Spring 5-2018

Using the SOAR Approach to Teach Middle School Students about Math and Science Concepts Found in Engineering

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Abstract

In order to address the lack of knowledge about the engineering profession in middle-level students, the project described in this Honors Thesis was developed. Through the creation of an after-school program centered on engineering, students were able to apply the math and science concepts covered to design, build, and test a bridge. One particular lesson from this after-school program was highlighted in this thesis, the lesson covering the Pythagorean Theorem, to demonstrate the use of SOAR methodology in the lesson’s development and later use in the classroom. The effectiveness of the Pythagorean Theorem lesson was evaluated positively based on the analysis of student learning by their performance on sample Pythagorean Theorem problems. After a semester of instruction, students showed greater interest in engineering and were more likely to see themselves becoming engineers in the future.

Key Words: STEM Education, SOAR Techniques, After-school Activity Building, Engineering Education, Middle-level Learners
Using the SOAR Approach to Teach Middle School Students About Math and Science Concepts Found in Engineering

The Creation of Engineering Club

Studies have shown that female students lose interest in math and science as early as elementary school (Greenberg-Lake, 1994). They consider careers in STEM half as often as male students do by eighth grade (National Science Foundation, 2007). As a female engineer, this saddens me. I know how great the engineering profession is and the many opportunities it provides. I want other young women to understand this as well. But I understand why these girls feel the way they do. As a middle schooler, I had no idea what an engineer was or what they did. This problem is not just limited to females: there are plenty of boys who might be interested in engineering, but do not know what the field is about. I believe if these students knew about the awesome things engineers do, there would be an increased interest in the profession even from a young age. Engineers all over the world are working to make people’s lives better, safer, and easier. They work on teams and are creative when solving important problems.

I wish I had known more about engineering and what being an engineer was like when I was in middle school. At that stage of education, most students are beginning to investigate different career opportunities. I would have felt more confident taking engineering classes in high school if I had learned about engineering in middle school. I would have been more confident declaring mechanical engineering as my major as an incoming college freshman if I would have known more about engineers in high school.

To address these problems I experienced for the benefit of other students, I thought of creating an after-school program that introduced students to engineering and laid out a path for them to learn more if they were interested. This after-school club would be specifically designed by an engineering
student (me) who had recently experienced what these middle school students were experiencing. I envisioned that the after-school program curriculum could be used by other educators as well, especially those teaching after-school clubs, to teach a wider middle-level audience about engineering. Thus, the Engineering Club was born.

To develop the curriculum for Engineering Club, I needed expert guidance and structure for motivation, therefore the idea became my thesis project for the UNL Honors Program. I met with Dr. Ken Kiewra, an educational psychologist, who became my advisor and introduced me to the SOAR method that I applied in my lesson plans. This teaching method not only helps students learn the math and science concepts addressed in the club, it can also be used to coach them to be more effective students later in their education. I easily found an avenue to teach this curriculum to current middle school students. My father is a teacher at a local middle school, Irving Middle School, of which I am an alumnus. Irving has an after-school, city-run recreation center that sponsors many clubs. Naturally, this is where I chose to build my after-school program.

The source material for Engineering Club centers on the systematic engineering design of a bridge (using the engineering design process) and important math concepts that middle-level students have learned in their classes, including ratios and the Pythagorean Theorem. Each lesson is crafted using the SOAR techniques and followed by an “activity” meeting where students apply what they learned the previous week. For this Honors Thesis, I focused on the Pythagorean Theorem lesson.

**The SOAR Method**

Dr. Kiewra's SOAR method is an academic tool that educators use to help students learn more effectively. It involves guiding student to select the important information, organize and associate it, and then regulate learning. In *Teaching how to learn: The teacher's guide to student success* (2009), Dr. Kiewra suggests a wide variety of techniques for educators to use for each step of the SOAR method.
The SOAR method begins with select, or aiding students in selecting the key information from a lesson in order to better learn it. Controlling and directing student’s attention is important when helping them select; students’ attention should be directed towards the important material they are learning and away from distractions hindering the learning process (Kiewra, 2009). Teachers can focus students’ attention by helping them search for specific stimuli that demand their attention, for example, through the use of pre-questions (Kiewra, 2009). Attention and learning during a lesson is closely tied to note taking, which is positively correlated with achievement. Students typically record only 35% of important information during a lesson, and only have a 5% chance of recalling unnoted information on exams (Kiewra, 2009). With this knowledge, Dr. Kiewra recommends a number of strategies teachers can employ to help students better learn during instruction. These include the use of skeletal notes and complete notes, providing lesson cues, and re-presenting the lesson.

The next step of the SOAR method is helping students organize the information they have selected. Dr. Kiewra explains that students often try to ineffectively memorize huge lists of information, ignoring the connections between different bits of information (Kiewra, 2009). In order to promote student learning, educators should effectively organize the information they are presenting to students in a way that shows connections between different aspects of the information. This means that information should not typically be presented as a list or an outline, but so the relationships between key bits of information are clear (Kiewra, 2009). There are a couple different methods recommended for this such as using hierarchies where hierarchical relationships between components are clear, using sequences where ordered processes are apparent, and using matrices that highlight shared categories of information (Kiewra, 2009).

The A in the SOAR model stands for associate. Association of information is imperative to learning because it aids students in how information gets encoded into memory for retrieval. There are two types of associations covered: internal and external associations. Internal associations connect
ideas with one another, and external associations connect ideas with other ideas and experiences that were previously learned (Kiewra, 2009). Educators can help students make associations by raising questions that stimulate students to make associations and by using mnemonics (Kiewra, 2009).

The final component of the SOAR model is helping students regulate. Regulation is how students monitor, contextualize, and assess how well the information has been learned (Kiewra, 2009). Teachers typically regulate learning through students’ graded work and exams. However, they often fail to help students understand what and how they will be evaluated. In order to help students understand what learning is expected of them, teachers can provide students with additional information and instruction on how learned material should be regulated. This can be done through the use of clearly stated objectives, grading rubrics, timelines, and different types of regulation assessments they will be expected to complete. This could be fact learning (testing how well students recall facts), concept learning (how well students recognize new examples) or skill learning (how well students can perform a task) (Kiewra, 2009).

The methods I selected for each SOAR strategy are described in my lesson plan (included later). Because the concepts I am teaching are mainly math and science based, I chose SOAR strategies that are applicable and practical for students in their future math and science classes. For example, I choose to have every Engineering Club lesson include skeletal notes for students to complete as they learn about each new topic. Finally, Dr. Kiewra recommends using strategy instruction to help students learn how to do the SOAR strategies themselves. Therefore, I have additionally written and practiced some strategy instruction to “sell” these methods to them for use in the future.

The Pythagorean Theorem Lesson

The Pythagorean Theorem can be a difficult topic for seventh graders to understand, as they have only briefly covered it during their math classes in 6th grade. The Pythagorean Theorem is an
important concept engineers use daily and is especially applicable to trusses (the type of bridge that we build during Engineering Club). Therefore, to teach this important and difficult lesson effectively, I wanted to make sure to fully implement the SOAR method. Another goal for this lesson was to refine and perfect the lesson with direct coaching from Dr. Kiewra. As with the other Engineering Club lessons, I used skeletal notes as a select method for students, but I also wanted to include some additional learning mechanisms. Therefore, I chose to include pre-questions about my lesson objectives. By referencing these questions while teaching the lesson, students can understand why certain topics (see more in the lesson plan) are important. To help the organization of the information presented during the lesson, I made several tools for students to use, including a sequence of steps for them to follow when solving problems and a matrix organizing different triangles and information about them. Next, I generated a list of important associations (internal and external) I wanted students to make based on the lesson objectives. I made sure that I would state those associations explicitly for students or make them apparent in my other examples and tools. Finally, to help students regulate their learning, I included example problems to do together and practice problems for students to do themselves (which I check and review with them later). As a final regulation of their learning, they use the Pythagorean Theorem to calculate the amount of material they need to build their bridges later in the project.

In the following sections, the teaching materials used for the Pythagorean Theorem lesson are described. Also included are details on how they were developed using SOAR techniques.

**Pythagorean Theorem lesson plan in the SOAR format.**

The following section is the SOAR-guided lesson plan that I used for my Pythagorean Theorem lesson. The SOAR lesson plan is divided into sections by each step of the SOAR model: selection methods, organization methods, association methods, and regulation methods. It also includes the skeletal notes, a set of complete notes and other teaching aids.
Introduction

The lesson, titled “The Special Equation that Engineers Use Everyday and How They Use It,” covers the Pythagorean Theorem for the afterschool program. The topics of the mathematics part of the lesson include right triangles, the definitions and vocabulary involved with the theorem (Part 1), problems and solution procedures (Part 2), an altered solution procedure for calculator use (Part 3), Pythagorean Triangles (Part 4), and a final solution procedure form. For the engineering application side, the ways mechanical engineers, electrical engineers and civil engineers use the Pythagorean Theorem are discussed.

