Hydraulic Battle Bots

A fun S.T.E.M. Maker Lab

Detailed instructions and illustrations!

S.T.E.M. ON A SHOE STRING

By Brad Fulton
Educator of the Year, 2005
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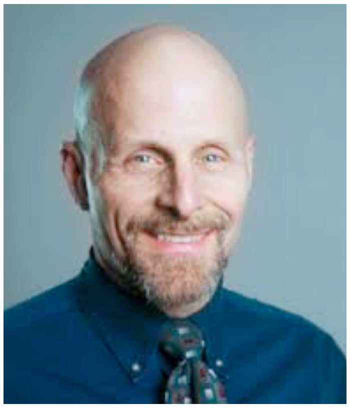
Brad Fulton

Educator of the Year



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- ♦ **Educator**
- ♦ **Author**
- ♦ **Keynote presenter**
- ♦ **Teacher trainer**
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Known throughout the country for motivating and engaging teachers and students, Brad has co-authored over a dozen books that provide easy-to-teach yet mathematically rich activities for busy teachers while teaching full time for over 30 years. In addition, he has co-authored over 40 teacher training manuals full of activities and ideas that help teachers who believe mathematics must be both meaningful and powerful.

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- ♦ California Math Council and NCTM national featured presenter
- ♦ Lead trainer for summer teacher training institutes
- ♦ Trainer/consultant for district, county, regional, and national workshops

Author and co-author of mathematics curriculum

- ♦ Simply Great Math Activities series: six books covering all major strands
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References available upon request

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Hydraulic Battle Bots

Overview:

Students will love designing, building, and battling these inexpensive robotic arms as they learn about the principles of hydraulics. The simple instructions make this an ideal S.T.E.M. maker lab for eager engineers in grades five through eight. Most of the simple and easily accessible materials can be reused year after year to keep the cost low. Complete illustrations make the construction process simple, but students can modify and improve the designs if they wish.

Required Materials:

- ☒ Tongue depressors
- ☒ 10 mL syringes
- ☒ bamboo skewers
- ☒ 1/8" plastic tubing
- ☒ ½" dowel
- ☒ ½" pvc pipe
- ☒ Glue guns and glue sticks
- ☒ zip ties
- ☒ small drill

Acquiring and preparing materials:

Each hydraulic arm needs four 10 mL syringes. I ordered mine on line, but you could also find them at a pharmacy. Try to find ones that don't come with needles!

I also ordered 1/8" plastic tubing online. Each arm needs two one meter sections.

The bamboo skewers were purchased at Dollar Tree (www.dollartree.com). One package is plenty for a class. These are very sharp, so I cut off the pointed ends.

Lastly I ordered tongue depressors online. I allowed 50 for each build, and that is more than enough. These and the zip ties, skewers, and glue sticks are the only materials that are not reused for subsequent builds and they are also the least expensive. My students dismantle their bots at the end of the activity and recycle the syringes, tubing, dowel, and pvc pipe for next year.

Zip ties, dowels, and pvc pipe can be purchased online or at a hardware or home improvement store. Small zip ties are best for this activity.

Pvc pipe is the white plastic pipe and typically comes in 10' lengths, but can often be purchased in more convenient shorter lengths. A 10' length is currently less than $3.00. Each arm needs 5" of pipe, so a ten-footer will provide enough for 24 bots.

Hardwood dowels are typically sold in 3' and 4' lengths. Each arm will also need 5" of dowel. It is important that the dowel will fit easily inside the pvc pipe allowing it to turn. Theoretically, the pvc pipe has ½" inside diameter and the dowel's diameter is ½" outside. However, I found that the wooden dowels likely shrunken a bit from drying and fit fine. Test them before buying and if necessary buy a dowel of a different diameter.

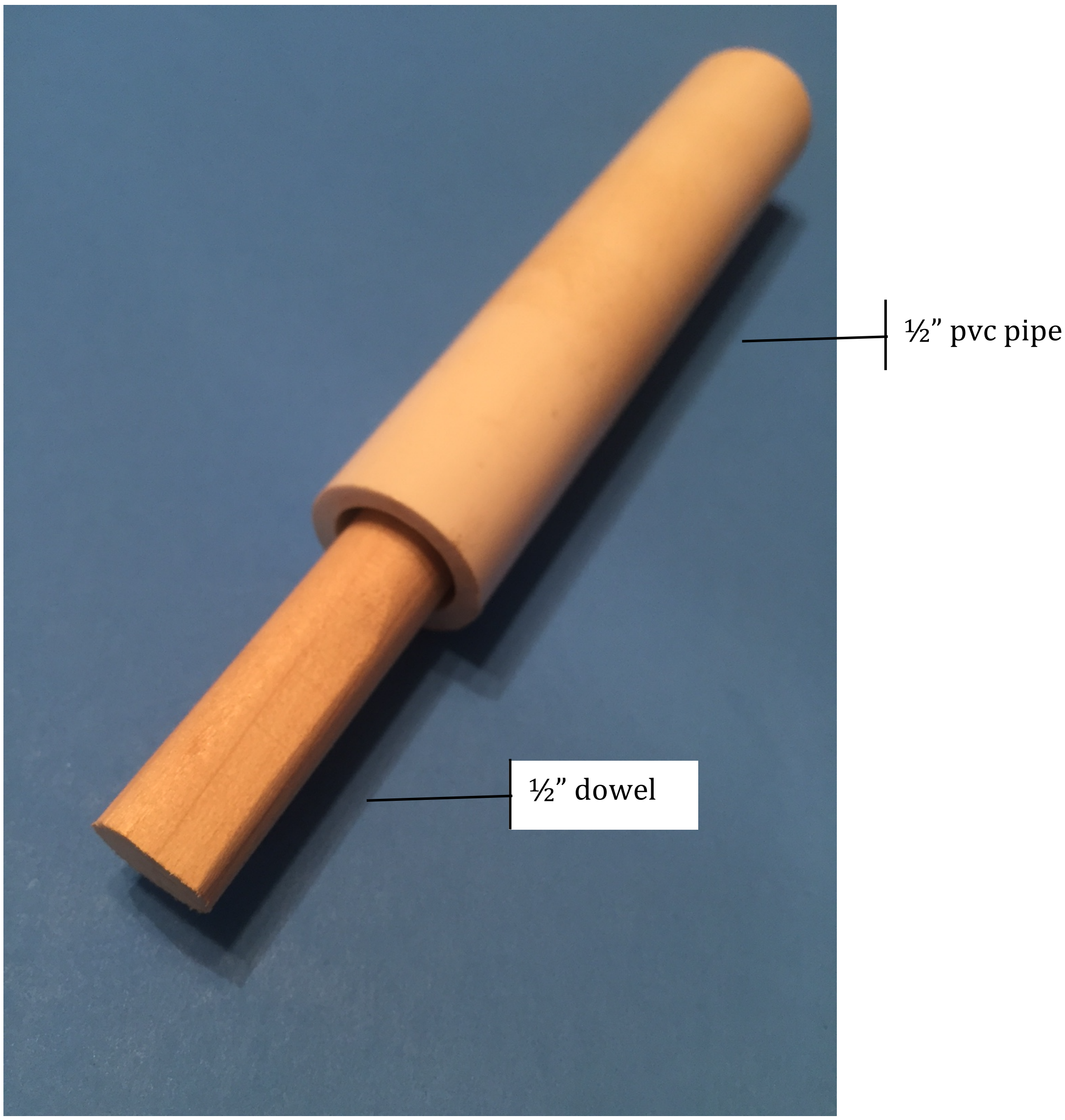
A few of the tongue depressors will be drilled to allow the skewers to be inserted.

