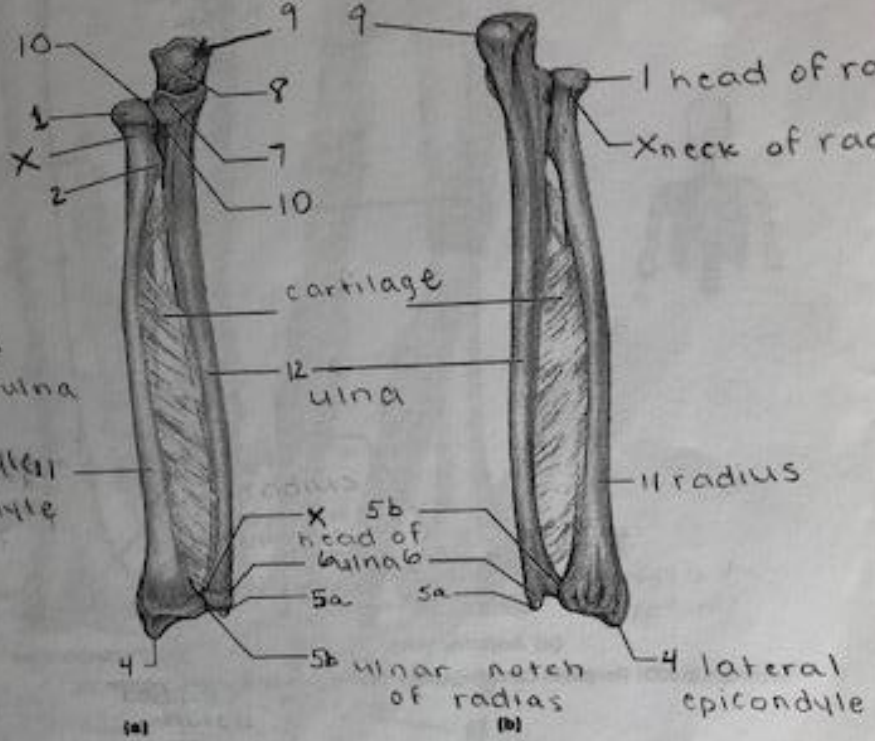
UNIT TEST LONG-TERM MEMORIZATION (STUDENT COPY)


2/14/2017
Skull Labeling
Skull Labeling
Frontal bone
Nasal bone
Sphenoid bone
Ethmoid bone
Zygomatic
lateral nasal concha
Maxilla
parietal bone
Temporal bone
Mandible
Frontal bone
Nasal bone
Sphenoid bone
Maxilla
Mental foramen
Parietal
Lambdoid suture
occipital
Temporal
Zygomatic
https://www.biologycorner.com/anatomy/skeletal/skulls_labeling.html
1/2

Label image:



1. #1 and 2 are attachment points for _____ that move _____.
2. #4 articulates with the _____ in the _____.
3. #7 is an attachment for the _____ muscles.
4. #8 articulates with the _____.
5. #9 articulates with the _____ of the _____.
6. #10 and 12 are attachments for _____.
7. #11 articulates with the _____.
8. #13 articulates with the _____.

