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Antenna Design Challenge

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Antenna Design Challenge

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Report

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Antenna Design Challenge

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Abstract

In today's new and changing world, Science, Technology, Engineering, Math (STEM) education has come to the forefront of educational reform. The expectation for better prepared workers for today's technology infused businesses requires a better trained student, not only at the post-secondary level, but also at the secondary level. Today's student has access to technology that could have only been dreamed of 60 years ago. With this need for higher level skills in the STEM field for the work force, it would only be logical to expose students to aspects of engineering in younger grades, particularly at the high school level. The Antenna Design challenge has been designed to expose students to the engineering process and technology that is relevant to their everyday lives. This report will examine how an engineering challenge can be incorporated into the physics classroom, while observing how different levels of scaffolding affect mastery of the material and implementation of the lesson.

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<u>Chapter 1: Introduction</u>

When it comes to the U.S. educational system, it undergoes changes, sometimes over decades and sometimes over just handful of years. As of recent, there has been a strong push for Science Technology Engineering and Math (STEM) education and understandably so. According to the Department of Commerce, over the past 10 years, STEM jobs have grown three times as fast as non-STEM jobs. With technology and demands from industry becoming more high tech, requiring more skilled workers, the need for qualified workers is ever increasing. Aside from the need for more qualified individuals for STEM related fields of work, STEM education must provide necessary skills for students to be successful in college and K-12. With this large demand and need, there is obviously a need for highly qualified teachers to aide this change. From the 2011 State of the Union address by President Obama, "We want to prepare 100,000 new teachers in the fields of science and technology and engineering and math. In fact, to every young person listening tonight who contemplating their career choice: If you want to make a difference in the life of our nation, if you want to make a difference in the life of a child, becomes a teacher. Your country needs you." The push is not only for better prepared students, but also for better prepared teachers.

This report investigates how an engineering design challenge can be incorporated into a high school physics curriculum and the insights that can be learned while doing so. While implementing such a challenge and related activities into the core classroom, the purpose is not to have the perfect lesson plan, but to show that it can implemented in a public secondary school.

At the secondary level, in a public high school, a class will have a wide range of student ability and interest. Some of the students in the classroom may have no interest at all and yet some could possibly be future scientists and engineers. This report attempts to measure and quantify the level of student engagement in this design challenge. Thus the use of cell phone applications is adopted to specifically target the students' engagement by using a piece of equipment that they have every day interactions with. To also engage the students the use of an engineering design challenge is selected to give students the opportunity to think creatively and problem solve.

While converting this design challenge to fit the secondary science classroom, we will look into whether different applications of the design challenge affect students' engagement and ability to successfully assimilate the new knowledge. There will be two groups that will be scaffolded differently; one will undergo instruction with minimal instructions, while the other group where they will have samples present to help inspire and help students begin their design challenge. The latter group will also have certain processes modeled to provide students with guidance in data collection and other scientific investigative processes. This opportunity gives us a chance to determine whether scaffolding students differently through this design challenge will affect how successful they are at learning new concepts. The comparison of the two groups will also help determine which method of application might be more appropriate in applying engineering challenges at the secondary level. With the materials created and tested, the end result will also provide an example of an engineering design challenge that educators can implement in their everyday physics classroom.

Chapter 2: Literature Review

STEM education

In today's changing world, STEM education is the future. Our natural world is explained through science and math, everything from weather patterns to the smallest virus. Not only do we use it to understand our natural world, but it is a necessary need for our virtual world. Everything from smartphone technology and microchips to the buildings that house the machine that builds them. The U.S. Labor Department listed their top 10 fastest growing occupation from 2008-2018, which included professions in the biomedical field, medical scientists, and biochemists (see Appendix B). All 10 of the professions on the list require extensive training in STEM related education. Eberle (2014) states that "STEM education creates critical thinkers, increases science literacy, and enables the next generation of innovators. Innovation leads to new products and processes that sustain our economy. This innovation and science literacy depends on a solid knowledge base in the STEM areas. It is clear that most jobs of the future will require a basic understanding of math and science—10-year employment projections by the U.S. Department of Labor show that of the 20 fastest growing occupations projected for 2014, 15 of them require significant mathematics or science preparation."

With this increasing need for STEM education in public education, the antenna challenge attempts to address this by taking a challenge that is performed at a post-secondary level and adapting it appropriately for the secondary level. The post-secondary level involves engineering students who participate voluntarily in the program, whereas the secondary level involves students who are placed in the class as a requirement of the state's graduation requirements. In this challenge they will measure and analyze wireless signal strength from an everyday router and then research and design their own antenna to use on the router and analyze their results. At the post-secondary level they have specific goals, for example, to have the longest range or smallest physical size. For the secondary level it will be more about exploration and introducing them to designing and testing their creations.

The 2010 American College Testing's College and Career Readiness report found only 43% of the tested 2010 graduates are considered college-ready in math and a mere 29% were considered college-ready in science. This study also found that 52% of students were considered college ready in Reading and 66% ready in English. (Appendix B). In education there is a growing urgency to have college ready graduates, and the American College Testing report shows a gap when it comes to having students graduate with the appropriate academic skills for college. Of the ones that do graduate with the appropriate college level skills, a small portion of them decide to go into a STEM related field. Morella (2013) mentions that even with the number of jobs in science and engineering is expected to surge in the years to come, close to 60 percent of the nation's students who begin high school interested in science, technology, engineering, and math, or STEM, change their minds by graduation. Not only is there difficulty in getting students into STEM fields, but there is difficulty in keeping them in their STEM related majors. However, there are some good signs when it comes to STEM education, according to Mills and Treagust (2000) students are graduating with good knowledge of fundamental engineering science and computer literacy, but they don't know how to apply that in practice. That study found that many engineering programs focus too much on the engineering and science concepts without putting enough emphasis on practicing the actual design process and lack of emphasis on the collaboration aspect of engineering. Finally when looking at this particular issue, not only do we have a lack of college ready students, the ones who do choose to go into a STEM path have a low success rate, and then the ones that finally do graduate, are not prepared to the workforce standards. So it is vitally important to go back as far as we can to help with this issue at the earliest point possible instead of fixing each particular transition. Thus the massive push for STEM education in secondary schooling.

Could it be that we cannot capture the imagination of young inspiring minds in grade school. Does the school system beat them down to where they feel they cannot succeed or feel inadequate? Maybe there is a lack of inspiration. Arguably there hasn't been a "first walk on the moon" moment in a long while. Nonetheless, we must work and do everything we can as educators, to inspire and encourage our youth to challenge themselves and to view STEM careers as a possibility. One could argue that it is a losing battle and that we cannot force students to become interested in something they are not, but that doesn't mean there shouldn't be any attempt to do so.

Many times young minds are not fully aware of what they are capable of, and many do not know what is available in the STEM fields. The antenna design challenge is not the end all of solutions, but it is a step towards improving STEM education and related issues.

Problem Solving

Problem solving is a natural way to learn as children. In early ages of child development we see children push, pull, smash, and break things down to understand how they work. We as human beings have a desire to construct and deconstruct our knowledge of things around us. So by offering an opportunity to our students in schools to go through the engineering process, which we as humans seems to naturally be accustomed to, we can provide them great opportunities to learn in a fashion that is absent from the contemporary classroom . Other studies have found that "Concrete examples that require hands-on solutions mean far more to kids than abstract concepts" (Draxler, 2013, p. 57). By providing a design challenge, the students will be able to use their problem solving skills in collaborative settings, much like that of the real world engineer.

Brophy (2008) mentions that hands-on learning associated with the making activities provides a first-hand experience of the properties of materials and principles of physics associated with technical fluency. In these types of activities, the design process forces students to reflect on their structure and function of their device. It forces students to think about how they work, what factors affect it, and how can it be modified to meet the challenge goals. Arguably this method will be more engaging and involve deeper learning experiences than rote memorization of facts.

By giving students the opportunity to participate in problem based learning; they will be able to practice skills that are valued in the workplace. "PBL promotes students' confidence in their problem solving skills and strives to make them self-directed learners" (Stanford University newsletter on teaching, 2001). Offering students multiple design goals creates a multitude of ways the students can compete in the challenge. They have to decide whether to excel at one of the three goals, or be good at all of them. "The use of project-based learning as a key component of engineering programs should be promulgated as widely as possible, because it is certainly clear that any improvement to the existing lecture-centric programs that dominate engineering, would be welcomed by students, industry and accreditors alike." (Mills, 2003, p. 13). This is why the antenna challenge is being applied at the high school level. This particular activity, which has been conducted at the post-secondary level, is being modified to fit the physics curriculum in a public high school. High school students will attempt to design an antenna that will perform well. They have choices between creating an antenna with strongest signal possible in one direction or in all directions. The antenna challenge will attempt to present students with a design challenge that is engaging and challenging. It will force students to make adjustments, test, and re-test their designs constantly.

This challenge offers some guidance in the topic but the students will have to do much of the research themselves. Many students will get frustrated even though the challenge may be interesting to them. The idea of having unlimited design possibilities create a sense and fear of failing or building the "wrong" design. This is not surprising since our students are raised in a school environment where there is always a "correct" answer and everything they do is graded on whether they achieve that correct answer. "The students solving more complex and ill-structured problems without assistance experienced frustration than other groups received teacher-directed facilitation. Despite appearing to fail in their problem-solving efforts, the unsupported students solving the ill-structured problems outperformed their counterparts on both the well-structured and higher-order transfer problems. Although frustrating, it appears that the productive failure approach engaged deeper level learning and problem solving in students" (Householder, 2011, p. 4). With some guidance and reassurance educators can help the students into thinking in this more "ill-structured" challenge which they may not be comfortable with.

By presenting this lesson in the format of an engineering design challenge, one can arouse a student's need to know by giving them an opportunity to learn by doing, which is a natural desire of many students.

Collaboration

Students will interpret the same lecture in different ways due to their varying backgrounds and preconceived notions they have on the topic, they may walk away from the class period with a different idea on what was taught and emphasized. This lab attempts to involve many students in small group collaboration and collaboration on a class level by having them collect data individual or in a group, and then comparing their data with other groups. Through this process they will have to talk to each other and collaborate in the data collection so the whole class may be successful. A study by Falkenheim (2012) reports shows that one in six scientists and engineers in the United States reported working with individuals in other countries in a given week. The antenna design challenge is setup to where students must work with a partner or group of students to design the best antenna for the challenges set forth. It is also setup so that the class has to collect data together, requiring all of them to work together to pool all the data together to analyze what is happening. "Most engineering is done cooperatively, not individually, and technical skill is often less important than interpersonal skill in getting the job done. In survey after survey, representatives of industry place communication and teamwork at the top of their lists of desirable skills for new engineering graduates" (Felder, 2000, p. 12). Some may argue that individual ability is the most crucial component in a competent engineer but no one can deny the fact that collaboration and the ability to work with others is a huge part of being successful in the workforce.

In today's education system, students are tested on a regular basis to determine who is "better". As a result many classrooms have turned to memorization, drills, and repetitive practices to prepare students for their standardized tests. Many teachers may fear that taking the time to conduct a collaborative group challenge may result in lost time where they could have been working on practice problems that will prepare them for the state exams which are required to graduate. As a result, many classes rely heavily on the drill and practice, which involves individual practice. However a study by Gokhale (1995) found that students who engaged in collaborative learning performed higher on critical thinking problems compared to those who studied on their own. The collaborative learners also performed equally with those who worked alone when it came to the drill and practice test.

When collaborating with peers, there are many different levels of development within a single grade level classroom. Many students come in with varying levels of ability and past experiences. Having students collaborate with one another in pairs, small groups, and at the class level, encourages learning in a social setting. According to Vygotsky (1978) "human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them" (p.88). Learning, since the beginning of time, has a social nature to it. People learn from one another, with one another, and with the help of one another. Not only is it a natural way or learning, it is also something a future engineer must face.

This social interaction is paramount in the engineering field. However there is a huge void in current engineering education when it comes to communication skills. There is a large focus on the engineering thought process from design to constraints but communication is not always a priority. One study found that communication skills were ranked as an essential skill by 62% of engineers and that 90% listed it as essential or important on the job (Nicomento, 2014). By arranging the design challenge into two parts, the students will have to collaborate together at a class level all the way down to collaborating with small groups or pairs. Having students use communication skills with many different people on a regular basis in the classroom will allow students time to practice their communication skills, specifically in an engineering problem solving challenge. Vygotsky (1978) says that a child begins to perceive the world not only through his [or her] eyes but also through his speech. He believed that knowledge is built and learned through social interaction. Construction of knowledge occurs and relies upon interaction between students but also between the student and teacher with real world examples and tasks. The antenna challenge does exactly this.

