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Building a Better Understanding of Equine Anatomy Through Integrated Learning

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Most people tend to have horses as their first contact with livestock animals. They are usually more common to see or interact with than cows, sheep, or other farm animals. This makes them a good starting animal for students learning about livestock, as well as the fact that they can be used for show, for work, or as a pet, making the equine industry a big one. While models have been used to teach students in topics such as architecture, cycles, and human muscles, little published research was found on the topic of having students build models of equine anatomy and physiology. Using hands-on methods of teaching can lead to a better understanding of a topic, as well as increasing levels of other skills important to students, like teamwork or problem-solving. To understand how students learn when constructing a model, we had two groups of two high school students with some previous knowledge of horses take a pre-test, build a model of a horse’s leg out of PVC pipe, and take a post-test, then answer metacognitive questions about the process. All of the students increased their scores and understanding of equine anatomy, and most of the students enjoyed learning in this manner. The kits we made for the students to put together could easily be made and used as a lesson in a classroom, or in a club, such as 4H. However, more research is needed to measure the model’s effectiveness as a learning tool across a wider variety of students of different ages, genders, and levels of knowledge. The workshop and tests can be made easier or more challenging, and other parts of the body or other animals can be used as the basis for the model. With a better understanding of anatomy and physiology, equine owners, veterinarians, racing trainers,
and others involved in the industry can prevent injuries and increase the quality of life for horses.
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INTRODUCTION

The Problem

Equine injuries can potentially cost owners a lot of money, the horse a lot of pain, and can even lead to the animal being euthanized. The most common cause of death in racing horses are catastrophic musculoskeletal injuries, and they are also the most common cause of falls causing injury to the jockey [1]. Diab, Stover, et al published a paper on the importance of knowing equine anatomy and pathology to better care for race horses and prevent injury [1]. Another common racing injury is superficial digital flexor tendon injury, which affects about 30% of racing Thoroughbreds; it can happen to both old horses and those that often exercise intensely [2]. While much is known about anatomy and these injuries, more preventative measures need to be created and implemented.

The owners are not the only people invested in the horses’ wellbeing. Racing fans, horse lovers, and animal activists all have strong opinions about horse racing, and the injuries that it causes. Recently in Melbourne, there was outrage when a horse had to be put to sleep after fracturing a shoulder during a race [3]. People for the Ethical Treatment of Animals (PETA) is calling for an investigation, while fans took to social media to discuss and share what happened [3]. With more negative ideas and news about racing, the overall opinion of racing could become more negative. This is not good news for racers, owners, trainers, or anyone else involved. However, when these professionals have proper training and knowledge of equine anatomy and biomechanics, they can
decrease the frequency and severity of injuries, or even prevent them. This may lead to a more positive idea of racing, and benefit everyone from fans to the horses to the jockeys.

There are already some other methods trying to make racing safer in different ways, such as an equine industry database [4]. After injuries occur at the race, a veterinarian would fill out a report and include details on the equipment, track length, track surface, where the injury occurred (on the body and on the track) and what kind of injury, and the track the horse trains on. There will also be information on horses that do not get injured, to analyze their training and histories to compare and identify what they are doing right. It is all uploaded to the Internet and available for veterinarians to add to and compare [4]. But just keeping a database will not be enough to help prevent injuries. Knowledge of the anatomy and biomechanics is important to develop injury prevention methods.

**A Possible Solution**

Gaining a better understanding of equine anatomy through active educational opportunities may be able to help people working with horses to treat and prevent more equine injuries. Books can provide students with helpful information, but reading words and looking at pictures may not provide the same learning experience as creating or using hands-on models. Dissection can also be an option, but it can be expensive, or students may object to using real animals. In *Biomechanics and Physical Training of the Horse*, there are many useful photographs, diagrams, and images of parts such as superficial anatomy of the forelimb, muscle groups of the forelimb, and muscle action [5]. *The Dynamic Horse* includes more in-depth reading on subjects such as actions of muscles, the digital flexor tendons, and the suspensory apparatus [6]. *Equine Locomotion* includes
many charts and graphs on joint angle compared to time, ground reaction forces, and
limb/toe axis deviation in forelimbs [7]. While these books provide important and
relevant information, they may not provide the same kind of education as creating or
even using a model would. Bloom’s Revised Taxonomy is a hierarchical ordering of
skills that help with teaching and can help gauge the level of learning in students [8, 9].
The lowest level is the remember level, which includes recalling facts and definitions.
The highest level is the create level, when complex ideas are understood, and students
can design and construct. Reading textbooks would fall around the lowest level, whereas
building a model would be at the highest level and lead to a better understanding [10, 11].
Students also have different methods of learning that work best for them individually,
such as visual, auditory, reading/writing, and kinesthetic methods. Building models
incorporates a few of those methods, which reaches more students than one method such
as reading textbooks [13].

**Similar Projects**

There have been several studies about hands-on learning experiences leading to a
deeper understanding of the material, in a wide variety of subjects. A study done by
Duzenli, Yilmaz, and Alpak had landscape architecture students use models to solve an
assigned problem, and they found that making models helps students’ understanding of
dimension, form and the relationship between both, among other positive results [14].
Lee, Jonassen, and Teo did a study in elementary science classes, having students create
models of the water cycle. Their results showed the students had improved problem-
solving skills and positive conceptual change on the topic [15]. In one done by
Rodenbaugh, Lujan, and DiCarlo, undergraduate nursing students constructed models of
sarcomeres to explain complex ideas and engage all types of learners [16]. In teaching, design can lead to improved scientific knowledge and real-world problem-solving skills. A study done specifically on design-based models created by ninth grade classes had results that were similar to those of the other studies, but the researcher suggested there needs to be more research done outside of a normal classroom setting [17]. I will build on ideas similar to previous studies in my thesis, and conduct an exploratory analysis of a small group of learning through an animal model construction activity outside of school.

**What We Hope to Learn**

We would like to know how much students learn through integrated, or active, learning and if building a model is an effective learning tool. There have not been studies specifically using equine models as an active learning tool. One student who worked on the PVC model before me wrote a thesis and also included why building models is important for educational purposes, but she built her part of the model herself [18]. I am hoping to take it further in this qualitative, exploratory study to assess how building models can improve student learning. While the anatomic and biomechanical knowledge gained during this project will be important, the other skills developed will also be valuable. Through student reflection questions, I will evaluate student skill development that cannot be understood through the pre-test and post-test. Reflective journaling can help the instructor to better understand the student’s process and thoughts, and the student can also better understand their own processes and connect their inner and outer world experiences to gain life skills [19]. Although we focus on horses, the implications of this study may be relevant and applicable to courses focused on humans and other animals. Animals have been used as models for human illnesses and injuries, and creating models
of animals or humans could lead to more positive education and research results for people and animals alike [20].
HYPOTHESIS AND OBJECTIVE

There is evidence that interactive and introspective approaches to learning, such as building a model of part of a horse and journaling throughout the experience, can lead to a deep understanding of anatomy while also teaching other skills useful to students. The objectives of this project were to guide a group of students in building a model of a horse leg, to give a pre-test and post-test and evaluate student learning, and to better understand students’ experiences through reflection questions.