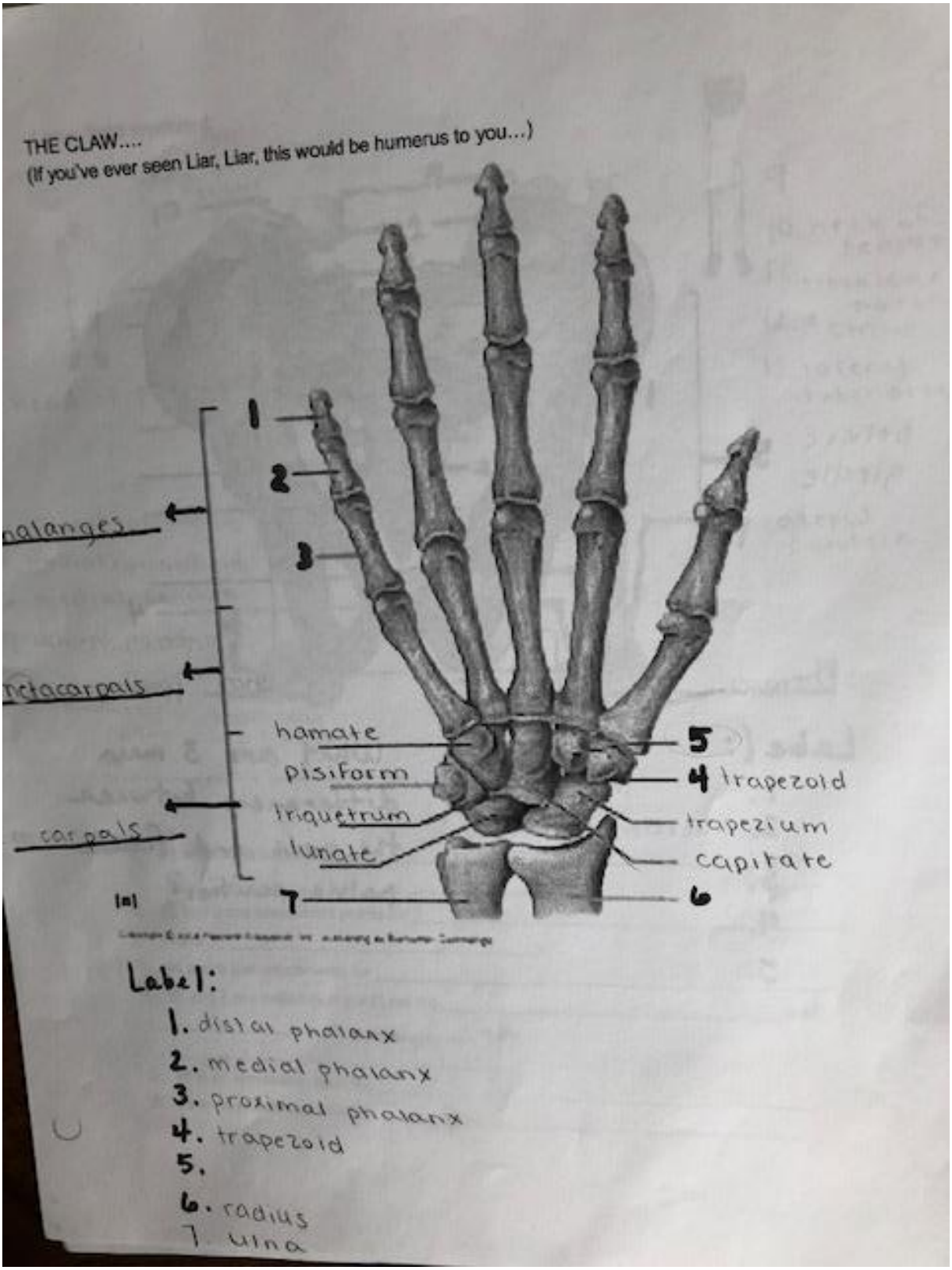


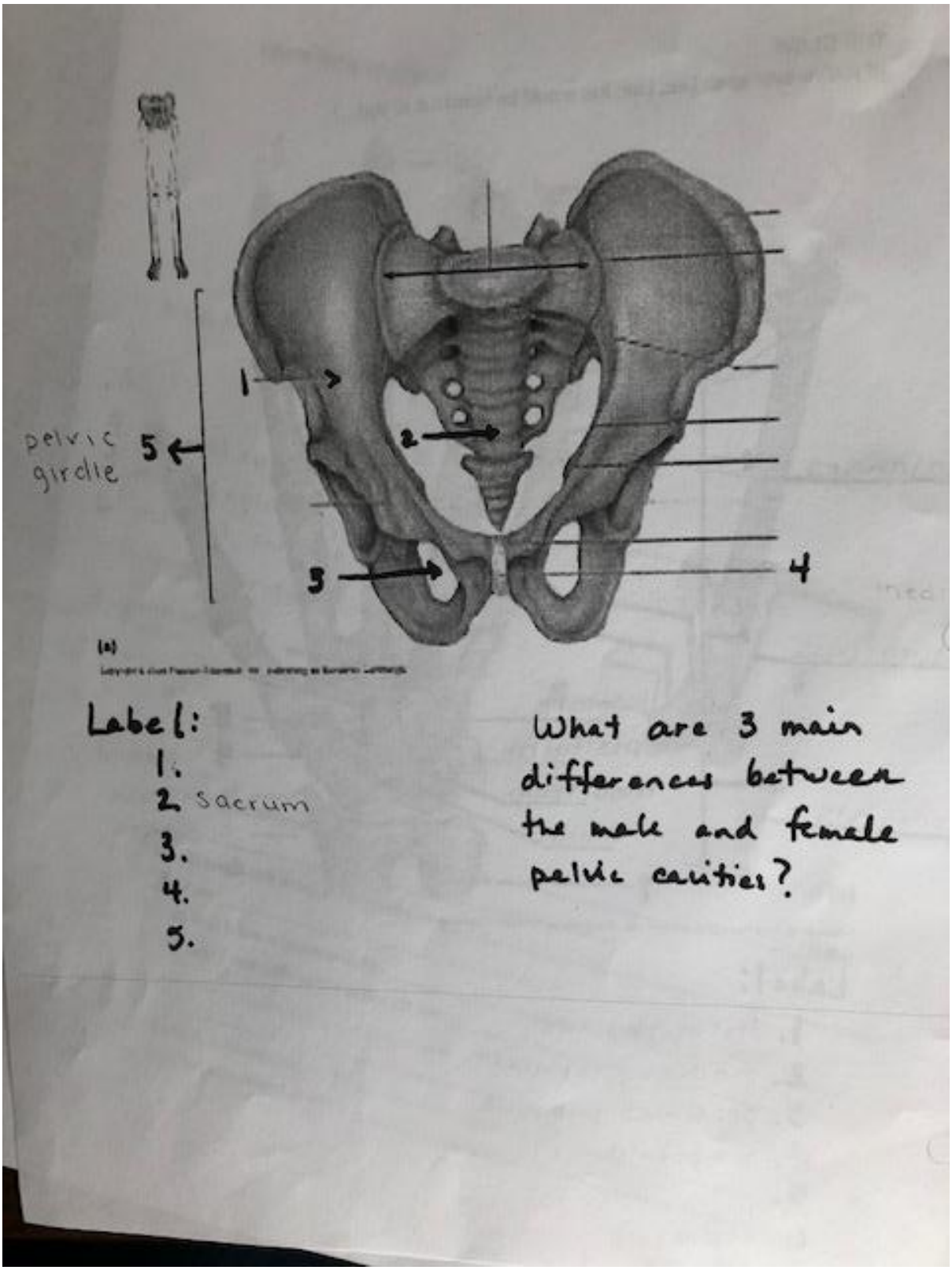
1:
head of radius
radial notch of ulna

lateral epicondyle
medial epicondyle

0
11: radius
12

1. #1 articulates with the _____ of the _____.
2. #2 is an attachment for _____.
3. #4 and 5are attachments for _____.
4. #5articulates with the _____ of the _____.
5. #6 articulates with _____.
6. #7 articulates with the _____ of the _____.
7. #8 articulates with the _____ of the _____.
8. #9 articulates with the _____ of the _____.
9. #10 articulates with _____.


