



Design of an Endoscopic Spine Trainer

BME Design 200/300

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### **Abstract:**

The medical field has had recent advancements in minimally invasive spinal surgeries made possible by endoscopic cameras and tools. Due to decreased patient recovery time there has been a drastic shift from general surgery to endoscopic surgery. Neurosurgeons generally have not practiced the hand-eye coordination skills necessary for endoscopic type of procedure. The current methods for endoscopic surgery which requires a specific type of hand-eye coordination training are expensive. For this project, we are designing a low cost, easily translatable endoscopic spine trainer for surgeons to master the skills of popping membranes, sweeping away tissue, and general camera maneuverability. The team showed a 29% improvement based on timed trials. However, there were many sources of error and much work is needed to implement more quantitative feedback.

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## **1. Introduction**

### **1.1 Motivation**

Our design is centered on the idea of our training simulator being translatable and cost-conscious. Any surgeon that desires to train for endoscopic spine surgery should be able to recreate our project no matter what corner of the world they are practicing in. The need for our project stems from several expensive simulators currently on the market and the lack of low cost alternatives. There is a need for our trainer because ours will be simple to build and will allow for hand-eye coordination training in a low-risk environment. The project itself is not focused on the anatomical correctness of an endoscopic surgery, but rather addressing the disconnect between neurosurgeons skilled in general surgery and the high-precision, low-maneuverability of an endoscopic procedure.

### **1.2 Existing Devices/ Current Methods**

The competing design with the most focus on only endoscopic spine surgery training is the SimBionix Spine Mentor. The Spine Mentor costs \$65,000 and is highly technological, as seen in figure one. The Spine Mentor mimics the surgical area by showcasing a 8” by 5” patch of skin like material. Beneath the layer of skin, are an array of polymers that mimics muscles, tissues, and spinal cord to create a high degree of anatomical accuracy. Also included is a virtual reality function which allows the user to both see what is happening during the procedure and the correct anatomical markers along the way [1]. The downfalls of the Spine Mentor mostly lie within cost. The cost of the spine simulator itself and the cost to replace the sophisticated polymers deter medical institutions away from purchasing it. The simulator also provides a sense of redundancy for neurosurgeons who are already familiar with the anatomy of the spine due to years of performing similar procedures with general surgeries. These surgeons need to learn how to use the endoscope and its tools, not rehash the anatomy. Therefore, a low cost trainer focused only on learning the skills associated with endoscope use is needed.



**Figure 1: Spine Mentor that shows increased anatomical correctness.**

## **1.3 Problem Statement**

Minimally invasive spine surgery is becoming more commonplace in the world of medicine. Despite endoscopic spine surgery being introduced for the first time in 1975, many hospitals did not begin implementing it until the last decade [2] which has led to the creation of a group of skilled neurosurgeons that excelled in general spinal and neurological surgeries but lack the skills required to make the switch to endoscopic spine surgery. The tools used in endoscopic procedures (i.e the angled camera) are significantly different from those used in standard procedures, and require the surgeon to use only one hand to maneuver the camera, and the other to manipulate the tools attached. Despite spinal surgery being a high-chance procedure, there is not a strong need for expensive training materials, even in countries with the means to purchase more expensive simulators. Surgeons are already well versed in the anatomy of the spine, and do not need to relearn anatomy, as they are training for endoscopic surgery. Current simulators on the market are expensive to purchase, expensive to maintain, and require difficult set up and a lot of room to use. There is a need for a low cost simulator that allows surgeons to develop the fundamental hand-eye coordination and skills needed to perform minimally invasive spine surgery on their own time and anywhere in the world. This also means it needs to be compact and easy to store due to varying states of medical institutions around the world. The disconnect does not lie within the anatomy. There is a need to simply practice camera skills and maneuverability by each surgeon on their own time and in an environment that focuses on only the skills themselves.

## **2. Background**

### **2.1 Endoscopic Surgery**

#### **2.1.1 Relevant Physiology and Biology**

To begin, we looked into how endoscopic spine surgery began to understand our workspace. The entire procedure takes place within a cannula that is placed using existing fluoroscopy technology, and the general methods used during a spinal tap such as the spinal needle test. A sheath that contains the endoscope and the tools attached to the endoscope such as specialized tweezers. The type of endoscope used in endoscopic spine surgery is known as a rigid endoscope. Cannula placement is minimally invasive and is such a common task for neurosurgeons that there is not need to focus on it in an endoscopic surgery [3].

We then strove to understand the different types of endoscopic spine surgery. The first type is an endoscopic lumbar discectomy. Lumbar discectomy surgery is used to remove herniated disks from any given part of the spine. The surgeon must traverse and push aside the nerves leading to the area of interest. Using saline solution the surgeon will clear the area of interest, locate the disk, and then pull it out of the affected area

relieving pressure in the patients spine. The second type of surgery is an endoscopic foraminotomy. The goal is to relieve pressure on spinal roots caused by bone spurs, disk herniation, and scar tissue by widening the hole in the intervertebral foramina. Another type of surgery is endoscopic facet rhizotomy. Endoscopic facet rhizotomy revolves around deadening damaged nerves in the spine so they can no longer send signals of pain the the brain. Next we looked at third ventriculostomy, which is used to alleviate hydrocephalus which is when there is too much fluid collected in your brain and it needs to be drained. With this surgery, a neurosurgeon needs to be aware that they pop through the desired membrane, but not other membrane beyond that. The last type of surgery we found was pituitary surgery, where a neurosurgeon needs to remove tumor tissue from the pituitary gland while avoiding damaging the carotid artery [2].

### **2.1.2 Endoscopic Access**

First we did more research on the tools that the surgeons would be using with our prototype. It is assumed that the surgeons will have access to the tools that they would use during normal non invasive spine surgery when they are practicing. The endoscopes that may be used consist of two different types. One is a laparoscope (used inside an abdominal cavity) and the other is an arthroscope (used inside a joint). These endoscopes are typically 5-7mm without the use of a canula or 14-18mm if they use a cannula [4]. The other tools that are not necessary but may be used include the cannula, bevel, and surgical grabber. These were discussed by our client Dr. Brooks but the universality of our prototype usal with multiple different kinds of surgery leaves other tools as options as well.

## **2.2 Client Information**

Nathaniel Brooks is a neurosurgeon and assistant professor at the University of Wisconsin Hospital. He specializes in disorders of the spine including herniated discs, spinal stenosis, and spinal tumors. He has extensively trained in the areas of revision spine surgery and minimally invasive spine surgery, giving him knowledge about both general surgery and endoscopic surgery. He received his M.D. from Medical College of Wisconsin, Milwaukee in 2002 and served a Fellowship in Cleveland Clinic Spine Institute before becoming a member of the Department of Neurological Surgery at the University of Wisconsin School of Medicine and Public Health [5].