The goals for the lesson are:

1. Students can identify a right triangle given a diagram.
2. Students can name and properly label the parts of a right triangle given a diagram.
3. Students can recall the formula for the Pythagorean Theorem.
4. Students can find the missing third side length of a right triangle given two side lengths.
5. Students can perform the operations involved in the above process using a calculator.
6. Students can identify Pythagorean Triangles given two side lengths.

Objectives

1. Given images of triangles (condition), students will be able to identify a right triangle (behavior), without error (standard). [CONCEPT]
2. Given images of right triangles (condition), students will be able to label the sides as a, b, or c (behavior), without error (standard). [CONCEPT]
3. Given images of right triangles (condition), students will be able to label the sides as legs or the hypotenuse (behavior), without error (standard). [CONCEPT]
4. Given two side lengths of legs of a right triangle (condition), students will be able to find the third side length, the hypotenuse (sometimes using a calculator) (behavior), with 80% accuracy (standard). [SKILL]
5. Given two side lengths of a leg and the hypotenuse of a right triangle (condition), students will be able to find the third side length, the other leg (sometimes using a calculator) (behavior), with 80% accuracy (standard). [SKILL]
6. Given a Pythagorean Triangle with two known sides (condition), students will be able to identify it is a Pythagorean Triangle (behavior) without error (standard). [CONCEPT]
7. Given a Pythagorean Triangle with two know sides (condition), students will be able to automatically find the third side length and recite the third side length (behavior) without error (standard). [SKILL]
To help students select important information from the lesson in accordance with the SOAR model, I incorporated pre-questions and skeletal notes into the lesson plan as the primary selection methods. The pre-questions later serve as organizational lesson cues; as new Parts are begun during the lesson, I related the subject back to its corresponding pre-questions. Organizational cues significantly increase student’s achievement on a lesson topic (citation: Titsworth & Kiewra, 2004 /pg 31). By providing students with skeletal notes, they can increase the amount of important information they record by nearly 20% (citation: Kiewra, Benton, Kim, Risch & Christensen, 1995 /pg 29).

Students answered a set of pre-questions about the Pythagorean Theorem covering the objectives of the lesson. These pre-questions are included in the student’s engineering notebooks, just before their skeletal notes (see below). The students try to answer the questions by themselves initially, and then the answers are reviewed together before starting the lesson. Pre-question 1 covers objective 1, pre-questions 2 and 3 cover objectives 2 and 3, and pre-question 5 covers objectives 4, 5, 6 and 7. Throughout the lesson, I referenced the pre-questions when we covered the topic pertaining to each one. Pre-questions 1, 2 and 3 are covered in Part 1 of the lesson, and are referenced in Part 2. Aspects of pre-question 5 are discussed in Part 2, Part 3, and again in Part 4.

Additionally, there is a set of skeletal notes for the students to fill out on the material during the lesson. In the long term, the skeletal notes are incorporated into a workbook (or engineering notebook) that the students can complete. To complete their set of skeletal notes, students looked towards the PowerPoint used during the lesson, actual problems done on the board, and verbal cues. For example, I said “be sure to write the procedures steps shown on the PowerPoint in the place given for them in your notes,” or while working a problem on the board, “use the space given in your notes to solve the problem with me.” The following pages are the skeletal notes the students are provided, followed by the complete notes I have (including verbal annotations). Students are also provided with their own set of complete notes to reference afterward, so they can copy anything they missed during the lesson.
The Special Equation That Engineers Use Everyday

and

How They Use It

Pre-questions

1. What is a right triangle?

2. What principle would you use to find the side lengths of a right triangle?

3. What formula would you use to find the side lengths of a right triangle?

4. Have you learned about the Pythagorean Theorem before?

5. How much room is needed to unload the truck using the ramp?

5 ft
3 ft

?
All About the Pythagorean Theorem – Part 1

___________ ________ is used to find the unknown side lengths of _________ triangles.

It can be used whenever two side lengths of a right triangle are ____________.

The formula is: __________________________.

The side _________ is the side length next to the 90° angle of the triangle, or the side length

of a __________ of the triangle.

The side _________ is the side length next to the 90° angle of the triangle, or the side length

of the other __________ of the triangle.

The side _________ is the side length opposite to the 90° angle of the triangle, or the side

length of the __________________________ of the triangle.

Label the sides of the triangle: Label the names of each side of the triangle:
An easy way to remember the hypotenuse is:

How to Use the Pythagorean Theorem – Part 2

Sequence of steps to do when using the Pythagorean Theorem

<table>
<thead>
<tr>
<th>Label</th>
<th>Known Sides</th>
<th>Unknown Sides</th>
<th>Plug in</th>
<th>Simplify</th>
<th>Add or Subtract</th>
<th>Square Root</th>
<th>Simplify Again</th>
</tr>
</thead>
</table>

Find the unknown side length of this triangle:

1. Label the legs and ________________________ of the triangle.

   ![Diagram](image)

   \[ c = 4 \]

2. Identify the ____________ sides.

   **Known:**

3. Identify the unknown side lengths

   **Unknown:**

4. Plug the ______________ side lengths into the Pythagorean theorem:
\[ a^2 + b^2 = c^2 \]

5. Simplify the known ________________:

\[ 3^2 + 4^2 = c^2 \]

6. Add the ________________:

\[ 25 = c^2 \]

7. Take the _____________ ____________ of both sides:

\[ \sqrt{25} = \sqrt{c^2} \]

8. Simplify for the final answer of side length:

\[ 5 = c \]

As you can see, it saves time to know your perfect squares really well! Here is a sequence that has the example problem below it for you to follow:

**Sequence of steps to do when using the Pythagorean Theorem with Example**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>b=4</td>
<td>a=3, b=4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a=3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How to Use the Pythagorean Theorem with a Calculator – Part 3

Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a ___________________________ when using the Pythagorean Theorem.

Find the unknown side length of this triangle:

Steps 1-4 are the same:

1.  
2.  
3.  
4.  
5c. Use the ^ button on your calculator to find the ____________.

\[ 8^2 + 5^2 = c^2 \quad \Rightarrow \]

6c. Use _________________ for adding squares on your calculator.

\[ ((8^2) + (5^2)) = c^2 \]

7c. Use the sqrt button and ANS key to find the ____________ __________ of both sides.

\[ \text{sqrt}( \text{ANS} ) = c \]
The unknown side length (round to 2 decimal places) = ____________

Solution Summary

Sometimes you have to find the side length of a triangle that is not the ________________, it’s a ________________.

You can find an ______________ for the unknown side length using ________________.

It is the same equation for either ________________. The ‘a’ or ‘b’ only depends on how you labelled the triangle at the beginning.

Matrix organizing the different ways to use the Pythagorean Theorem with Examples

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>a</th>
<th>c = ?</th>
<th>b</th>
<th></th>
<th>a</th>
<th>c</th>
<th>a = ?</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown Side:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When solving a Pythagorean Theorem problem, you can use the ________________ equation during ________________, and all the other steps will the same!
Example Problems

Now, we will do two practice Pythagorean Theorem problems together.

1.

2.

3.

4.

5.

6.

7.

8.
Pythagorean Triangles – Part 4

As we saw in the last example, sometimes triangles don’t require a __________________ to be solved if you learn your perfect squares.

This is a special type of _______________ _______________ that has side lengths that are all perfect squares. It’s called a _______________ ________________.

Here are some common examples of Pythagorean Triangles you may encounter:

Matrix organizing the different types of Pythagorean Triangles

If you know these triangles, then you can ______________ most of the procedure.

Do steps _____, _____ & ________.

1.

2.

3.

3a. Is it a Pythagorean Triangle? YES NO
If YES, go to step ___________ and fill in values from memory. If NO, go to step 4.

The final answer would be:

Final Procedure

Final sequence of steps to use to solve any Pythagorean Theorem Problem

1. Label
2. Known Sides
3. Unknown Sides
4. No Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

Is it a Pythagorean Triangle?

Use \( ^2 \)
Use \( \)\
Use \( \sqrt{\text{ANS}} \)

Using the __________ __________ of our procedure, we can solve any type of Pythagorean Theorem problem.
Practice Problems

Find the length of the unknown sides on the triangles shown.

![Triangle with sides 10 and 6](image1)

![Triangle with sides 7.6 and 3.21](image2)
Applications of the Pythagorean Theorem

List three applications of the Pythagorean Theorem:

1.

2.