Procedure:

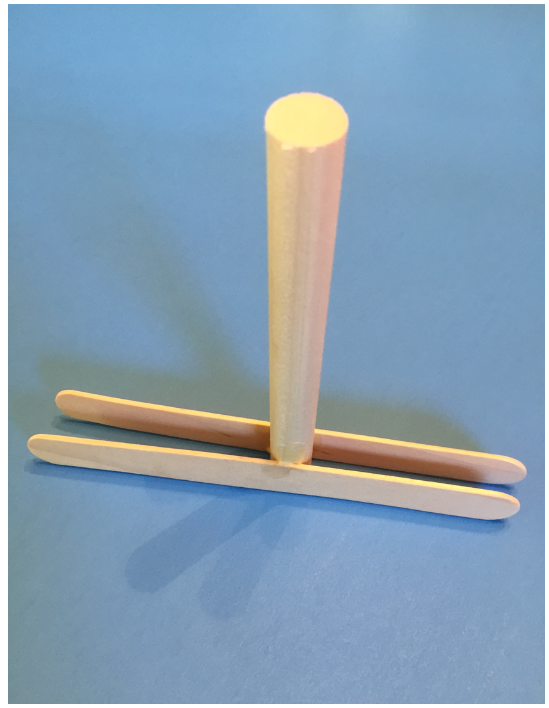
1. You may wish to show students some examples of hydraulics online. Just do a Google image search to find illustrations. A car's brake system is a common example. When the brake pedal is depressed, a *master cylinder* is pushed. This forces hydraulic fluid through the brake lines where it pushes against and extends the *slave cylinder*. This in turn pushes on the brake pads. Students will operate the master syringes which in turn affect the slave syringes on their hydraulic arms. One syringe operates the lifting of the arm and the other operates its rotation.
2. I have also uploaded a short video of my students battling their bots on my YouTube channel: youtube.com/watchtttpress. You can search for it there or use this url: https://www.youtube.com/watch?v=cw5NKJZ-tNI&feature=youtu.be
3. I had my students work in pairs to promote teamwork and communication. When it came time for the contest, each student operated one of the two master cylinders, so they had to work as a team. To further promote cooperative work, a team had to win three rounds, exchanging syringes after each time.
4. Each team was given 50 tongue depressors. They were also given 5" of dowel and the pvc pipe cut into a 4" piece and a 1" piece. The 1" ring is used later to elevate one of the two syringes, but students may devise a different design.
5. Each hydraulic battle arm was composed of three assemblies: the tower, the arm, and the base. I had my students design their tower first as this is the most technical component. I encouraged them to use my design as a jumping-off point and engineer their own improvements. If you wish, you can print the following pages as an assembly manual for the students.

Step 1: Designing the rotating tower

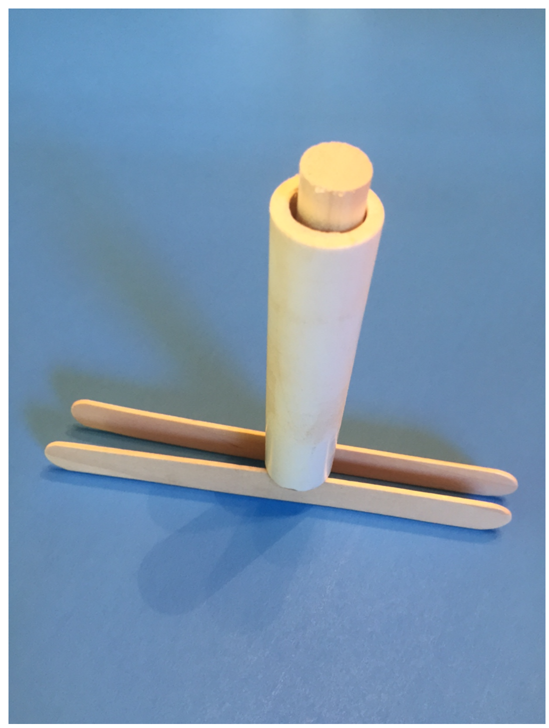
Here you can see that the dowel fits inside the pipe. I have sanded the lower sides of the dowel flat to provide more gluing surface for the tongue depressors, but this is optional. I also used wood glue and clamps for a stronger connection, but this too is optional and will make it impossible to take it apart if you want to recycle your dowels.



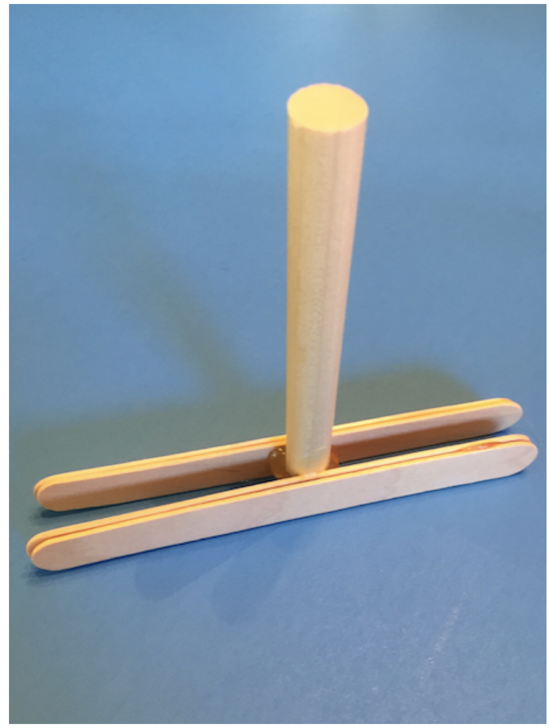
Next have the students attach stabilizers to the base of the dowel as shown here.