I constructed a “simple” version of a leg, compared to the detailed one for the current PVC horse model, and documented how it was done. The simple model had less steps and less parts than the complicated model, and was easier for high school students to work with. I then guided two groups of two students each to construct their own models, having pre-cut and pre-drilled the parts. The students took a pre-test before starting and answered questions about their feelings on the process afterward. After completion of the models, the students took a post-test. The pre-tests and post-tests were compared, and the reflection entries were reviewed. Both quantitative and qualitative data were analyzed to identify evidence of improved skills and improved learning.

Students may show an improved understanding of equine anatomy and physiology after construction of the model. They may increase their scores on the tests by several points, and improve on each question. This workshop may be done in about two hours, and as an output of this research, it could be replicated in college courses, K-12 schools, or 4-H clubs. The costs of the materials should be low enough to be affordable for more rural schools, and the time it takes to complete everything should be short enough to fit in one session or split between two class periods.
MATERIALS AND METHODS

Materials:

- Rigid workstation vice (Figure 1)
- 1 2” x 5’ PVC pipe $7.17
- 2 PVC 2” 45-degree elbows $1.68 each (Figure 3)
- 2 PVC 2” P traps $3.86 each (Figure 3)
- 4 PVC 2” T junctions $2.78 each (Figure 3)
- 2 3” x 2” PVC coupling $4.48 each (Figure 3)
- Drill and drill bits (5/16 and 9/64) (Figure 2)
- Dremel
- Reciprocating saw (Figure 2)
- Permanent marker
- Safety goggles
- Fishing line
- A thin type of rope
- Lighter
- Needle nose Pliers
- Scissors
- 1-inch Hex washer slotted screws (Figure 2)
Figure 1. *The Rigid workstation vice.*

Figure 2. *The drill, drill bits, saw, & screws.*

Figure 3. *Some of the PVC pieces used (from left to right: two PVC 2” P Traps, two PVC 2” 45-degree elbows, four PVC 2” T Junctions, and a 3” x 2” PVC coupling).*
Building the Legs

The following methods were used to make one kit. We made two kits, so we doubled most of the materials and we repeated the steps to build them. The PVC pieces were purchased from the Bangor Lowe’s, and the prices listed above reflect the costs on 2/28/19. We did not take accurate measurements before the cutting and drilling, so the actual numbers may vary slightly from kit to kit. We briefly consulted Zandalee Toothaker’s construction manual for the simple model to ensure we weren’t missing anything, but we generally figured it out on our own [14]. We cut the pieces, filed the edges, and drilled the holes, and only put the pieces together. We cut and drilled the pieces so the students would not need to use any of the power tools, thereby lowering any risk to the students participating in the workshop.

Using a reciprocating saw, we cut a 2’ piece of 2” PVC pipe into an 18” piece (the cannon bone), a 5” piece (the end of the cannon bone), and a 6” piece (the long pastern bone, short pastern bone, and coffin bone). Next, we trimmed the 5” piece down about ¼” on each side to allow the correct movement, but the amount may vary based on the length of the T junction pieces. Then, two 2” PVC T junctions were cut about 1½” from the bottom of the long opening, (as shown in Figure 4). One of these pieces was then attached to an end of the 18” pipe, and the other was attached to an end of the 6” pipe, to each create a long T shape.
Next, we cut a PVC 2” P trap piece in half lengthwise. One half was used, and the piece was cut to about 1¾” - 2” in length on the smaller inner curve (see Figure 5). This piece made the sesamoid bone. These were all of the pieces that needed to be cut, and next marks were made for where to drill the holes.
We marked the pieces using a permanent marker, and again we did not measure them, but eyeballed the distances. We placed marks where the holes needed to be drilled. On the 5” piece, two holes were placed on each side, about \( \frac{7}{8}\)” and \( \frac{1}{2}\)” from the edges (seen in Figure 6). The 18” piece had two marks placed 4” from the end of the pipe, spaced a little less than an inch from each other. The 45-degree elbow (the coffin joint) had two marks drawn about 1¼” from the bottom of thicker end, and about \( \frac{7}{8}\)” apart. The T junctions had four marks on each side placed about \( \frac{3}{8}\)” from the end (as shown in Figure 7). The 6” piece had two holes, separated by about \( \frac{5}{8}\)” marked about two inches from the top, and a similar two holes about 1½” below the first ones.

Figure 6: Markings indicating where to drill holes on the 5” PVC piece.
We drilled the holes using the $\frac{5}{16}$” drill bit for the 18” piece and the elbow. The holes in the T junction pieces and the 5” pieces were drilled with the $\frac{9}{64}$” drill bit. In the P trap, two holes were drilled with the $\frac{5}{16}$” drill bit about $\frac{1}{2}$” from the top of each side, and one about 1½” from each side. The $\frac{5}{16}$” drill bit was also used to drill two holes about 1½” from the edge of the middle. The $\frac{9}{64}$” drill bit was used to make two holes on each side of the bigger holes in the middle, and two holes on each side 1 3/4” and 2” from the top (Figure 9).
Figure 8: Drilling the holes in the 18” piece.

Figure 9: The holes drilled in the P trap piece.

We smoothed the pieces with the Dremel, so they would fit together and move easily. Next, 1” hex washer slotted screws were put in about 1¼” from the bottom of the
T junction into both sides of the end of the 18” piece, and the 5” piece was attached to the same T junction, screwed in about ¾” from the edges. The other T junction was screwed onto the 6” piece about 1¼” from the bottom, into both sides of the end.

Figure 10. Where the screws are placed on the T junctions.

**Attaching the Pieces**

To attach the pieces of the model, we used the fishing line and the rope, and represented the tendons in a horse’s leg. Suture knots were used to tie the fishing line. To tie a suture, the ends of the line are crossed to form a loop, and one end is wrapped around the other. The short side is then again crossed over the longer side, then wrapped around and passed under the longer end. The sides are then pulled to tighten. This can be done by hand or with the help of needle nose pliers. The pliers also came in handy when
pulling the line through the holes of the PVC. That method involved sending a piece of fishing line through a hole, then sending another piece through the second hole as a loop. The loop would catch the end of the line from the first hole and pull it through the second one.