3.
Lesson Plan:

The Special Equation That Engineers Use Everyday and How They Use It

<< For this class, I’ve provided you with skeletal notes in your engineering notebooks. You should complete the notes as I teach you the material. I will have the information you need on the PowerPoint and in the examples we do. You should have enough space to write down everything you will need to know from this lesson for your project (Introduce)

I know that during middle school, a lot of times your notes are given to you complete and you don’t have to do notetaking. Or sometimes you aren’t provided notes and you don’t need to take them. That will be different in high school and especially in college, where you are expected to take your own complete set of notes. Taking notes is SUPER important for learning: most people don’t remember 95% of what they don’t write down on tests! Most people only write down 35% of the important topics in class, which means in a best-case scenario, they will only know about 40% of the information on a test. For this program, and for all your classes, I hope you will try to take complete notes. I take really good notes in my classes in school, and it makes me a better student. No lie, my friends always regret not taking as good of notes as I do and will ask me about what I wrote before tests! (Sell) >>

Pre-questions

1. What is a right triangle?

2. What principle would you use to find the side lengths of a right triangle?

3. What formula would you use to find the side lengths of a right triangle?
4. Have you learned about the Pythagorean Theorem before?

5. How much room is needed to unload the truck using the ramp?

<<Here I would tell them a story about how Pythagoras discovered the truth of this theorem and why it is funny>>

<<I would also ask: (in connection with the powerpoint)

“How would you find the distance you have to dig to get straight through a mountain?”

“How would you determine the dimensions of a computer or TV screen?”

“How would you find the length of the cable on the bridge?”

You would have to use Pythagorean's theorem!>>
All About the Pythagorean Theorem – Part 1

The Pythagorean Theorem is used to find the unknown side lengths of right triangles.

It can be used whenever two side lengths of a right triangle are known.

The formula is: \( a^2 + b^2 = c^2 \) ________________  

<< What could help you remember this formula?

It helps me to remember that the theorem goes a, b, c (like the alphabet), and then ALL the letters have squares. A is the first letter (1) plus the second B (2) equals C the third (3).

This is the answer to pre-questions 2 and 3>>

The side \( a \) is the side length next to the 90° angle of the triangle, or the side length of a leg of the triangle.

The side \( b \) is the side length next to the 90° angle of the triangle, or the side length of the other leg of the triangle.

The side \( c \) is the side length opposite to the 90° angle of the triangle, or the side length of the hypotenuse of the triangle.
<<What about the formula tells us that the hypotenuse has to be the longest?

The hypotenuse HAS to be the longest side because the other two sides add up to it. The hypotenuse sounds like hippopotamus, which are big animals, so it has to be the longest side. I usually label the legs of the triangle clockwise a-b-c, but you can do it however you like, as long as the C side is opposite the right angle. The hypotenuse, C, is opposite the RIGHT angle because the C is usually on the RIGHT side of the equation. >>

Label the sides of the triangle: Label the names of each side of the triangle:

An easy way to remember the hypotenuse is:

The hypotenuse HAS to be the longest side because the other two sides add up to it. The hypotenuse sounds like hippopotamus, which are big animals, so it has to be the longest side
How to Use the Pythagorean Theorem – Part 2

Sequence of steps to do when using the Pythagorean Theorem

1. Label
2. Known Sides
3. Unknown Sides
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

Find the unknown side length of this triangle:

<< For these problems, I will teach you how to solve them by writing the steps as a sequence. Sequences show how to solve a problem by showing you the thought process behind each step. You can complete the sequence in your notes as I show you how to use a sequence with the example. Writing and using a sequence is very helpful anytime you have to do math problems that use similar logic over and over. (Introduce)

How many of you have ever gotten stuck in the middle of a math problem and you don’t know what to do next? Sequences help guide you through a problem and help to prevent you from getting “stuck” because they can tell you what to do next. Sequences for easy problems can often be applied to harder problems as well, which helps you understand harder problems better. I create sequences for the math problems I do when my teachers don’t give them to me. I can stay focused on how to solve the problem and not get lost when my homework is hard! (Sell)>>

1. Label the legs and hypotenuse of the triangle.

2. Identify the known sides.

   **Known:** \(a=3, \ b=4\)

3. Identify the unknown side lengths
Unknown: \( c=? \)

4. Plug the known side lengths into the Pythagorean theorem:

\[
a^2 + b^2 = c^2 \quad \Rightarrow \quad 3^2 + 4^2 = c^2
\]

5. Simplify the known squares.

\[
3^2 + 4^2 = c^2 \quad \Rightarrow \quad 9 + 16 = c^2
\]

<<Be careful to square BEFORE adding, if you do it the other way around you will get the wrong answer.>>

6. Add the squares:

\[
25 = c^2
\]

7. Take the square root of both sides:

\[
\sqrt{25} = \sqrt{c^2}
\]

8. Simplify for the final answer of side length:

\[
5 = c
\]

As you can see, it saves time to know your perfect squares really well! Here is a sequence that has the example problem below it for you to follow:
How to Use the Pythagorean Theorem with a Calculator – Part 3

<< Now, I want to do an example applying the procedure to a not-perfect-square triangle. I want to add another procedure to teach students how to do square roots with non-perfect squares. I will include pictures on the powerpoint I want to use.>>

Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a calculator when using the Pythagorean Theorem.

Find the unknown side length of this triangle:

Steps 1-4 are the same:

1. labeled on diagram
2. known: \( a = 8 \), \( b = 5 \)
3. unknown: \( c = ? \)
4. plug in: \( a^2 + b^2 = c^2 \rightarrow 8^2 + 5^2 = c^2 \)

5c. Use the \(^\) button on your calculator to find the square.

\[
8^2 + 5^2 = c^2 \quad \rightarrow \quad 64 + 25 = c^2 = 89
\]
6c. Use parenthesis for adding squares on your calculator.

\[(8^2) + (5^2) = c^2\]

7c. Use the \text{sqrt} button and ANS key to find the square root of both sides.

\[\sqrt{\text{ANS}} = \sqrt{\text{ANS}} = c = 9.43\]

The unknown side length (round to 2 decimal places) = 9.43

Solution Summary

Sometimes you have to find the side length of a triangle that is not the hypotenuse, it’s a leg.

You can find an equation for the unknown side length using algebra.

It is the same equation for either leg. The ‘a’ or ‘b’ only depends on how you labelled the triangle at the beginning.
Matrix organizing the different ways to use the Pythagorean Theorem with Examples

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>a \rightangle c = ?</th>
<th>a \rightangle b = ?</th>
<th>a \rightangle b = ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown Side:</td>
<td>Hypotenuse</td>
<td>Leg</td>
<td></td>
</tr>
<tr>
<td>Equation:</td>
<td>$a^2 + b^2 = c^2$</td>
<td>$a^2 = c^2 - b^2$</td>
<td>$b^2 = c^2 - a^2$</td>
</tr>
</tbody>
</table>

<<This matrix organizes unknown side types of triangles and their formulas for you!
Matrices are a great way to arrange information in a way you can remember it, with the rows or columns having similar properties. Why do both cases of triangles on the right have the same side name and formula?>>

When solving a Pythagorean Theorem problem, you can use the leg equation during step 4, and all the other steps will the same!

Example Problems

Now, we will do two practice Pythagorean Theorem problems together.
Pythagorean Triangles – Part 4

As we saw in the last example, sometimes triangles don’t require a calculator to be solved if you learn your perfect squares.

<< Here I would ask them: What is a perfect square?
Yes, a perfect square is a number that has a square root that is a whole number.>>

This is a special type of right triangle that has side lengths that are all perfect squares. It’s called a Pythagorean Triangle.
Here are some common examples of Pythagorean Triangles you may encounter:

<table>
<thead>
<tr>
<th>Matrix organizing the different types of Pythagorean Triangles</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-4-5</td>
</tr>
<tr>
<td>![Diagram of 3-4-5 triangle]</td>
</tr>
</tbody>
</table>

<<Why do you think these triangles are called Pythagorean Triangles?

Pythagorean Triangles are made of up all perfect squares because they are the PERFECT triangles to use with the Pythagorean Theorem.

You will notice that the 3-4-5 triangle is the same one we encountered in pre-question 5>>

If you know these triangles, then you can skip most of the procedure.

Do steps 1, 2 & 3.

1.

2.

3.

Do steps 1, 2 & 3.

1. **Labelled on diagram**

2. **Known:** $a = 5, b = 12$

3. **Unknown:** $c = ?$

3a. Is it a Pythagorean Triangle? *YES* *NO*
If YES, go to step 8 and fill in values from memory. If NO, go to step 4.

The final answer would be:

<< Tell them in this instance, you can write your final answer on the triangle. 

What is a Pythagorean triangle? (I will ask the class)>>

Final Procedure

Using the final form of our procedure, we can solve any type of Pythagorean Theorem problem.

<< Now that I’ve taught you the final sequence to use when solving a Pythagorean Theorem problem, you can see how it may help someone work a really difficult Pythagorean Theorem problem with decimals and non-perfect squares. The sequence will help you with
your project. By writing down each step of the sequence while you solve a problem, it keeps your work organized and logical for you to look at and understand. If you do this for your project, you can look back next week and easily see what you are working on and what your answer is. I will be able to as well. (Perfect)

If you create sequence for the math you are doing in your math class and use it on the test, your teacher will be better able to understand your work. They might even give you partial credit on problems where you might get the answer wrong (if you make a calculator error, say) but still know how to get the right answer. (Generalize)

In order for them to associate the steps of this final process with an example, I think I’m going to write the steps up on the board and the math beneath it for them to follow along with.>>

Practice Problems

Find the length of the unknown sides on the triangles shown.