From a Constructivism stand point, this antenna challenge will provide students with a social learning experience that involves language and real world situations. The hope is that this challenge will encourage students to be self-motivated and actively engaged in the lesson at hand. According to this point of view this will allow students to take part in an activity that will allow them to absorb and build their knowledge, thus internalizing their knowledge rather than just memorizing facts.

Real world Technology

Finally there is a "real world" aspect to this lesson and a strong connection to technology. Not only is it connected to technology in the general sense, but it specifically incorporates the use of their personal technology, their cell phones. This will encourage students to participate and be engaged through the use of technology that is relevant to their everyday lives. The idea was that the use of cell phones would help dismiss the usual comments of "When will I ever use this again?"

With technology in the classroom, there is a downside. The availability of technologies in certain schools can be difficult due to budgetary constraints. If that isn't an issue, the availability of the technology to the students can be an issue, since many of them do not have the access to certain technologies once they leave the classroom. To avoid this issue of high material costs, this activity includes materials that would not cost schools a significant amount of money to purchase. The choice of cell phones as the measuring device for this activity is ideal since it is readily available to students and is relevant to their everyday lives. With the emergence of low cost smart phones, most students have access to one, whether theirs or a friends in class. Cell phones also serve as a form of technology that students have interest in and can access anywhere.

However some may argue that cell phone proliferation is not as great as it may seem, especially in low income areas. According to Madden (2013) "37% of teens have their own smartphone, which is up from just 23% in 2011" (p. 3). So in certain areas, especially low income areas, there are classrooms where there might not be a single smartphone in use. Even though the unit created does rely on smartphones, there is alternative, the laptop. In The National Center for Education Statistic's *Teachers' Use of Educational Technology in U.S. Public Schools: 2009* (NCES 2010-040), it was found that in 2009, 97 percent of teachers had one or more computers located in the classroom every day, while 54 percent could bring computers into the classroom. Internet access was available for 93 percent of the computers located in the classroom every day and for 96 percent of the computers that could be brought into the classroom. With laptops and computers being so readily available in most classrooms across the nation, one can conduct the antenna design challenge as written with those laptops and computers. There are many alternative applications that can be installed for free through google.com, which requires no special equipment, like Wi-Fi Analytics created by Amped Wireless. It installs readily to any computer that has access to google.com through their app store for free.

Kaminski from Ohio State University's Center for Cognitive Science found that college students who learned a mathematical concept with concrete examples couldn't apply that knowledge to new situations. The argument that concrete examples do not help students learn is misleading; even she stated that it helps some students, not all. There will never be solely one method that will reach all types of students, there are so many different learning styles and abilities in a public classroom that it makes this virtually impossible. However, using real life concrete examples does encourage relevance and spur interest in students. Also, she mentions that the real life example itself can distract students from the mathematical concepts that need to be learned, but that can easily be adjusted by purposefully making a lesson where the mathematical concepts are not taken for granted.

The antenna design challenge will allow students to use everyday technology that they have access to. Students will use technology that they are accustomed to and affects their everyday life. This technology is seen throughout society from coffee shops to their homes, so it will resonate with them and be more relevant than traditional physics labs. Bernard (2009) believes that students need a personal connection to the material, whether that's through engaging them emotionally or connecting the new information with previously acquired knowledge. Without that, students may not only disengage and quickly forget, but they may also lose the motivation to try. When writing the antenna design challenge, a significant amount of thought is put into how to implement it in the high school classroom, from the questions asked to the types of equipment used. Certain technologies are not chosen due to the complexity of the equipment and how foreign they may be to the students.

Guided vs. Structured Inquiry

At the high school level, the question of concern is, how much freedom the students should be allowed when performing these types of activities. This uncertainty is certainly justified, as different students react differently to varying types of scaffolding. According to Fernandez (2001) the metaphor of a 'scaffold' implies a temporary support that can be removed once the construction work has been completed. With this in mind two groups are created; one that will be called the guided group and the other called the structured group. The reason this is included in the report is to compare and analyze how much scaffolding would be ideal for this type of activity.

According to Colburn (2000) guided inquiry is where the teacher provides the materials and problem to investigate, but does not give students a set procedure to solve the problem at hand. To stay in line with this definition, the guided group will be given materials but the students will be allowed to choose their procedures in how to perform the challenge. The teacher acts as a resource and helps guide the students towards their goal. When it came to researching the different types of antennas and designing their own, they were not given any specific instructions or help unless they asked clarifying questions.

Once again, going by the definition laid forth by Colburn (2000), structured inquiry is where the teacher provides students with materials and a problem to investigate. However the thing that differentiates this from guided inquiry is that students are given procedures also. Students are still expected to discover relationships between variables and data, much like the guided group. With this in mind, the structured group in this report will have parameters and procedures in place and will also be given samples to help guide them and serve as examples of what can be created. They will also have certain processes modeled so students can use sound scientific methods while collecting data and testing their designs. However they will still be encouraged to devise any methods or procedures as they wish. By paying attention to critical features of the task and providing models of actions that students can use, it helps minimize any frustrations the students may have.

One can argue that problem based learning can be difficult for students to adjust to, especially if they have not been exposed to those types of activity in the past. For example, in this challenge many students work with equipment in a way they have not done in the past, and to perform data collection that they are not familiar with might require some scaffolding help students from getting frustrated and demoralized. With this in mind, since this is a particularly new experience for students, this antenna challenge could possibly use some scaffolding to help build the skills the students need.

Alignment of Learning Standards

It is crucial that this activity be aligned with the TEKS (Texas Essential Knowledge and Skills) due to the fact that every public school and many charter and private schools must meet these standards for each subject. The challenge in this situation comes from taking a lesson that is done on a post-secondary level with undergraduate students in the University of Texas and modifying it to be beneficial at the secondary level. In doing so, there is an adjustment of what objectives and steps must be taken to mold this activity so it is beneficial to the high school students in a physics classroom. So certain aspects of the challenge will be emphasized differently than it has been at the collegiate level. Also many things were added to the challenge and lesson plan to ensure that TEKS were aligned and would be mastered in this antenna challenge.

One of the major hurdles for public educators is that design challenges and problem/project based inquiry takes a significant amount of time to perform. To incorporate a design challenge while covering major TEKS can be overwhelming to a teacher who has never performed such an activity. This antenna design challenge has been designed to take 1-2 class days (1.5 hour long classes).

Chapter 3: Methods

The school, in which the two classes were selected, is a public high school in the greater Austin Texas metropolitan area. The school has approximately 1950 students in grades 9-12. The population is made up of 60% Caucasian, 22% Hispanic, 6% African American, 8% Asian, and 4% other. From the graduating class of 2013, approximately 57% of the graduates went on to four-year universities, with another 39% attending two-year colleges. The two classes that are being referenced in this report are two physics courses that are taught by the same teacher.

Research for this lab was broken into two parts. For the first portion of the lesson, students analyzed how an unmodified router and modified router distributed its wireless signal. The purpose of this was to have the students determine whether the signal was directed a certain direction or if wireless signal was spread equally around the room. This portion was also used to allow students to utilize their smart phone and the Wireless Overview 360 application from the Android App Store. This free program was used to determine and measure how the signal was spread throughout the room. Setup for this part of the activity requires a wireless router to be connected and placed into the center of a room. Wireless overview 360 is not available in the Apple store, so many Apple users will have to find someone with an Android phone.

In part 2 of the study, students worked together to research, design, and test their own antennas. One class of students was given a design challenge with little guidance, while the other was given more structured and modeled version of the lesson and activity. The purpose of this was to determine how some modeling and samples would affect students in learning about wireless signals and antenna designs.

All materials, including lesson plans and worksheets, are given in Appendices D through I. Two classes deemed to be of relatively equal ability were selected. Class size was a challenge since none of the classes was exactly identical in number, and depending on the day, any number of students could be absent. To combat the absence issues, data were only taken from students if they had been present through the entirety of the activities.

When collecting data, the chosen method was that of a pre- and post-test, to determine how well each student mastered the material. To go along with the quantitative data from the tests, their graphical mapping was also analyzed to determine mastery of specific skills and knowledge.

3.1 Materials

Setting up the wireless challenge doesn't require a large amount of specialized nor expensive equipment. One of the main concerns when implementing engineering challenges is that the funding might not be readily available, so this activity was designed to use items that are affordable and readily available at local retail stores. One would have to start by purchasing a wireless router with a removable antenna(s). Other than having removable antennas, there is no other special requirement for the router. Many IT departments within schools might already have these placed throughout the school or might possibly have one available to use, so many educators will not have to bare the financial burden for this particular part. The price range for these routers can be anywhere from $30 and up, depending on where one can purchase it from. For this particular study a router manufactured by TP-Link was used. It was obtained for $70 through Amazon.   There were many other choices but this was the one that was chosen for this purpose. 18 gauge wire was purchased from Fry's, a national electronics store chain, for $17. The 100ft spool of solid copper wire was more than enough for 100 students to use when doing the lab in groups of 2-4. The remaining connectors can be found online and at local retailers; costs are shown below in Figure 3.1.

Materials	Cost
Wireless Router	$70 ($30+)
Solid copper wire (100 ft.)	$17
SMA to Reverse Polarity SMA (RPSMA) connector	$4
female-to-female SMA connector (x2)	$5
Coax with male SMA connector	$10

Figure3.1

3.2 Equipment Setup for Part 1 of Design Challenge.

For part 1 of the challenge, students were asked to determine how wireless signal is propagated from the router without any modifications. The router is placed in a central point in the room and students are given a map (Appendix G) of the room with reference points, so they can determine the strengths of signal throughout the room, and so the students can collaborate with each other. Giving students a map with several reference points allows the students to share data with each other without having difficulties in understand each other's data, so accuracy when sharing is much better than without have a pre-made map. One thing to note is that different groups cannot necessarily use each other's data being that each phone that is measuring the signal strength has a unique antenna themselves, so data in one spot may measure differently depending on the phone that is used.

The following figures show the assembly of the parts needed to perform the first part of the antenna challenge where the students map out the signal strength of an unmodified wireless router. The first crucial part of the antenna challenge is having a router with removable antenna(s). In this case the router that was used was a T-Link Wireless N Gigabit Router, model number TL-WR1043ND (Figure 3.2). This particular router has 3 antennas, it would be ideal to find a router that has only one removable antenna. Setup of the router is very simple because one does not need to configure the network. The phone app, Wireless Overview 360 doesn't require students to log into the network to see the signal strength. Since the program allows students to view the strength of the router without configuring it, all that needs to be done is to plug the router into a power outlet and an Ethernet port. Once the wireless router has had time to start up, this portion of the antenna challenge is ready to begin.

Figure 3.2 (note: All three antenna are removed and the middle is utilized for the cantenna)

3.3 Equipment Setup for Part 2 of Design Challenge.

After students have completed mapping the unmodified router's wireless signal, one will need to assemble the extra parts required for the "cantenna" portion of the challenge. A cantenna is a basic monopole antenna placed inside of an aluminum or tin that changes the distribution of the wireless signal in the room.

The base (antenna mount) is composed of a 1/16 inch thick plate of aluminum. A hole is drilled in the middle of the plate so that the female-to-female SMA connector can be mounted into it as shown in figure 3.3 below.

