Team T.E.A.M. Group 1

Gabrielle Briones, Steve Maloney, Anuj Shelat, Jacqueline Tucker

G.R.I.D. Grid

Our group's task was to find a way to ensure that a 6 meter x 6 meter area was a perfect square and was level in order to build a greenhouse within ten minutes. Our design would measure out where each of the posts would be placed and determine if the land was flat enough for the greenhouse to be built. The materials we had to build our design were nylon string, wood, and metal bars. We are also assuming the person using our design does not know how to read, so we must make sure that the design is simple to use and can be easy to figure out upon the use of picture diagram instructions.

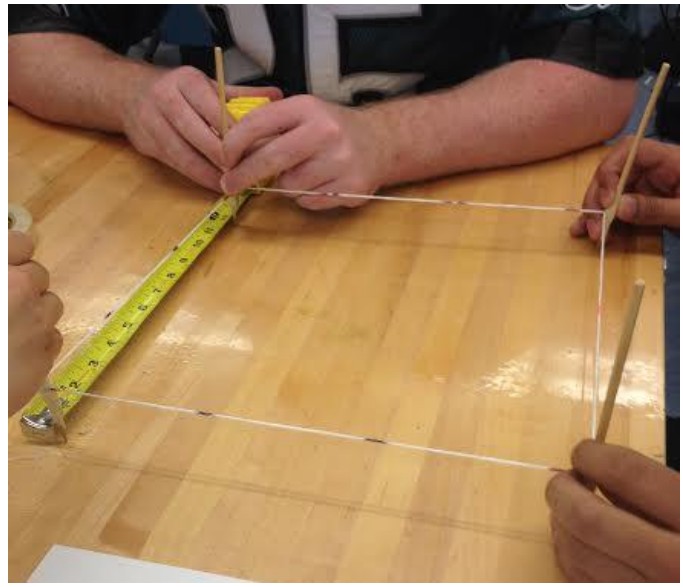


Figure 1: G.R.I.D Grid final design.

Our team picked Mozambique as our location for our design. We each did research on the area and found that there are some flat lands along the coast which are ideal for the greenhouses ("Mozambique Climate"). We also found that the weather here is typically warm which is good for vegetation. However, in the central regions of Mozambique the land is mostly mountainous. The weather in these regions is also different with each season. The summers are very rainy which could result in mudslides or other disasters and the winters are cold which is not ideal for plant growth. With this in mind, we decided that we would build the greenhouses in the coastal regions. We also found that the GDP of Mozambique is fairly low ("Africa: Mozambique"), thus we needed to keep in mind that the prototype must be affordable for the citizens to be able to purchase our device, and our device should increase efficiency so more greenhouses can be built more quickly.

In order for us to make our design efficient we needed to come up with some features that would be required for our design. We decided our design had to be durable, lightweight, easy to use, and affordable. It had to be durable so it can be used multiple times without having to be replaced. Being lightweight was important because people need to carry the tool to different locations with ease. Our design also had to be easy it to use so that the greenhouse can be built in less than ten minutes and the builders can understand how to use the tool. Finally, it had to be $10 or less so that citizens would not have an issue purchasing our product to build their greenhouses. Our design had to be the perfect tool fofor easily measuring and leveling a 6 x 6 meter area.

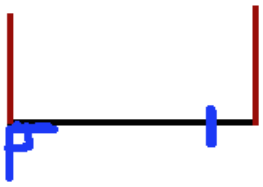


Figure 2: Rough sketch of prototype #1.