![Triangle 1](image1)

![Triangle 2](image2)

<<I will give them time to solve both problems on their own, then I will go over them.

For this one, I will first solve normally. Then explain we could have done it with a lot less work. Ask the class what I will explain how this is still a Pythagorean Triangle, just doubled.>>

<<Here, I will explain to round as little as possible until the last step to get the most accurate answer. I will also highlight how using parenthesis helps with that.>>
Applications of the Pythagorean Theorem

List three applications of the Pythagorean Theorem:

9. Mechanical Engineers use right triangles to design their machines.

10. Electrical Engineers use the Pythagorean Theorem to model electricity.

11. Civil Engineers use the Pythagorean Theorem analyze trusses.

<< Now that I've gone through all the material, take a little time to make sure you have everything in the notes written down. If you are missing anything, I can provide the complete notes for you to check. I will go through the PowerPoint one more time so you can see if your notes are correct. If you are ever in a class and you miss something important that you think should be in your notes, make sure to ask the teacher about it, raise your hand or even ask after class. That way, you know you got all the information. You can use your notes for your project as much as you need. (Perfect)
As this program goes on, I will help you guys learn to take really good notes by lessening the amount of outline I give you in your skeletal notes. This will help you learn how to record the important information that you are taught for the future. I will always let you see the complete notes if you need them. Make sure you practice taking good notes during your classes, this will prepare you for high school and college. (Generalize)
The students hopefully should successfully select the important information from the lesson by using and filling out the skeletal notes provided. In the skeletal notes, I include several tools for them to organize the information they are learning, which is the next step of the SOAR model. Some of the tools used to organize the information for students include illustrations, sequences and matrices. While teaching the lesson, I highlighted the importance of each as a tool for their learning.

Sequences are an important organization tool for repeated processes, like those found when solving a particular type of math problem. By referencing steps shown in the sequence, students learn the order relationships of different parts in the analysis for Pythagorean problems. The steps to solve Pythagorean Theorem problems under varying conditions are shown in order from left to right, sometimes including examples. At the end of the lesson, I presented a final sequence that summarizes the lesson with an example below it to link the steps to what they are completing.

Matrices are extremely important for showing comparisons between subjects by locating analogous aspects near each other. Matrices can improve learning of interconnected lesson materials because they encourage two-dimensional analysis of information (citation: Kauffman & Kiewra, 1999 /pg 41). In this lesson, matrices were used to organize the relationships between different expressions of the Pythagorean Theorem and Pythagorean triangles.

Here, the organizational tools are again included:
### Matrix organizing the different ways to use the Pythagorean Theorem with Examples

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>a</th>
<th>c = ?</th>
<th>a</th>
<th>c</th>
<th>a = ?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td></td>
<td>b = ?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unknown Side:</th>
<th>Hypotenuse</th>
<th>Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation:</td>
<td>(a^2 + b^2 = c^2)</td>
<td>(a^2 = c^2 - b^2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b^2 = c^2 - a^2)</td>
</tr>
</tbody>
</table>

### Matrix organizing the different types of Pythagorean Triangles

<table>
<thead>
<tr>
<th>3-4-5</th>
<th>5-12-13</th>
<th>8-15-17</th>
<th>7-24-25</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="3-4-5 Triangle" /></td>
<td><img src="image2" alt="5-12-13 Triangle" /></td>
<td><img src="image3" alt="8-15-17 Triangle" /></td>
<td><img src="image4" alt="7-24-25 Triangle" /></td>
</tr>
</tbody>
</table>

### Final sequence of steps to use to solve any Pythagorean Theorem Problem

1. **Label**
2. **Known Sides**
3. **Unknown Sides**
4. **NO**
5. **Plug in**
6. **Simplify**
7. **Add or Subtract**
8. **Square Root**
9. **Simplify Again**

**Is it a Pythagorean Triangle?**
- **Yes**
- **No**

**Steps:**
- Use ^
- Use 0
- Use √ANS
The next component of the SOAR model is association. It is a teacher’s job to help students associate the material so it is more easily learned. I wanted anchor the topic in real life applications, so students can see how the Pythagorean Theorem could be and is useful. It is important that those applications are things they have maybe seen before or heard of before to be effective. I did this by telling them a story at the beginning of the lesson of how the theorem was discovered and why the Greeks used it once it was discovered. I also started off the lesson with application problems to provide some context to the lesson. At the end of the lesson, I provided and described examples of how engineers use Pythagorean’s Theorem every day, using examples that they are familiar with. Additionally, it is important that the students make internal and external associations on the mathematical portion of the lesson and the mechanics of how a problem is done. The following is a list of those internal and external associations, and explanations of how I demonstrated those key associations resulting from the lesson.
<table>
<thead>
<tr>
<th>Internal Associations</th>
<th>External Associations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OBJECTIVE 1</strong></td>
<td></td>
</tr>
<tr>
<td>1a. The Pythagorean Theorem can only be used on right triangles, not obtuse, acute or equilateral triangles.</td>
<td></td>
</tr>
<tr>
<td>1b. The orientation of the right triangle does not matter.</td>
<td></td>
</tr>
<tr>
<td><strong>OBJECTIVE 2</strong></td>
<td></td>
</tr>
<tr>
<td>2a. The letters a, b, and c represent the length of the legs and hypotenuse (respectively) in a triangle, no matter the size or length of the legs.</td>
<td>2b. It helps me to remember that the theorem goes a, b, c (like the alphabet), and then ALL the letters have squares.</td>
</tr>
<tr>
<td></td>
<td>2d. A is the first letter (1) plus B is the second (2) equals C which is the third (3).</td>
</tr>
<tr>
<td>2c. The legs, a and b, are interchangeable when labelled, so long as they are consistent throughout the problem.</td>
<td>2e. I usually label the legs of the triangle clockwise a-b-c, but you can do it however you like, as long as the C side is opposite the right angle.</td>
</tr>
<tr>
<td></td>
<td>2f. The hypotenuse, C, is opposite the RIGHT angle because the C is usually on the RIGHT side of the equation.</td>
</tr>
<tr>
<td><strong>OBJECTIVE 3</strong></td>
<td></td>
</tr>
<tr>
<td>3a. The hypotenuse HAS to be the longest side because the other two sides add up to it.</td>
<td></td>
</tr>
<tr>
<td>3b. The hypotenuse sounds like hippopotamus, which are big animals, so it has to be the longest side.</td>
<td></td>
</tr>
<tr>
<td><strong>OBJECTIVE 4</strong></td>
<td></td>
</tr>
<tr>
<td>4. Have side lengths that are decimals are normal and OK.</td>
<td></td>
</tr>
<tr>
<td><strong>OBJECTIVE 5</strong></td>
<td></td>
</tr>
<tr>
<td>5a. The adjusted theorems for finding unknown side lengths for the legs of the triangle mean the same thing, the only difference is how the triangle is labelled.</td>
<td></td>
</tr>
<tr>
<td>5b. The adjusted theorems for finding the unknown side lengths for the legs of the triangle ARE the Pythagorean Theorem, just stated differently (using a little algebra).</td>
<td></td>
</tr>
<tr>
<td><strong>OBJECTIVE 6</strong></td>
<td></td>
</tr>
<tr>
<td>6. Pythagorean Triangles are right triangles, but not all right triangles are not Pythagorean Triangles.</td>
<td></td>
</tr>
<tr>
<td><strong>OBJECTIVE 7</strong></td>
<td></td>
</tr>
<tr>
<td>7. Pythagorean Triangles are made of up all perfect squares because they are the PERFECT triangles to use with the Pythagorean Theorem.</td>
<td></td>
</tr>
</tbody>
</table>

The Internal Associations are connected to the notes and organizers. The following is a list of where students should be seeing and making these associations:

1a. and 2a. is enforced by the example figure in the “All About the Pythagorean Theorem” section of the skeletal notes. They are also reinforced through the supplemental teaching materials used to present this lesson.
1b. is demonstrated through the example and practice problems.

2c. is covered during the “Solution Summary” notes and reinforced while working through the example problems as a class.

4. is covered in the “How to Use the Pythagorean Theorem with a Calculator” notes and is demonstrated when we work through example problem 1 and practice problem 2.

5a. and 5b. are clarified in the “Matrix organizing the different ways to use the Pythagorean Theorem with Examples” organizer.

6. is demonstrated with the “Matrix organizing the different types of Pythagorean Triangles” and with the first practice problem.

I also helped student make external associations through cues and questions I used while teaching. I had made annotations in my complete notes above with specifics of what I intended to say and the external associations included and labelled. For example, in order to help students recall the theorem in associations 2b. and 2c., I would have asked “what could help you remember this formula?” and then shared my methods for recalling it.