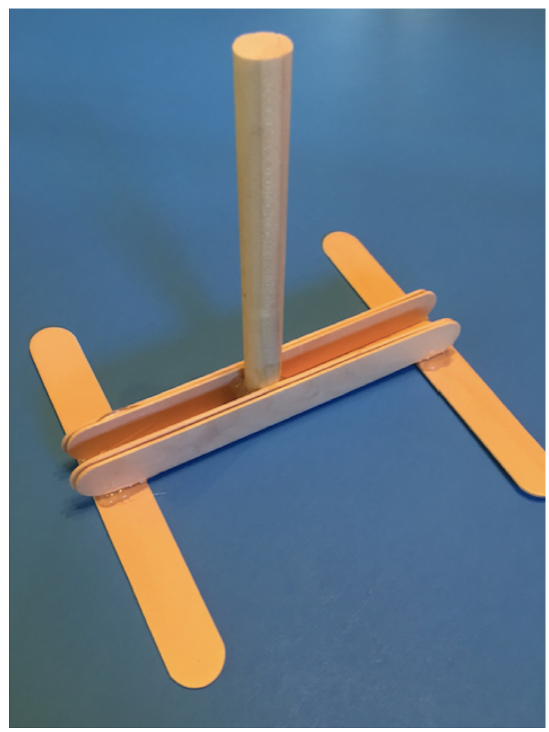
Notice that the dowel is slightly longer and slightly smaller in diameter than the pvc pipe.



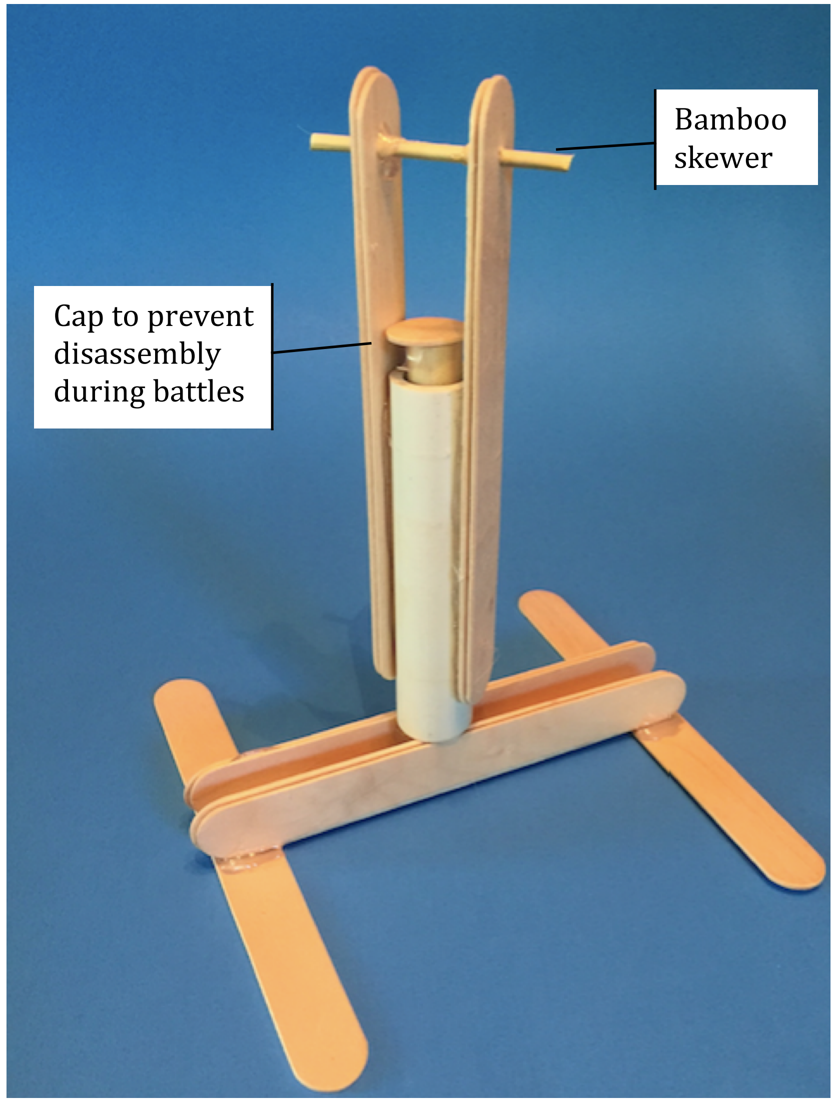
Next, I doubled my lower supports for greater strength.



The lower supports are glued to cross pieces that will be a part of the base.

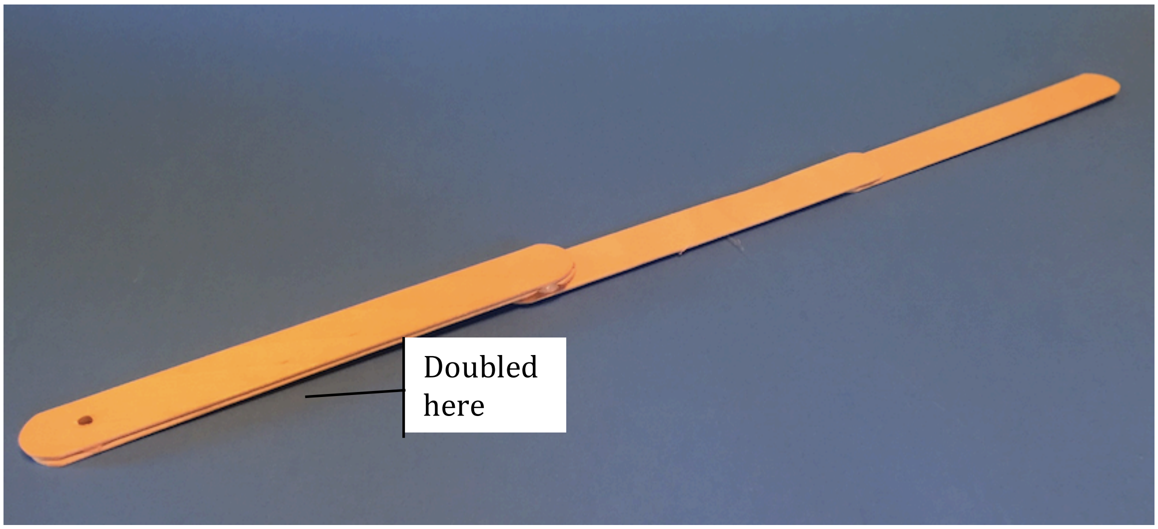


Here the sides of the tower are glued on (and doubled). These must be drilled to accept the skewer on which the arm will hinge. Notice that I have also glued on a small piece of tongue depressor so that the pipe cannot come off the dowel during a battle. A zip tie would also work here and could be removed easily if modifications were to be made.
This tower is one stick tall. Some of the teams made their towers higher by gluing on more sticks.