Table 1: Summary of Prototype #1 Testing (Room 316 Hammond)				
Order	**Test**	**Explanation**	**Testing Process**	**Result**
1	Makes a Perfect Square	A requirement of the prototype was that it made a perfect square. This is important for the construction of the greenhouse, and the prototype needs to make a perfect square in order to be able to build a good and sustainable greenhouse. For this test we used our prototype on graph paper to see if it made a perfect square.	Use the prototype and graph paper to test if the prototype makes a perfect square. This is done by placing a pole on the ground and aligning the poles with a makeshift ninety-degree angle measure and stretch the string until it is taught. Mark where the corner is. Do the diagonal and the other side like this until all corners are marked. Then use the graph paper to check if it made a square. Extend the lines from the marks where the poles were and see if the intersections line up with the mark. The intersection did not line up with one post so the grid was not square.	FAIL
2	Works to Level the Ground	The greenhouse needs to be on level ground to ensure that the foundation is level, so that once the greenhouse is constructed, it will not topple nor lean—it would have a solid foundation. For this test we used a bubble level.	The bubble level was placed on the string between the two poles to test if the ground was level. The bubble was in the middle of the markings, showing that the ground was flat.	PASS
3	Durable	We submerged the prototype in water and also dropped it from standing height. We decided to test the durability by doing this because if it rains or if someone carrying the actual device and accidentally drops it, the prototype would still be functional.	The prototype was dropped from the arm height of a team member to see if it would survive the drop.	PASS Survived a 1.8796 m drop.
4	Easy to Carry	We said if the prototype was less than 5 pounds then it would pass this test. People may have to carry the device place to place, and in order to do this, the device cannot be very heavy.	The prototype was placed on a scale to see if it was indeed less than 2.3 kg (about 5 lbs.).	PASS It weighed about 0.68 kg.
5	Simple to Use	How long it took to make a perfect square and check if the ground was level was timed, and we knew that we would have to teach others how to use it. If the time were under 10 minutes then it would pass. This process should take the same amount of time as the design is efficient. Others need to be able to use our device and complete the project when we are not there to help to maintain efficiency.	We used a stopwatch in order to time how long it took to make a perfect square as well as level the ground.	PASS It took about 7 min and 42 seconds.

Figure 3: Perfect Square Test

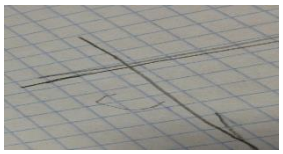


Figure 4: Prototype failing the perfect square test

Figure 5: Level Ground Test

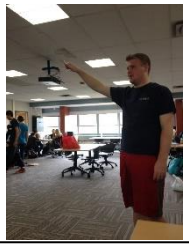


Figure 6: Drop Test

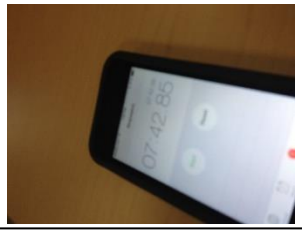


Figure 7: Simplicity/time Test

Prototype #1 consisted

of two poles tied together with string that, fully extended, would be the length of the diagonal of the square, and when rolled, would create a ninety-degree angle with one pole. A mark was put on the post for what the side length was supposed to be. Our team learned that many aspects of our prototype worked and served their purpose. The prototype passed several tests including the drop test, the time test, and level ground test. This means that it was durable, simple to use, easy to carry, and worked to level the ground. However, during the tests it became clear that some things did not work and should be improved. For instance, our prototype failed the perfect square test. We realized that measuring the layout of the square using one corner angle is not as accurate as using two corner angles. Also, finding the corners of the square appeared to be much more accurate than using the measurement of the diagonal of the square, thus we should only use the markings on the string that indicate the side lengths. We later discovered that our measurement for the diagonal was incorrect (which could be due to a mistake in our mathematical calculations). We also learned that lining up the posts might be more difficult than originally thought because only one corner had an angle. All in all, our prototype was a good start but definitely needed much improvement.

To improve our tests for our second prototype, we took a different approach in how we used our design. We had previously thought about adding more parts to our previous design, but after the Design Thinking Workshop, we decided to change the shape of the design completely. We focused on measuring the sides of the square rather than using the diagonal. The diagonal had not worked as the measurements were not as precise due to the calculations (the square root of the side length was difficult to accurately replicate in length). We had all drawn a similar design during the workshop, and we decided upon using a more box-like design with an x in the center so that the poles with string could be collected in the middle, and then only need to be extended to the correct locations. We believed that this would improve the accuracy of the perfect square, as well as make it easier to level the grid and carry the device. We believed that using the x and pulling the strings taut would be able to accurately replicate a square, and then moving the poles back to the center would be easy set-up, clean up, and carrying.