Finally, students observed some of these internal and external associations, specifically 1b., 2c., and 4. as they applied the Pythagorean Theorem to calculate their material needs for their bridge project. This is done by calculating the total of all the side lengths of the triangles they incorporated into their bridge design.
Regulate

In order to have student regulate their learning, the final component of the SOAR model, I tested their knowledge before, during and after the lesson. Before the lesson, the students completed a pretest with an application problem in to gage their understanding level. During the lesson, I allowed them to do portions of the example problems (and later, entire practice problems) before reviewing the procedure and solutions with the class. Additionally, I asked questions of the class to serve as transitions to new topics, but also to get a feel for their understanding. After the lesson, they used the Pythagorean Theorem to work on their project, a bridge design, where they calculated the amount of material that they needed to use. Before giving them the amount of bridge material they calculated, I checked their work and saw if their calculations were correct. The example and practice problems I used are included below, along with the objectives being measured by each one:
Pre-questions (All objectives, see Select):

1. What is a right triangle?

2. What principle would you use to find the side lengths of a right triangle?

3. What formula would you use to find the side lengths of a right triangle?

4. Have you learned about the Pythagorean Theorem before?

5. How much room is needed to unload the truck using the ramp?
Objectives 2 and 3:
Label the sides of the triangle: Label the names of each side of the triangle:

Objectives 4 and 5:
Now, we will do two practice Pythagorean Theorem problems together.

Objectives 4, 6 and 7:
Find the length of the unknown sides on the triangles shown.
Strategy Instruction

In order to help the students learn not just the material, but learning strategies to become better students, I introduced, “sold,” perfected, and generalized the SOAR strategies used during the lesson. For this particular lesson, I focused on good notetaking for selecting information and sequences for organizing information. I verbally communicated the following strategies as part of the lesson (see the complete notes for reference).

NOTETAKING FOR SELECTING

For this class, I’ve provided you with skeletal notes in your engineering notebooks. You should complete the notes as I teach you the material. I will have the information you need on the PowerPoint and in the examples we do. You should have enough space to write down everything you will need to know from this lesson for your project (Introduce)

I know that during middle school, a lot of times your notes are given to you complete and you don’t have to do notetaking. Or sometimes you aren’t provided notes and you don’t need to take them. That will be different in high school and especially in college, where you are expected to take your own complete set of notes. Taking notes is SUPER important for learning: most people don’t remember 95% of what they don’t write down on tests! Most people only write down 35% of the important topics in class, which means in a best-case scenario, they will only know about 40% of the information on a test. For this program, and for all your classes, I hope you will try to take complete notes. I take really good notes in my classes in school, and it makes me a better student. No lie, my friends always regret not taking as good of notes as I do and will ask me about what I wrote before tests! (Sell)

Now that I’ve gone through all the material, take a little time to make sure you have everything in the notes written down. If you are missing anything, I can provide the complete notes for you to check. I will go through the PowerPoint one more time so you can see if your notes are correct. If you are ever in a class and you miss something important that you think should be in your notes, make sure to ask the teacher about it, raise your hand or even ask after class. That way, you know you got all the information. You can use your notes for your project as much as you need. (Perfect)

As this program goes on, I will help you guys learn to take really good notes by lessening the amount of outline I give you in your skeletal notes. This will help you learn how to record the important information that you are taught for the future. I will always let you see the complete notes if you need them. Make sure you practice taking good notes during your classes, this will prepare you for high school and college. (Generalize)

SEQUENCES FOR ORGANIZING

For these problems, I will teach you have to solve them by writing the steps as a sequence. Sequences show how to solve a problem by showing you the thought process behind each step. You can complete the sequence in your notes as I show you how to use a sequence with the example. Writing and using a sequence is very helpful anytime you have to do math problems that use similar logic over and over. (Introduce)
How many of you have ever gotten stuck in the middle of a math problem and you don’t know what to do next? Sequences help guide you through a problem and help to prevent you from getting “stuck” because they can tell you what to do next. Sequences for easy problems can often be applied to harder problems as well, which helps you understand harder problems better. I create sequences for the math problems I do when my teachers don’t give them to me. I can stay focused on how to solve the problem and not get lost when my homework is hard! (Sell)

Now that I’ve taught you the final sequence to use when solving a Pythagorean Theorem problem, you can see how it may help someone work a really difficult Pythagorean Theorem problem with decimals and non-perfect squares. The sequence will help you with your project. By writing down each step of the sequence while you solve a problem, it keeps your work organized and logical for you to look at and understand. If you do this for your project, you can look back next week and easily see what you are working on and what your answer is. I will be able to as well. (Perfect)

If you create sequence for the math you are doing in your math class and use it on the test, your teacher will be better able to understand your work. They might even give you partial credit on problems where you might get the answer wrong (if you make a calculator error, say) but still know how to get the right answer. (Generalize)
Pythagorean Theorem lesson PowerPoint.

The screen captures of the slides I used for teaching the Pythagorean Theorem are included next. They include the information missing in the skeletal notes that students need to learn, both from listening to me and from reading the slides. This allows information in the notes to be supported by visual and verbal evidence.
THE SPECIAL EQUATION ENGINEERS USE EVERYDAY AND HOW THEY USE IT

PLEASE ANSWER THESE PREQUESTIONS

How would you find the distance you have to dig to get straight through a mountain?

How would you determine the dimensions of a computer or TV screen?

How would you find the length of the cable on the bridge?

ALL ABOUT THE PYTHAGOREAN THEOREM AND A STORY
The Pythagorean Theorem is used to find the unknown side lengths of right triangles. It can be used whenever two side lengths of a right triangle are known.

The formula, the Pythagorean Theorem, is $a^2 + b^2 = c^2$

The side $a$ is the side length next to the 90° angle of the triangle, or the side length of a leg of the triangle.

The side $b$ is the side length next to the 90° angle of the triangle, or the side length of the other leg of the triangle.

The side $c$ is the side length opposite to the 90° angle of the triangle, or the side length of the hypotenuse of the triangle.

Let's do some practice.
An easy way to remember the hypotenuse is...

**HOW TO USE THE PYTHAGOREAN THEOREM**

This is the general process for a Pythagorean Theorem problem.

1. Label the legs and hypotenuse of the triangle.

   ![Diagram](image)

   - \( b = 4 \)
   - \( a = 3 \)
   - \( c = ? \)

2. Identify the known sides.

   **Known:** \( a = 3, b = 4 \)

3. Identify the unknown side lengths

   **Unknown:** \( c = ? \)
4. Plug the known side lengths into the Pythagorean theorem:

\[ a^2 + b^2 = c^2 \]

\[ 3^2 + 4^2 = c^2 \]

5. Simplify the known squares.

\[ 3^2 + 4^2 = c^2 \rightarrow 9 + 16 = c^2 \]

6. Add the squares:

\[ 25 = c^2 \]

7. Take the square root of both sides:

\[ \sqrt{25} = \sqrt{c^2} \]

8. Simplify for the final answer of side length:

\[ 5 = c \]

As you can see, it saves time to know your perfect squares really well!

HOW TO USE THE PYTHAGOREAN THEOREM WITH A CALCULATOR
Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a calculator when using the Pythagorean Theorem.

<table>
<thead>
<tr>
<th>Label</th>
<th>Known Sides</th>
<th>Unknown Sides</th>
<th>Plug in</th>
<th>Simplify</th>
<th>Add or Subtract</th>
<th>Square Root</th>
<th>Simplify Again</th>
</tr>
</thead>
<tbody>
<tr>
<td>5c.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5c. Use the ^ button on your calculator to find the square.

$$8^2 + 5^2 = c^2 \rightarrow 64 + 25 = c^2$$

6c. Use parenthesis for adding squares on your calculator.

$$((8^2) + (5^2)) = c^2$$

7c. Use the sqrt button and ANS key to find the square root of both sides.

$$\sqrt{\text{ANS}} = c = 9.43$$

The unknown side length (round to 2 decimal places) = 9.43
Sometimes you have to find the side length of a triangle that is not the hypotenuse, it’s a leg.

You can find an equation for the unknown side length using algebra.

It is the same equation for either leg. The ‘a’ or ‘b’ only depends on how you labelled the triangle at the beginning.

This matrix shows when to use which equation.

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>Hypotenuse</th>
<th>Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown Side:</td>
<td>( a^2 + b^2 = c^2 )</td>
<td>( a^2 = c^2 - b^2 )</td>
</tr>
</tbody>
</table>

When solving a Pythagorean Theorem problem, you can use the leg equation during step 4, and all the other steps will the same!
As we saw in the last example, sometimes triangles don’t require a calculator to be solved if you learn your perfect squares.

This is a special type of right triangle that has side lengths that are all perfect squares. It’s called a Pythagorean Triangle.

**EXAMPLE PROBLEM 2**

![Diagram of a right triangle with sides 5, 12, and c.]