## **2.3 Design Specifications**

The ideal design will mimic these three surgical tests utilized in endoscopic surgery: sweeping away tissue, maneuvering the camera on the endoscope, and popping through a membrane. These tasks come from three surgeries our client focuses on. Tissue sweeping is used in most endoscopic surgeries, but it is a large part of an endoscopic lumbar discectomy. In order

to mimic the lumbar discectomy, we must provide a material that is easy to clear with the sheath of a rigid endoscope as well as a material that pushes back when the user has reached an area they are not supposed to pass through. The material that pushed back will be representative of bones, nerves around the spine, and/or arteries (such as the carotid) that are present during a specific surgery.

Our camera maneuverability task must help the user understand the disconnect between what they are seeing on a screen outside of the body and what is actually happening in the body. The camera of an endoscope comes at a 30 degree angle. The user must be able to test their ability to rotate the endoscope a certain amount of degrees clockwise and counterclockwise as well as understand how far they are from their target.

The final task is designed to mimic a third ventriculotomy. The material chosen for a membrane must be representative of the third ventricle in difficulty to pop. There must also be some feedback of signal that allows the user to know if they have applied too much force to the membrane and have actually hit the basal artery behind the third ventricle.

The box must be under five pounds. It needs to be easily transported from the user's office to their home or wherever they may want to practice their skills. The outer shell of the box must last a year without needing replacement to avoid exorbitant costs. The materials used to build our trainer must be available at a local hardware store and must be able to be constructed easily. The design must also come with a guide on how to construct it in simple, easily replicable terms. The guide is to be added to a website or blog that will go on the client's website. Refer to Appendix A for full Product Design Specifications.

### **3. Preliminary Designs**

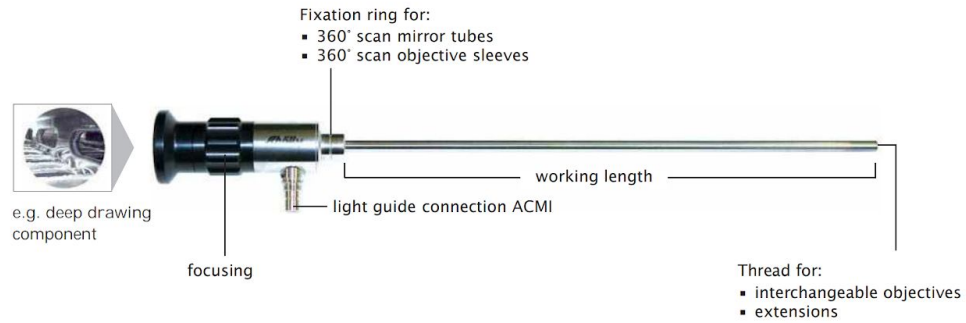
#### **3.1 Preliminary Designs**

##### **3.1.1 Commonality Between Designs**

Below are the team's three preliminary designs that will be used to house the three tasks mentioned in section 2.3. The tasks in these three boxes will be the same to avoid excess variability in the design. As of right now, these are materials and processes that will be utilized within each box

###### **3.1.1.1 Endoscope and Endoscopic**

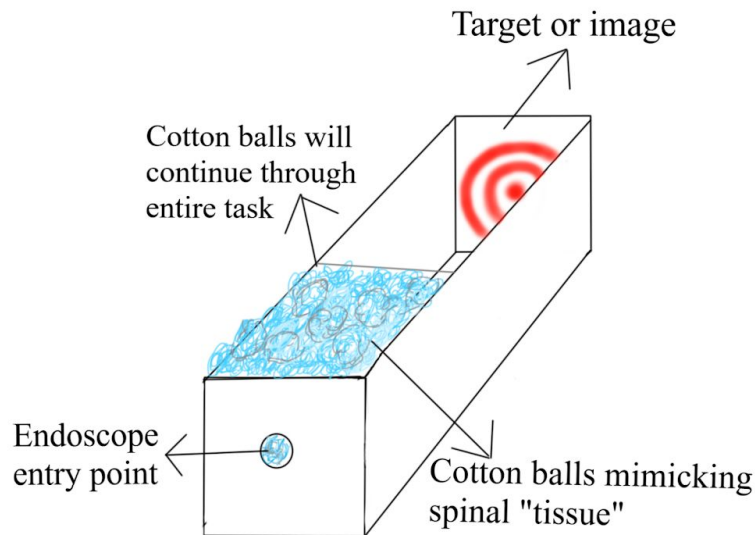
Our design will be utilizing existing endoscope technology (see Figure 1). The endoscope includes a rigid working length that houses the camera itself as well as three or four interchangeable tools chosen by the surgeon. The endoscope is then placed into a working sheath that is housed in the cannula mentioned in section 2.1.2. The sheath can be moved freely, has a beveled end, and is often used as a tool in surgery as well.



**Figure 2:** A specific type of rigid endoscope. Rigid endoscopes are utilized in minimally invasive spine surgery and all feature a common design.

### 3.1.1.2 Sweeping Tissue Task

To mimic tissue we will be using cotton balls packed in between the entry point of the design and the target at the end of said design. The user will need to sweep away the cotton balls to reveal a picture at the end of the task and success will be measured on how much of the work space/target that they are able to reveal.

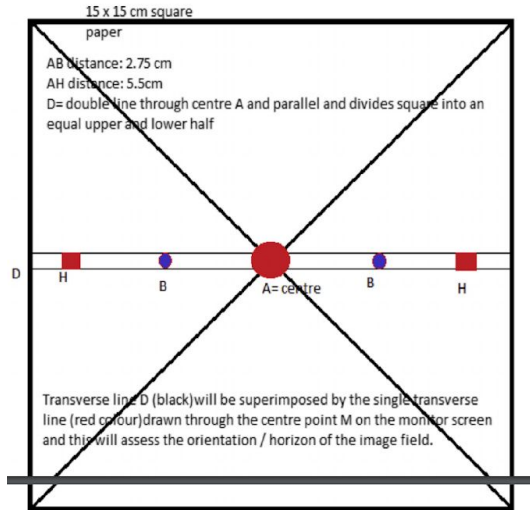


**Figure 2:** Layout featuring the path between the task entrance and task target

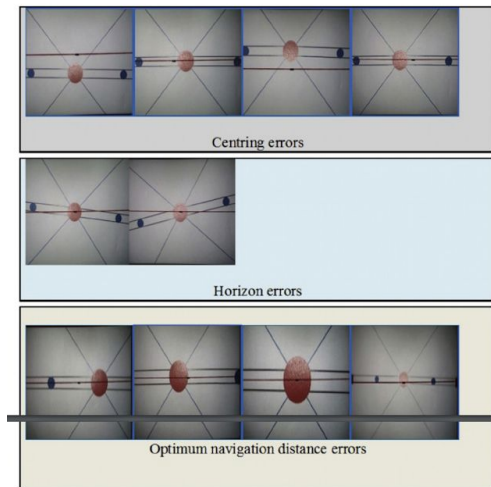
### 3.1.1.3 Camera Maneuverability

This task will be based upon the procedure set by M. Alam, M. Wilson, et al. in "A training tool to assess laparoscopic image navigation task performance in novice camera assistants" [6]. A target of our own creation will be placed on a wall of the trainer. The user will have to perform different tasks such as camera rotation to test how accurately they understand where the camera is within their work space.