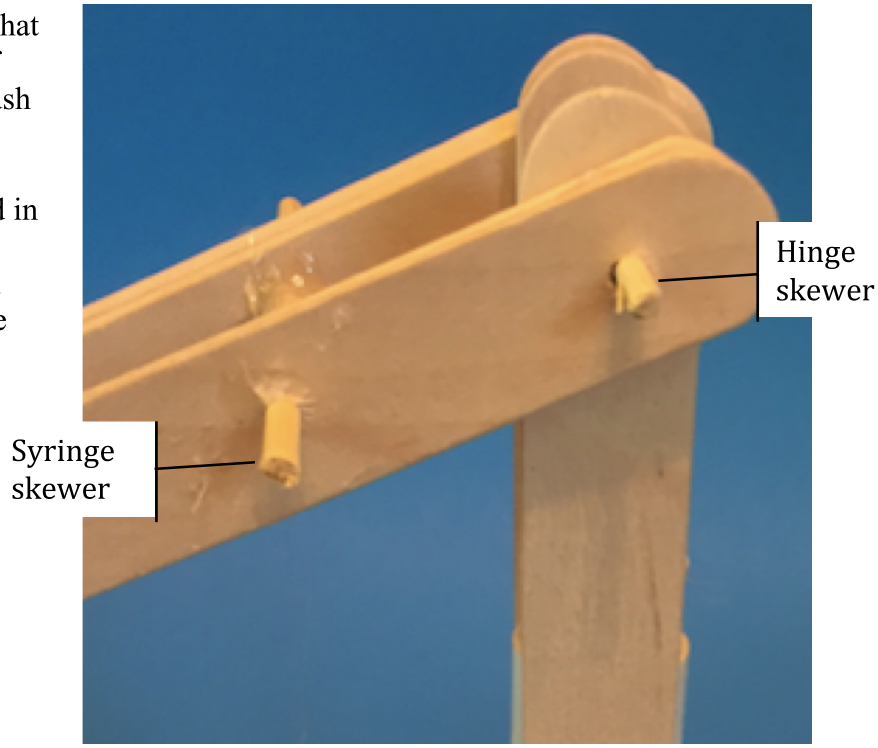
Step 2: Constructing the arms

Arm design can vary widely. Encourage your students to think about how to engineer the most effective design. They should be long enough to reach the opponent, but if they are too long or heavy, the bot may tip over more easily.
I kept mine simple and built two of the assemblies shown below. Notice that one end is drilled to hinge on the skewer. I also doubled the tongue depressors at the hinge end.



After assembling two of them, I put a sweeper on the end to try to get under my opponent's bot.

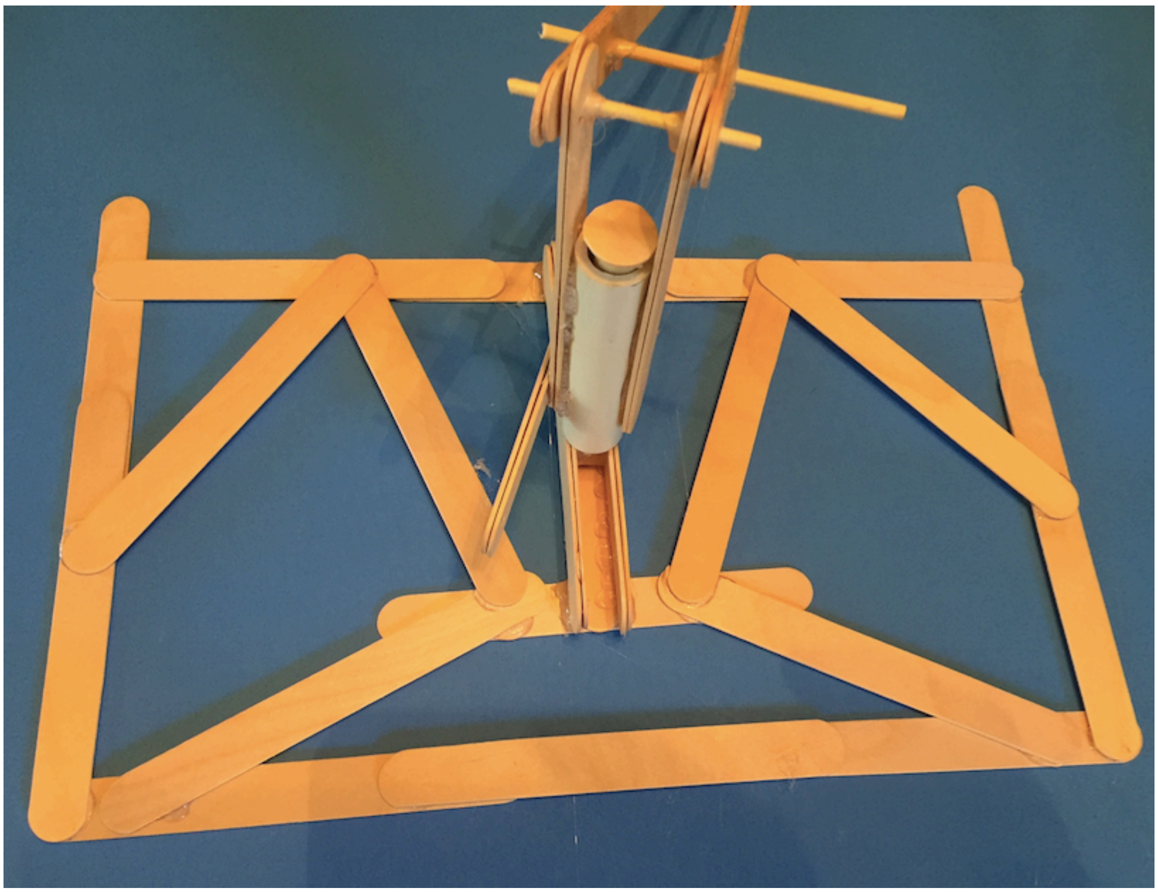
This shows how the two arms attach to the tower. Notice that I attached a second piece of skewer for the syringe to push against. Your students may engineer a different design. This second skewer is glued in place and doesn't rotate. It helps to keep the arms from spreading and falling off the hinge skewer.



Step 3: Assembling the base

I gave my students restrictions on the size of their base. It had to fit inside a 36 by 24 cm rectangle. This kept the competition fair. Otherwise students could create massive bases that could never be tipped.