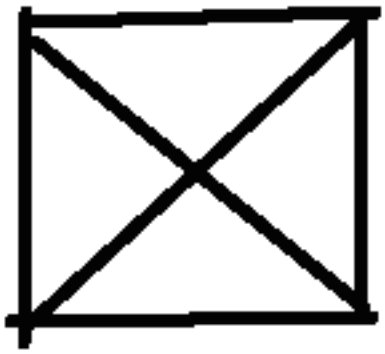


Figure 8: Rough sketch of prototype #2.

Figure 15: Simplicity/time Test

Figure 9: Perfect Square Test

Figure 10: Level Ground Test

Table 2: Summary of Prototype #2 Testing (Alumni Center Lawn)				
Order	**Test**	**Explanation**	**Testing Process**	**Result**
1	Makes a Perfect Square	A requirement of the prototype was that it made a perfect square. This is important for the construction of the greenhouse, and the prototype needs to make a perfect square in order to be able to build a good and sustainable greenhouse. We took the prototype outside to see how effective it would be.	Fully extend the poles of the prototype until all strings are taut. Measure the sides of the square to ensure that they are all the same length, as well as the angles to ensure that they all have ninety-degree angles. The way we had measured the sides and angles before we took the design outside, once the strings were taut and the poles were fully extended, the angles should all be ninety-degree angles.	PASS
2	Works to Level the Ground	The greenhouse needs to be on level ground to ensure that the foundation is level, so that once the greenhouse is constructed, it will not topple nor lean—it would have a solid foundation. For this test we used a bubble level.	The bubble level was placed each string to test if the ground was level. The bubble was in the middle of the markings, showing that the ground was flat.	PASS
3	Durable	We submerged the prototype in water and also dropped it from standing height. We decided to test the durability by doing this because if it rains or if someone carrying the actual device and accidentally drops it, the prototype would still be functional.	The prototype was dropped from the arm height of a team member to see if it would survive the drop.	PASS Survived a 1.8796 m drop.
4	Easy to Carry	We said if the prototype was less than 5 pounds then it would pass this test. People may have to carry the device place to place and in order to do this the device cannot be very heavy.	The prototype was placed on a scale to see if it was indeed less than 2.3 kg (about 5 lbs.).	PASS It weighed about 1.36 kg.
5	Simple to Use	We timed how long it took to make a perfect square and check if the ground was level, as well as kept in mind that we would have to teach others how to use it. If the time were under 10 minutes then it would pass. This is important to test so that others can easily use our device and complete the project when we are not there to help, thus maintaining efficiency.	We used a stopwatch in order to time how long it took to make a perfect square as well as level the ground. It took a little over four minutes to complete. However, this was after it took about a half-hour to untangle the mechanism. There were far too many strings on our device, thus they became impossibly tangled and extremely difficult to separate.	FAIL It took about 4 min and 13 seconds once untangled. It took over 30 min to untangle.

Prototype #2 consisted of five poles—four to mark the outer edges, and a center pole—and eight strings to connect the outer edges together and the edges to the center pole. Each side length had marked where the poles for each row were to be placed. The idea is that these would easily mark where the side poles should be, and then the middle poles could be found by bringing the outer poles closer to the center at the marked locations to find the placement of the middle poles. Our design was very successful in that it was able to accurately create a perfect square and tell if the ground was level in record time, however, the time it took to untangle the project was more than seven times

the time it took to use the device. From this major failure, we decided that a prototype that did not include the middle pole but still had all the markings would be easier to work with, as only four strings would be implemented. We also forgot to add a way to check the angle measurements of our design, which would be bad as if used improperly, the device would make a rhombus shape.