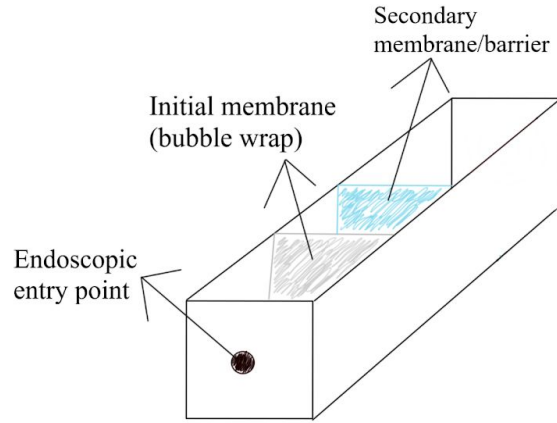
**Figure 4:** An example of a target that was used to test laparoscopic camera handling [6].



**Figure 5:** A range of errors that the test should be able to properly identify [6].

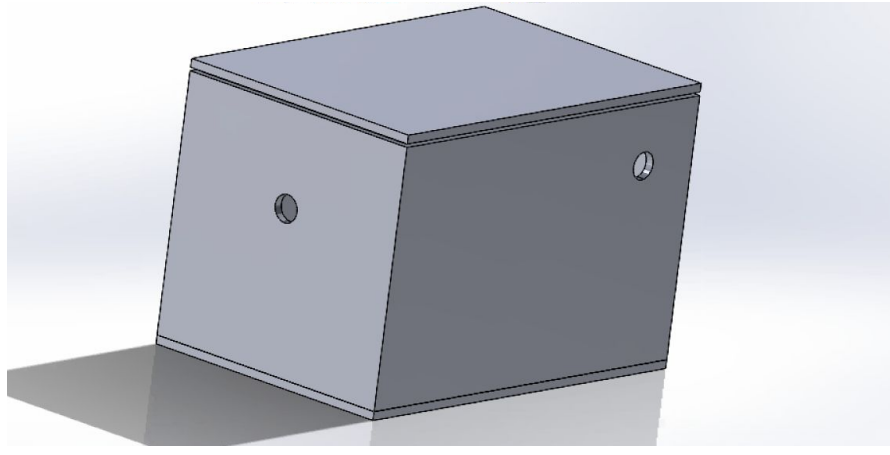
### 3.1.1.4 Popping Through Membrane

This task will utilize a sharp tool at the end of the endoscope of our choosing to pop through a material mimicking the third ventricle. The “membrane” will be created by securing a piece of bubble wrap on the walls of our box so it is taut and offers a certain level of resistance

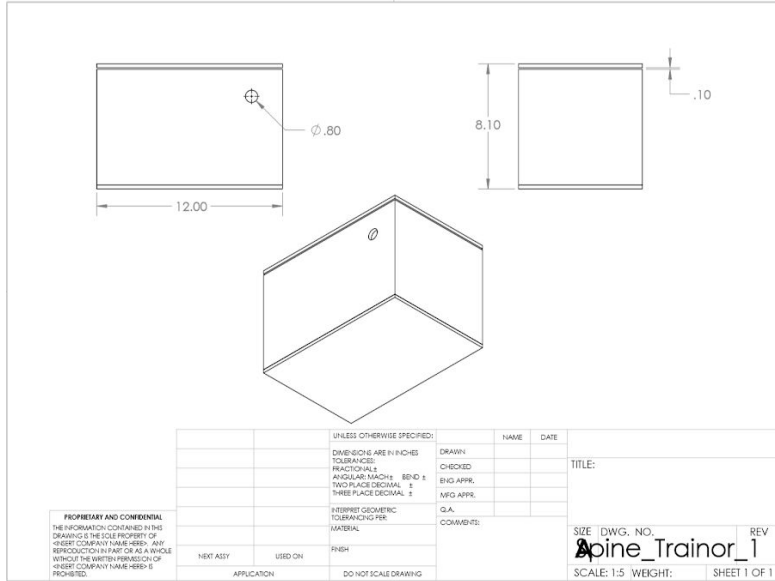


**Figure 6:** Layout of membrane placement within the trainer

**3.1.2 Interchangeable Task Design**



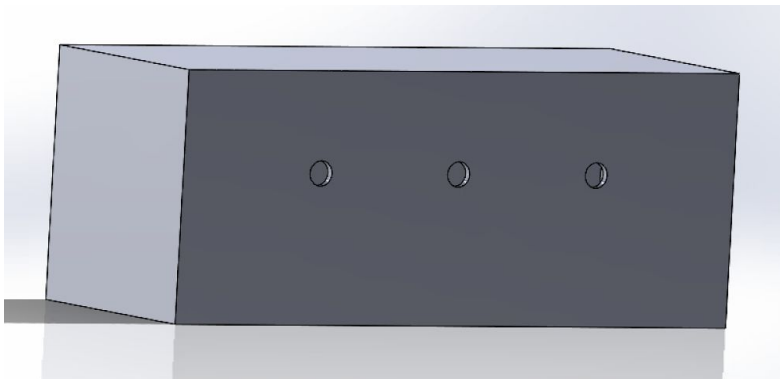
**Figure 7:** Interchangeable design created in Solidworks. Inside is one of the three tasks explained above. See Figure #2 for the Solidworks' schematic.



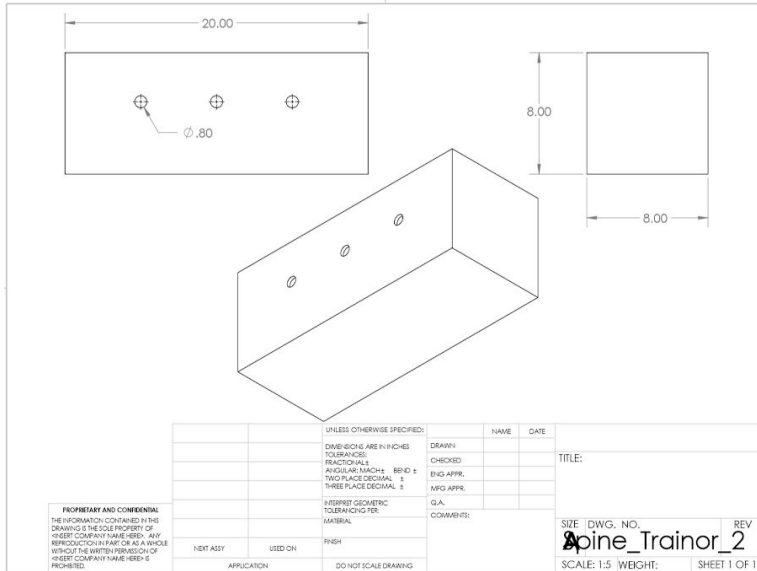
**Figure 8:** Dimensions/Schematic of the Interchangeable Design.