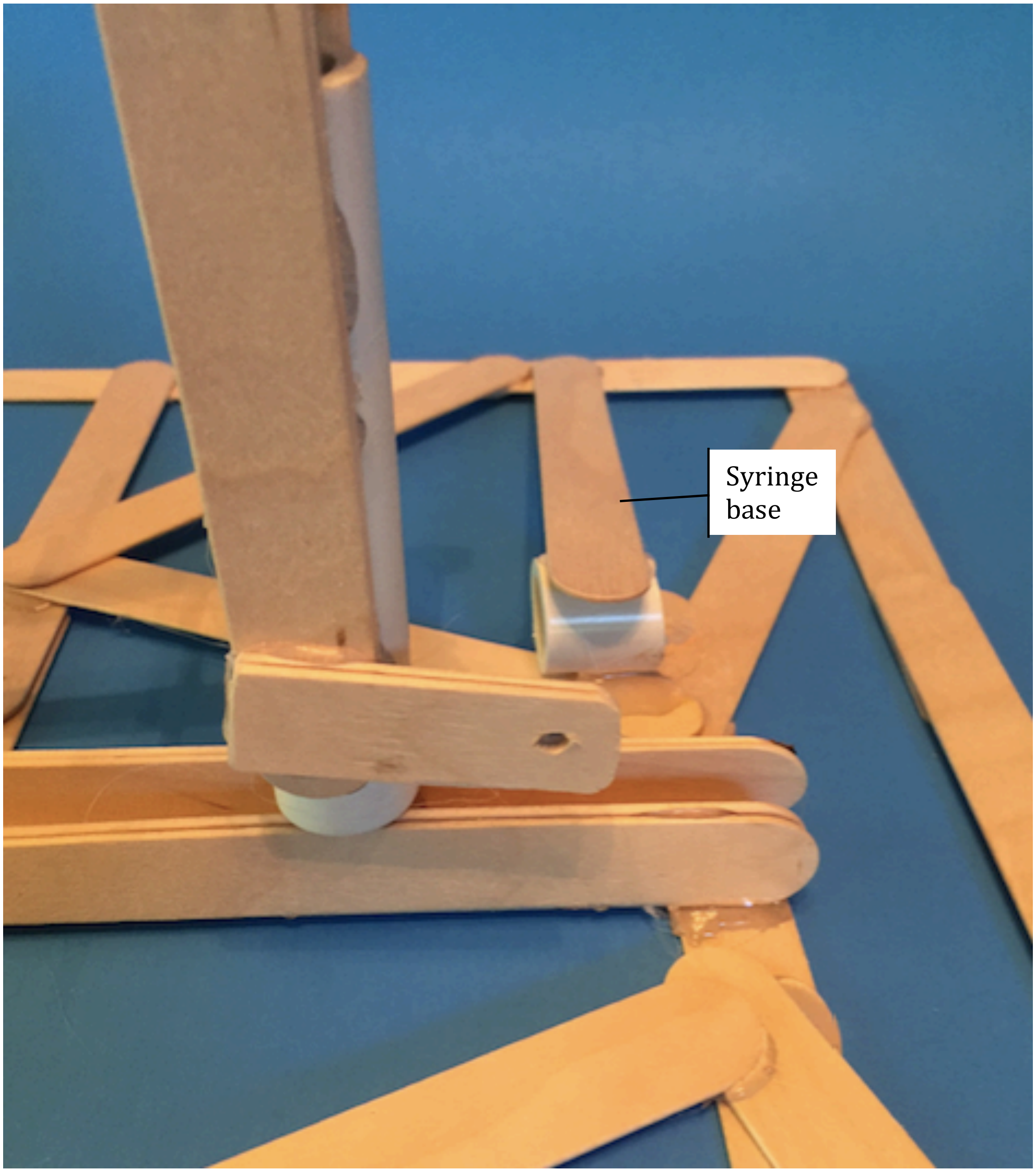
Like the arms, base designs vary widely also. Have your students think about how best to design it so that it can't be tipped easily. Again, I opted for a simple design. My goal was to minimize areas where my opponent might get underneath my base. I added diagonal bracing for strength and to increase the weight of the base. My total design used 39 tongue depressors, so I could have made the base or arm more substantial if I had wished.