First, the fishing line attached the two T junctions, by threading the line through one of the holes on the end of the T junction attached to the 18” piece (cannon bone) to the corresponding hole in the T junction attached to the 6” piece (pastern bones), then over to the next hole. This was repeated until all four holes of the T junctions were attached, on both sides, and the ends were knotted. These were the collateral ligaments of the fetlock joint. At this point the model could bend but was still pretty loose.

Next, the P trap (sesamoid) was attached to the model by threading the line through the top left hole of the sesamoid, on the left side behind the ligaments threaded to attach the T junctions, and through the innermost hole on the left side of the 5” piece. The end was pulled through the outermost hole on the left side, and up through the bottom left hole of the sesamoid bone. The ends were tied together, and this was all repeated for the right side of the model. These were the palmar annular ligament.

Then, the sesamoid was attached to the pastern bones by threading the line through the bottom hole of the left side of the pastern bone. It was then fed up through the bottom hole on the right side of the pastern bone. Then it was sent down through the outermost right bottom hole of the sesamoid, and up through the outermost left hole. The ends were tied tight and cut. This represented the oblique sesamoid ligament.

The straight sesamoid ligament was created by sending the fishing line down the left hole on the top of the pastern bone, and up through the top right hole. The line was
sent down the second outermost right hole of the sesamoid, and up through the second outermost left hole. The ends were knotted and tied.

To represent the short sesamoid ligament, fishing line was sent down through the left hole of the T junction attached to the pastern, and back up through the right hole of the T junction attached to the pastern. The line was then sent down through the bottom innermost right hole of the sesamoid, and back up through the bottom innermost left hole of the sesamoid. The ends were tightened, tied together and the fishing line was cut.

The suspensory ligament was represented by the rope. To start, the rope was sent down through the right hole of the coffin joint, and back up through the left hole. The rope was crossed to the right side and sent into the large upper left hole of the sesamoid. It was then threaded through the large upper right hole, then the large lower right hole of the sesamoid. The rope was then fed through the left hole at the top of the cannon bone, then out through the upper right. The rope then went through the large lower left hole of the sesamoid. It was then threaded through the large upper left hole, then the large upper right hole of the sesamoid. The rope should fit snugly over the curve of the T junction attached to the cannon bone. On the front of the model, the rope was twisted several times, then sent through the left hole of the coffin joint. It was pulled back up through the right hole of the coffin joint, and knotted. The lighter was used to burn the ends of the rope to prevent fraying and used to make pulling the rope through the holes easier.
The Building Workshop

We recruited students through email after getting IRB approval. I sent an email to Laura Wilson, a University of Maine 4-H STEM Ambassadors Program coordinator, and asked for her assistance in finding local 4-H high school students that may be interested. She sent our email out and we received interested responses, which we then sent consent forms to.

We held the workshop at Witter Farm at the University of Maine on a Saturday from 10 am to 1 pm. Witter, a working farm, houses live cows, sheep, and horses, and students take care of the animals as part of a class or a club. The PVC skeleton is currently located there as well, and there is a real equine skeleton in the classroom of the barn. Dr. Causey and Megan Demers, a fellow Animal Science senior also working with the PVC model, were there to help the students while I took notes and photos. They answered any questions the students had and guided them to tie suture knots. They did

Figure 11. Our practice model (top) and Toothaker’s simple model (bottom).
not provide step-by-step instructions or directly tell students what they needed to do. We had two groups of two students each, with another group of two who had to leave early, so they were just watching the process. Everyone participating was a high school-age girl, and all were either involved in 4H, riding lessons, or had some previous knowledge of horses. The students were told they could leave questions blank or state if they did not know something on any of the tests, and they were allowed to stop the model building at any time if the felt like they did not want to proceed. No answers were left blank and all four students participated in the whole workshop.

Students silently took the pre-test (Appendix A) after they arrived at the Witter Farm classroom, and we briefly described the outline for the day. They took about ten minutes to finish. The first question of the pre-test had the students label the Suspensory ligament, extensor branch of the suspensory ligament, lateral collateral sesamoid ligament, short sesamoid ligaments, straight sesamoid ligament, oblique sesamoid ligament, cannon bone, long pastern bone, fetlock, sesamoid bones in a picture of a horse’s lower leg. Each correct label equaled one point, for a total of ten points. The second question was “What is the stay apparatus?” and the accepted responses (Appendix D) included the mechanism that allow horses to stand and bear weight using ligaments instead of muscles (for one point), or that ligaments lock in place to save energy while the horses sleep (for one point). Any extra detail would get a full three points. The third question was “How can creating this model help you or students like you learn?” and any on-topic attempt to answer would earn three points. Some of my ideas were learning the anatomy and physiology, getting hands-on learning experience, and understanding the mechanics of the movement.
Next, we took the students out to the barn to see Whiteout, one of Witter Farm’s mares. Dr. Causey gave them a mini lesson on the lower leg and showed them the stay apparatus in motion. This real-life example was included to give a little bit of background information, and to help the students visualize the leg before constructing the model. This may not be replicable for everyone, and possible replacements could be watching online videos of the stay apparatus and horses’ legs, or perhaps by using a pre-constructed PVC model.

The students started to build the legs at about 10:40 am. They had the post-tests in front of them to use the picture (Figure 12) as reference if needed, but they were not allowed to fill them out yet.
Group 1 was Student 1 and Student 2, and Group 2 was Student 3 and Student 4. They were shown the cannon bone, sesamoid bone, and lateral collateral ligaments on the example model we had previously built. The equine skeleton in the classroom also served as a brief example of where parts were. We did not offer them any specific directions, but they were able to ask for help and to see the model we had made as a reference. Megan and Dr. Causey offered help when the groups asked for assistance, either by explaining the parts of the model or the actual anatomy of the leg, or by answering questions students had. The groups were able to see each other, and listen to the answers of any
questions, but they did not interact or help each other. Dr. Causey showed both groups how to tie suture knots with needle nose pliers, which was how they connected the pieces and tied the fishing line.

Figure 13. The setup for each group.

Both groups figured out where the line went and put the pieces together, but both groups had to untie and retie some knots several times. Megan showed Group 2 how to connect the sesamoid to the attached cannon bone and position it correctly, and then did the same for Group 1. The groups had to stop, and Megan and I had to drill 4 more hole on each pastern bone, which had been overlooked as we were making the kits. When the groups were attaching the sesamoid bone to the short pastern, Dr. Causey gave them an explanation of several differences between the model and the real thing, such as the
sesamoid and navicular bones, and again compared the model to the skeleton in the classroom.