This design focuses on allowing the user to choose what tasks they are practicing. The box will house one of the three tasks at any given time. If the user desires to work on a task different than the one they have inside they will have to change out what is inside every time. This allows for specification of surgery on the part of the use. The box will be 8”x12”x8” and have one 0.8” hole to allow the sheath and the endoscope to fit inside snugly to assure no extra light enters the area. The box will be made from cardboard to stay within weight constraints. There will be hinges on the lid, or the lid will be removable for easy access of the tasks inside while still providing darkness during skills testing.

### 3.1.3 Comprehensive Design



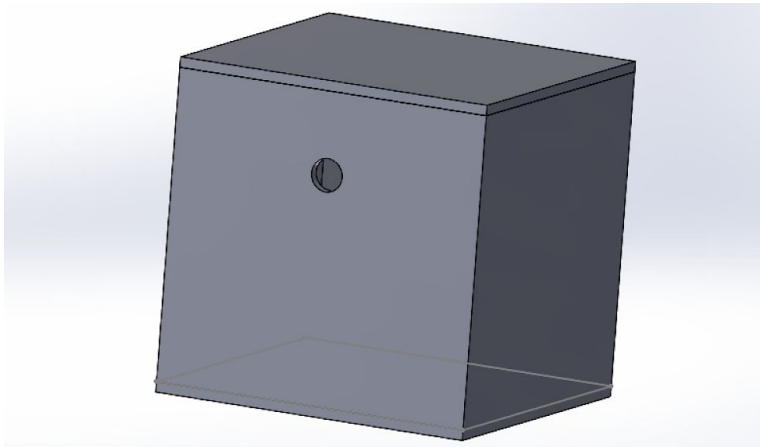
**Figure 9:** Comprehensive Design as a whole in Solidworks. Houses all three task seen above. See Figure #4 for the Solidworks’ schematic.



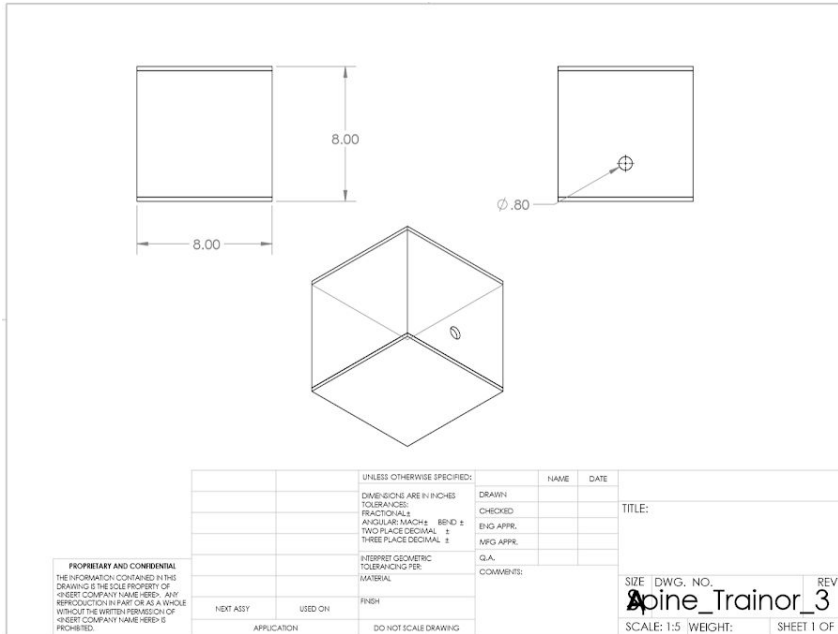
**Figure 10:** Comprehensive Design schematics in Solidworks.

This design focuses on including every task in one place. The box will also be made of cardboard and will house all three tasks, separated by cardboard walls equidistant from each other within the box. There will be three 0.8” holes, one for each task. This trainer is 8”x 20”x8” and will also utilize hinges or a removable lid.

### 3.1.4 Separate



**Figure 11:** Separate Box Design created in Solidworks. Houses one of the tasks mentioned above. See Figure #6 for the schematic.



**Figure 12:** Separate Box Design Specifications.

This design is focused on having all three tasks represented. Users can focus on an individual task but have the option to switch tasks without replacing the inside of the trainer. Three 8”x8”x8” cardboard boxes will each hold one of the three specified tasks. Each box will have one 0.8” diameter holes for the reasons mentioned in section 3.1.2. Each trainer will have hinges or a replaceable lid.

## 4. Preliminary Design Evaluation

### 4.1 Design Matrix

| Designs                   | Interchangeable   |    | Comprehensive |    | Separate |    |
|---------------------------|-------------------|----|---------------|----|----------|----|
|                           | Criteria (weight) |    |               |    |          |    |
| Degree of Accuracy (30)   | 3/5               | 18 | 4/5           | 24 | 3/5      | 18 |
| Ease of Construction (20) | 3/5               | 12 | 5/5           | 20 | 4/5      | 16 |
| Translatability (20)      | 4/5               | 16 | 4/5           | 16 | 4/5      | 16 |
| Ease of Use (10)          | 2/5               | 4  | 4/5           | 8  | 4/5      | 8  |
| Cost of Materials (10)    | 5/5               | 10 | 4/5           | 8  | 3/5      | 6  |

|                    |     |   |     |    |     |   |
|--------------------|-----|---|-----|----|-----|---|
| Time (10)          | 4/5 | 8 | 5/5 | 10 | 4/5 | 8 |
| <b>Total (100)</b> | 68  |   | 86  |    | 72  |   |

\*Scores are out of 5. Displayed as: score | weighted score

#### 4.1.1 Summary

This design matrix features six criteria on which we judged each design. Each criteria was weighted based on its importance to the successful creation of our product. Below are the justifications for said importance.

Degree of accuracy was weighted most heavily based on the idea that our trainer needs to adequately prepare the user for an actual endoscopic procedure, which is the main goal of our project. We must be able to properly mimic the force needed to pop through the third ventricle, the feeling of hitting a nerve while moving around a workspace, maneuvering the endoscopic sheath as a tool, etc. Even though our design will not be anatomically correct, the skills practiced within the trainer must match the skills actually needed in an endoscopic surgery. If we do not accomplish this, we do not accomplish the project itself, hence its importance. Next in importance was ease of construction. In order for our trainer to reach the universality that was stressed in our design specifications, it must be easy to construct. No more than a simple “How To” guide on our website should be needed to build our project. On the same level is translatability. Translatability would be how well the skills learned from our trainer would translate to actual endoscopic surgery. This will have to be a large focus later on in the project once it is fully developed and is able to be tested, but it does not diminish the importance of this criterion in our preliminary designs. Then comes the final level of criteria: ease of use, cost of materials, and time. These entail how easy it is for the user to operate the trainer and all of its parts (including replacement), how much the materials of the trainer cost, and how much time it would take to construct and replace, respectively.