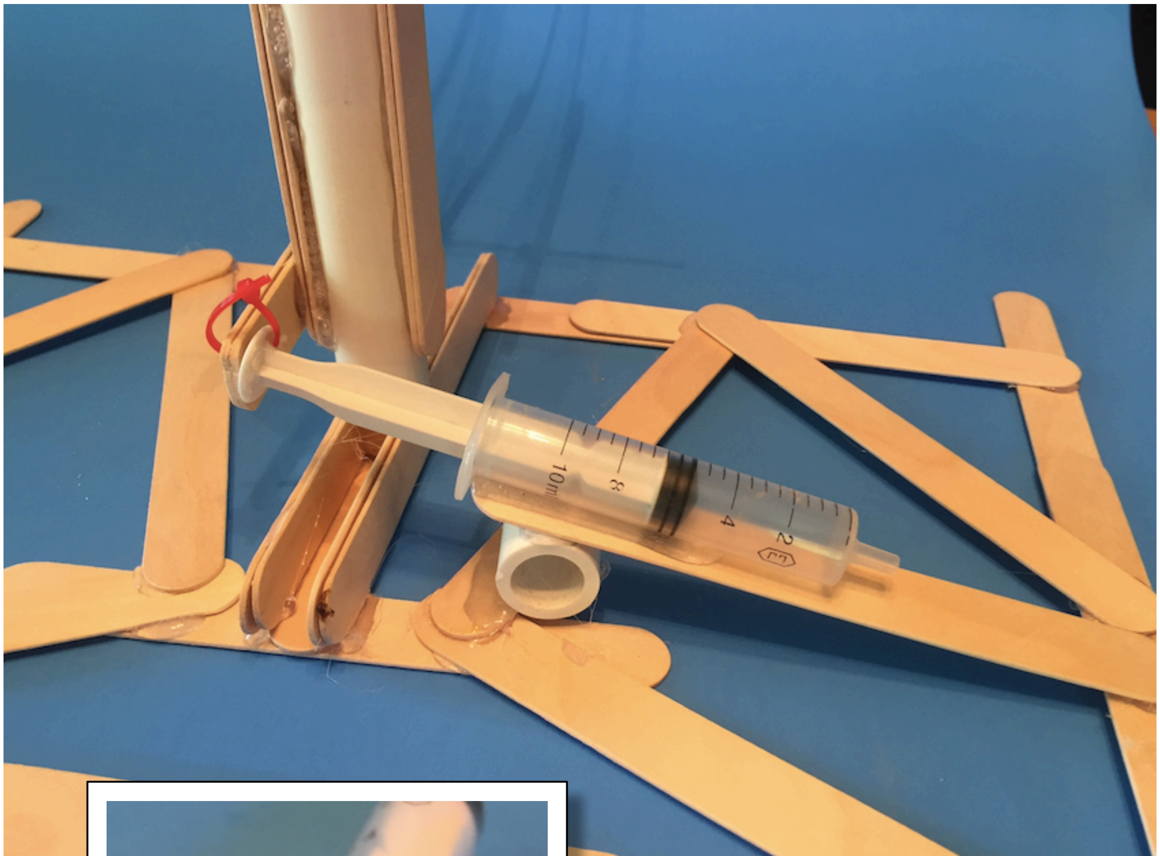
Step 4: Mounting the syringes

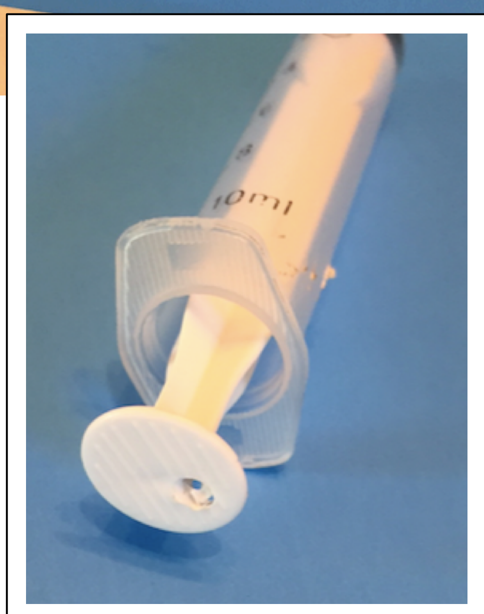
On my design, I cut a tongue depressor in half, glued the two halves together, and drilled a small hole in the ends. This was attached to the base of my tower to serve as a swing arm for the rotational hydraulic.

In this view, you can see that I have also glued a tongue depressor onto the small pvc ring and glued that to the base. This serves as a mounting platform for the rotational slave syringe as shown on the following page.

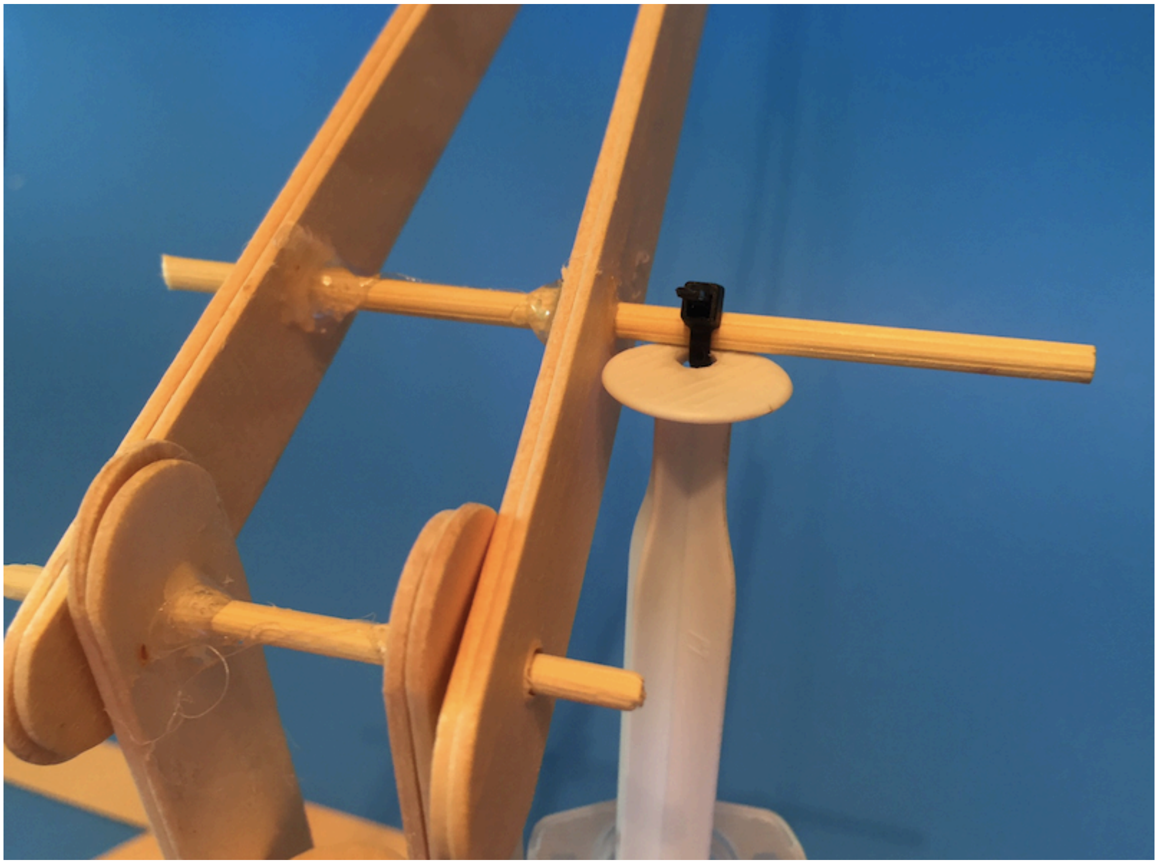


Here is the rotational slave syringe glued onto its inclined base. A hole has been drilled in the top of the syringe A zip tie attaches the syringe to the rotation arm.
Make sure your students think about where to mount this syringe to allow the arm to swing to the left and the right. Notice that the 10 mL syringe is currently set at 5 mL when the arm is facing directly forward. This allows for a movement of ± 5 mL of travel.