Figure 14. Group 1 threading the fishing line.

Figure 15. Group 2 comparing their model to ours.
After the fishing line had been tied, the groups tried to move and bend the legs. But we had not trimmed the tops of the T junctions as much as they should have been, so we had to stop again so Megan, Dr. Causey and I could trim them for both groups. Group 2 had been finishing their model faster than Group 1. By around 11:55 am, both groups were ready to use the rope. They were given the option to choose between the ropes shown in Figure 15, and both groups chose the red rope. Group 1 finished with their model by 12:15 pm, and Group 2 finished theirs by 12:20. Dr. Causey went over the parts of the leg on the model again and demonstrated how the ligaments worked.

Figure 16. The rope options and fishing line.
Figure 17. *Group 1 pulling the rope through.*

Figure 18. *Group 2 pulling the rope through.*
Figure 19. Final Product: *Group 1 model (left) and Group 2 model (right).*

The post-test was administered after the students completed their models. They did the post-test (Appendix B) and reflection questions (Appendix C) at the same time, and everyone was finished within 25 minutes. Group 1 was quiet, but Group 2 was talking amongst each other, mostly off-topic, but discussing what “hinder” meant. They landed on the correct definition but still seemed to misunderstand, based on the answers on the reflection questions. The post-test had the same first and second questions, and same answers, as the pre-test. Question three of the post-test was “What are some differences between this model and an actual horse’s leg? E.g. Extra or missing joints, size comparisons, etc.” I was looking for answers like the bones aren’t the correct shape or number, the size or scale of the model doesn’t correspond, the hoof angle and shape is incorrect, etc., but each true answer would earn a point.
The reflection questions I included (Appendix C) were “How did working with others help you during this process?” and “How did it hinder you?” so we could evaluate the teamwork portion of the process. The questions “What did you do that worked the first time you tried it?” and “What part took many tries to get right?” were to see what might need to change if this project were done again, to make it easier or more challenging. To evaluate how the students felt about this particular workshop, we asked, “What was the best part of this process and why?” and “What was the worst part and why?” The final question was “What advice would you give other students working on a similar project in the future?” and their answers could be provided to students doing this workshop in the future.

**Qualitative Coding Process**

In this exploratory study to pilot and analyze model-building as an effective learning tool, to ensure validity, I worked with Drs. McGuire and Causey to develop Bloom’s Revised Taxonomy codes to evaluate student learning. We analyzed the language of the students’ answers to the pre-test and post-test. A level 0 would be a blank, or an “I don’t know” answer. A level 1 answer includes language that shows the student remembered something. Level 2 would be students showing an understanding from their language in the answers. This continues up until level 6, create (Figure 21). Using the pre- and post-test responses, we collectively coded several student quotes, and came to a consensus on the codes, ensuring validity and reliability.
RESULTS

Student 1 received a 5/16 on her pre-test, Student 2 received a 6/16, Student 3 received a 3/16, and Student 4 also received a 6/16. All four of the students answered, “I don’t know” for question 2 on the pre-test. All of the students, at the least, doubled their scores from the pre-test to the post-test. For the post-tests, Student #1 got a 11/16, Student #2 got a 12/16, Student #3 got a 9/16, and Student #4 got a 13.5/16.
Question 1 of both the pre-test and the post-test was, “Match the names to the correct bones and ligaments: Suspensory ligament, extensor branch of the suspensory ligament, lateral collateral sesamoid ligament, short sesamoid ligaments, straight sesamoid ligament, oblique sesamoid ligament, cannon bone, long pastern bone, fetlock, sesamoid bones.” The students’ answers are presented in the table below.
Table 1. Correct answers for Q1 of the pre- and post-tests from each student

<table>
<thead>
<tr>
<th>Ligaments</th>
<th>Pre S1</th>
<th>Pre S2</th>
<th>Pre S3</th>
<th>Pre S4</th>
<th>Post S1</th>
<th>Post S2</th>
<th>Post S3</th>
<th>Post S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspensory ligament</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>extensor branch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>lateral collateral sesamoid ligament</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>short sesamoid ligaments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>straight sesamoid ligament</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>oblique sesamoid ligament</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bones</th>
<th>Pre S1</th>
<th>Pre S2</th>
<th>Pre S3</th>
<th>Pre S4</th>
<th>Post S1</th>
<th>Post S2</th>
<th>Post S3</th>
<th>Post S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>cannon bone</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>long pastern bone</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>fetlock</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>sesamoid bones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Student 1 originally only labeled two bones and ligaments correctly, but she labeled eight right in the post-test. Student 2 went from labelling three correctly to all ten correctly. Student 3 had not had any correct labels in the pre-test, but she got five right on the post-test. Student 4 started out with three correct for question 1, and nine right in question 1 for the post-test.
Question 2 of the pre-test and the post-test was, “What is the stay apparatus?” All four students answered, “I don’t know” for the pre-test. Student 1’s answer for the post-test was “It is a way for the horse to stand without the horse using muscles, only ligaments.” Student 2 said, “The ligaments lock in place so the horse doesn’t use energy to stand.” Student 3 answered, “Stay apparatus is where they don’t have to use there [sic] ligaments when they stand so they save energy.” Student 4 replied, “The mechanism (way the joints are arranged) that allows the horse to bear weight on its legs without using any muscle energy.”

None of the students had an answer for question 2 of the pre-test, and afterward, they demonstrated some understanding of what the stay apparatus was after the model building, and all earned at least one point.

For post-test question two, Student 1 earned one point because she had a basic understanding of the stay apparatus, but did not provide many more details to get extra points. Student 2 also only earned one point for the same reason. For Student 3’s answer for question 2, she received one point for a partially correct answer. She had the right idea, but had replaced muscles with ligaments. I could not tell if “muscles” was meant to be erased or left as part of the answer, but “ligaments” was written darker and more legibly, so that is what I went with. Student 4 earned two points for this question because she had a better understanding of the stay apparatus, or at least added more details. She still did not include all of the details I was looking for, so she did not earn the full three points.

Question 3 of the pre-test was, “How can creating this model help you or students like you learn?” Student 1 said, “This will help me learn parts of the horse leg and show
me how they move.” Student 2 replied, “Interactive learning, visualize what is where and why, and get a deeper understanding.” Student 3 answered, “Knowing where all of the bones and ligaments are.” Student 4’s answer was, “Learn names of bones and ligaments, and learn the mechanics of a horse leg.”