As shown within the matrix, the comprehensive design had the highest overall score as well as the most categories won. Degree of accuracy was decided upon the principle that the user would be able to practice all three task in rapid succession, mimicking long surgeries better than the designs that required set up switches in between tasks. The same design then won ease of construction because there was only one box to construct (unlike the separate design) and there was is no need for internal task replacement when another task is desired. In terms of translatability, since all three designs will be utilizing the same three tasks, they should all be at the same level. If properly utilized, the skills learned should all translate the same to surgery. For ease of use there was a tie simply because the comprehensive and separate designs do not require the user to switch out the contents of the trainer while in the midst of practicing. The cost

of materials ranking was solely based on the size of the design and how much cardboard/how many boxes are needed to build it. Finally, the time needed to construct the box. To accomplish it, we took into account time spent changing out tasks, as well as how many boxes there were to fill, therefore the comprehensive design had the highest ranking.

## **4.2 Proposed Final Design**

Based off of the results of our design matrix we have decided to focus our attention on the comprehensive trainer design as it scored the highest overall and scored the outright highest in the most criteria. The comprehensive design scored the highest in all but the cost of material, and even in cost of material it was still under the budget we are going to be supplied.

## **5. Fabrication/Development Process**

### **5.1 Materials**

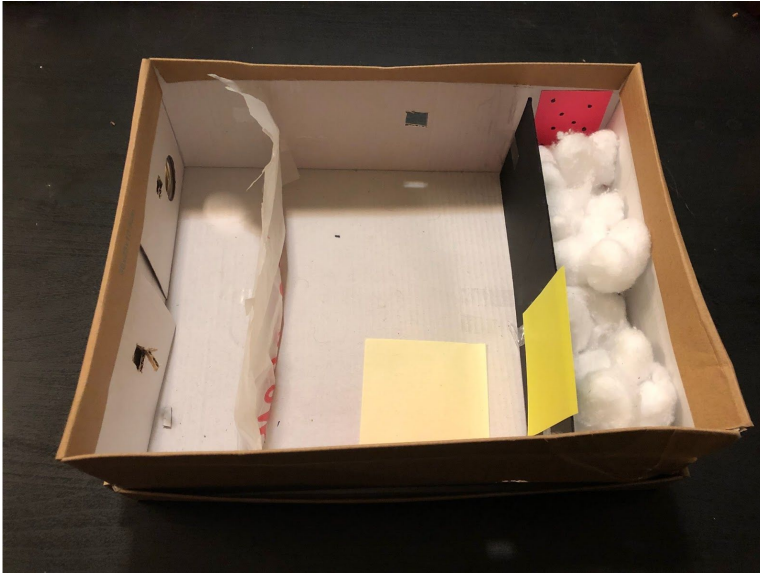
Please see Appendix B for a detailed and comprehensive list of materials utilized in our product. Also note that we had a desired budget of under \$200 to keep the entire design cost-effective. Below is a short overview of the materials used by the team and the rationale behind them.

- Depstech endoscope: An affordable endoscope that allowed us to test our design without scheduling a lab visit within the University Hospital.
- Medical latex gloves: The material provided the most accurate popping pressure to represent the third ventricle as identified by Doctor Brooks.
- Cotton balls: Material that provided the most accurate feeling and representation of general tissue swept away in endoscopic spine surgery
- Standardized cardboard box: The box used to house all three tasks made of a cardboard more durable than a normal shipping box to increase time between replacements
- Colored straws: Used as landmarks within the tissue task to allow the user to know how far down the task they were as well as acting as an obstacle
- Smoothie straws: Created a rigid sheath around the camera of the endoscope

### **5.2 Methods**

To create our final prototype we first had to cycle through two initial prototypes. As shown in Figure 13, the first iteration was built inside a shoebox. An exacto knife was used to cut out holes for our endoscope. The initial version of our tissue sweeping task had an image at the end. The goal was clear as much of the image as possible. The tissue in the tissue popping task was made from a taut plastic bag. Our camera maneuverability

task required the user to rotate around the middle column to locate different colored sheets of paper to test mobility. All items were secured using Scotch tape.



**Figure 13:** Overhead view of our first iteration of the trainer.

Then came the second prototype which was designed around the feedback of Dr. Brooks. To begin, we purchased large straws to act as the rigid sheath around an endoscope. The team purchased a box of standard size and insured that the holes cut on the side of the box were the exact diameter of the sheath to create a smoother fit. The box was divided evenly into three sections with cardboard dividers. Our sweeping tissue task gained plastic straws that were hot glued to various walls to act as obstacles for the user to touch and go around, but not move out of the way. The image at the end of the task was removed and a target was put in its place. The goal is to have this target run on image registration software, allowing the user to know the exact percentage of the work space they cleared off. Our camera maneuverability task became the same target placed on the opposite wall of the entry point. Image registration software and tactics, such as those seen in 3.1.1.3 are to provide the user feedback on distance from the target, centering issues, and angle of rotation. Finally, the membrane was replaced with a taut latex glove. Behind the glove, a cardboard barrier was placed to act as a secondary membrane that can not be pierced through if the task is done correctly. All items were secured using hot glue.



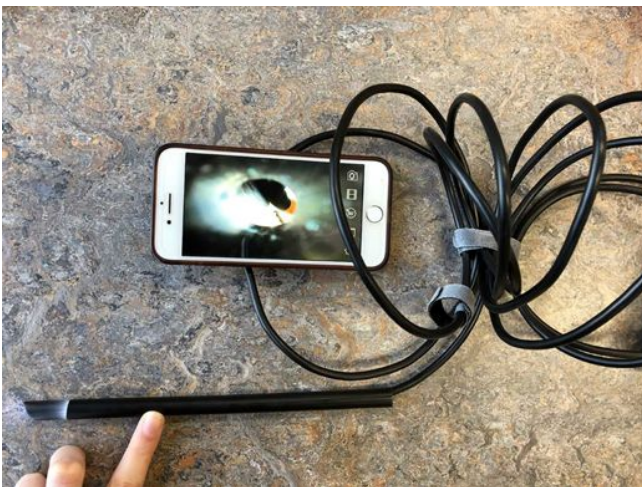


**Figure 14:** An overhead view of the second iteration of the trainer, including three tasks.

The final prototype was also influenced by the qualitative feedback of Dr. Brooks. The box retained the same size and internally the split between the three tasks is the same. In the tissue task, straws were ordered by color to act as landmarks. The user would be able to know how far they are in the task based upon what colored straws they are viewing. The camera maneuverability task remained the same. In the membrane popping task, the cardboard barrier was replaced with a different colored latex gloves, three in a row. Users now need to pop the first membrane without piercing the second. They can then pop the second membrane, without popping the third, which reduces the need for membrane replacement.