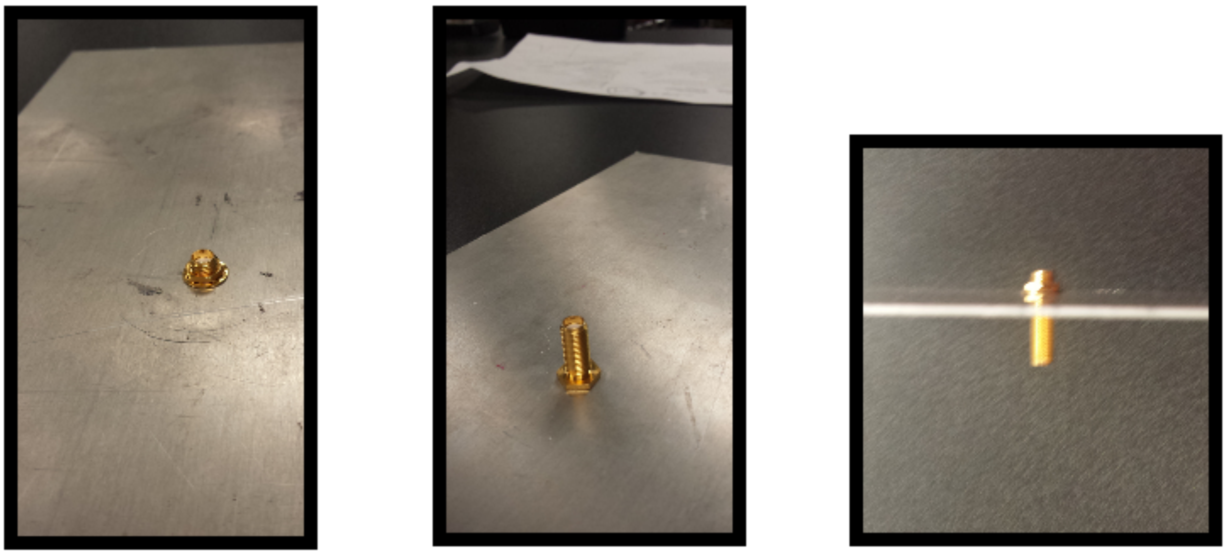


Figure 3.3

Next one will take the SMA to Reverse Polarity SMA (RPSMA) connector and the female-to-female SMA connector and connect the two. Be careful to take note that the RPMSA has a male and female end and that they must be connected in the correct format, as shown in figure 3.4. After this has been completed, the two connectors can now be connected to the coax cable as shown in figure 3.5.

Figure 3.4: picture 1 shows RPSMA on left and female-to-female SMA connector on right in each picture

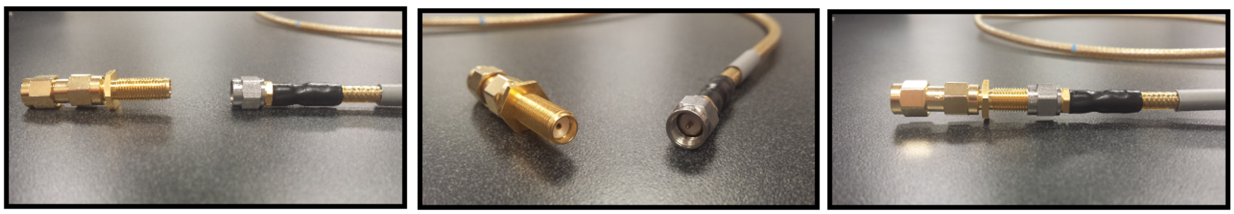


Figure 3.5 shows how the previous assembly in figure 3.3 connects to the coax cable.

Now the coax cable end, shown in figure 3.6 is then connected to the back of the router where the original antenna was. The other end of the coax cable will go to the mounting plate (Figure 3.5). Once completed this portion of the assemble should look similar to the one shown in figure 3.7.

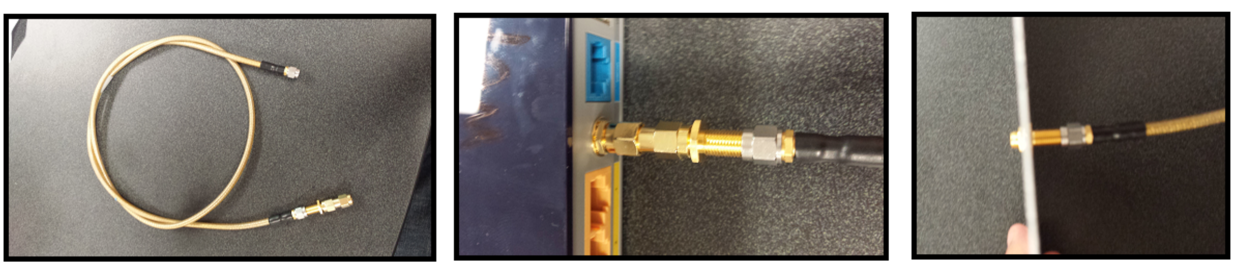


Figure 3.6: coax cable on left, RPSMA end connected to modem in middle, coax cable connected to mounting plate on right.

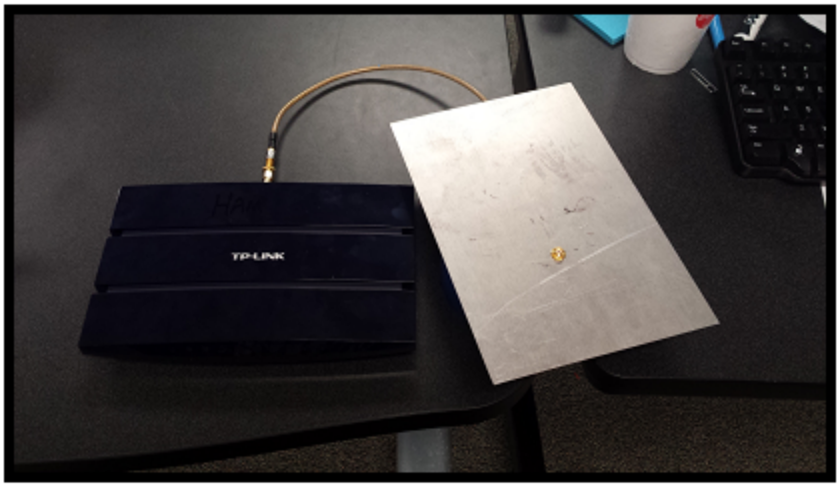


Figure 3.7

Now the only piece left is the "cantenna". The cantenna requires a can made of a metal. The particular container used in this study was a leftover Christmas themed tin that was found in the storage room of the school. All that must be done to the can is to put a small hole in the side. This is where the can will meet the mounting plate.(Figure 3.8) the hole is necessary to allow the monopole antenna to poke through the can.

Figure 3.8: Pictured above is the can used for the cantenna.

A small wire was used to mount inside the cantenna. In this situation the teacher calculated the optimal length for the monopole design. Since the router worked on a 2.4GHz frequency, the formula $C=f\lambda$ was used to calculate the optimal length. So the wavelength of the wave calculated out to be 12.5 centimeters. If a 5GHz frequency were to be used, the appropriate length would be 6 centimeters. The most common form is the quarter-wave monopole, in which the antenna is approximately 1/4 of a wavelength of the radio waves. So the ideal length of monopole is ¼ of the wavelength, so at 2.4 GHz, the monopole should ideally be 3.125cm tall. (Note: 9.375 would work just as good, and so would 15.625). The actual monopole used in this particular cantenna is shown below in Figure 3.9. Please note that the length is slightly longer than 3.25 cm because some of the antenna slides into the mounting base. Once mounted, the height of the monopole was 3.25 cm.

Figure 3.9: Monopole antenna used for the cantenna

Assembly of the cantenna is very simple, as shown below in Figure 3.11.   Duct tape was used to secure the cantenna in place because in this particular cantenna, the hole was slightly larger than needed and thus did not fit tightly. With the tape holding the cantenna in place, there were no issues with transporting the cantenna or the function of it. The actually design of the cantenna was a version of many that are found on the internet. Many people make their own, so there are many other ways to create one with differing parts that the ones shown in this study.

Figure 3.11: assemble can with router setup

3.4 Guided Inquiry vs. Structured Inquiry

For part 1 of the antenna challenge, the two classes observed were split into two different groups. The lesson for one of the class periods (1st) leaned more on the side of guided inquiry whereas the 2nd period was more structured. 1st period students were given materials and a goal but were left to determine the procedure when it came to mapping the strength of the wireless signal that the router had given in the classroom. 2nd period was given the same materials and goal; however mapping was modeled by the instructor. There was also discussion as to why the modeled method would help yield better results, but students were encouraged to use their own system if they pleased.

For part 2, both classes are asked to create their own antenna to design the most effective antenna they could. They were allowed to pick whether they wanted to create a directional antenna or omnidirectional antenna. The guided vs. structured inquiry differentiation was continued through this portion of the challenge also. The guided group (1st period) was asked to create an antenna and that it could either be the best directional, omnidirectional antenna, or they could try to build one that did both very well. They were encouraged to test and design their own antenna with their group but were not given any ideas. They were told to research different styles of antennas and try what they would like. The structured group (2nd period) was asked to do the same challenge but were presented with several different examples and some ideas they could test, such as length, number of coils, antenna area, and other factors that may or may not affect the strength of an antenna. During the process of testing their designs, they were given suggestions they could also try, and given feedback on their testing results. Another difference was that this group was encouraged strongly to write down their results and keep track of what worked and what did not.

The guided group was also left to research many of the topics that are expected to be learned for this particular lesson. For example, they were not led to discover the different types of antennas, what an antenna is, what electromagnetic waves are, or if electromagnetic waves can be directed or not. They were left to go through the activities and challenges with minimal structure. With the use of the data collected, an attempt will be made to determine if this was more effective or less effective than the structured group.

3.5 Pre-Test and Post-Test

Students were given a 9 question pre-test to determine what previous knowledge they may have when it comes to electromagnetic waves and wireless signals. They will be given no resources and will have to work on their own test individually. Students will not be graded on their results but will be encouraged to put forth their best effort. There is no identifiable information and no responses can be traced to any specific person. These preliminary results will be crucial in determining if the learning objectives will be met by the students as they go through the engineering design challenge. Finally, the post-test will have an additional question that the pre-test did not. It will be a ranking question, where they can rate their engagement/interest in the activity without any negative or positive consequences. This was chosen as the preferred method of quantifying their engagement level since it can be difficult to quantify a student's engagement based on visual and audio cues. Also because some visual cues may be misleading as that some students are highly motivated and they will go through the activity actively, however this does not mean that they enjoyed the activity.

Chapter 4: Data Analysis

4.1 Pre-Test

Students were given 9 questions regarding electromagnetic waves and wireless signals. They were not taught any of the material beforehand and students were encouraged to write in full sentences and with their best possible answers. Each student was asked by the teacher to work alone without the use of any textbooks or internet access. None of the information regarding this unit has been discussed before this pre-test, so the results are based purely on previous knowledge they may have from other sources outside of this course, which are shown in Figure 4.7. Students show that they had very little specific knowledge about specific types of antennas, which was evident in the pre-test where zero students could successfully name a technical name for a type of antenna in either class. They did however have a concept of what an antenna was and its general purpose, but even those responses were somewhat limited in that most of them responded that they were used in devices like radios and televisions. When it came to mapping how wireless signal travels from the router, most students understood that the wireless signal radiates outwards from the router in all directions. There were several students who noted that the signal could be blocked by walls and drew it accordingly or mentioned it in writing along with their sketch. One thing to note is that wireless signals and electromagnetic waves are not discussed in previous grade levels and that these students are gaining the little knowledge they do have about the topic from personal experiences with technology in their everyday life. When asked specifically for some examples of electromagnetic waves on the pre-test, only 18.5% of the guided group and 53.3% of the structured group were able to list one or more examples. With the proliferation of wireless networks and cell phones, this comes as no surprise that they have some general information about the topic but are not fully versed in the connection they have with electromagnetic waves. The previous knowledge that the students come to the physics classroom shows varying levels of understanding when it comes to wireless signal and electromagnetic waves. Even between the two classes the pre-test results were not consistent so this brings into question how effective the lesson may be when the initial results vary between the groups.