THE CLAW....
(If you've ever seen Liar, Liar, this would be humerus to you...)
1
2
3
hamate
pisiform
triquetrum
lunate
7
5
4 trapezoid
trapezium
capitate
6
Label:
1. distal phalanx
2. medial phalanx
3. proximal phalanx
4. trapezoid
5.
6. radius
7. ulna

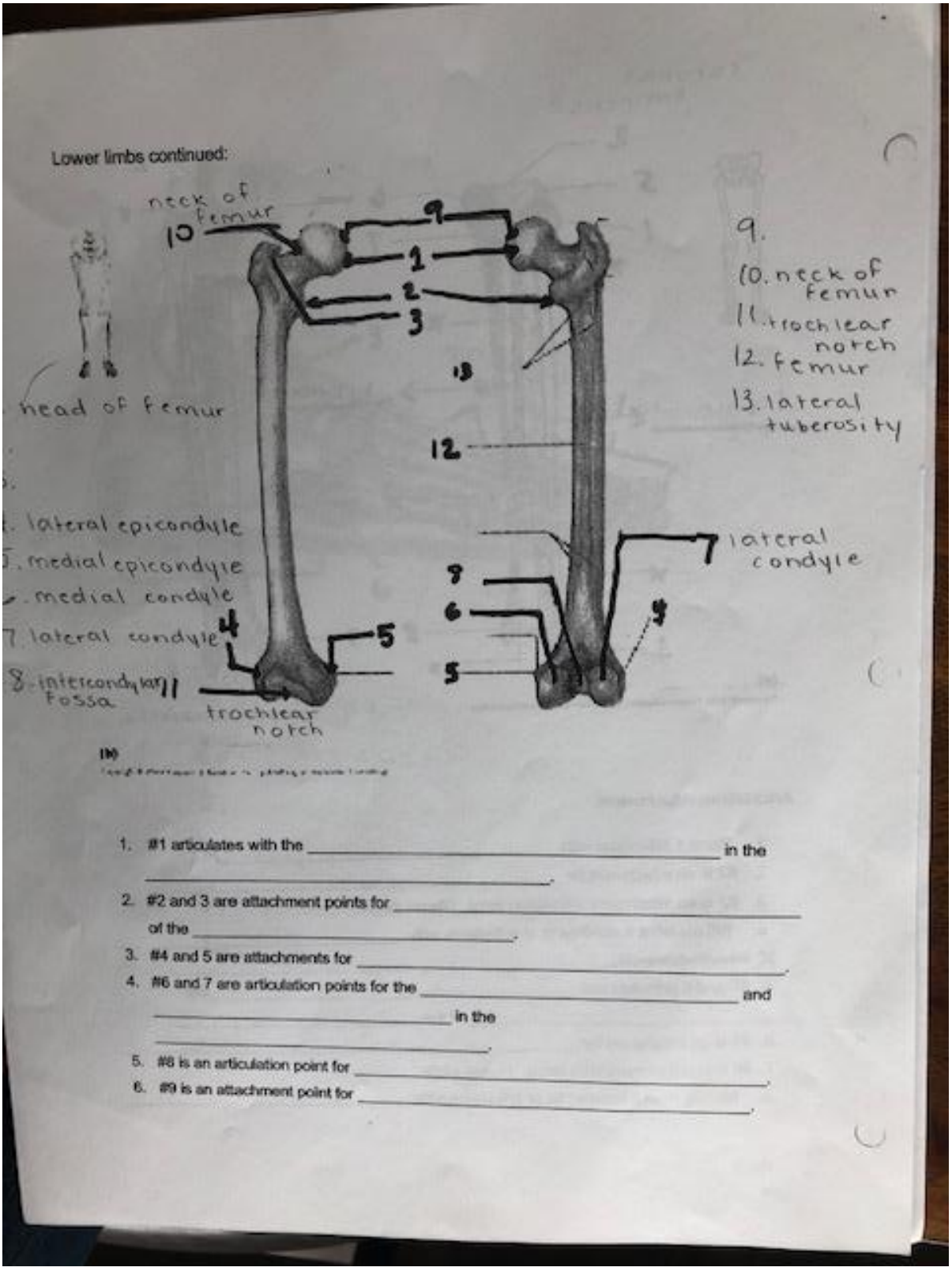


Label:

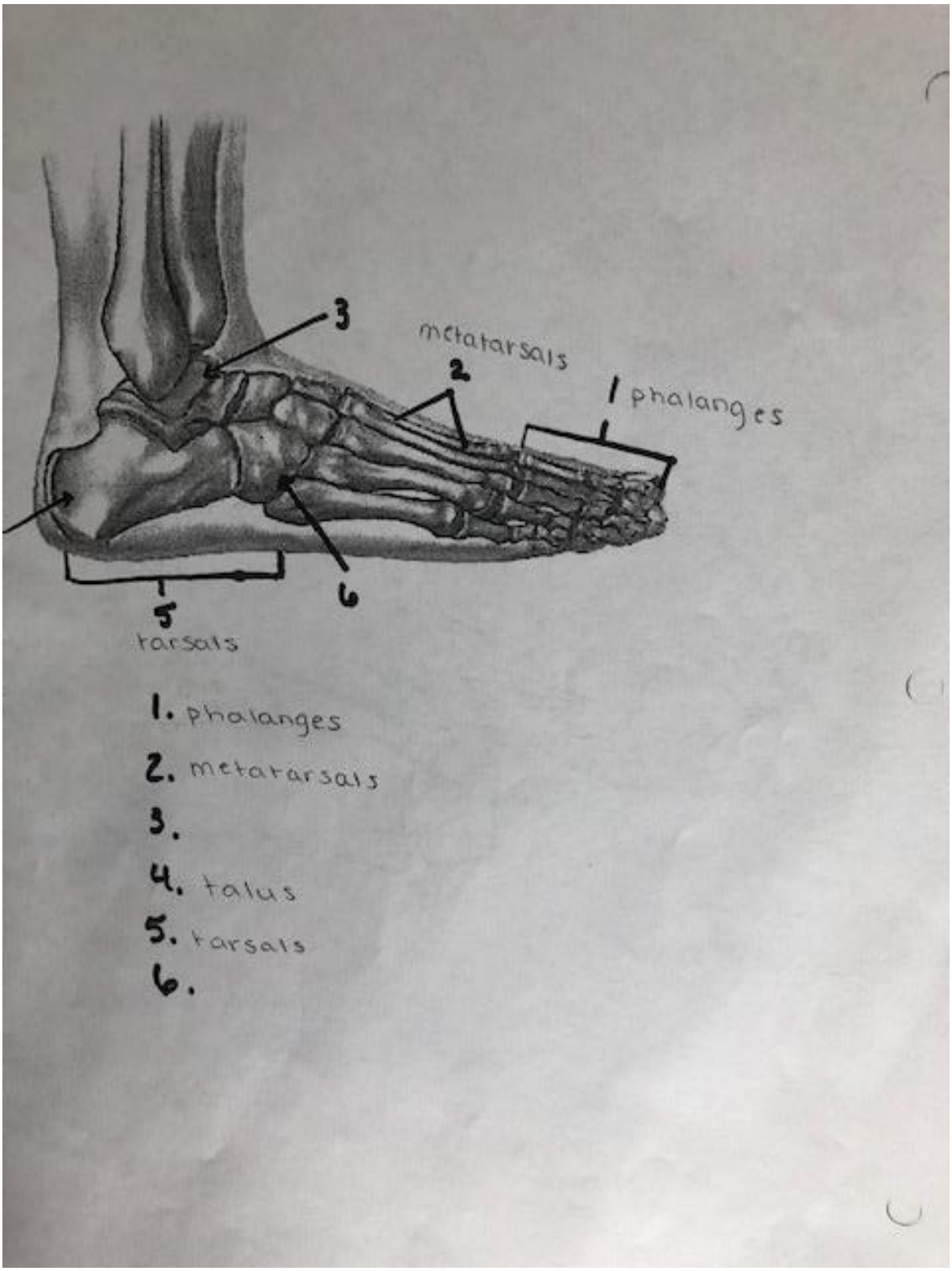
1.
2. Sacrum
3.
4.
5.

What are 3 main differences between the male and female pelvic cavities?