Please also refer to Appendix C where there is the “How To” guide that is to be posted on the website of our client to allow neurosurgeons to begin implementing our project. This includes the exact dimensions and techniques used to construct our project,

### 5.3 Final Prototype



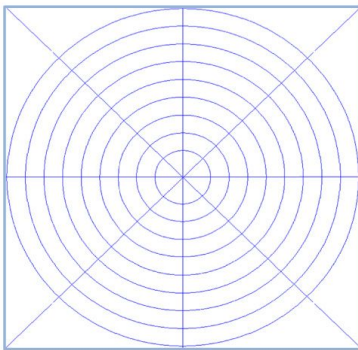
**Figure 15:** Depstech endoscope and rigid straw sheath.



**Figure 16:** Overhead view of final prototype.



**Figure 17:** Side view of three endoscopic entry points



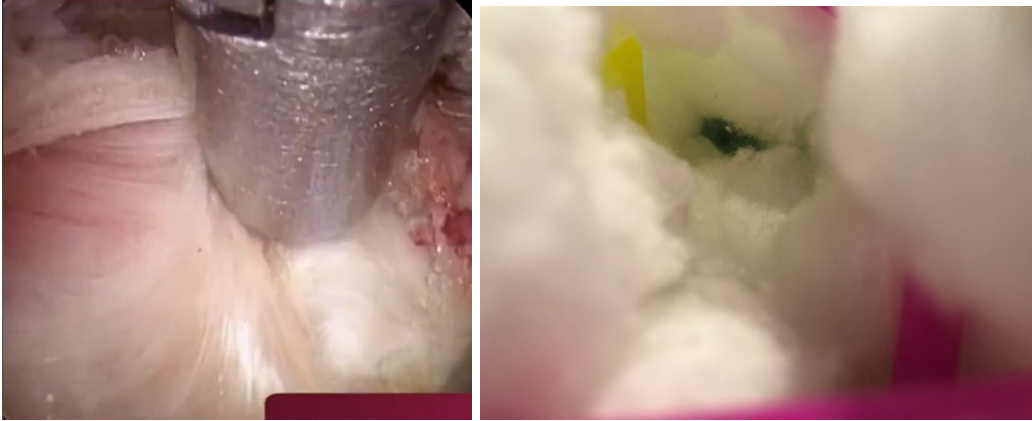
**Figure 18:** Target placed at the end of the sweeping tissue and camera maneuverability task



**Figure 19:** Tissue sweeping task without cotton balls



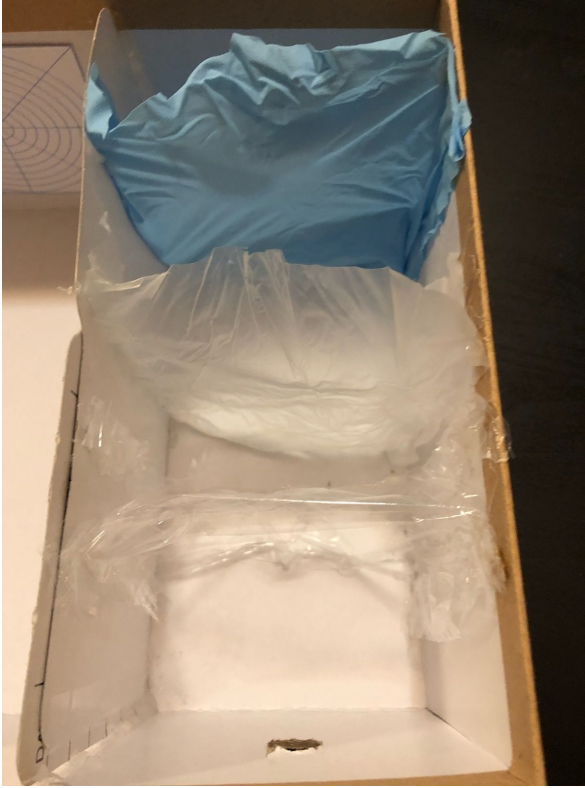
**Figure 20:** Tissue Sweeping task with cotton balls



**Figure 21:** Comparison between our tissue sweeping task and an endoscopic dissection



**Figure 22:** Camera maneuverability task



**Figure 23:** Membrane popping task



**Figure 24:** View of the membrane popping task from the view of the endoscope



**Figure 25:** Rigid sheath without needle tool and rigid sheath with needle tool

## **5.4 Testing**

### **5.4.1 Client Testing**

Client testing was our largest source of qualitative feedback throughout the entire process that allowed our design to provide an accurate representation of the hand-eye coordination of endoscopic spine surgery. For the formation of our final prototype, we had Dr. Brooks take a video of him running through every single task using the video capabilities of the Depstech endoscope.

Through each video he would provide feedback on the feel of the task as well as how it should be implemented. Through this, the team selected a new membrane material, ideas for new tasks, and the suggestion to use straws as color coded landmarks instead of obstacles alone. Most of his feedback was based on feeling and provided extremely qualitative results such as “the membrane lacks resistance” or “the membrane is not soft enough”.

### **5.4.2 Team Time Trials**

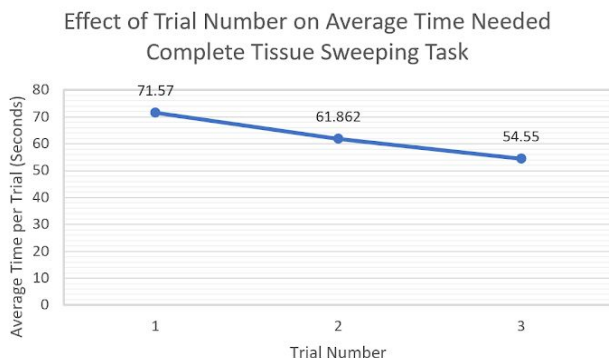
To gain some numerical feedback, the design was tested by the design team to receive initial feedback on the effects of our trainer. The team was unable to test the camera maneuverability task because the image registration code needed to run said task is not yet fully developed. The membrane popping task

also offered no quantitative data in its current state of setup, so the tissue sweeping task was chosen to collect data.

Each team member was asked to run through the tissue sweeping task using the endoscope/sheath combination. The guidelines required the user to reach the end of the task and clear off four rings of the target at the end of the task without damaging any of the straws along the way. Specifically, the task would be timed from moment of entry into the trainer until the endoscope was pulled out of the trainer. Each team member performed the task three times, and trial times were all recorded. See Appendix D for data table.