In the pre-test, Student 1 was given three points for an answer for question 3 because her answers were true and on-topic. Student 2’s answer got 3 points, because she was also on-topic, and her answers made sense. For Student 3’s pre-test question 3, she got all 3 points for an on-topic and true answer. Student 4’s answers earned her all three points for the same reason.

Question 3 on the post-test was, “What are some differences between this model and an actual horse’s leg?” Student 1 replied, “Not the same size, and not a perfect 90-degree angle.” Student 2 answered, “Sesamoid bones; there are normally 2 [proximal].” Student 3’s answer was, “A horse has bigger ligaments or bones then [sic] the model, the horse model leg is not as accurate as a real horse leg, and it doesn’t represent blood flow.” Student 4 said, “A horse’s leg is much bigger than the model, there is no way to represent skin and blood flow to the hoof, and there idk [with a picture of the bottom of the leg, and I assumed it represented the bend or angle at the fetlock].”

Student 1’s answer for post-test question 3 received two points for valid answers. She only had two ideas, so she earned two points. I gave Student 2 one point for her valid but short answer for this question. For question 3, Student 3 received all three points because she provided three answers. Student 4’s answer for number three earned her 2.5 points. She could have earned the full three points if she had more clearly explained her picture.
Question 3 of both tests cannot be compared because they are not the same question. These questions are more of an application type of question. They were included as another reflection question, one before the process and a different question after it, as opposed to the knowledge questions. Question 3 of the pre-test could be considered a level 2 on Bloom’s taxonomy because the students would understand what they are doing and why they are doing it. None of the students “applied” their answers, so it would not reach level 3. The answers to question 3 of the post-test can be considered level 3 or level 4 of Bloom’s taxonomy, because students need to analyze and apply their knowledge to interpret differences between the model and a real leg.

Students were given partial credit for some answers because while they may not have included all of the points I was looking for, they did have some idea of the answers. For example, if they did not include both of the main ideas that were the answer for question 2, then they would not get both points. But if they included one of them in their answer, they received one of the points. Partial credit was given to partial answers, such as the drawing one student included. I partially understood what she meant by the image.
Table 2. Percent change of the students’ scores from pre-test to post-test

<table>
<thead>
<tr>
<th>Q1. Labeling ligaments and bones</th>
<th>% change</th>
<th>% change</th>
<th>% change</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>60.00%</td>
<td>70.00%</td>
<td>50.00%</td>
<td>60.00%</td>
</tr>
<tr>
<td>Student 2</td>
<td>33.33%</td>
<td>33.33%</td>
<td>33.33%</td>
<td>66.67%</td>
</tr>
<tr>
<td>Student 3</td>
<td>37.50%</td>
<td>37.50%</td>
<td>37.50%</td>
<td>46.88%</td>
</tr>
<tr>
<td>Student 4</td>
<td>37.50%</td>
<td>37.50%</td>
<td>37.50%</td>
<td>46.88%</td>
</tr>
</tbody>
</table>

For the reflection questions, the first was “How did working with others help you during this process?” Student 1 responded with, “I wouldn’t be strong enough or be able to do it alone.” Student 2 said, “Made some work easier.” Student 3 replied, “That if more people then there is someone to help you and hold things.” Student 4 answered, “There are more sets of hands, and you can discuss challenges and problems with the other people in your group.”

The second reflection question was “How did it hinder you?” Student 1 said, “I don’t know.” Student 2 replied, “To remember previous knowledge of bones.” Student 3’s answer was “it was good working with a partner because I get distracted.” Student 4 answered, “I didn’t get the ‘fun’ experience (honestly I don’t think I would’ve figured it out alone).”

Reflection question 3 was “What did you do that worked the first time you tried it?” Student 1 said, “Tying the knots with the plier.” Student 2 responded, “Nothing, it
had to be tighter or we put the line through the wrong hole.” Student 3’s answer was, “Knotting the strings that needed to be tightened.” Student 4 said, “Knotting and tightening the strings.”

The fourth reflection question was, “What part took many tries to get right?” Student 1 answered, “Doing the loop to pull it through in another hole.” Student 2 said, “Most of it.” Student 3 replied, “Getting the rope through the holes.” Student 4 responded, “Getting the rope through the holes.”

The fifth of the reflection questions was, “What was the best part of this process and why?” Student 1’s answer was, “It was really cool to see it all come together and learn new things.” Student 2 answered, “Doing the rope because it was more fun.” Student 3 said, “The best part was getting to know more so when my horse has a problem I can help.” Student 4 replied, “How much I learned about the structure of a horse’s leg, and working with others to figure out challenges.”

Reflection question six was, “What was the worst part and why?” Student 1 said, “Nothing.” Student 2 responded, “Having to keep redoing things.” Student 3 answered, “Struggling and getting angry that the rope won’t go in because the holes aren’t big.” Student 4 replied, “Getting frustrated with the rope- but that was short-lived anyways.”

The last reflection question was, “What advice would you give other students working on a similar project in the future?” Student 1’s answer was, “Don’t get frustrated, accept help, listen/pay attention, and tie tight.” Student 2 answered, “To really pay attention where things go.” Student 3 replied, “Work together, be persistent, and make sure the holes are big.” Student 4 said, “Ensure you have all the materials and holes drilled necessary before you start.”
Table 3. Bloom's taxonomy levels for question 1

“Match the names to the correct bones and ligaments: Suspensory ligament, extensor branch of the suspensory ligament, lateral collateral sesamoid ligament, short sesamoid ligaments, straight sesamoid ligament, oblique sesamoid ligament, cannon bone, long pastern bone, fetlock, sesamoid bones.”

<table>
<thead>
<tr>
<th></th>
<th>Student 1</th>
<th>Student 2</th>
<th>Student 3</th>
<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 pre-test</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Q1 post-test</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Students 1, 2, and 4 were rated at a level 1 for the pre-test because they all remembered at least some bones or ligaments from past lessons or their own experiences. Student 3 did not label any parts correctly, so she was rated at a level 0. For the post-test, they all achieved a level 2 because while they didn't remember most of the bones and ligaments before, afterwards they understood where the parts are and how they connect.

Table 4. Bloom's taxonomy levels for question 2

“What is the stay apparatus?”