Lower limbs continued:



1. #1 articulates with the _____ in the _____.
2. #2 and 3 are attachment points for _____ of the _____.
3. #4 and 5 are attachments for _____.
4. #6 and 7 are articulation points for the _____ and _____ in the _____.
5. #8 is an articulation point for _____.
6. #9 is an attachment point for _____.

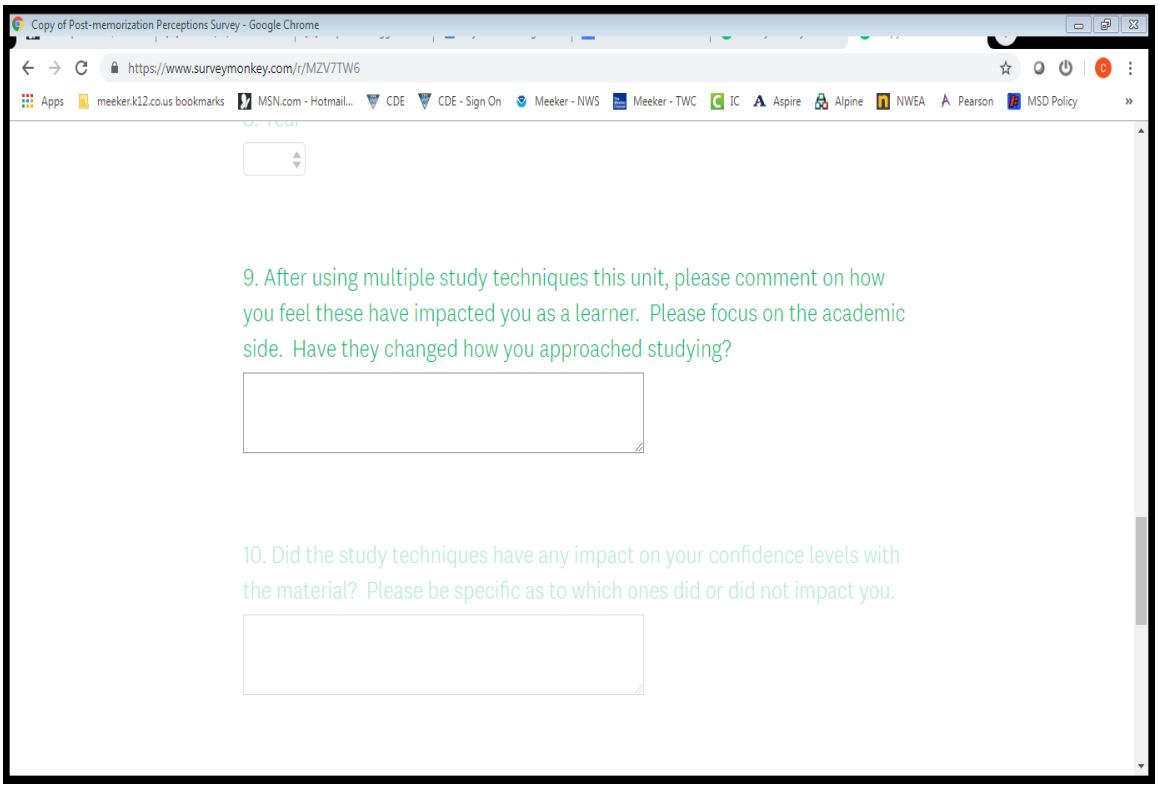


1. phalanges
2. metatarsals
3.
4. talus
5. tarsals
6.

APPENDIX G

POST-TREATMENT SURVEY

https://www.surveymonkey.com/r/MZV7TW6



APPENDIX H

CLASS INTERVIEW QUESTIONS

Interview Questions asked during class discussion and to individual students

1. How effective did you feel this memorization technique was?
2. What were other methods you relied heavily on when studying for this material?
3. What were other factors that may have impacted your performance on this test?
4. What was your confidence on this quiz due to the technique implemented?
5. How do you feel the memorization tool taught affected your stress levels?
6. Will you use this tool in the future to help you remember information?