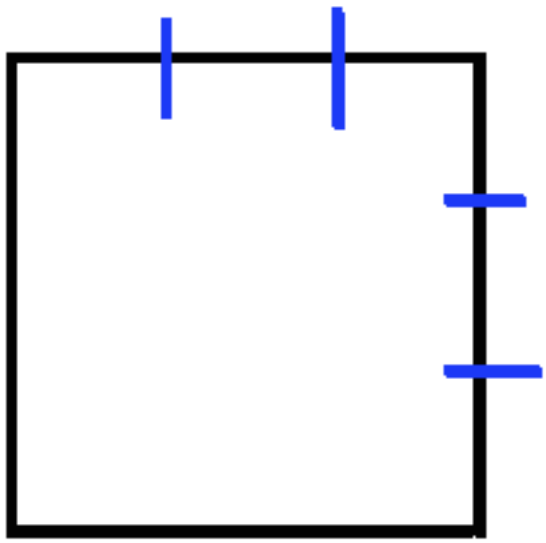


Figure 12: Rough sketch of prototype #3.

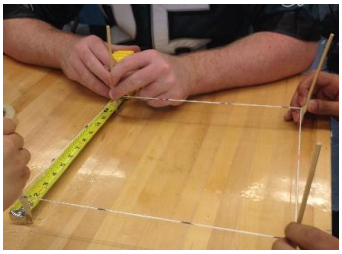


Figure 13: Perfect Square Test

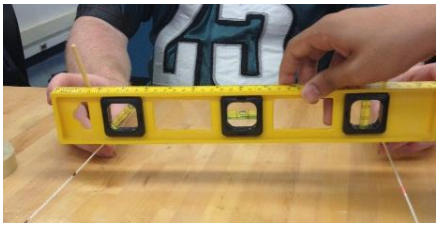


Figure 14: Level Ground Test

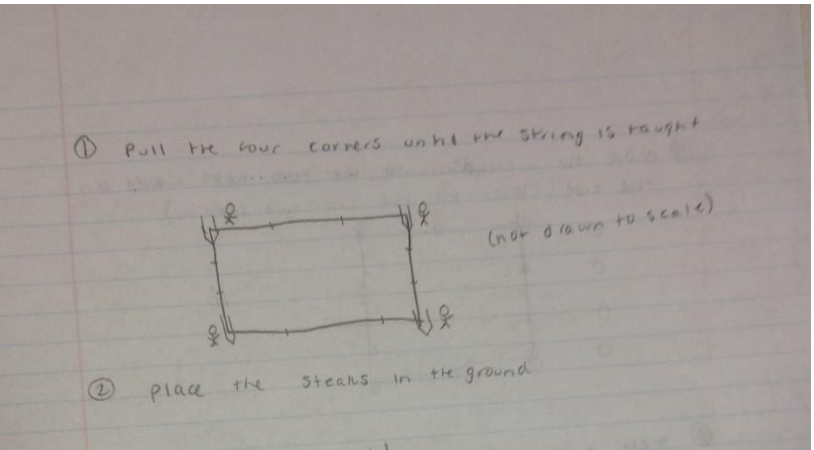
Table 3: Summary of Prototype #3 Testing (Alumni Center Lawn)				
Order	**Test**	**Explanation**	**Testing Process**	**Result**
1	Makes a Perfect Square	A requirement of the prototype was that it made a perfect square. This is important for the construction of the greenhouse, and the prototype needs to make a perfect square in order to be able to build a good and sustainable greenhouse. We took the prototype outside to see how effective it would be.	Fully extend the poles of the prototype until all strings are taut. Measure the sides of the square to ensure that they are all the same length, as well as the angles to ensure that they all have ninety-degree angles.	PASS
2	Works to Level the Ground	The greenhouse needs to be on level ground to ensure that the foundation is level, so that once the greenhouse is constructed, it will not topple nor lean—it would have a solid foundation. For this test we used a bubble level.	The bubble level was placed each string to test if the ground was level. The bubble was in the middle of the markings, showing that the ground was flat.	PASS
3	Durable	We submerged the prototype in water and also dropped it from standing height. We decided to test the durability by doing this because if it rains or if someone carrying the actual device and accidentally drops it, the prototype would still be functional.	The prototype was dropped from the arm height of a team member to see if it would survive the drop.	PASS Survived a 1.8796 m drop.
4	Easy to Carry	We said if the prototype was less than 5 pounds then it would pass this test. People may have to carry the device place to place and in order to do this the device cannot be very heavy.	The prototype was placed on a scale to see if it was indeed less than 2.3 kg (about 5 lbs.).	PASS It weighed about 0.91 kg.
5	Simple to Use	We timed how long it took to make a perfect square and check if the ground was level, as well as kept in mind that we would have to teach others how to use it. If the time were under 10 minutes then it would pass. This is important to test so that others can easily use our device and complete the project when we are not there to help, thus maintaining efficiency.	We used a stopwatch in order to time how long it took to make a perfect square as well as level the ground. It took only a little over two and a half minutes to complete.	PASS It took about 2 min and 37 seconds.
6	Measures Where to Put All 16 Posts Accurately	We wanted to ensure that all 16 posts would be able to be placed in the appropriate spots with this final design, as this is a major requirement for practical purposes for building the foundation of a greenhouse.	We measured the distance between each mark to make sure they were the same and put all the posts in our cardboard to make sure we knew where to put them, and checked if they all lined up.	PASS