<table>
<thead>
<tr>
<th></th>
<th>Student 1</th>
<th>Student 2</th>
<th>Student 3</th>
<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2 pre-test</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Q2 post-test</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The students all started at a level 0 for the pre-test, because their answers were all “I don’t know,” so they were not up to the remember of level 1. In the post-test, they all achieved level 2 because they not only remembered what the stay apparatus was, but they understood the purpose of it. Some of the words that allow us to realize this include “the ligaments lock SO THAT…” or “NO muscle is USED, BUT.” This showed that the
students were able to explain and describe their answers. Student 1 earned a level 2 because she explained that muscle is not used, and explained what is used instead.

Student 2 also earned a level 2, and that is because she explained why the ligaments lock. Student 3 earned a level 2 because she explained how horses save energy using the stay apparatus. Student 4 achieved a level 2 because she described the mechanism and what it allows, as well as what it doesn’t include.
DISCUSSION AND CONCLUSIONS

This was an exploratory study to understand how an active-learning design of model building could be used to improve student learning of anatomy. It is an extension of the life-size PVC model construction that has been going on for several years. The workshop was part of an ongoing curriculum development process, and these results will inform the next iteration of the process. We found through our Bloom’s Revised Taxonomy [12] analyses, that all of the students increased their scores and their understanding from the pre-test to the post-test. The overall positive direction of change supports continuation, expansion, and further assessment of model building as an effective educational tool.

One common theme of the answers from reflection question 1 was that working with someone else made the process physically easier. One student said discussing challenges and problems in a group made things easier. These were both answers I was hoping for when I decided to put them in groups. The model building can be done by one person, but two or more makes the process faster and easier. This is relevant to the project because the amount of students working together can affect the quality of learning for both the anatomy, and the other skills such as teamwork.

For the second reflection question, I believe a few of the students may have been confused about what “hinder” meant or did not want to write an answer that their group member may have been able to see. The student that answered, “to remember previous knowledge of bones,” may have been talking about how she could not remember the bones of the leg, but did not really have much to do with her partner. Two other students...
mentioned more positives about working with a partner, like not getting distracted as much, or not being able to figure out the construction of the model on her own. This again suggests that for future workshops, students should be kept in pairs or small groups of three or four.

For reflection question 3, using the pliers and knotting and tightening the line and rope worked pretty well the first time the groups tried it. One student said nothing worked the first time, but with no written or step-by-step instructions, this process was meant to be trial-and-error. This method of teaching was important to understand how the students learned not only the anatomy and physiology portion, but the other skills such as problem-solving.

In reflection question 4, the same student that said nothing worked the first time said most of the process took multiple tries to get right. For example, the sesamoid bone was facing the wrong way the first time both groups attached it to the leg. All of the other students said getting the rope through the holes took the most tries, but that can easily be fixed by drilling bigger holes or using slightly smaller rope.

One student enjoyed seeing the model come together, and another said she enjoyed the rope part. Most of the students said that learning was the best part, for the fifth reflection question. One of the main goals for the students was to make learning more fun and interactive. One student mentioned working in a group as a positive, which was good since not everyone enjoys group projects.

Frustration with getting the ropes through the holes seemed to be the main annoyance with this workshop, but it could easily be fixed by drilling the holes slightly
bigger. The need to redo things was one student’s answer to reflection question six. And one student said there were no worst parts, which is a good thing to know.

The last reflection question provided useful information for any future workshops. Telling students to be sure to tie tightly and pay attention to what goes where could save some frustration. And on our part, making sure we have drilled all the necessary holes and have made them large enough for the rope, would also make things go a little smoother. The tautness of the rope is important for the stay apparatus. A smaller width of rope could work as long as it’s mobile enough.

The trial-and-error process frustrated the students at first, as evident through their responses to the questions and appearance during the workshop. But they became more comfortable as the building continued. Giving the students step-by-step instructions could lead to different results than the “broad task” method we used, because different skills would be used.

In the pre-test, several of the students labeled some parts incorrectly. Student 1 mislabeled the fetlock. Student 2 mislabeled the suspensory ligament and the straight sesamoid ligament. Student 3 incorrectly labeled the cannon bone, the long pastern bone, and the fetlock. Student 4 incorrectly labeled the oblique sesamoid ligament, the lateral collateral sesamoid ligament, the straight sesamoid ligament, and the sesamoid bones.

In the post-tests, there were more guesses for labeling, even if some were still incorrect. Student 1 incorrectly labeled the fetlock and the straight sesamoid ligament. Student 2 labeled everything correctly. Student 3 mislabeled the lateral collateral sesamoid ligament, the extensor branch, the oblique sesamoid ligament, the suspensory
ligament, and the short sesamoid ligaments. Student 4 only mislabeled the oblique sesamoid ligament.

The labels students got wrong on the first question were included in the data because it shows the students attempted an answer. They had the confidence to try and label more of the parts in the post-test than they did in the pre-test, and they did not answer any questions with “I don’t know” in the post-test. I believe they had increased confidence because they knew and understood the answers. The reflection questions might suggest this, with the students saying they had better understandings or the anatomy.

Prior to this workshop, three of the students knew each other. The fourth did not know any of them. When we told them they would be working in pairs, two of the girls that knew each other automatically chose each other, and the third girl was going to work with the girl nobody had known before. They all seemed comfortable splitting themselves up in this way. The group that had known each other was Group 2, Student 3 and Student 4. They giggled and had quite a bit more noise than the other group, and worked together pretty well. Student 1 and 2 were the partners in Group 1 that hadn’t known each other, and they were a little reserved and shy at first. But as they got working together they warmed up and worked well.

Since this workshop was successful in that students ended up with a better understanding of equine anatomy and they enjoyed the process, one day it may be possible to sell kits like the one we created. They would be precut and predrilled, so the students would only need to put them together, but they could still make in more in depth with labeling parts and learning about anatomy. If schools wanted to implement this
project by themselves, they could go out and buy the necessary equipment and have the students cut and drill, or a teacher could do it for them. The PVC pipe used in the kit is a relatively cheap cost for schools with low budgets, like my hometown school. Many schools, 4H programs, or other institutions interested in using this method to build a model would have the means to.

A school or 4H program with more resources and access to a 3D printer would be able to print more accurate bones and have better sizes and measurements. Schools without the means to purchase the materials could be sponsored by 4-H programs, or partner with veterinary schools or practices to host the workshop. The University of Maine has the capacity to help schools in this way, with a Research Practice Partnership program. Programs such as the Animal and Veterinary Sciences (AVS) department, the Maine Center for Research in STEM Education (RiSE), and the Center for Innovation in Teaching and Learning (CITL) could all be resources available to local schools looking to hold this workshop.