The results of the test should reveal whether the trainer improves camera handling, even in amateur users. In the future, the same test would have to be run with experienced users to verify that there is improvement (or lack thereof) that matches that of the amateur. The times of Dr. Brooks were not used within the data because during the videos of him performing the tissue sweeping task, he was making comments. This invalidated his time and would have skewed our data, hence the focus on amateur users.

## 6. Results



**Figure 26:** Graph of time trial data based upon team data (N=4).

Using the equation:

$$\text{Equation (1)} = (\text{trial 3}/(\text{trial 1}-\text{trial 3})) \times 100\%$$

the team showed a 29.01% improvement in proficiency between trial 1 and 3.

There are several sources of error from these time trials. Since there is no image registration software, there was no numerical way for a user to know how much of the target was cleared off. Different users had different definitions of “cleared” and therefore led some testers to be more thorough in their clearing. This would have led to elevated times and introduced a new variable. There was also a problem with the test itself. Once the test was run through once, there was a tunnel left in the cotton balls that would lead the next user to already have a clear

path to the target. To alleviate the problem, the cotton balls were reset in between trials, but again, this adds new variability.

## **7. Discussion**

In our results section, the time for each trial between different users is possibly not comparable due to the variability in the amount of visibility of the target needed to complete a trial. In order to minimize this discrepancy between users, perhaps we could implement in the future another picture on the box for the user to compare with. Once the image looks the same between the two the trial can conclude. With more reliable testing times between users we can then more accurately compare the data. Another possible source of discrepancy could be in the test itself. After each test we would move the cotton balls around so that way there isn't a clear route already presented after each trial. This in itself is problematic because each trial run is going to be slightly different each time causing slightly different times as well. There is not a viable option yet to fix this that would include cheap material as well as molding back to the original same shape.

One of the main ethical considerations we have to take into account is the reusing of material for our popping membrane task. With the constant switching of membrane each time we prod through it, it can be very wasteful and not environmentally friendly. We want to change this to eventually have a more efficient way to switch in and out the membrane while using as little material as we can. Another way we can solve this problem is to have another task that would test similar skill sets while not having as much waste product. Additionally, if our trainer is bought and sold by a company, ethical dilemmas arise between the surgeons using the product and the company due to conflict of interests.

## **8. Conclusions**

In order to aid in the switch from general surgery to minimally invasive endoscopic surgeries, surgeons need to be able to practice the skills needed to use an endoscope. The surgeons already know the anatomy and need a low cost trainer for the different skills they need to learn. The surgeons have to learn how to maneuver the endoscope with one hand, account for having less of a visual field for surgery, account for the difference with the angled lens, and learn to perform surgical tasks like targeting, sweeping tissue away, and popping membranes. The final product of our spinal trainer allows for a low cost and low risk environment for the surgeon to practice these skills.

Based on client feedback we tried to mimic the surgical environment in the materials we used for the tasks. We also tried to use the box ourselves to see if we improved by completing the first task multiple times. Although our analysis showed improvement in the proficiency of the task, the data is not reliable enough to confirm improvement. There was too much variability



between users and not enough data for comparison.

Future work is still needed on the final product and its user website in order to give more quantitative feedback to the user on their progress and to account for reusability of each trial. In order to give the user more quantitative feedback on the first task, we first need to address how to establish when the task can end. We then would need to create software that could compare the times between the trials and have it uploaded onto the website for use by every user. Ideally, the user would put the amount of time it took for them to complete the trial and see where they fall in comparison to others. However, more testing between both amateurs and experienced endoscopic surgeons would be needed in order to create a goal time for amateurs to aim for or more data for comparison. Currently, the first task of sweeping tissue away does not allow for practice multiple times without resetting the cotton balls. After one use, a pathway through the tissue is made which makes the trial easier and can skew the timed data. This issue needs to be addressed as well.

For the second task, manipulation of the target is needed due to the absence of asymmetry. The asymmetry of the target is important when analyzing the degree of counterclockwise or clockwise movement. To account for this overlook, the task should instruct the user to use a different target or to simply number the circle like a clock for differentiation. In addition, a target needs to be selected based on software packages available that can analyze the data. It needs to be able to compare the picture the user uploads into the website (after taking a screenshot off of their recording of the task) to the goal image. The goal image is the target rotated a certain amount in a certain direction. The software should be chosen or written in order to give the user quantitative feedback on the difference between their image and the goal image in terms of degrees off and the size of the image to test the users distance from the target. Additionally, one should have the goal image in sight or incorporate some kind of way to tell how close the user is to the target. For example, in one target analysis study, the target had lines on it in order to tell how level the keeps the camera when rotating and helps the user choose a distance by having two smaller spheres on the sides [6]. Once those are in view, the user knows when they are at the correct distance for testing [6].

For the third task, the main future work needed is to account for reusability. We tried to do this to some extent between iterations of the box by putting up more membranes to pop without hitting the next. However, even with more membranes the task can only be done a few times before having to put up more.

In addition, more testing is needed in the future after these adjustments to the tasks and website. We will need to consider how to show that the trainer improves the surgeons' surgical skills during minimally invasive spine surgeries compared to those who did not train with our device.

## 9. References

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## 10. Appendix

### A. Product Design Specifications:

## Preliminary Product Design Specifications

### *Design of a Spine Trainer*

**Client:** Dr. Nathaniel Brooks

**Advisor:** Walter Block

**Team:** Shannon Sullivan - Team Leader

Yoon Cho - BPAG

Austin Gavigan - BWIG

Madison Hodgson - Co-Communicator

Katarina Martinet - BSAC

Sophia Nehs - Co-Communicator

**Function:** Minimally Invasive Spine Surgery is becoming more commonplace; however, there is minimal opportunity in spine surgery residency for neurosurgery and orthopedics training because the tools that are used for these procedures are significantly different from the standard procedures performed today. There is a need for a low-cost simulation environment to be developed to provide spine surgery trainees with the practice and training space to develop the fundamental scope-handling and manipulation skills necessary to perform minimally invasive endoscopy based surgical treatments. Ideally, it will be made with simple materials to allow for its building and use globally.

**Client Requirements:**

- Low-tech design with simple materials available at any hardware store
- Mimic the sweeping away tissue and poking holes through membranes as tasks to train hand-eye coordination surgical skills
- Create a maneuverability task to fix the disconnect between looking at a spine straight on and the 30 degree angle lense of a rigid endoscope
- Create a how to for creating the box and setting up the surgical spine training tasks
- Create a website or blog type platform to share this how to
- Must be able to use in a hospital or home environment
- Focus on tasks for surgical skills and not the anatomy
- No 3D printing allowed

**Design Requirements:**

1. Physical and Operational Characteristics
  - a. *Performance Requirements:* Must be able to use the box for practice of each surgical task up to 50 times.
  - b. *Safety:* Must prevent injuries to the user as the product undergoes wear and tear from the surgical tasks training. Must not damage the equipment utilized during training such as the endoscope or the tools attached.