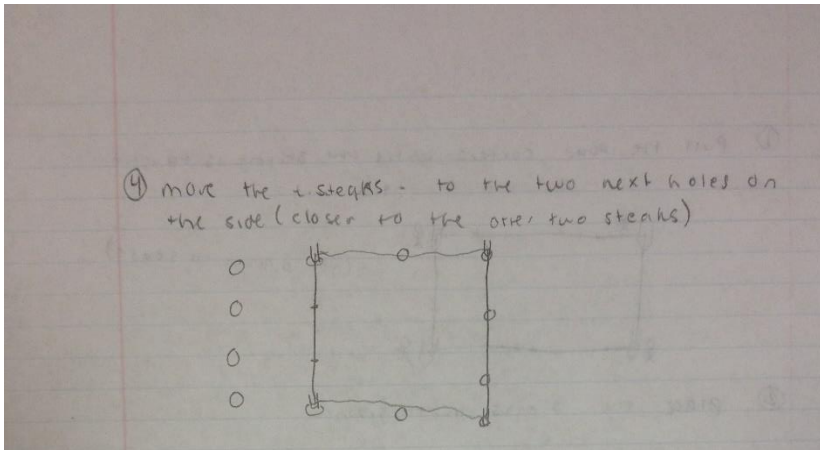
Prototype #3 consisted of four poles tied together by equal length string, making a square. Each string had marks on them, equal lengths apart for where the other posts should go. The idea is that you can use these marks and the positioning of the outer poles to find where the middle poles should go, as you move the poles to each marked spot. The string will still be pulled taut between the posts, making leveling efficient. The ratio for the length of the string for the area between the posts should not be difficult to replicate on a larger scale. Should there be any issues, the only issue

would be if the string were to get tangled, but seeing as there is only one string connection between each two poles, untangling the string should not be difficult to do. Our team learned that this design was very successful. In fact it passed all of the tests. These tests include the perfect square test, level ground test, durability test, lightweight test, time test and 16 post test. Because it passed all of these it leads us to believe that this prototype is better than the first. However, there is still room for improvement. The major place for improvement is to make sure our angles are 90-degree angles. When we set our prototype up we could eyeball it to check if it is ninety degrees but with an actual sized device this would be much harder to do and instead of a square we could end up with a rhombus. We should add a ninety degree device to one of the posts that allows us to line the string up to create a ninety degree angle for our future device.