4.2 Wireless Signal Mapping

Looking at the Mapping portion of the inquiry activity, there was an interesting trend between the two classes (Figure 4.1). 1st period (guided) class had poor results when it came to discovering the intended trends. 57.7% of students noticed that the signal got weaker the further away they were from the router, and that the signal strength was relatively even throughout the room. 34.6% of students noticed one of the two trends, and 7.7% did not mention either of these two trends. Compared to the structured group (2nd period), which had 83.3%, 16.7%, and 0% respectively. There is a noticeably different success rate when it comes to discovering the two trends of the router signal. This lower success rate of the guided group could have occurred because the students did not have a model to follow on how to map the strength of the signals. Whereas the structured inquiry group (2nd period) had the teacher model how to get measurements, thus giving the students in that group a stronger background in sound data collection. Figure 4.5 and 4.6 shows an example of how a majority of students mapped their signals in the structured group. Note that they used consistent spacing when recording data points and that they also chose to sample directions in a symmetrical pattern around the router. This trend also followed when it came time to switch the antenna to the cantenna. The guided group had a 57.7% success rate on noticing that the cantenna caused the signal to be stronger in one direction or focused, whereas the structured group had a 100% success rate. Students in the guided group did not have someone model how to map the signal in a systematic fashion, so many of them took random samples around the room, causing them to have pockets of missing data in the room or data points which did not cover the room thoroughly. In Figures 4.2 through 4.4 are examples of students' maps which have missing data points due to a lack of systematic sampling when taking measurements around the room. The samples also show data points that are not consistent and look like they may have made error when collecting the data with Wi-Fi Overview 360 or other technical problems. Why are students making these mistakes or lacking solid scientific method when recording values during the lab? Could this be caused by a lack of ability to recall on past experiences or the inability to apply those experiences in a manner to help guide them in gathering data in an effective manner? Students may lack practice in creating and conducting inquiries on their own in the classroom. When students become accustomed to having all the steps in a science lab laid out in step by step format, they become reliant on those procedures and struggle to adjust. Furthermore, they never develop the skills needed to adapt their knowledge to different situations. The other possibility is that the students have had past experiences that would be useful, but due to the foreign nature of the topic, they do not think to use those experiences because they may be deemed inappropriate in this situation. The compartmentalization of those past experiences may be the reason why they do not think to use them in this case, or they deem them to be not valid in their usage for this topic. The structured group had the teacher model a way for them to collect and sample data, which seemed to improve the students' ability to record accurate data. (Figures 4.5 and 4.6) Many of the students' maps looked very much like the ones shown in Figure 4.5 and 4.6. Due to the modeling done by the teacher, many of the groups decided to use that method instead of discovering their own. By modeling a method of sampling the data, the students in this structured group did not have to recall past experiences and apply them to this new situation. Some may argue that this is a negative aspect to the lesson application since students are not creating their own methods or thinking critically and creatively for the challenge at hand.

With consistent practice and more opportunities for students to apply their knowledge in varying situations, they should be able to improve their application skills for future events. This calls for educators to apply different strategies and more practice when it comes to improving the students' abilities to adapt their previous knowledge to different settings.

Wireless Mapping Results

	1st period Unmodified Router Mapping (26 students)	1st period Cantenna Router Mapping (26 students)	2nd period Unmodified Router Mapping Test (30 students)	2nd period Cantenna Router Mapping (30 students)
Did students observe what they should have on both situations?	15 - Noticed weakening signal the further away and evenly spread 9 – noticed one trend only 2 – Did not mention either trend	15 - Noticed signal was stronger in front of the cantenna 11 – Noticed no trend at all or Did not notice trend, but mentioned that they though it should focus signal strength	25 - Noticed weakening signal the further away and evenly spread 5 – noticed one trend only 0 – Did not mention either trend	30- Noticed signal was stronger in front of the cantenna 0 – Noticed no trend at all or Did not notice trend, but mentioned that they though it should focus signal strength

Figure 4.1

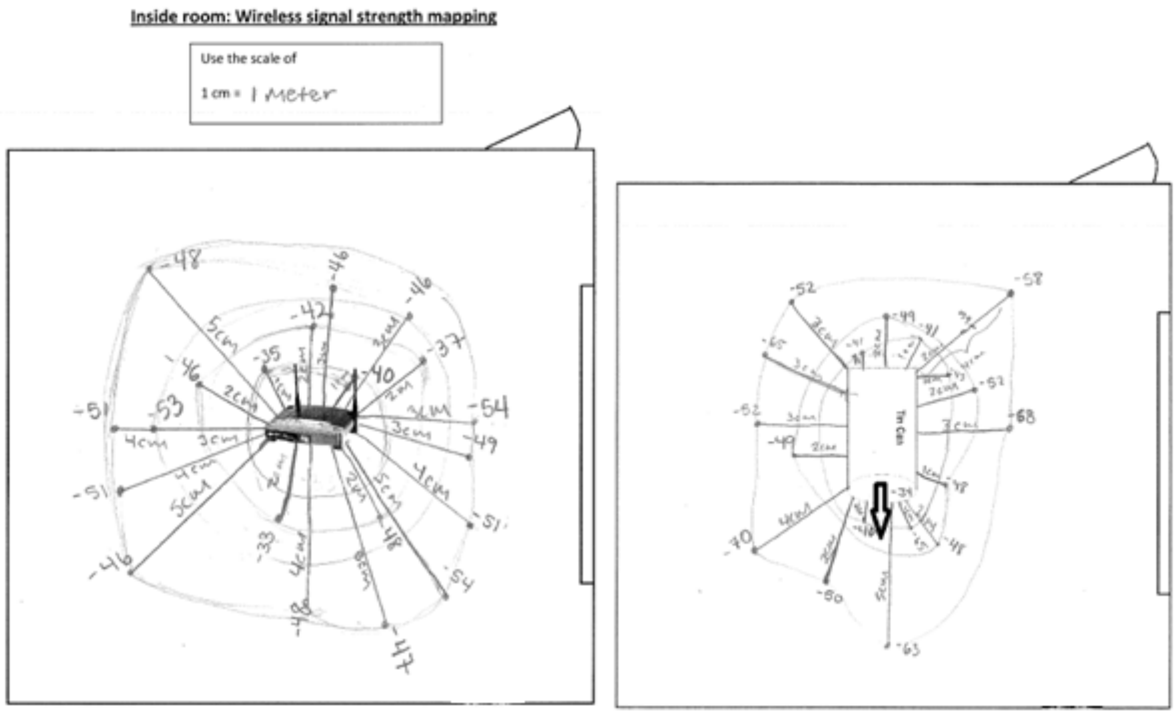


Figure 4.2: Guided Group Example (note: the random sampling process)

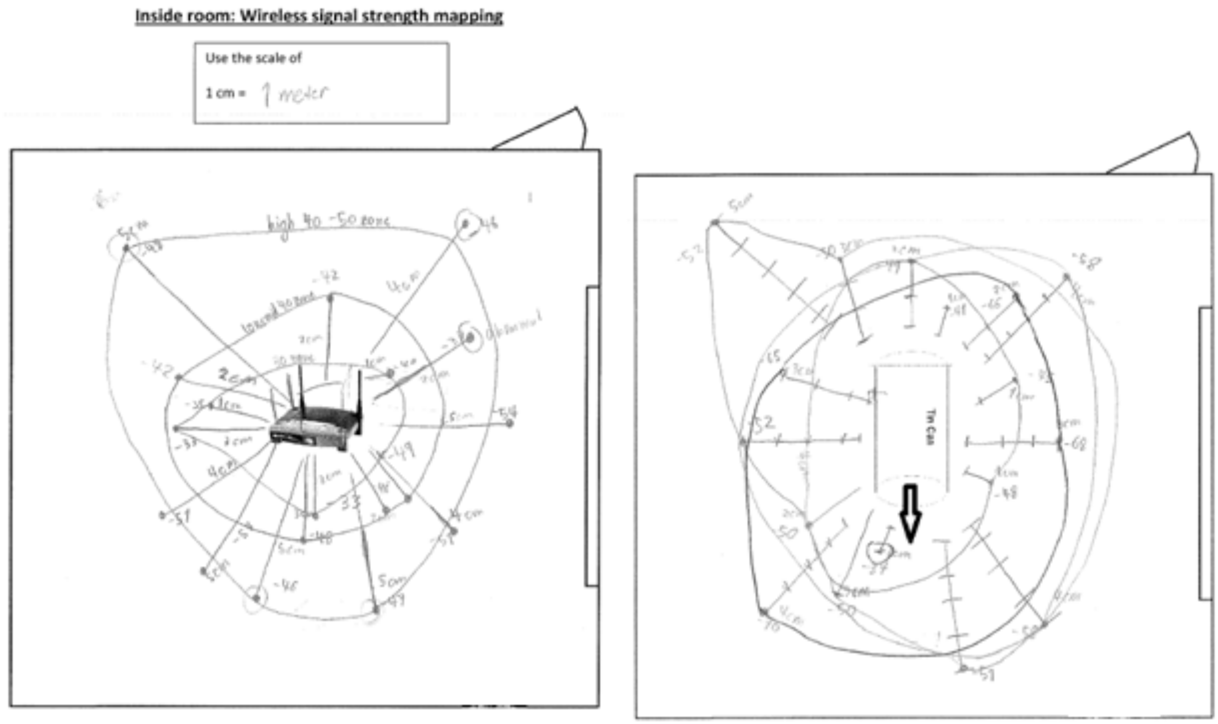


Figure 4.3 : Guided Group Example (note: random sampling process)