The outcome of this workshop is relevant to horse racing because education of equine anatomy can lead to prevention or treatments of injuries sustained by racing. The age of a horse when it starts racing matters, because development is at different stages. In Europe, they wait until horses are older than the two-year-olds that race in America. Ethics of racing is a gray area, but by educating those involved, it may be better for all involved. There are deaths from racing injuries, but with lessons such as this, injuries, especially fatal injuries, might be lessened. By understanding the stay apparatus and the anatomy of the leg, horse owners and trainers can spot problems sooner. This workshop could be held for trainers of all ages and experience levels to give them this
understanding, too. If they know what it’s supposed to look like, then if there is a problem, they could understand how it works and see the impact of racing over time. Another reflection question to add to future workshops could be, “How does this activity help you understand horse racing?” It could be reworded to allow students to answer at the apply or analyze level.

**Study Limitations and Curriculum Changes**

I would make changes to these methods if the workshop was replicated. More accurate measurements would lead to a more accurate model. Actual measurements and calculations for the distances between holes when drilling, the sizes of the holes, the lengths and angles before cutting, and even the lengths of the rope and fishing line would be better. It is important to double check that all the parts are included, and that all the holes are drilled and pieces are cut.

For future research, I would suggest including larger and more diverse groups of students in the workshop. My participants were all females, because no males responded to the invitations. I chose to work with high school-aged students for their assumed knowledge base, but this activity could be simplified for middle school students or made more difficult for college students. I also specifically asked for those with some knowledge of horses, and next time it could be done with either students who know nothing about horses, or equine minors at the college level. The way the students are split up could have an effect on the learning, too. So letting the students choose their partners may yield different results than selecting the groups beforehand, depending on the focus of the study.
In the case of a group with more specific or diverse base of knowledge, I would suggest adapting the pre-tests and post-tests to the student group. More questions could be added about just the anatomy and physiology, or more thought questions about how the process went, depending on the angle of the research. To get higher scores overall from Bloom’s taxonomy, the tests can ask higher-level application questions. If this workshop was done again, a good post-test question to ask would be, “How would you redesign this model to make the anatomy more accurate or easier to construct?” Questions such as this one could allow students to reach a higher level of Bloom’s taxonomy, such as apply or evaluate. Other deeper questions could include, “In what scenario would a horse use the stay apparatus?” or “What other animals do (or do not) have a stay apparatus?” A study designed with a control group that only read a textbook or listen to a lecture to compare to a group that builds the model would be a valuable extension of this work. Especially with a larger, more diverse sample, a future study could develop more extensive codes, and include additional validity and reliability measures.

The wording of the questions can also affect the results, by allowing students to answer at higher levels of Bloom’s Revised Taxonomy. The questions can also be changed to specifically ask about the different aspects of the workshop. One question about difficulties could be split up into, “What was the most physically challenging part?” and “What were some challenges with the collaboration?” Questions can be asked about not receiving instructions compared to step-by-step guidelines and how the students feel about that, depending on the method the researchers choose.
Conclusion

This would be possible to do in schools with the time constraints, over a few periods or in one lab, depending on the class times in different schools. If clubs or 4H groups would be interested, they could make weekend or evening workshops. It would also be possible to build models of different parts of the horse, or other animals. Students could work alone, or in groups as big as four. Hands-on building and integrated learning may not be the best methods for all students, but most teachers and students could benefit.

All of the students involved in this workshop showed a deeper understanding of the anatomy and physiology of the equine lower leg, based on the increase in test scores. Although none of them achieved a perfect score, their test scores all at least doubled between the pre-tests and post-tests. In discussions with the students before they left Witter, they all said the workshop was worthwhile, and overall they enjoyed the process. They would like to see more hands-on activities in their classrooms, and they believed they learned more from this method than they would have learned from reading papers or listening to a lecture from a teacher. This workshop not only helped the students learn equine anatomy and physiology, but taught them in an enjoyable way that they appreciated.
REFERENCES


APPENDIX A

Pre-test

1. Match the names to the correct bones and ligaments.

Suspensory ligament, extensor branch of the suspensory ligament, lateral collateral sesamoid ligament, short sesamoid ligaments, straight sesamoid ligament, oblique sesamoid ligament, cannon bone, long pastern bone, fetlock, sesamoid bones.
2. What is the stay apparatus?

3. How can creating this model help you or students like you learn?
APPENDIX B

Post-test

1. Match the names to the correct bones and ligaments.

Suspensory ligament, extensor branch of the suspensory ligament, lateral collateral sesamoid ligament, short sesamoid ligaments, straight sesamoid ligament, oblique sesamoid ligament, cannon bone, long pastern bone, fetlock, sesamoid bones.
2. What is the stay apparatus?

3. What are some differences between this model and an actual horse’s leg? E.g. Extra or missing joints, size comparisons, etc.
APPENDIX C

Reflection Questions

1. How did working with others help you during this process?

2. How did it hinder you?

3. What did you do that worked the first time you tried it?

4. What part took many tries to get right?

5. What was the best part of this process and why?

6. What was the worst part and why?

7. What advice would you give other students working on a similar project in the future?
APPENDIX D

Test Answers

1. (Ten points) One point for each correct label (listed on the test), out of the ten.

2. (3 points) We were looking for something along the lines of: the mechanism that allow horses to stand and bear weight using ligaments instead of muscles (1 point), or that ligaments lock in place to save energy while the horses sleep (1 point). Any extra detail would get a full three points.

Pre-test 3. (3 points) Student would get all three points if they attempt a relevant answer. Ideas like: learning the anatomy and physiology, getting hands-on learning experience, and understanding the mechanics of the movement.

Post-test 3. (3 points) We were looking for answers like: the bones aren’t the right shape or the correct amount, the sizes or scale of the model, the hoof, etc., but each valid answer would get a point.
APPENDIX E

IRB Application Approval

APPLICATION COVER PAGE

- KEEP THIS PAGE AS ONE PAGE – DO NOT CHANGE MARGINS/FONTS!!!!!!!!!
- PLEASE SUBMIT THIS PAGE AS WORD DOCUMENT

APPLICATION FOR APPROVAL OF RESEARCH WITH HUMAN SUBJECTS
Protection of Human Subjects Review Board, 400 Corbett Hall

(Type inside gray areas)
PRINCIPAL INVESTIGATOR: Emily Gorney EMAIL: emily.gorney@maine.edu
CO-INVESTIGATOR: EMAIL:
CO-INVESTIGATOR: EMAIL:
FACULTY SPONSOR: Robert Causey & Julia McGuire EMAIL: rcaus@maine.edu;
    julia.mcguire@maine.edu
(Required if PI is a student):
TITLE OF PROJECT: Building a Better Understanding of Equine Anatomy Through Construction of a
Model
STATUS OF PI: FACULTY/STAFF/GRADUATE/UNDERGRADUATE U (F,S,G,U)

If PI is a student, is this research to be performed:

☐ for an honors thesis/senior thesis/capstone? ☐ for a master’s thesis?
☐ for a doctoral dissertation? ☐ for a course project?
☐ other (specify)

Submitting the application indicates the principal investigator’s agreement to abide by the responsibilities outlined in Section I.E. of the Policies and Procedures for the Protection of Human Subjects.