Prototype #3 can be built for full-size greenhouse gridding and meet the price goal of $10 in materials. Four metal bars and nylon string need to be purchased to construct this design. The metal bars should be hollow, and then we could drill holes close to the bottoms of the poles where the strings could be attached. The metal bars will be made out of aluminum, which is one of the most affordable metals that will still be able to hold shape, and nylon string is also very inexpensive. Not only is aluminum affordable, but it is lightweight as well, making it easy to put the metal bars in the ground and make holes for posts. The cost to purchase the items could be significantly below $10, making the device even more desirable to developing nations as the device would be cost effective for citizens while increasing efficiency. The cost for aluminum metal bars that are one foot in length, on Amazon.com, is only $2.47 for a pack of three (Aluminum 3003 Seamless Round Tubing, 1/8" OD, 0.097" ID, 0.014" Wall, 12" Length (Pack of 3). Therefore, two packs can be bought for the low price of $4.94, and there would even be two metal bars left over that could be used for future replacement or the construction of another device. The bars do not to be much longer than one foot in length each, as these bars are only used to mark where the stakes need to be placed for the foundation. Mozambique is actually one of the world's greatest contributors of aluminum, so we would not need to import the aluminum ("2010 Minerals Yearbook: Mozambique."). Nylon string from Amazon.com is only $3.84 for 200 feet of string, which is equivalent to over 60 meters of string, and since only 24 meters of string is needed per device, there is enough string left over for more devices or to replace the string once it becomes old from multiple use, which we believe would be after no less than ten uses ("IIT 48870 Nylon String with Built-In Cutter, 200-Feet"). Thus, the final total for the device would be $8.78. While this might not seem that much less than $10, this amount saves the Mozambican consumer 31 Meticals, as $1=30.8999 MZN ("XE Currency Converter").

Diagrams for Use of the G.R.I.D. Grid:





The HESE students were incredibly helpful in their evaluation during our showcase. As judges, they were honest and blunt about what worked and what did not. The big thing that stood out to us was knowing how these designs work in the real world. They were able to take our idea and use real world reasons for why certain portions would work and what would not work. Specifically, one judge pointed out how a lack of an exact 90 degree angle would make the square grid almost impossible to perfect. Another judge referred to our materials, and how they weren't natural to Mozambique and would be difficult to perhaps send them there. All in all, having students who have been there and seen how building a greenhouse works in real practice was definitely beneficial to our project.

One thing we would definitely recommend is to perfect the 90 degree angle on our prototype. Perhaps if the four people holding the posts started in the middle and walked the same number of steps out would be a solution, but we were not quite sure how to make sure that each step was the same size, unless the people walking all had the same foot size, which could be difficult to find and would limit our resources as we would have to find certain day laborers, or the same person would walk each of the stakes out, but that would be inefficient. Also, we'd recommend using more accessible materials that don't take away from durability. Our dream prototype would be a four post (with the four posts tied together on the outside), a 90 degree angle on the bottom of each post to line up the strings, and more accessible materials to the people of Mozambique. This would be the ultimate solution, in our opinion, of improving the greenhouse setup.

Works Cited

"Africa: Mozambique." *The World Factbook*. Central Intelligence Agency, n.d. Web. 10 Sept. 2014. <https://www.cia.gov/library/publications/the-world-factbook/geos/mz.html>.

"Aluminum 3003 Seamless Round Tubing, 1/8' OD, 0.097' ID, 0.014' Wall, 12' Length (Pack of 3)." *Amazon.com*. N.p., n.d. Web. 19 Oct. 2014. <http://www.amazon.com/gp/product/B000HLRXE8/ref=ox_sc_act_title_1?ie=UTF8&psc=1&smid=ATVPDKIKX0DER>.

"IIT 48870 Nylon String with Built-In Cutter, 200-Feet." *Amazon.com*. N.p., n.d. Web. 19 Oct. 2014. <http://www.amazon.com/gp/product/B005CBGCKO/ref=gno_cart_title_1?ie=UTF8&psc=1&smid=A2UDNPGKURPVSY>.

"2010 Minerals Yearbook: Mozambique." *U.S. Geological Survey Minerals Yearbook*: 31.1-31.6. *USGS: Science for a Changing World*. Web. 9 Nov. 2014. <http://minerals.usgs.gov/minerals/pubs/country/2010/myb3-2010-mz.pdf>.

"Mozambique Climate." *Mozambique Climate, Weather in Mozambique*. Maps of World, n.d. Web. 10 Sept. 2014. <http://www.mapsofworld.com/mozambique/geography-and-history/climate.html>.

"XE Currency Converter." *XE*. N.p., n.d. Web. 19 Oct. 2014. <http://www.xe.com/currencyconverter/convert/?Amount=1&From=USD&To=MZN>.