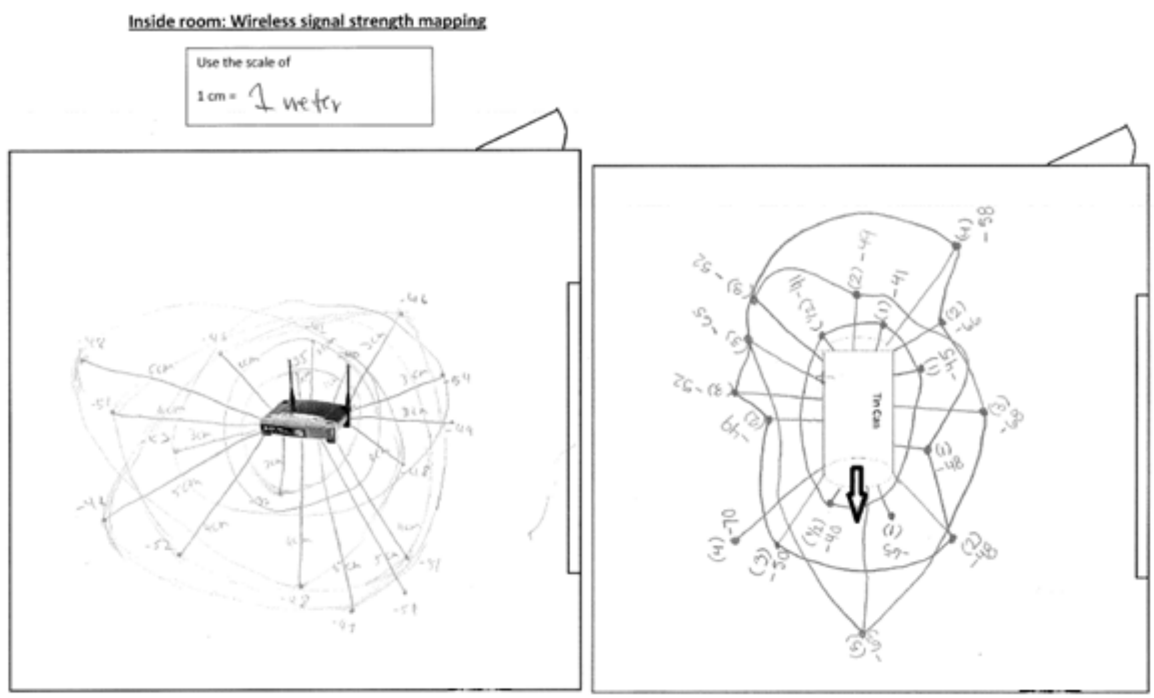


Figure 4.4 : Guided Group Example (note: random sampling process

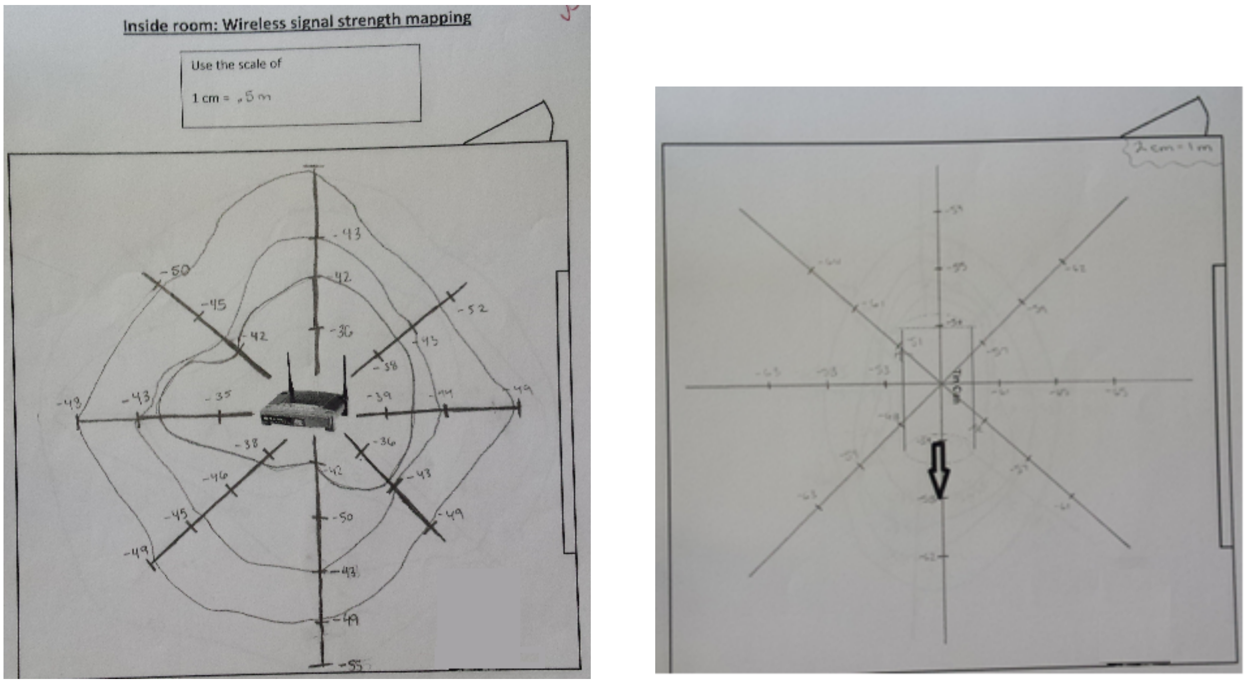


Figure 4.5: Structured Group Example

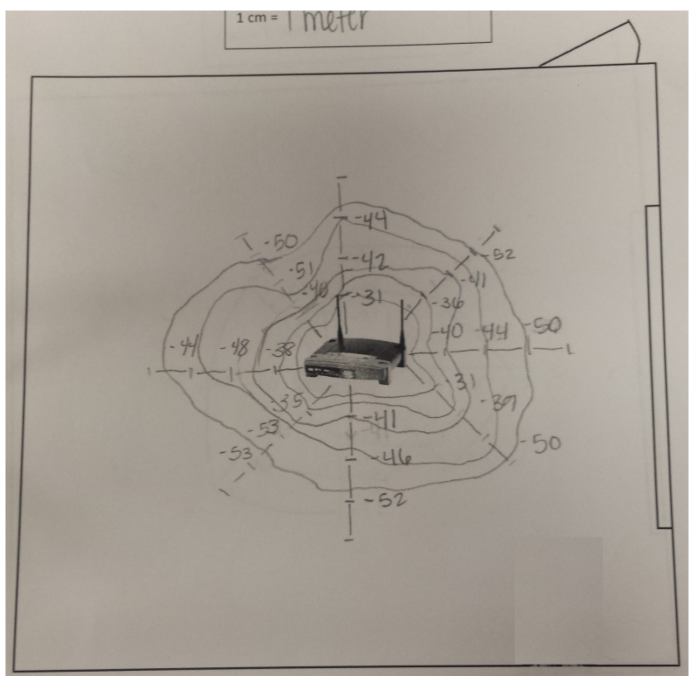


Figure 4.6: Structured Group Example

4.3 Pre-Test and Post-Test Comparisons

Both groups, guided and structured, were both given the same pre and post-test. Answer choices where categorized into to two categories for each of the nine questions. Each class was given similar time periods to answer the questions to the best of their abilities. In the pre-test, the results were almost identical on certain questions but varied greatly on others. Questions 4 and 5 were the only ones where there was a noticeable difference (Figure 4.7). The difference in question 4 might not be an accurate representation because on the pre-test it was a yes or no question, which does not take into different levels of understand a student may have. When it comes to question 4, sound was covered in the previous unit, before starting on the antenna challenge. This is typically an easy knowledge question that many students already know the answer, however it is presented in this new unit, and somehow many of them missed the correct answer. This brings into question whether or not students can recall on previous knowledge and that there may be difficulty in de-compartmentalizing information. However on question 5, the structured group listed at least one correct answer for naming a type of electromagnetic wave. With very similar results on the pre-test, the assumption is that both groups were on a fairly level playing ground when it came to recalling on previous knowledge for this challenge.

After the antenna challenge, there was a lapse of 2-3 days for the students before they could take the post-test due to scheduling issues with school activities and holidays. Overall there was still improvement all across the board except when it came to question number 3 and 7 (Figure 4.7). Nevertheless, when looking at the pre-test answers, in both situations, a high percentage of the students had already known a correct answer. So to see large gains on the post-test wasn't likely since they had already had such a strong result in success on the pre-test when it came to those questions. However it is troubling that there is 1 student who missed those in each situation. Was this a student who was not engaged or passively participating in their group? It was observed that not every single student was fully engaged with the task at hand, however it was not noted as to which specific students were fully engaged or not. So this makes it unclear as to if the student who did miss those questions was disengaged and did not master the concept, had misconceptions, or possibly just made an error in understanding the question itself.

Another thing to note is that when comparing the guided and the structured group, the end results were very close in many of the questions. The only exceptions to that were on questions 2 and 9, in which the structured groups end results were higher. This is most likely a result of the extra help they received in discovering the information needed for those two questions. Those two questions also ask about material that is arguably the most foreign when compared to their previous knowledge. Students may struggle in discovering the correct information or may never come across this in the guided group since the material is difficult to understand without expert help and guidance. Another explanation could be that the students in the guided group do not ever come across the information needed to answer such questions when they are doing their research. This could be from the open ended nature of the challenge and lack of guided questions and resources from the teacher in that group. This brings to question on how many resources and guidance a teacher can give to students to help them retrieve the knowledge.

Looking at Figure 4.8, results can be seen in graph form. When looking at the percent improvement for each class, there are certain questions in which there was an improvement. When it came to questions 2 and 4, the structured group did much better than the guided. In these situations, the structured group was introduced to some examples of antennas and different types of electromagnetic waves through discussions, whereas the guided group was left on their own to discover this information through research. The guided group did how an increase when it came to question number 5, which was noticeable greater than the increase that the structured group had. However this is deceiving because the guided group started with a much lower percentage of correct answers when it came to that question on the pre-test, 18.5% correct compared to the 53.3% correct in the structured group. Both groups performed almost equally on question 5 on the post-test.

Figure 4.7 Pre and Post-Test results

Questions	1st period Pre-Test (27 students)	1st period Post-test	2nd period Pre-Test (30 students)	2nd period Post-test
1. What is an antenna?	22 (84.6%)- responded that that they pickup, receive, and send signals or radio waves. 5 (15.4%)- Did not put anything or put that they did not know.	26 (96.3%) - responded that that they pickup, receive, and send signals or radio waves. 1 - Did not put anything or put that they did not know.	28 (93.3%) - responded that that they pickup, receive, and send signals or radio waves. 2 (6.7%) - Did not put anything or put that they did not know.	30 (100%)- responded that that they pickup, receive, and send signals or radio waves. 0 (0%) - Did not put anything or put that they did not know.
2. What types of antenna are you aware of?	0 (0%) - could name a specific type of antenna 27 (100%)– did not answer or answered incorrectly	2 (7.4%) - could name a specific type of antenna 25 (92.6%)– did not answer or answered incorrectly	0 (0%)- could name a specific type of antenna 30 (100%)- did not answer or answered incorrectly	15 (50%)- could name a specific type of antenna 15 (50%)- did not answer or answered incorrectly
3. Where do you see antennas? What specific devices use antennas?	26 (96.3%) - responded with specific devices from TV, cell phones, cars, radios, etc.. 1 (3.7%) – incorrect example or did not have answer	26 (96.3%) - responded with specific devices from TV, cell phones, cars, radios, etc.. 1 (3.7%) – incorrect example or did not have answer	29 (96.7%)- responded with specific devices from TV, cell phones, radios, cars, etc.. 1 (3.3%)– incorrect example or did not have answer	30 (100%)- responded with specific devices from TV, cell phones, radios, cars, etc.. 0 (0%)– incorrect example or did not have answer
4. Is sound an electromagnetic wave?	Correct – 17 (63%) Incorrect – 10 (37%)	Correct – 21 (77.8%) Incorrect – 6 (22.2%)	Correct – 5 (16.7%) Incorrect – 25 (83.3%)	Correct – 22 (73.3%) Incorrect – 8 (26.7%)
5. What are some types of electromagnetic waves?	5 (18.5%) - Correctly listed at least one type. 22 (81.5%)- Did not list any correct examples / Don’t know	25 (92.6%) - Correctly listed at least one type. 2 (7.4%) - Did not list any correct examples / Don’t know	16 (53.3%) - Correctly listed at least one type. 14 (46.7%)- Did not list any correct examples / Don’t know	27 (90%) - Correctly listed at least one type. 3 (10%)- Did not list any correct examples / Don’t know

Figure 4.7 continued				
6. Diagram	23 (85.2%)– described and drew signal radiating in all direction from the router 4 (14.8%) – incorrect answer, or did not know/didn't answer	27 (100%)– described and drew signal radiating in all direction from the router 0 (0%)– incorrect answer, or did not know/didn't answer	27 (90%)- described and drew signal radiating in all direction from the router 3 (10%) - incorrect answer, or did not know/didn't answer	30 (100%) - described and drew signal radiating in all direction from the router 0 (0%) - incorrect answer, or did not know/didn't answer
7. Where will signal strength be the strongest?	26 (96.3%)- said that the strength will be strongest closer to the router you are. 1(3.7%) - Did not know, wrong answer	26 (96.3%) - said that the strength will be strongest closer to the router you are. 1(3.7%) - Did not know, wrong answer	29 (96.7%)- said that the strength will be strongest closer to the router you are. 1 (3.3%) - Did not know, wrong answer	29 (96.7%) - said that the strength will be strongest closer to the router you are. 1 (3.3%)- Did not know, wrong answer
8. Can waves that antennas send and receive be directed in a specific direction?	6 (22.2%)– said they can be directed 21 (77.8%)– said they cannot be directed, did not know/didn't answer	16 (59.3%)– said they can be directed 11 (40.7%)– said they cannot be directed, did not know/didn't answer	9 (30%)- said they can be directed or focused more strongly in a direction 21(70%) - said they cannot be directed, did not know/didn't answer	22 (73.3%) - said they can be directed or focused more strongly in a direction 8 (26.7%) - said they cannot be directed, did not know/didn't answer
9. What is the wavelength of a radio wave at 2.45GHz?	0 (0%)- correct 27 (100%)- incorrect	8 (29.6%)- correct 19 (70.4%)- incorrect	0 (0%) - correctly 30 (100%)- incorrect	22 (73.3%)– correct 8 (26.7%)- incorrect

Figure 4.8: Pre-Test and Post-Test results in graph form

When looking at question 4 of the pre- and post-test, sound is addressed to determine if students can recall previous information and differentiate sound from electromagnetic waves. The guided group started off with a higher percentage of correct responses on the pre-test compared to the structured group. They both ended up with similar end results on the post-test. Yet the level of mastery seems to be low for a question that is on the lower level of Bloom's Taxonomy.

The points where the students did poorly include questions 2 and 9 (Figure 4.7). Students were not very successful in naming specific types of antennas, however they were very strong and describing different devices that used an antenna. This may be caused by foreign nature of antenna design, something that is not readily studied by students in the secondary curriculum. It is not a topic the students have come across in previous classes. The overall foreign nature of antenna design and the language used to describe their purpose and design in online resources could explain the lack of success when it came to remembering some examples. This was especially apparent in question number 2 when it came to the guided group, who scored 7.4% correct on that question compared to the 50% on the structured group. Since the guided group was the one that were to research on their own without any hints or structured instruction, many of them many never of even come across the specific types or felt overwhelmed and decided not to research any further. On question 9, the guided group's gains were lower than the structured group. Once again, this is probably a result from the foreign nature of the question and lack of modeling from the teacher.

4.4 Antenna Designs

Students were encouraged to try their best on designing an antenna. As they collaborated in groups, they came up with many different designs and underwent various design procedures. Due to time constraints, students did not get to map out their signal strength on a map, much like they did with the unmodified router and the cantenna. Students were not graded on the quality of their final designs. Due to this, some groups did not test as many designs as time had allowed and stopped early when they felt they reached a sufficient design. One could argue that if a minimum goal was set, then the students would work harder to reach that goal. This was not the case with these two groups, because that would alter their genuine interest in the activity and can skew the results. With no grade being attached to the results, one can observe how engaged they might be and let them internalize how interested they are in the process without external pressures. Figure 4.9 below shows some of the completed antenna designs of both classes.