**COMMON RIGHT TRIANGLES**

**THAT YOU MAY ENCOUNTER**

Here are some common examples of Pythagorean Triangles you may encounter:

<table>
<thead>
<tr>
<th>3-4-5</th>
<th>5-12-13</th>
<th>8-15-17</th>
<th>7-24-25</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 3 4</td>
<td>13 12 5</td>
<td>17 8 15</td>
<td>25 7 24</td>
</tr>
</tbody>
</table>

**FINAL PROCEDURE**

If you know these triangles, then you can skip most of the procedure.

Do steps 1, 2 & 3.

3a. Is it a Pythagorean Triangle?

If YES, go to step 8 and fill in values from memory. If NO, go to step 4.
Using the final form of our procedure, we can solve any type of Pythagorean Theorem problem.

**Applications of the Pythagorean Theorem in Engineering**

Mechanical Engineers use the Pythagorean Theorem when they design machines.

**Practice Problems**

Find the length of the unknown sides on the triangles shown.

Electrical Engineers use right triangles and the Pythagorean Theorem to model electricity.
Civil Engineers use The Pythagorean theorem when they design and analyze trusses.

NOW, YOU HAVE TIME TO WORK ON YOUR PROJECT
The Impact of Engineering Club

To determine if the goals I had for Engineering Club were met, I collected data on certain key outcomes. For one, I created surveys with the purpose of directly measuring the primary goal of the club: building an interest in engineering in the students. Additionally, after every Engineering Club lesson I recorded my general reflections on how the lesson went and any improvements to be made.

For further analysis, I collected many of the tangible products from the club, such as scans or images. These include records of student’s responses to the pre-questions, skeletal notes, example problems, and practice problems during the Pythagorean Theorem lesson. Further materials contain complete engineering notebooks, various student design sketches of the bridges project, and pictures of the bridges they built.

Analysis of Engineering Club Surveys.

Two surveys were taken over the course of the semester. The first survey was taken at the beginning of club before I had described the club objectives to students. The second survey was taken during the beginning of the final Engineering Club meeting, twelve weeks later, using the same survey questions. The students likely did not remember the survey from the beginning of the semester. Scans of the surveys are included in the Appendix A.

The survey statements are shown in Table 1. Students responded to the statements by circling a number corresponding to their reaction, with 1 = Strongly Disagree, 2 = Disagree, 3 = No Opinion, 4 = Agree, and 5 = Strongly Agree. On the first survey, students were also asked to complete a sentence on why they joined the club. For the second survey, students were asked what they liked about the club and one thing they would change about the club.
Table 1. Survey Results by student for each question

<table>
<thead>
<tr>
<th>Student</th>
<th>Question 1: I know what engineering is</th>
<th>Question 2: I know what an engineer might do everyday</th>
<th>Question 3: I could be an engineer when I grow up if I wanted to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricardo</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Ellie</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Jimmie</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Will</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Maddie</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ethan D.</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Mu</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Alivia</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>DJ</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Amir</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Anna</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Cate</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Dakkon</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Joel</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>4.21</td>
<td>3.93</td>
<td>4.14</td>
</tr>
</tbody>
</table>

Survey 2 (Post-semester)

<table>
<thead>
<tr>
<th>Student</th>
<th>Question 1: I know what engineering is</th>
<th>Question 2: I know what an engineer might do everyday</th>
<th>Question 3: I could be an engineer when I grow up if I wanted to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellie</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Jimmie</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Alex</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Maddie</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Ethan D.</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Mu</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Alivia</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Amir</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Anna</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cate</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Joel</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Ethan C.</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>4.67</td>
<td>4.58</td>
<td>4.58</td>
</tr>
</tbody>
</table>

Increase in average score

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.45</td>
<td>0.66</td>
<td>0.44</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>0.52</td>
</tr>
</tbody>
</table>
From the first survey, it appears the students knew the least about what engineers do every day (average score was 3.93). They felt moderately more confident in their abilities to become an engineer if they wanted to (4.14). Finally, almost all students agreed that they knew what engineering is (4.21). Inspecting the comments on the survey forms, 9 of 14 students cited engineering or interest in engineering as a career path. Other common answers included wanting to build things or interest in math and science.

On the second survey, however, there was an increase in students agreeing to the statements about engineering. The average score for each one was around 4.5, with the Question 1 mean (4.67) the highest. There was a distinct increase in average response to each question at the end of the semester; the largest average increase was seen for Question 2 with a difference of 0.66. The average increase across all questions was 0.52.

Other observations can be made from these surveys. When asked what they would change about the club, a few students cited wanting time to learn more, and one even wanted to spend a longer time at the College of Engineering during our visit to UNL. While looking at individual student responses, Ellie increased all the 3's she answered to 4's, and her 4 to a 5. Alivia also shifted all her answer choices from 4's to 5's. Because of this increase in numerical answers to the survey, I have confidence that students developed their interest in many of the topics covered during the club.

**Analysis of Pythagorean Theorem lesson pre-questions.**

As previously described, during the Pythagorean Theorem lesson students completed pre-questions asking about lesson objectives. Responses to the pre-questions varied widely among students. Sixth graders had not covered the Pythagorean Theorem before, whereas two seventh graders and the single eighth grader had learned about it during their math classes previously. Pre-questions appear in
the SOAR lesson plan above and select sample student responses to the pre-questions are included in Appendix B.

All students correctly identified what a right triangle was, however, there was some incorrect information too. For example, Ricardo suggested that right triangles have sides that are all the same length (which is impossible), and DJ said that all sides must be different lengths (which ignores isosceles right triangles).

Most students had not learned about the Pythagorean Theorem before, and thus could not answer the pre-questions asking them what the theorem was, how to use it, and to do a practice problem. Two seventh graders, Ethan C. and Mu, had learned about the Pythagorean Theorem before but had forgotten how to use it and therefore left their pre-questions unanswered as well.

Only four students successfully solved the practice Pythagorean Theorem problem provided in the pre-questions (finding the missing side length for pre-question 4): Ethan D. (Grade 7), DJ (7), Jimmie (7), and Aidan (8). However, only Aidan likely recognized that triangle as a Pythagorean Triangle and solved it without using the theorem equation. It should be noted that Jimmie, Ethan D., and DJ were sitting next to each other and are close friends, which might explain their similar responses to the pre-questions. Because neither Ethan D. or DJ responded that they had previously learned about the Pythagorean Theorem, Jimmie was likely the originator of their nearly identical answers.

All of these students, except Aidan, were confident in their ability to use a calculator (pre-question 3) to solve for squares and square roots for non-perfect squares. However, few conclusions can really be drawn from this. Based on Aidan’s response to pre-question 3, he likely misunderstood the question which asked how to use a calculator as a tool to solve a Pythagorean Theorem problem.

From the varied student responses to the pre-questions at the beginning of the lesson, it is safe to conclude that most students had not been exposed to the Pythagorean Theorem before this lesson.
Many of the learning outcomes observed in individual student performances of solving Pythagorean Theorem problems later was likely a direct result from the instruction they received during the lesson.

**Analysis of Pythagorean Theorem lesson skeletal notes.**

The skeletal notes completed by students during the lesson, and especially their work on the practice problems, allowed analysis of the students’ learning behaviors. During the lesson about the Pythagorean Theorem where students filled in their skeletal notes, the students completed some example problems on the Pythagorean Theorem in a structured manner as a class. The first example problem was done step-by-step with my guidance. Then, the second example problem was set up with the class (Steps 1-4) but left for individual students to finish on their own. The practice problems were completed at the end of the lesson by each student individually during quiet work time. I only provided guidance to students if they asked for it by raising their hands. In the following sections, the degree of student learning is analyzed based on their note completeness, their work on the example problems, and their work on the practice problems. Sample completed skeletal notes are included in Appendix B for reference.

**Completeness of student notes.**

Most students adequately completed their skeletal notes. As a general trend, most students did miss one or two blanks, not pursuing the option to look at the complete set of notes I provided (or to get notes from their neighbor) to fill them in. A majority of the students who completed their skeletal notes (with only 1-2 items left blank) consistently got both example problems and both practice problems correct. Only 3 students (Aidan, Alivia, and DJ) who completed their skeletal notes thoroughly erred on at least one of the example problems or practice problems. Of the remaining students (Cate, Ethan C., Ricardo) who did not adequately complete their skeletal notes, they completed few example and practice problems or completed them incorrectly. However, Cate was absent for part of the
Pythagorean Theorem lesson, so that justifies her missing work. Data on the completion of pre-questions, skeletal notes, example problems, and practice problems can be seen in Table 2.

Included in the skeletal notes were example triangles where students were asked to state the letters representing each side length and the names of each side. These questions are examples of how concept learning is regulated during the lesson. The students are regulating their ability to identify the parts of the triangle and what those parts are called. Students completed the activity on their own during quiet work time. Most students had no problems labelling the triangles, though a few (such as Maddie) labelled both of the example triangle’s sides with only a, b, and c and not leg, leg, hypotenuse (and vice versa).