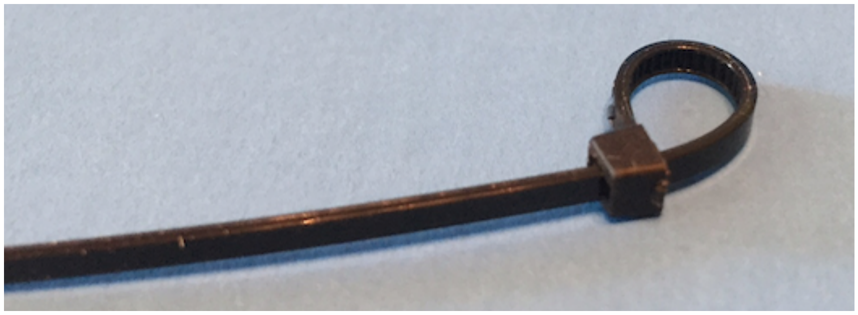




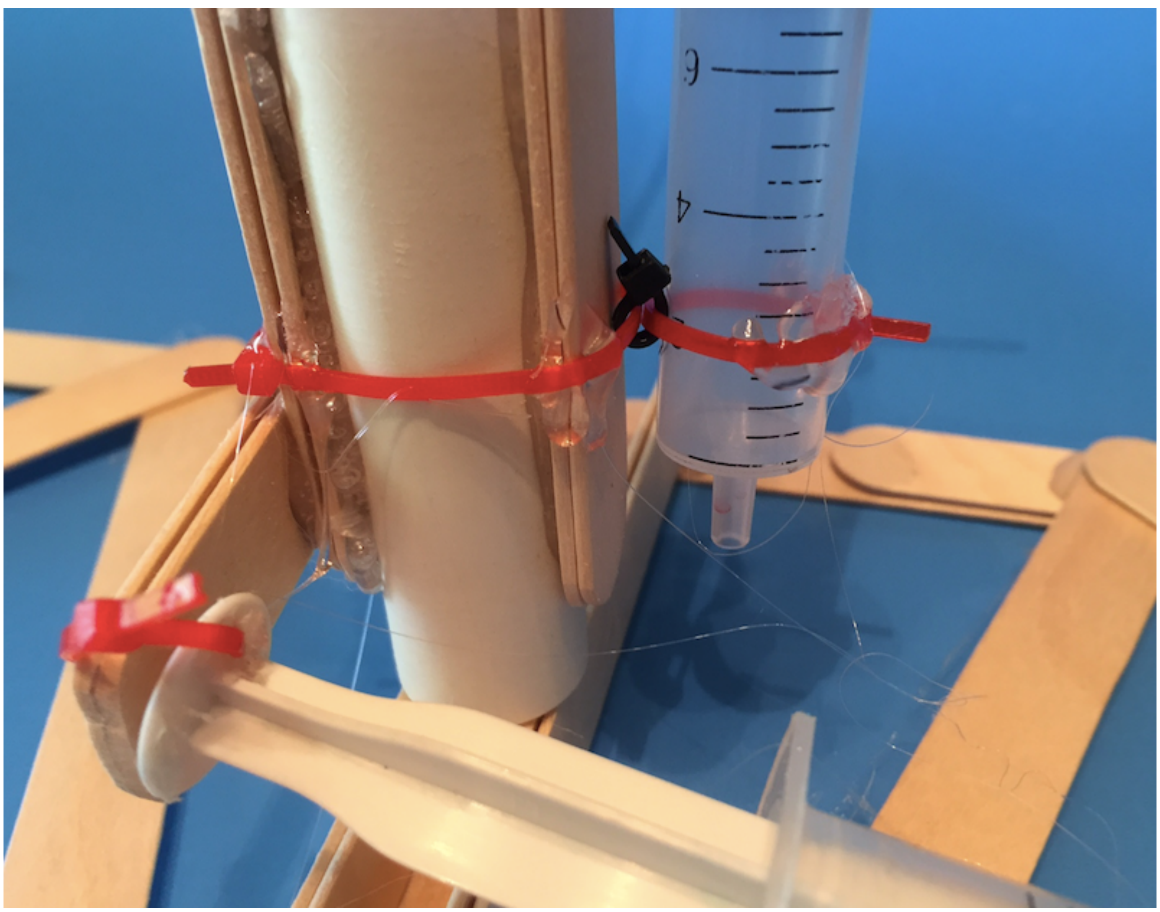
The lift slave syringe is also drilled and zip tied to the upper support skewer as shown here.



Next a zip tie is formed into a small loop.

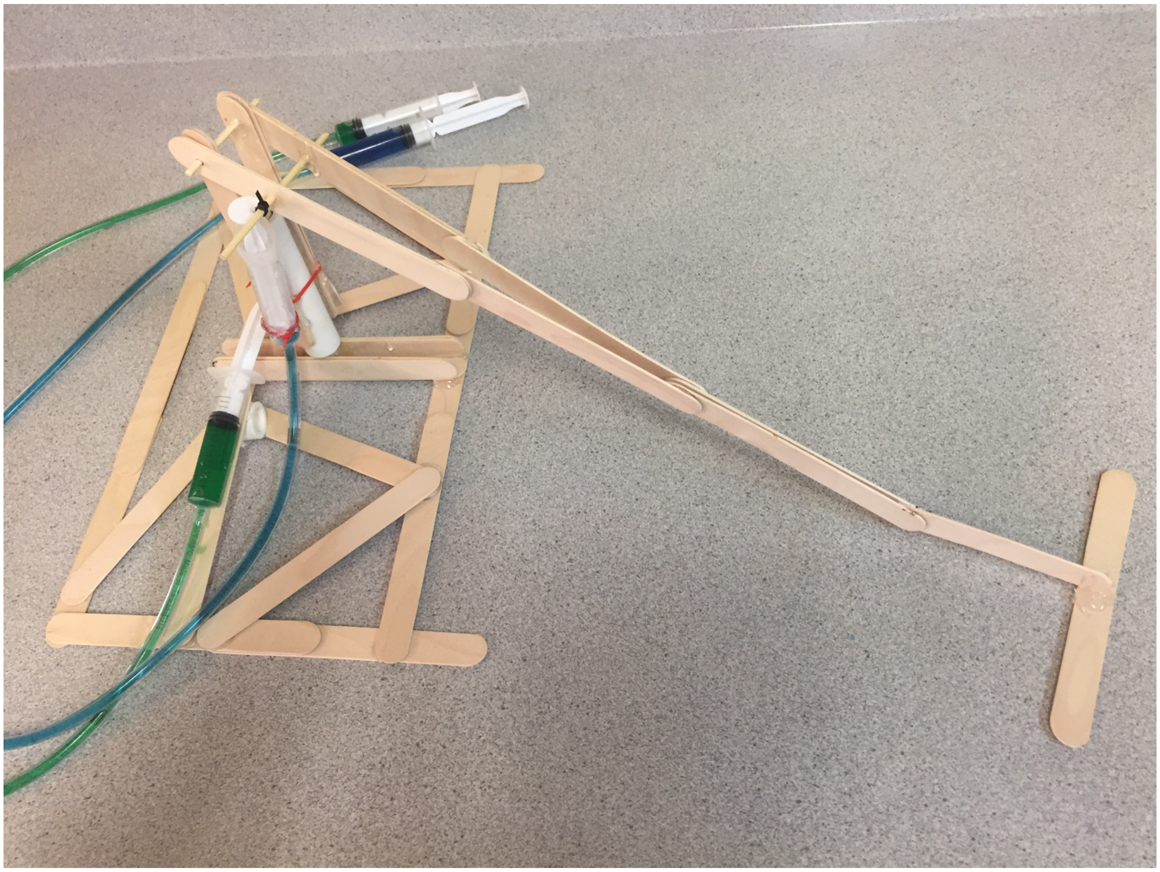


A second zip tie is passed through this and wrapped around the tower and a third is passed through and wrapped around the lift slave syringe. These are tightened and secured with a bit of glue so they don't slip. This assembly serves as a hinge for the lift slave syringe as the arm moves up and down.