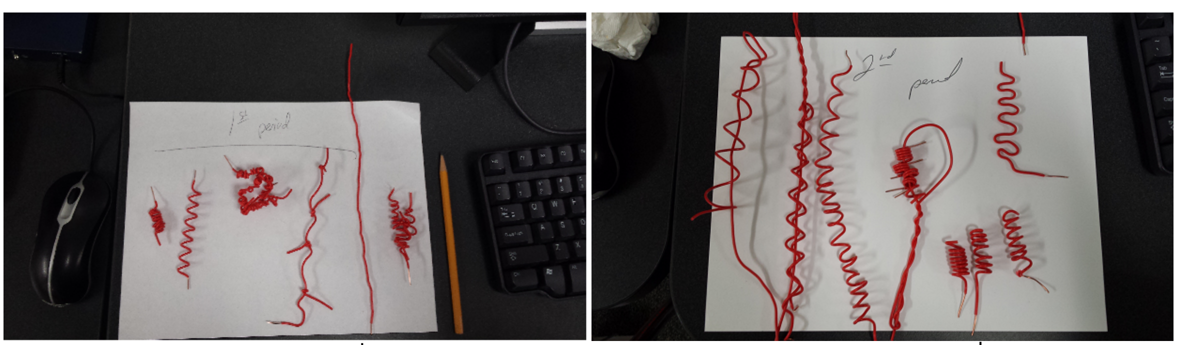


Figure 4.9: Left is the 1st class (guided) and the right shows the (2nd) structured.

4.5 Engagement Results

A question on the post-test was added to gauge engagement and interest in this engineering design challenge. When it comes to engagement, it is difficult to quantify a student's engagement level, so a 1-10 scale was used. The scale system can be vague and will not allow students to explain specific reasons as to why they may have liked or disliked the activity. Sometimes students may look like they are engaged but may not be interested in the activity and may merely be doing the work because they are hard workers and want to complete the assignment. Some may look like they are engaged but could be day dreaming or may be passively participating. So the last question asking how interested/engaged they were was added to the post-test to see how engaged/interested the students truly were. They were told to be honest about that question and that no negative or positive consequences would occur from that question. Students mostly answered with a number answer from 1 to 10. A few did not put a number down but instead left comments on how much they enjoyed or disliked the activity, and one put down a suggestion on how it could have been more interesting. Overall, there is very little difference in engagement when comparing the two classes when it came to a quantitative value. (Figure 4.10). In retrospect, there should have been an open ended question that could have been added to the scale system that was in place to help identify what aspects of the lesson they liked or disliked. This would have given some insight that the 1-10 scale system cannot.

1st period (guided)	**7.4**
2nd period (structured)	**7.2**

Figure 4.10: Question 10 averages regarding level of engagement.

Chapter 5: Conclusion

5.1 Proof of Concept

Through this report we have seen the implementation an engineering design challenge that can be incorporated into the physics classroom. Taking this opportunity to implement such an activity, it provided an additional opportunity to discover how the application and scaffolding of the activity would affect a student's mastery of specific skills and knowledge. This antenna design challenge serves as an alternative activity to help engage students in learning and serves as an example of a lesson that they can incorporate into the core Physics classroom compared to the usual notes and worksheet method. Engineering can be done on many levels and to varying degrees of intensity, this antenna challenge demonstrates one way to do this. It is not the perfect lesson, nor does it attempt to be so, it is merely an example that educators can use, modify, or reference in their own attempt to incorporate engineering in the math and science courses.

5.2 Limitations

One noticeable issue with the antenna challenge is that this material is not covered in depth in previous grade levels. Middle school curriculum covers some information about light, but does not get as technical and as in depth at the high school curriculum. So there is definitely a gap of information, which shows on the pre-test. Had the material been of something that had been covered more in depth at the earlier grade level science classes, the results may have been better all around, from the test questions to the graphing and collecting of data. Even if a student is able to draw upon previous knowledge, they have never used this type of equipment on a regular basis, or studied wireless signals up to this point. This calls for more studies done at earlier grade levels to see how STEM education is incorporated before high school.

One final note was that the terminology on the pre-test and post-test may be vague for students. On question 8 (Figure 4.7), there needs to be revision on the question or an additional note to define what "directionalized" refers to. Students seem to have varying ideas of what it means to send signals in a specific direction. Some students wrote in answers specifying that signals can be "focused" or "concentrated" however they cannot be focused solely in a single beam. They explained that the signal strength can be stronger or focused in a specific direction but can still propagate through the room. The question should be re-worded since the cantenna will only focus or favor signal in one direction, but not completely focus it in solely one direction. There is a good chance that many of the students who answered "no" might have been under the impression that it had block signal in all directions except the side that was open.

5.3 Further Studies

One of the concerns with the activity is the amount of time given in class to this design challenge. With the waning interest in the designing and testing process (most notable in the guided group), are there any other ways to keep student interested in the engineering though process and testing processes? This could be further studied in the future to determine what an ideal length for an engineering design activity would be in the high school classroom. One of the concerns is that if not enough time is given, the students will not discover answers to their questions and TEKS may not be covered in the given time. The opposite may be true if too much time is given, and students interests may wane and could possibly leave a negative connotation of these type of activities in their mind. With this in mind, it would be beneficial to record how much time was spent on the designing and testing of their constructions.

This activity could also be modified to have the student measure signal strengths outside of the classroom and see how walls affect signal. Another possibility is to see if how the cell phone antennas affected their results by comparing two phones. The students took particular interest and excitement when they got to use their phones and even compare theirs to their counterparts. There are other ways this lesson can be modified and it is encouraged that educators do so.

Students internal motivation should be noted in future studies. What drives these students to do that activity? Is it because the activity is interesting and they want to learn more, or are the motivated by other external factors such as grades or rewards and punishments from their parents. Many people are motivated to do well for different reasons and studying the "why" behind what they do would be a valuable avenue to study. Further studies should record what the factors for their engagement and motivation are and how it may affect their responses.

Some of the results bring up to question whether the systematic compartmentalization of information may hinder students from adapting to new situations and problem solving. One might argue that the compartmentalization of units in a course's curriculum could be causing some of the difficulties when it is time for students to use prior knowledge in differing situations. Students might have experience inquiry labs that require them to create their own procedures, but they might not be making the connection that those skills learned can be applied to this new situation. Educators also practice such grouping of material to present information in related units and lessons for students to learn. Students in biology learn only about biology, not in history, and vice versa. Educators test over one unit, take a test, and then move on to the next. Pushing aside any previous learned material to where it may never be seen again. The school system has unintentionally trained students to compartmentalize everything they learn, and that is a major hurdle if one would want to have students recall on previous knowledge and apply it to new situations. Even in the work force, and other entities that people interact with are compartmentalized also, it is human nature to compartmentalize things. Engineers must recall information from many different sources and they do not just dabble in one specific set of knowledge or past experiences, but many interlinking ones. It would be interesting to see how this compartmentalization of information affects problem solving and the mastery of new material for students.

When it comes to the guided and structured groups, the pre and post-test results bring into question what the ideal amount of guidance and structure a group may need to be successful. This report only covers two types of groups and leaves a large gap between the levels of scaffolding between the two. Further studies could include how varying degrees of structure may affect mastery of skills in an inquiry lab or design challenge. Having many different levels of scaffolding could shed some interesting light on to what is effective for students when it comes to conceptual knowledge and technical knowledge.

Chapter 6: Applications to Practice

6.1 Developing Engineering Awareness

With more practice and trainings, educators can build the knowledge and confidence necessary to incorporate more design challenges in the high school setting. Not only can teachers attempt to incorporate these activities into the science classroom outside of physics, they can attempt to introduce aspects of engineering into the math classrooms. With the push to have more college ready students that transition from high school to college, and also the demand of having more work ready college students who graduate, this is a good start to bridging the gap that each transition seems to have.

Activities like the antenna design challenge show that it is possible to take post-secondary engineering challenges and modify them to fit TEKS for students in a secondary educational setting. From the results of this study, it can be argued that there could be some work done to incorporate more of the TEKS into the lesson, and that is true. This design challenge was not designed to be the ultimate example of incorporation of engineering design in high school, but instead to serve as an example of lesson that works even though it has its own flaws. It serves as a basis in which other teachers can attempt to duplicate the activity and modify it to their needs.

Activities like these will be able to engage students in engineering design and encourage them to explore engineering as a possible option for college. There is also a growing demand for female engineers and exposing students in the core classroom to these activities could spur interest in the field and future career path. The antenna design lesson serves as an example of what can be done to incorporate technology and engineering design in the core classroom without sacrificing time to teach the TEKS. With more studies, examples, and training; educators can become more comfortable in incorporating such activities to engage our students and improve their STEM related skills.

By creating opportunities for students to engage in engineering design challenges, it has forced me as an educator to think about specific engineering aspects, such as the design process. Through the process of creating such activities for students, there must be intensive thought on how to construct the lesson and the constraints that relate to the lessons in mind. With this kind of practice, the educator can refine their engineering habits of mind and also become the expert. With this new found knowledge, I can work to create situations in which the students must also practice these habits.

6.2 Developing an Understanding of the Design Process

Through the process of creating the lesson and studying the data, I have been able to participate in the design process from varying points of view. As the creator of the lessons, I had to think about the design process in creating the antenna challenge activity. This allowed me to personally partake in the design process, from working with constraints and budgets, to redesigning my processes. As the observer, I was also able to watch students participate in the design process themselves. However, I do not feel that I fully participated in the complete design process set forth by UTeach Engineering. Due to the nature of the report, I felt that it was difficult to correlate the steps that I went through with the experiences I had in the classroom. From my perspective, I felt that I followed the general guidelines and process but may have not followed it perfectly. I wonder if from a third party perspective would have the same verdict, for I may be harder on myself than others would be. This uncertainty on my part my also be due to a lack of confidence, as I do not fully feel that I am an expert in this process. With more practice and further studies, I believe that I can refine and improve my abilities to the point where I may feel confident enough to call myself an expert in this process.

6.3 Developing Knowledge for and of Engineering Teaching.

Many of the experiences that I have had through the MASEE program have already affected me in my educational practices and thinking process. These past years I have been incorporating many more engineering design challenges in my core classroom, some that were specifically taken from my personal experiences in the classroom, to others that I have created from scratch for my students. I have seen positive feedback from many sources, from students to administrators, about the effectiveness of these design challenges. I also have a much improved confidence and abilities when it comes to engineering concepts. I have taken the knowledge that I have learned and have a better grasp on many different aspects regarding the engineering field. This experience through UTeach has also increased my eagerness to learn and advance in my field. Reflecting back on all the people I have met and the classes I have gone through, I do not regret a single moment. Everything from the deep class conversations about education theories and history to the hands on experiences in the engineering classrooms have been beneficial to me on many levels.

6.4 Engaging Students

Design challenges forces students to think creatively and out of the box. They must apply ideas from varying subjects and work collaboratively with other students to build and test their designs. Hands on activities like these will engage those GT (gifted and talented) students and traditionally low performing students in a subject who they might have felt was too easy or too difficult. Incorporating design challenges as these, students get exposed to a different application of physics that they would normally not see in a traditional setting. This activity can be adjusted to give more differentiated instruction, as it now leans on the students to differentiate their own learning.

Collaboration among peers is arguably one of the favorite ways for students to work. By nature people are social creatures and working with others tends to be a favorite of the students. However, there some students who tend to favor working alone, whether it is from a lack of trust of other students or by their own social preference. In reality, engineers and many other STEM related professions require collaboration among workers, so this activity leans towards collaboration among peers. It would be great to study how types of groupings affect results. For example, grouping students by similar ability levels or varying ability levels.

The use of familiar technology to explore unfamiliar technology is also part of what makes this activity engaging for students. Through the activity, they are allowed and encouraged to use their phone as a measuring device. They are familiar with the operation of their s mart phones due to the proliferation of cell phone technology in today's society. The phone itself has shaped society and how people interact in the world and has become a status symbol also. In an era where students grow up with cell phones, it is a great tool to incorporate when engaging students in classwork. With further advancements in technology, this activity may need modification to stay relevant.