Table 2. Notetaking data and problem performance by student (F represents 1-2 blanks incomplete)

<table>
<thead>
<tr>
<th>Name</th>
<th>Pre-Question Completion Y/N</th>
<th>Complete Notes Y/F/N</th>
<th># of Correct Example Problems</th>
<th># of Correct Practice Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alex</td>
<td>Y</td>
<td>F</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Anna</td>
<td>Y</td>
<td>Y</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Maddie</td>
<td>Y</td>
<td>F</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mu</td>
<td>Y</td>
<td>F</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ellie</td>
<td>Y</td>
<td>F</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Joel</td>
<td>Y</td>
<td>Y</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ethan D.</td>
<td>Y</td>
<td>F</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Jimmie</td>
<td>Y</td>
<td>F</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Amir</td>
<td>N</td>
<td>Y</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Alivia</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Aidan</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cate</td>
<td>N</td>
<td>N</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ethan C.</td>
<td>Y</td>
<td>N</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DJ</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ricardo</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Noticeably, there were a few students who made a connection between the size of a hippopotamus and the length of the hypotenuse and put it in their notes – really going above and
beyond the limits of the skeletal notes model. This is an example of excellent notetaking and will help students’ overall learning of the concepts in general. These students were Joel, Aidan, and Ricardo.

Another topic that should be discussed is the students who recognized the 6-8-10 triangle (#1 of the practice problems) was really a double (scaled proportionally) 3-4-5 triangle. I did not expect students to make this connection, I merely explained it to them after we reviewed the practice problem. However, some students caught on. I think Aidan may have remembered from previous math classes. It is also encouraging that Alex took note of the 6-8-10 triangle in her work.

*Example problem performance.*

The inclusion of the example problems was a regulation tool that allowed students to see how they would be evaluated on their learning: through demonstrating how they would be questioned on their skill in solving Pythagorean Theorem problems. As previously mentioned, students generally performed better on the example problems if they had completed their skeletal notes.

Most students followed the sequence learned during the lesson to solve the Pythagorean Theorem example problems. This is likely because the example problems were guided with instruction from me and the inclusion of numbered spots for steps on the example problem workspace. Referencing Table 2, eight students completed both example problems correctly, and 5 students completed one example problem correctly. Some things, such as a lack of a calculator, did hinder students from completing the non-Pythagorean problem (this was Alivia’s case I believe).

There were a few students that erred on the example problems while not correctly following the sequence provided during the lesson. Notably, Aidan attempted to solve example problem #2 without the sequence and made an error (he later corrected).
Practice problem performance.

The practice problems were the main assessment of the lesson through which I was able to evaluate how well students could apply their skills in solving Pythagorean Theorem problems. Students were expected to use the sequence and other concepts learned in class to solve the Pythagorean Theorem problems on their own.

There were nine students who got both practice problems questions correct, and two students who got one practice problem correct. In general, most students did not follow the numbered sequence covered during the lesson to solve the practice problems. It should be noted that there were no numbered spaces for students to complete skeletal notes during each step in the workspace this time, however. Several students followed the sequence, not writing the step names and numbers down, but did end up solving the problems correctly. These students were Alex, Ethan D., and Mu. Anna was the only student who followed the numbered sequence herself while correctly solving the practice problems. Most students who did not solve the practice problems at all were either absent for part of the lesson (Cate, DJ) or did not take effective notes (Ricardo, Ethan C.).

Analysis of engineering notebooks and other tangible outcomes.

I believe students truly did complete a true engineering project for their age level through the completion of an engineering notebook containing all the details students used to build their bridge during the semester. The students have detailed accounts, through the skeletal notes they took, of the important engineering concepts they referenced throughout the project. They also have all their notes on the mathematical concepts involved in building their bridge project. Finally, in each notebook students have sketches of the various iterations of their bridge designs that they later built and tested. Scans of a few completed engineering notebooks are included in Appendix C.
Another outcome of Engineering Club includes the engineering drawings of their bridges that each student drew. Students used these 1:1 scale drawings as instructions to build their bridges. A few samples of these drawings (unfortunately only partial scans) and examples of how the drawings were used to build the bridges are included in the following pages.
Figure 1. Aidan’s Bridge in progress

Figure 2. Amir’s Bridge in progress
Probably the most significant outcome of Engineering Club was the bridge students built. Students built a physical bridge that they later tested. Bridges were tested by suspending a bucket (test mass) under the bridge using a wooden block across the top of the bridge to distribute the load (see Figure 5). The bucket started empty and students gradually increased the load on the bridge by pouring gravel into the suspended bucket. Students had the option to test only up to a certain weight in the bucket, however, all students chose to test until failure, or to the point at which their bridge broke. Then, students analyzed the efficiency of their bridge based on how much weight it held. Efficiency is defined as the amount of weight held by the bridge per unit bridge weight. Awards were given to students whose bridges held the most weight or had the highest efficiency. The following are images of some completed bridges and bridge testing.

Figure 3. Joel’s Bridge
Figure 4. Ellie’s Bridge

Figure 5. Testing Joel’s Bridge
In order to successfully complete their bridge and test it, students had to apply the math and science concepts they had learned during Engineering Club, including the Pythagorean Theorem. It is incredibly meaningful that students were able to see how the concepts they learned during club time are used every day by engineers. Beyond just applying the math and science-related material they studied, students also learned a great deal about engineering. They observed the iterative process engineers go through to refine their designs as they improved their bridges. Students had to pay close attention to detail, an important engineering skill, while building their bridge so all the parts came together properly.

The final outcome I discuss is the student “field trip,” or school visit, to the UNL College of Engineering. Students reported that this is one of their favorite parts of the club. During the visit, students went on a tour of the engineering buildings at UNL. They saw many of the labs for engineering students: the chemical engineering lab, the structures lab, the metal machining shop, and the aerospace
lab, among others. A final highlight for students was hearing a presentation by current engineering students. Afterward, they asked the engineering students questions about engineering, high school, and college. It is rare that middle-school students can visit a college and see themselves becoming engineering students in the future.

**Analysis of my reflections on student learning.**

Over the course of the semester, I reflected on each lesson after I had taught it. The records of these reflections not only became a useful tool for evaluating student learning but also a useful resource for identifying improvements for the club. Although there were a few stumbling blocks with technology issues early in the semester, overall student learning was positive. The following highlights reflect key instances of student learning during the semester.

Early in the club, the students were introduced to their engineering notebooks through the story of how Alexander Graham Bell won the telephone patent because of his engineering notebook. The story hit home and the students were amazed by the importance of good engineering note taking. I also emphasized the importance of taking excellent notes through *strategy instruction* throughout the club. By the end of the semester, most students had kept their engineering notebooks completely up to date.

My general observations on the Pythagorean Theorem lesson were mainly covered above, but it is worth reinforcing. By grade level, the sixth graders had not learned about the theorem before and thus required more coaching, whereas the lesson was comparatively boring for Aidan (the eighth grader) having learned the topic multiple times. However, I was excited to see Joel, a sixth grader, pick up on the lesson and successfully solve practice problems.

For the field trip, my reflections reinforced how well it went. During the tour, the students asked good questions of the guide. They were very interested in projects engineering students were working
on, like the CHEME car and the concrete canoe. All the students cited enjoying learning about the space projects in the aerospace lab.

Finally, on the day we tested our bridges, most students struggled to apply some of the dimensional analysis concepts covered previously in the semester. On a positive note, most students shared that they wanted to join Engineering Club again the following year because they had so much fun. In fact, two students did rejoin the next year.

Conclusions

Engineering Club was created with the intention of using an after-school program to develop an interest in engineering for its participants and to educate them more on what engineering is. Throughout the semester, the students learned about the application of math and science concepts to their bridge project, just as engineers apply their technical knowledge to solving problems. Students learned about engineering notebooks, good note taking, and the Pythagorean Theorem, among other topics. During their school visit and tour to UNL, students observed what studying engineering would be like in college and asked questions of current engineering students.

During the Pythagorean Theorem lesson, specifically, students learned how to solve for the missing side lengths of varying triangles. These included problems when either the leg or the hypotenuse were the unknown side, problems with and without a calculator, and problems identifying Pythagorean Triangles. In general, student successfully learned these topics because a majority were able to correctly complete the practice problems at the end of the lesson on their own, and later apply that knowledge to their bridges.
Opportunities for improvement.

As I will be teaching Engineering Club again in future semesters, there are a few revisions I can make to the curriculum based on what was learned during this thesis project. Many of these improvements are attributed to the notes I made during my weekly reflections after teaching the club.

When teaching the Pythagorean Theorem lesson again, I will encourage students to reference my complete set of notes more when their skeletal notes are missing portions. Additionally, I will add numbers to the practice problem workspace on at least one of those problems, so students will be encouraged to follow the sequence they had previously learned. I believe this will promote more student success on those problems. Within the SOAR method, I will communicate to students expectations and objectives for them during the Pythagorean Theorem lesson. This will help students regulate their learning and pick up on key information during the lesson.