Faculty Sponsors are responsible for oversight of research conducted by their students. The Faculty Sponsor ensures that he/she has read the application and that the conduct of such research will be in accordance with the University of Maine’s Policies and Procedures for the Protection of Human Subjects of Research. REMINDER: if the principal investigator is an undergraduate student, the Faculty Sponsor MUST submit the application to the IRB.

Email this cover page and complete application to UMRIC@maine.edu

*******************************************************************************
FOR IRB USE ONLY Application # 2019-01-16 Review (F/E): E Expedited Category: L,G3,g
ACTION TAKEN:

☐ Judged Exempt; category Modifications required? Accepted (date)
☐ Approved as submitted. Date of next review: by Degree of Risk:
☒ Approved pending modifications. Date of next review: by 2/25/2020 Degree of Risk: Minimal
  Modifications accepted (date): 2/26/2019
☐ Not approved (see attached statement)
☐ Judged not research with human subjects

FINAL APPROVAL TO BEGIN 2/26/2019
Date 10/2018
APPENDIX F

Question 2
(Pre- and post-test)

What is the stay apparatus?

<table>
<thead>
<tr>
<th>Pre-test</th>
<th>Student 1</th>
<th>Student 2</th>
<th>Student 3</th>
<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I don’t know</td>
<td>I don’t know</td>
<td>I don’t know</td>
<td>I don’t know</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post-test</th>
<th>Student 1</th>
<th>Student 2</th>
<th>Student 3</th>
<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>It is a way for the horse to stand without the horse using muscles, only ligaments.</td>
<td>The ligaments lock in place so the horse doesn’t use energy to stand.</td>
<td>Stay apparatus is where they don’t have to use there [sic] ligaments when they stand so they save energy.</td>
<td>The mechanism (way the joints are arranged) that allows the horse to bear weight on its legs without using any muscle energy.</td>
</tr>
</tbody>
</table>

Question 3 (Pre-test)

How can creating this model help you or students like you learn?

<table>
<thead>
<tr>
<th>Student 1</th>
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<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>This will help me learn parts of the horse leg and show me how they move.</td>
<td>Interactive learning, visualize what is where and why, and get a deeper understanding.</td>
<td>Knowing where all of the bones and ligaments are.</td>
<td>Learn names of bones and ligaments, and learn the mechanics of a horse leg.</td>
</tr>
</tbody>
</table>
Question 3 (Post-test)

What are some differences between this model and an actual horse’s leg?

<table>
<thead>
<tr>
<th>Student 1</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Not the same size, and not a perfect 90-degree angle.</td>
<td>Sesamoid bones; there are normally 2 [proximal].</td>
<td>A horse has bigger ligaments or bones then [sic] the model, the horse model leg is not as accurate as a real horse leg, and it doesn’t represent blood flow.</td>
<td>A horse’s leg is much bigger than the model, there is no way to represent skin and blood flow to the hoof, and there idk [with a picture of the bottom of the leg, and I assumed it represented the bend or angle at the fetlock].</td>
</tr>
</tbody>
</table>

Reflection Questions

Q1: “How did working with others help you during this process?”

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>I wouldn’t be strong enough or be able to do it alone.</td>
<td>Made some work easier.</td>
<td>That if more people then there is someone to help you and hold things.</td>
<td>There are more sets of hands, and you can discuss challenges and problems with the other people in your group.</td>
</tr>
</tbody>
</table>

Q2: “How did it hinder you?”

<table>
<thead>
<tr>
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<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I don’t know</td>
<td>To remember previous knowledge of bones.</td>
<td>it was good working with a</td>
<td>I didn’t get the ‘fun’ experience (honestly I don’t</td>
</tr>
</tbody>
</table>
partner because I get distracted. think I would’ve figured it out alone).

Q3: “What did you do that worked the first time you tried it?”

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Tying the knots with the plier.</td>
<td>Nothing, it had to be tighter or we put the line through the wrong hole.</td>
<td>Knotting the strings that needed to be tightened.</td>
<td>Knotting and tightening the strings.</td>
</tr>
</tbody>
</table>

Q4: “What part took many tries to get right?”

<table>
<thead>
<tr>
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<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doing the loop to pull it through in another hole</td>
<td>Most of it.</td>
<td>Getting the rope through the holes.</td>
<td>Getting the rope through the holes.</td>
</tr>
</tbody>
</table>

Q5: “What was the best part of this process and why?”

<table>
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<tr>
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<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was really cool to see it all come together and learn new things.</td>
<td>Doing the rope because it was more fun.</td>
<td>The best part was getting to know more so when my horse has a problem I can help.</td>
<td>How much I learned about the structure of a horse’s leg, and working with others to figure out challenges.</td>
</tr>
</tbody>
</table>

Q6: “What was the worst part and why?”

<table>
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<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing.</td>
<td>Having to keep redoing things.</td>
<td>Struggling and getting angry that the rope won’t go in because the holes aren’t big.</td>
<td>Getting frustrated with the rope- but that was short-lived anyways.</td>
</tr>
</tbody>
</table>

Q7: “What advice would you give other students working on a similar project in the future?”
<table>
<thead>
<tr>
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<th>Student 3</th>
<th>Student 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t get frustrated, accept help, listen/pay attention, and tie tight.</td>
<td>To really pay attention where things go.</td>
<td>Work together, be persistent, and make sure the holes are big.</td>
<td>Ensure you have all the materials and holes drilled necessary before you start.</td>
</tr>
</tbody>
</table>
AUTHOR BIOGRAPHY

Emily Gorney is from Sanbornville, New Hampshire. She has always been interested in working with horses, which led her to this project. She was also partially inspired to find new ways to learn by her high school Animal Science teacher, Carrie Hough, from Dover, New Hampshire. Emily chose to go to the University of Maine for the Animal Science program, and she is majoring in Animal and Veterinary Sciences.

After graduation, Emily will take a year to work and apply to the Kentucky Equine Management Internship before applying to veterinary school and would like to work with equine reproduction.