Appendix A

TEXAS LEARNING STANDARDS ADDRESSED (TEKS)

(1) Scientific processes. The student conducts investigations, for at least 40% of instructional time, using safe, environmentally appropriate, and ethical practices. These investigations must involve actively obtaining and analyzing data with physical equipment, but may also involve experimentation in a simulated environment as well as field observations that extend beyond the classroom. The student is expected to:

(A) Demonstrate safe practices during laboratory and field investigations; and

(B) Demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

(2) Scientific processes. The student uses a systematic approach to answer scientific laboratory and field investigative questions. The student is expected to:

(A) Know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) Know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;

(C) Know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;

(D) Distinguish between scientific hypotheses and scientific theories;

(E) design and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness;

(F) demonstrate the use of course apparatus, equipment, techniques, and procedures, including millimeters (current, voltage, resistance), triple beam balances, batteries, clamps, dynamics demonstration equipment, collision apparatus, data acquisition probes, discharge tubes with power supply (H, He, Ne, AR), hand-held visual spectroscopes, hot plates, slotted and hooked lab masses, bar magnets, horseshoe magnets, plane mirrors, convex lenses, pendulum support, power supply, ring clamps, ring stands, stopwatches, trajectory apparatus, tuning forks, carbon paper, graph paper, magnetic compasses, polarized film, prisms, protractors, resistors, friction blocks, mini lamps (bulbs) and sockets, electrostatics kits, 90-degree rod clamps, metric rulers, spring scales, knife blade switches, Celsius thermometers, meter sticks, scientific calculators, graphing technology, computers, cathode ray tubes with horseshoe magnets, ballistic carts or equivalent, resonance tubes, spools of nylon thread or string, containers of iron filings, rolls of white craft paper, copper wire, Periodic Table, electromagnetic spectrum charts, slinky springs, wave motion ropes, and laser pointers;

(G) use a wide variety of additional course apparatus, equipment, techniques, materials, and procedures as appropriate such as ripple tank with wave generator, wave motion rope, micrometer, caliper, radiation monitor, computer, ballistic pendulum, electroscope, inclined plane, optics bench, optics kit, pulley with table clamp, resonance tube, ring stand screen, four inch ring, stroboscope, graduated cylinders, and ticker timer;

(H) Make measurements with accuracy and precision and record data using scientific notation and International System (SI) units;

(I) identify and quantify causes and effects of uncertainties in measured data;

(J) Organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs;

(K) communicate valid conclusions supported by the data through various methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports; and

(L) Express and manipulate relationships among physical variables quantitatively, including the use of graphs, charts, and equations.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student;

(B) Communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;

(C) Draw inferences based on data related to promotional materials for products and services;

(D) Explain the impacts of the scientific contributions of a variety of historical and contemporary scientists on scientific thought and society;

(E) Research and describe the connections between physics and future careers; and

(F) Express and interpret relationships symbolically in accordance with accepted theories to make predictions and solve problems mathematically, including problems requiring proportional reasoning and graphical vector addition.

(7) Science concepts. The student knows the characteristics and behavior of waves. The student is expected to:

(A) Examine and describe oscillatory motion and wave propagation in various types of media;

(B) Investigate and analyze characteristics of waves, including velocity, frequency, amplitude, and wavelength, and calculate using the relationship between wave speed, frequency, and wavelength;

(C) compare characteristics and behaviors of transverse waves, including electromagnetic waves and the electromagnetic spectrum, and characteristics and behaviors of longitudinal waves, including sound waves;

(D) Investigate behaviors of waves, including reflection, refraction, diffraction, interference, resonance, and the Doppler Effect;

(E) Describe and predict image formation as a consequence of reflection from a plane mirror and refraction through a thin convex lens; and

(F) Describe the role of wave characteristics and behaviors in medical and industrial applications.

Appendix B

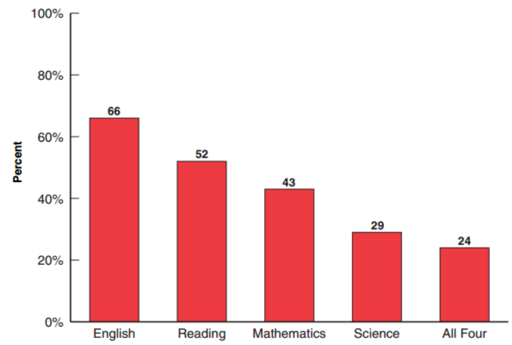
College Readiness

College Readiness Benchmarks by Subject

Sixty-six percent of all ACT-tested high school graduates met the English College Readiness Benchmark in 2010. Just under 1 in 4 (24%) met all four College Readiness Benchmarks.

In 2010, 52% of graduates met the Reading Benchmark, while 43% met the Mathematics Benchmark. Over 1 in 4 (29%) met the College Readiness Benchmark in Science.

Percent of ACT-tested High School Graduates Meeting College Readiness Benchmarks by Subject, 2010



Graph reads: In 2010, 66% of ACT-tested high school graduates met the ACT College Readiness Benchmark in English.

8

Appendix C

TABLE 3. Employed U.S. scientists and engineers reporting international collaboration, by means of communication, demographic characteristics, and employment sector: 2006

Characteristic and employment sector	Total	Means of collaboration (%)			
		Telephone or e-mail	Web-based or virtual communication	Foreign collaborator traveled to United States	U.S. collaborator traveled abroad
Total reporting international collaboration	3,157,000	94.6	56.0	49.4	32.2
Sex					
Male	2,293,000	95.2	57.0	53.1	36.2
Female	865,000	93.2	53.4	39.7	21.6
Place of birth					
United States	2,397,000	94.2	54.4	49.0	30.3
Outside of United States	761,000	95.8	61.3	50.8	38.2
Age group					
29 or younger	354,000	93.9	56.0	45.2	20.3
30-39	911,000	95.1	57.8	49.7	29.1
40-49	1,008,000	96.1	58.4	51.5	33.9
50-59	671,000	92.1	53.7	48.7	37.3
60-69	192,000	95.1	45.5	47.5	40.6
70 or older	22,000	89.0	38.9	52.1	40.5
Highest degree of educational attainment[a]					
Bachelor's	1,761,000	93.7	56.1	47.0	28.4
Master's	970,000	96.0	60.2	52.4	35.7
Doctorate	254,000	97.4	47.0	58.6	47.3
Employment sector					
Business/industry	2,653,000	95.8	58.3	50.5	32.2
For profit	2,048,000	96.1	59.7	52.4	31.6
Self-employed[b]	478,000	95.1	56.8	42.9	34.2
Nonprofit	127,000	92.7	40.5	48.4	33.4
Government	216,000	87.8	48.4	41.4	29.4
Federal	146,000	89.2	50.3	43.3	35.9
State/local	69,000	84.7	44.4	37.3	15.7
Education	289,000	89.2	41.3	45.3	34.2
4-year educational institutions[c]	229,000	92.7	41.5	48.5	37.7
Other educational institutions[d]	60,000	75.9	40.3	33.2	20.6

S&E = science and engineering.

[a] Professional degrees are included in total reporting international collaboration but are not shown separately.
[b] Includes those who are self-employed or business owners in incorporated or unincorporated businesses, professional practices, or farms.
[c] Includes 4-year colleges or universities, medical schools (including university-affiliated hospitals or medical centers), and university-affiliated research institutes.
[d] Includes 2-year colleges, community colleges, or technical institutes, and other precollege institutions.

NOTES: Scientists and engineers refers to all persons who have received a bachelor's degree or higher in S&E or S&E-related field, plus persons holding a non-S&E bachelor's or higher degree who were employed in an S&E or S&E-related occupation in 2003. Respondents can report more than one means of collaboration. Numbers rounded to nearest thousand. Detail may not add to total because of rounding.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2006.

Appendix D

Wireless Antenna Challenge part 1

Essential Question: How can we determine if a router is sending its electromagnetic waves Omni directional or directional?

Materials:
- Smart phone (Android or Google)
- WIFI Overview 360 (app)
- Router setup
- Can antenna

Background Information: Electromagnetic waves, in this case radio waves from a wireless router work on a 2.4 GHz antenna. This is the frequency that the device works on.

We can calculate the wavelength using C/F. C being the speed of light and F is the frequency.

3e8 m/s divided by 2.4e9 Hz = 0.125 meters = 4.92 inches.

Engagement		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Show video of directional sound weapon Show video of a directed-energy *weapon* Lead discussion about types of waves and technology that uses them.	Is sound an electromagnetic wave? [no, it is a type of mechanical wave] What do you notice about this weapon? There is no sound, and the people say that they feel heat. What do you think they are "shooting" at the people? [Various responses, waves, etc..] What is an electromagnetic wave? Since we have seen sound being	Students will use prior knowledge and attempt to answer question. students make observations Students will attempt to answer question using prior knowledge Students will attempt to answer question using prior knowledge.

	directionalized, can we do the same for electromagnetic waves? [Yes -no, not sure, maybe. - Some students may ask what an electromagnetic wave is. -Others may ask for examples of electromagnetic waves. -Some students may think of how sun light can be concentrated.] Ask students if they think the router is directional or Omni-directional. [I don't know, ombi, directional, can we find out?] What types of antennas are you aware of? [an antenna is a conductor that can transmit, send and receive signals such as microwave, radio or satellite signals] How do devices send and receive signals like radio waves and microwaves? [antennas] Does the antenna affect how the signals are sent out? [yes, no, I don't know, maybe] What types of antennas are you aware of? [car, phone, etc… however these are all devices that have antennas, not specific types, the correct answer can include monopoles, dipoles, yagi, etc..] Does the antenna affect how the signals are sent out? [yes, no, maybe]	
Transition		

<table>
<tr><td colspan="3">How could we find out which one our router is?</td></tr>
<tr><td colspan="3">Exploration</td></tr>
<tr><td>What teacher will do and Student misconceptions</td><td>Probing/Eliciting Questions and Students Responses</td><td>What students will do</td></tr>
<tr><td>Ask students to take out their smart phones and form groups of 2-4. In those groups, make sure that at least one person has an android/google smart phone.

Ask that phone holder to download WiFi Overview 360 from the "play store" and install and run the program.

Have them swipe once the right, to get to the "networks" tab and find the network you have setup for the lab.

Then have students find the physical router in the room.

Present the map of the classroom that students will use and point out the router location. Ask students to label the map with points and record their signal strength at each point to determine

[guided & structured] Ask students what they notice as they move towards and away from their router.
[students should note that their dBm will change as the come closer to the router, some will note the increase in the negative dBm as they come closer]

[guided] The guided group should be left on their own to figure out how to map the room.</td><td>

How does the negative value correlate to signal strength?
[The reason you see negative values is that you're representing small but positive numbers, on a logarithmic scale. In logarithms, the value indicated represents an exponent....]

So which represents a stronger signal strength, -40 dBm or -20dBm? [-20dBm]</td><td>Students take out their phones or find a partner

Install program on to their smart phone

Find correct menu to do lab

Look for router that you've pointed out

Brainstorm several locations, with their partner/group, that they can use to gather data points.</td></tr>
</table>

Teacher should be available for technical issues and to answer questions. **[structured]** For the structured group, model how to get a good set of data and let them modify and do the rest. Have students pick many different points around the room. Spots in front of the router, side, behind, etc… At those points students should record on their data table: how far away they are from the router, the angle at which they are respective to the origin, and what signal strength.		
Have students take the data and plot them on graph paper.		
Students should then see if there are any trends and should be able to determine if there are any trends and be able to answer the analysis questions on the map and come up with a conclusion.	Ask some groups what their data shows or doesn't show. [Students should notice that signal strength gets lower as they go away from the router and that being in front or behind or side does not affect strength]	Students should compare their data with other groups and analyze any similarities and differences.
Once all students are done with their mapping, students Switch out the original antenna and replace with a directional antenna (can antenna)		
Have student repeat and record data on another data table, graph, and then analyze and repeat the same steps as when they did with the original antenna. They should map this on another form which is	Ask some groups what their data shows or doesn't show. [Students should notice that signal strength is stronger in the front of the open of the cantenna.]	

identical.		
Transition		
Explanation		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Students will then post up their graphs on to the wall so that all groups can go around and see all the different data groups that were gathered. Students should then make a conclusion as to if electromagnetic waves can be manipulated to be directional. Directional might be a vague term, so it might require some elaboration. Summarize with the class what was discovered and lead discussion how different materials can reflect and absorb electromagnetic waves.	Do you notice any trends with the cantenna? [signal strength is stronger is one direction, the open ended side of the cantenna] How do you think foil will affect the signal strength of a router? [make it weaker]	
Transition		
Elaboration		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Discussion	Ask students to think of examples of real life devices that do this Ask students which types of waves travel farther? Do longer wavelength waves travel farther? If students are stuck, prompt	

	them with … Think of AM and FM stations. Which travel further?	
Evaluation		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Administer post test to see what students have learned.		