- c. *Accuracy and Reliability*: The box that houses the tasks must not need replacement for one year. The tasks within the box must replicate the actual feeling of sweeping away tissue and popping the third ventricle to properly train hand-eye coordination.
  - d. *Shelf Life*: Our goal is for the box to be used by one person for a year prior to needing to buy another box. The tissue sweeping and camera maneuverability tasks should also be functional for a year.
  - e. *Operating Environment*: The product must be able to be used with an endoscope for surgical practice or with a lens extension off of a cell phone if the product is updated.
  - f. *Ergonomics*: The product should be comfortable enough for the user to carry, place down, and use without causing any more stress to the body during training the surgical tasks than a typical spinal procedure would.
  - g. *Size*: The box should be smaller than or equal to the size of an average shoebox, which is 14in x 8in x 5in [7].
  - h. *Weight*: Must not exceed 5 lbs in weight
  - i. *Materials*: Materials must be simple and durable. The materials must be bought from a hardware store and allow for easy assemble of the box. The materials must also allow for training tasks at multiple depths.
  - j. *Aesthetics, Appearance, and Finish*: Aesthetics are not a main concern, but the product must still look professional.
2. Production Characteristics
- a. *Quantity*: Only one trainer will be needed that houses all three tasks
  - b. *Target Product Cost*: The product must be built under our \$200 budget.
3. Miscellaneous
- a. *Standards and Specifications*: For our project we don't expect to run into any problems with international or national standards. All of our resources we are using in our prototype are specifically chosen to be easy to use and make.
  - b. *Customer*: Trying to reach out to Dr. Brooks currently so we can successfully fill this section out.
  - c. *Patient Related Concerns*: Not applicable, the product just needs to be safe to the user training.
  - d. *Competition*: There are high tech versions of spine simulators that already exist, one example is the SPINE MENTOR. This simulator has the appearance and feel that goes along with minimally invasive spine surgery. 3D printing was used to make the simulator appear realistic and virtual reality technology was used to show surgeons exactly what they were doing inside the simulator [1].

## B. Materials and Budget

| Item   | Manufacturer                         | Part Number      | Date       | QTY | Cost Each     | Total           |
|--|--------------------------------------|------------------|------------|-----|---------------|-----------------|
| Depstech Wireless Endoscope                      | Depstech                             | 4331891326       | 10/21/2018 | 2   | \$35.99       | \$71.98         |
| Curad Disposable Medical Latex Gloves            | Walgreens                            | MSO-CUR8105<br>H | 12/03/2018 | 1   | \$12.45       | \$12.45         |
| AMMEX - VPF64100-BX - Medical Vinyl Gloves       | Walgreens                            | VPF64100-BX      | 12/04/2018 | 1   | \$5.45        | \$5.45          |
| Swisspers Cotton Balls Jumbo Plus Size, 70 Count | Walgreens                            | 969873(1)        | 11/19/2018 | 1   | \$4.70        | \$4.70          |
| 7.5 X 4 X 11 Cardboard box                       | Artist & Craftsman Supply<br>Madison | n/a              | 11/28/2018 | 2   | \$5.53        | \$11.06         |
| Multicolored Plastic Straws, 125 Count           | Bed, Bath, & Beyond                  | n/a              | 11/18/2018 | 2   | \$2.99        | \$2.99          |
| 3/16" Durabubble Cushion Wrap roll 100 feet      | University Bookstore/<br>FedEx       | 100001           | 11/28/2018 | 1   | \$8.66        | \$8.66          |
| Bubba Set of 5 Plastic Reusable Straws, 5 count  | Target                               | n/a              | 11/28      | 1   | \$3.99        | \$3.99          |
|  |                                      |                  |            |     | <b>TOTAL:</b> | <b>\$121.28</b> |

## C. Endoscopic Spine Training Simulator How To

### Materials:

Cardboard box with cover (7.5x4x11 in), cardstock paper, colored straws, large straw (boba straw), sewing needle, printed target, latex gloves ( 2 or 3 different colors), plastic wrap (optional), Depstech Endoscope

### Tools:

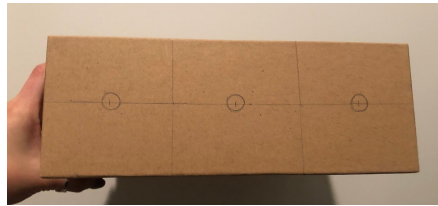
Exacto knife, hot glue gun, double sided tape

### Our website:

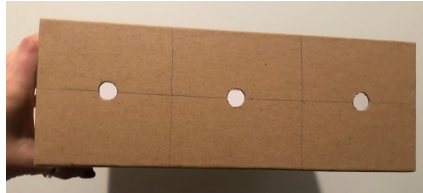
<http://endoscopicspinetraîner.blogspot.com/>

### Construction:

1. Measure 3 even sections length wise on the box, approximately 3.6 in each.



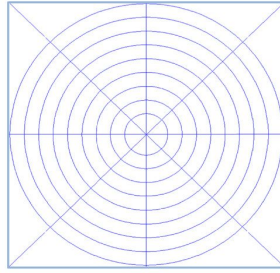
2. At the center of each section, trace around the diameter of your large straw as a guide to cut out entry ways for the endoscope using the exacto knife.



3. With the hot glue gun, glue in cardstock dividers between each section.



4. Print two 3x3 in targets. Trim around the target and tape one into the tissue and camera maneuverability sections.



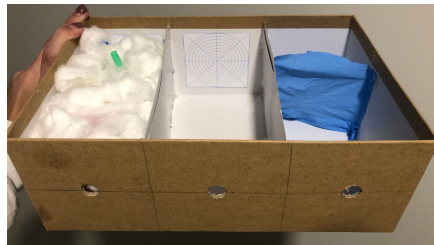
5. Cut colored straws in half and hot glue them in colored order, vertically and horizontally, into the tissue section. Trim straws to fit as needed.



6. Fill the rest of the tissue section with cotton balls and this section is complete.



7. Cut latex gloves into sections of 4x4 in. Only one section is needed of each color (if you have only two different colors of latex gloves, use plastic wrap as the third section).



8. Glue in first section of latex (4 in away from entryway). Glue the second section of latex 1.5 in behind the first. Glue the last section of latex/plastic wrap 1 in behind the second.



9. Finally, hot glue the sewing needle onto the slanted tip of the large straw.



#### D. Testing Data Tables

|         | Madison | Yoon  | Austin | Kat   | Sophia | Average |
|---------|---------|-------|--------|-------|--------|---------|
| Trial 1 | 56.11   | 50    | 147.93 | 50.85 | 52.96  | 71.57   |
| Trial 2 | 55.09   | 45.31 | 101.56 | 51.35 | 56     | 61.862  |
| Trial 3 | 48.65   | 34.11 | 95.27  | 48.16 | 46.56  | 54.55   |

**Figure 26:** Time (in seconds) it took each team member to complete the tissue sweeping task.