It is important to experiment with the placement of the lift assembly prior to securing it to the tower. The students will want to make sure that the arm lifts well but also that it will descend to the table top.

Here is the completed hydraulic bot.



Step 5: Filling the lines with hydraulic fluid

I had students use two colors of water to fill the two hydraulic systems. This helped them know which syringe controlled lift and which controlled rotation. The hydraulic systems work best when there are no air bubbles in the lines. To minimize the air in the system, follow these steps fill the lines.

1. The tubing should be disconnected from both the slave and master syringes to begin.
2. Get a beaker or glass of colored water.
3. Depress the slave syringe completely.
4. Depress the master syringe and dip it into the water.
5. Pull the master syringe to fill it completely with fluid.
6. Attach the tubing to the master syringe.
7. Put the other (free) end of the tubing into the water.
8. Depress the master syringe to inject fluid into the tubing. Bubbles will come up in the water from the end of the tubing.
9. When all bubbles stop, pull the master syringe again so that both the tubing and syringe are full of liquid.
10. Attach the free end of the tubing to the slave syringe.

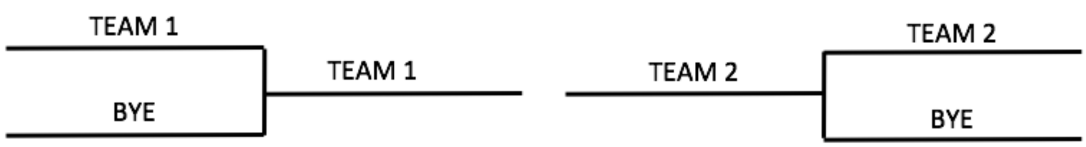
Now by depressing the master syringe, the slave syringe will extend. Pulling the master syringe will depress the slave syringe.

Conducting the tournament:

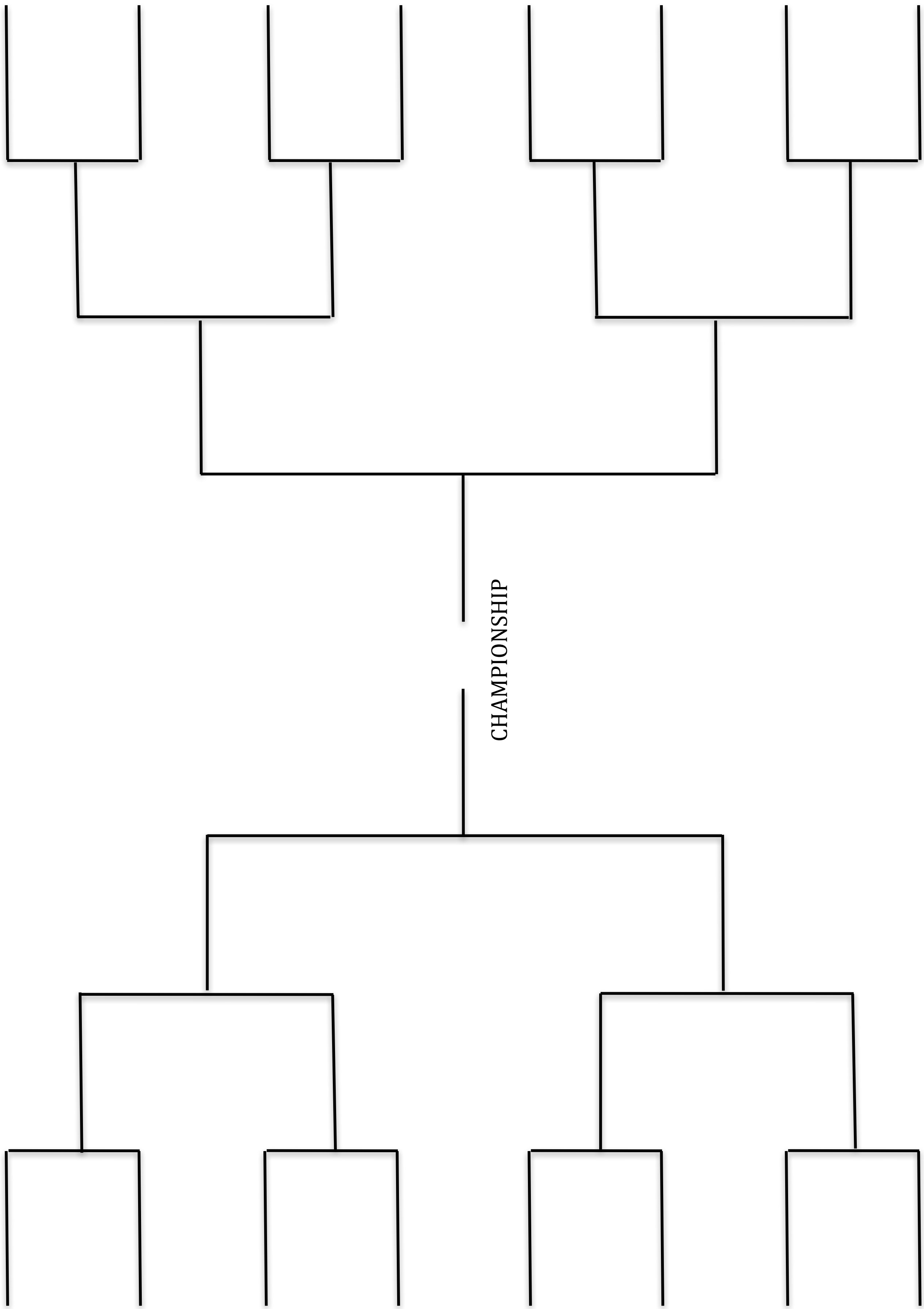
As I mentioned, I required the students to win three rounds to complete a battle. This is called “best three out of five”, as there could be as many as five rounds to decide a winner. After each round, the team members would exchange syringes.

Students who finished building their hydraulic arms first had more time to practice operating their bot or to make modifications in it.

A tournament bracket for 16 teams is provided on the following page. If you have less than these numbers of teams, I gave a “bye” to the first teams that finished their builds. These teams automatically advance to the next round. For example, if you have 28 students working in pairs, they will make 14 bots. The first two teams to finish their build would be seeded in the tournament brackets like this:



If you have more than 16 teams, use two copies of the bracket. The winning team from each bracket will play for the championship.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Happy teaching,

Brad