Appendix E

Wireless Antenna Challenge part 2

Engineering Challenge: Build an antenna that will accomplish the following tasks. Longest range, Strongest Signal (dBm), and smallest physics specifications.

Materials: Smart phone (android or google)
WIFI Overview 360 (app)
Router
Copper wire 18ga

Engagement		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Ask students where they see antennas and if the specific devices use a directional or Omni-directional antenna or why they think it would.	Where do you see antennas, give me some examples. [remote controlled cars, TV remote controls, inside phones, top of buildings] For each example, ask if they think it is a directional or Omni-directional antenna and why?	Students will think of different examples and call them out Students will think about previous knowledge of antennas and answer as best as possible.
[structured] Show students a few examples of different antennas.	Ask students what they think the strengths of each of the antennas are and what purpose each might have. [various responses]	
Transition: Bring out a couple of samples that are made so students can see how they are constructed.		
Exploration		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
[guided & structured] Introduce the design challenge. Build an antenna that will accomplish the following tasks.		**[guided]** Students should use internet resources to look up types of antennas and their function to help guide their

<table>
<tr><td>Longest range, Strongest Signal (dBm).

[structured] List some types of antennas and show them a few to give them an idea of the types of antennas available, but not the purpose of each type.

[structured]
Teacher will explain how length of antenna is important

Teacher will allow students time to build and test their designs. They will answer any questions they might have or lead them to an answer. In the end the student should explore and learn through inquiry.</td><td>

[structured] What type of shape do you think works best for each situation?

How do you calculate the optimal length for a monopole antenna?
[λ(cm) = 30(cm) / f(GHz)
(it's like c = f λ)
Frequency is 2.4 GHz, so the wavelength is 12.5cm
If frequency is 5GHz, the wavelength is 6 cm
Vocabulary needed: quarter-wave monopole
So ideal length of monopole is ¼ of the wavelength, so at 2.4 GHz, the monopole should ideally be 3.125cm tall. (note: 9.375 would work just as good, and so would 15.625)]</td><td>design.

[structured] Students will take sample designs that they see from the teacher or online and modify and test their antennas.

Students will be allowed to test their designs and build as many as they please in the time allowed.</td></tr>
<tr><td colspan="3">Transition</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Explanation</td></tr>
<tr><td>What teacher will do and Student misconceptions</td><td>Probing/Eliciting Questions and Students Responses</td><td>What students will do</td></tr>
<tr><td>Teacher will take out (or show</td><td>Which antenna is good for what</td><td></td></tr>
</table>

pictures) of a yagi, omnidirectional, and patch antenna.	use? Explain which ones are good for which type of purpose.	
Transition		
Elaboration		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Students can research on what antenna revisions they could have made now that they have learned about omni and yagi antennas.		
Evaluation		
What teacher will do and Student misconceptions	Probing/Eliciting Questions and Students Responses	What students will do
Teacher will hand out POST test		

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APPENDIX F

Pre-Test Antenna Challenge Questions

1) What is an antenna?
2) What types of antennas are you aware of?
3) Where do you see antennas? On what specific devices use antennas?
4) Is sound an electromagnetic wave?
5) What are some types of electromagnetic waves?
6) Draw a diagram of how you think the signal from a router is spread through your household. (note the router in the middle of the house)

7) Where will signal strength be the strongest?

8) Can the waves that antennas send and receive be directed specifically into a direction? Ex. Can you focus them north only, or do they travel all around and you cannot control which way they are sent. IMPORTANT: Please explain why you think so.

9) What is the wavelength (in cm) of a radio wave at 2.45GHz? (c/f = 12.24 cm)

APPENDIX G

Post Test: Antenna Challenge Questions

1) What is an antenna?
2) What types of antennas are you aware of?
3) Where do you see antennas? On what specific devices use antennas?
4) Is sound an electromagnetic wave?
5) What are some types of electromagnetic waves?
6) Draw a diagram of how you think the signal from a router is spread through your household. (note the router in the middle of the house)

7) Where will signal strength be the strongest?

8) Can the waves that antennas send and receive be directed specifically into a direction? Ex. Can you focus them north only, or do they travel all around and you cannot control which way they are sent. IMPORTANT: Please explain why you think so.

9) What is the wavelength (in cm) of a radio wave at 2.45GHz? (c/f = 12.24 cm)

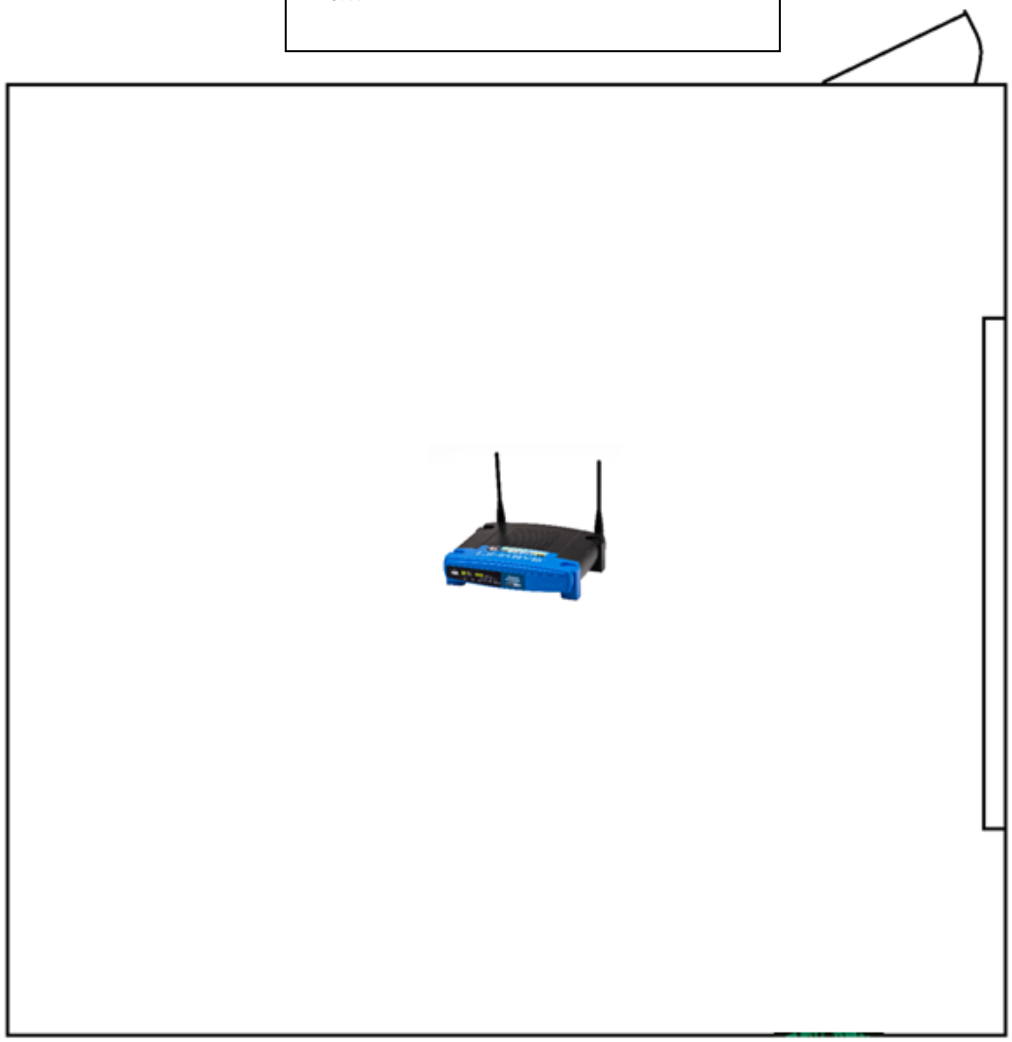
10) On a scale of 1-10, how engaged/interested were you during this activity? (this will not impact your grade positively or negatively)

Appendix H

Inside room: Wireless signal strength mapping

Use the scale of

1 cm =

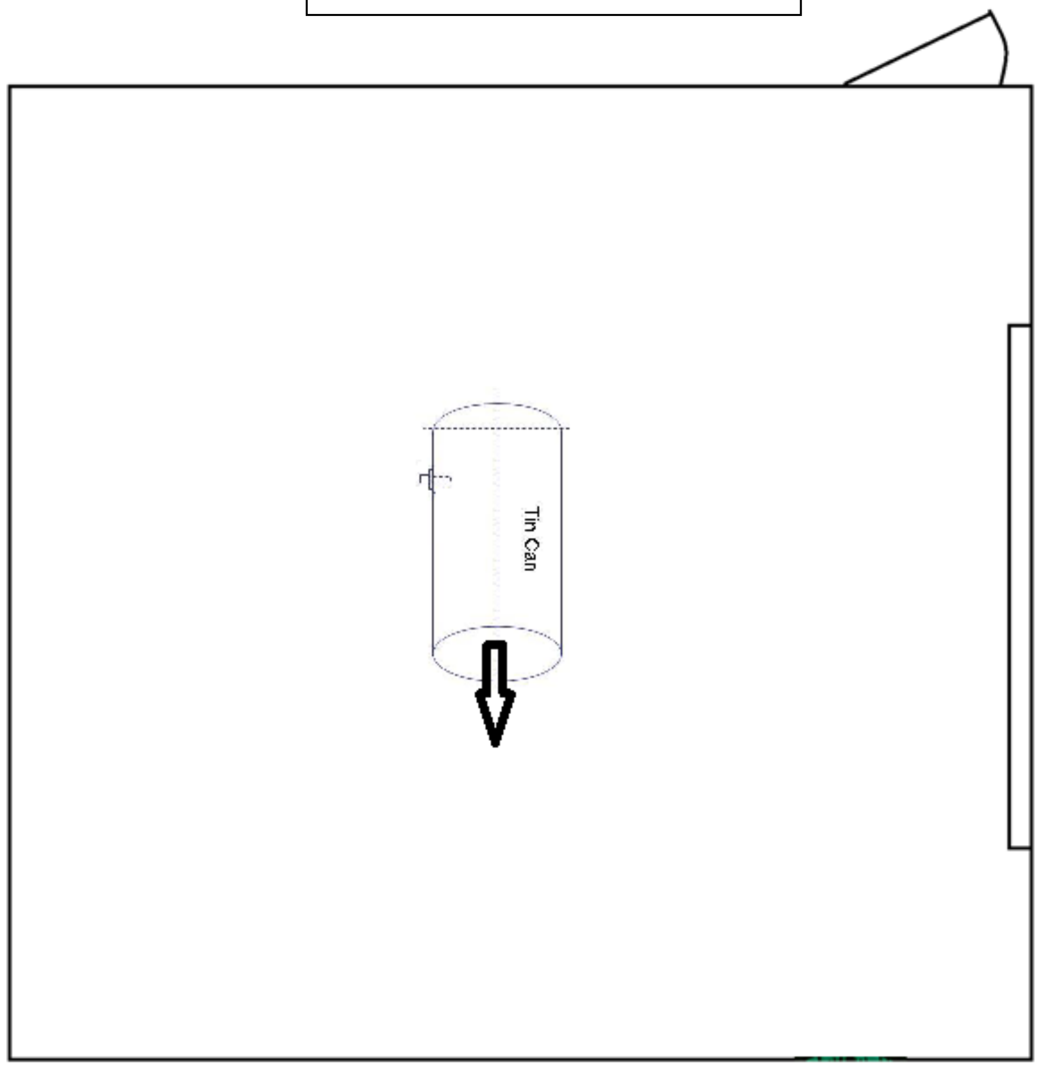


1. What are the observations that you noticed?
2. Do you think the signal strength is distributed evenly or strongly favors one direction or more?
3. Do you think the design of the antenna was supposed to do this?

Appendix I

Use the scale of

1 cm =



1. What are the observations that you noticed?
2. Do you think the signal strength is distributed evenly or strongly favors one direction or more?
3. Do you think the design of the antenna was supposed to do this?

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