As for general club improvements, I will try to recruit mostly seventh graders for the club, as the topics covered seemed to be about right for that grade level in terms of difficulty and previous knowledge required. Finally, I want to implement some of the suggestions that students included in their second survey. I will build in more work time for students to complete their bridge project at the end of the semester. I will provide more information to students about the engineering classes they can take in high school, so they have some solid next steps if they are really interested in engineering. I intend to better prepare students for the UNL trip by describing it to them ahead of time. That way, they can be more observant during the trip and better prepared to ask good questions of the engineering students while they have the opportunity.

Final thoughts.

I judge Engineering Club as successful. It achieved its goals based on survey information and student performance. The students showed increased positivity toward engineering. In addition, more
students stated that they understood better what engineering is, what engineers do, and that they could be an engineer if they wanted to be at the end of the semester than before it. I was also encouraged to see that two students returned the following semester to take Engineering Club again. Additionally, several students took engineering-based classes the following year in eighth grade and high school, setting them upon the path to become engineers themselves.
Bibliography


Appendix A

The following pages include scans of student Surveys 1 and 2.
Engineering Club Survey

Name: Ricardo Ramirez
Parent/Guardians: Robert Ramirez
Email: ricardogramirez17@gmail.com
Parents/Guardians Phone: 402-937-2088

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is. 
1 2 3 4 5

I know what an engineer might do every day. 
1 2 3 4 5

I could be an engineer when I grow up if I wanted to. 
1 2 3 4 5

I joined this club because:
I'm interested in becoming an engineer.
Engineering Club Survey

Name: Ellie Bomberger
First                                                                 Last

Email: jsturek@ips.org

Parents/Guardians: JoLynn Sturek

Parents/Guardians Phone: 402-617-3568

Circle a number in response to each statement.
1 = Strongly Disagree - 2=Disagree - 3=No Opinion - 4=Agree - 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

I joined this club because:
I like building things and am interested in engineering.
Aidan Carlson

Jon Carlson/Jenny Madden

402-474-1368  402-730-3252
Engineering Club Survey

Name: Jimmie

Email: tdough@lps.org

Parents/Guardians: Tamara & Jim Cover

Parents/Guardians Phone: 402-499-2037

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

1  2  3  4  5

I know what an engineer might do every day.

1  2  3  4  5

I could be an engineer when I grow up if I wanted to.

1  2  3  4  5

I joined this club because:

I was thinking about being an engineer for a career path.
Engineering Club Survey

Name: William Kempkes

Email: Wijkempkes2022@gmail.com

Parents/Guardians: Rebecca Kempkes

Parents/Guardians Phone: 402-570-9322

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

  1   2   3   4   5

I know what an engineer might do every day.

  1   2   3   4   5

I could be an engineer when I grow up if I wanted to.

  1   2   3   4   5

I joined this club because:

Mr. Wagner told me it was fun, and I like to build things
Engineering Club Survey

Name: Maddie Spang

Email: Maddie.louesella@gmail.com

Parents/Guardians: Rebecca Lee Snyder

Parents/Guardians Phone: 402-429-7910 402-429-7920

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

I joined this club because:
Because I thought it would be cool to learn new skills and combining skills would be great.
Engineering Club Survey

Name: Ethan Dahl

Email: 269301@classic.los.org

Parents/Guardians: Ben & Sue

Parents/Guardians Phone: 402-742-7911

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

1  2  3  4  5

I know what an engineer might do every day.

1  2  3  4  5

I could be an engineer when I grow up if I wanted to.

1  2  3  4  5

I joined this club because:
I like building and designing objects and structures
Engineering Club Survey

Name: Muthee  
First: Muthee  
Last: Paw

Email: Muthee423agmail.com

Parents/Guardians: Tha Be  &  Hla Thein

Parents/Guardians Phone: (402)-480-9049

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

I joined this club because:

I thought about becoming an Aerospace engineer when I grow up. So, I think this can increase my knowledge about engineering.
Engineering Club Survey

Name: Olivia Neater

Email: abndragon1@gmail.com

Parents/Guardians: Melissa Neater and Dain Neater

Parents/Guardians Phone: 402-488-5728

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.  
1  2  3  4  5

I know what an engineer might do every day.  
1  2  3  4  5

I could be an engineer when I grow up if I wanted to.  
1  2  3  4  5

I joined this club because:
I wanted to use togetherness skills and skills in science to create a fun and interesting project.
Engineering Club Survey

Name: Dejuba22 Barrow

Email: Dejuba22@gmail.com

Parents/Guardians: Kate Barrow

Parents/Guardians Phone: 602-324-1330

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

I joined this club because:

I like engineering and knowing how things work.
Engineering Club Survey

Name: Amir Tarkiani
First Name

Last Name

Email: kg.tarkiani@gmail.com

Parents/Guardians: Katherine Tarkiani Bagher Tarkiani

Parents/Guardians Phone: 402-479-4267  402-450-5399

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

I joined this club because:

I am interested in what engineers do
Engineering Club Survey

Name: Anna Dvorak

First

Last

Email: arnvorakh03@gmail.com

Parents/Guardians: Karrie Dvorak, Bruce Dvorak

Parents/Guardians Phone: 402-326-8391, 402-326-3496

Circle a number in response to each statement.
1 = Strongly Disagree – 2 = Disagree – 3 = No Opinion – 4 = Agree – 5 = Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

I joined this club because:

I love math and building things.
Engineering Club Survey

Name: Cate Frederick

Email: cloverfrederick@gmail.com

Parents/Guardians: Clover Frederick

Parents/Guardians Phone: 402-416-8255

Circle a number in response to each statement.

1 = Strongly Disagree – 2 = Disagree – 3 = No Opinion – 4 = Agree – 5 = Strongly Agree

I know what engineering is.  

1 2 3 4 5

I know what an engineer might do every day.  

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.  

1 2 3 4 5

I joined this club because:  

I like building things and I think it will be cool.
Engineering Club Survey

Name: Dakkon Prika
First Last

Email: 

Parents/Guardians: korrie zimmerman

Parents/Guardians Phone: 402-825-0192

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

I joined this club because:

I am interested in being here, so I want to learn as much as I can.
Engineering Club Survey

Name: Joel Buettner

Email: 240475@glassips.org

Parents/Guardians: Aaron and Jennifer Buettner

Parents/Guardians Phone: 402-429-2206, or 902-429-2205

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

I joined this club because:
I want to be an engineer and my dad is an engineer
Engineering Club Survey 2

Name: Maddie Spang

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
   1  2  3  4  5

I know what an engineer might do every day.
   1  2  3  4  5

I could be an engineer when I grow up if I wanted to.
   1  2  3  4  5

One thing I liked about this club was:

the bridge building.

One thing I would change about this club is:

Nothing.
Engineering Club Survey 2

Name: Mu Htee

First Name

Last Name

Circle a number in response to each statement.
1 = Strongly Disagree – 2 = Disagree – 3 = No Opinion – 4 = Agree – 5 = Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

One thing I liked about this club was:

Everything

One thing I would change about this club is:

Nothing
Engineering Club Survey 2

Name: Jimmie Cove

Circle a number in response to each statement.
1 = Strongly Disagree  -  2 = Disagree  -  3 = No Opinion  -  4 = Agree  -  5 = Strongly Agree

I know what engineering is.
1  2  3  4  5

I know what an engineer might do every day.
1  2  3  4  5

I could be an engineer when I grow up if I wanted to.
1  2  3  4  5

One thing I liked about this club was:
How we get to plan out everything and decide what to do.

One thing I would change about this club is:
Different materials for building
Engineering Club Survey 2

Name: Ethan Dahl

First          Last

Circle a number in response to each statement.  
1 = Strongly Disagree – 2 = Disagree – 3 = No Opinion – 4 = Agree – 5 = Strongly Agree

I know what engineering is.  

1  2  3  4  5

I know what an engineer might do every day.  

1  2  3  4  5

I could be an engineer when I grow up if I wanted to.  

1  2  3  4  5

One thing I liked about this club was:  

The idea of the bridge

One thing I would change about this club is:  

Less notes
Engineering Club Survey 2

Name: Anna Duorák

First Duorák Last

Circle a number in response to each statement.
1 = Strongly Disagree - 2=Disagree - 3=No Opinion - 4=Agree - 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

One thing I liked about this club was:
I really liked that we got
to go to UNL and that
we got to actually got to
make the bridge.

One thing I would change about this club is:
So that we could do the
computer program. IT
WAS GREAT!!!!!!
Engineering Club Survey 2

Name: Alexandra Jipp

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

One thing I liked about this club was:
The free-flow style, and lack of rules, and the way you did things was very well organized, and fun.

One thing I would change about this club is:
More meetings = more in-depth info
Engineering Club Survey 2

Name: Cate Frederick

Circle a number in response to each statement.
1 = Strongly Disagree – 2 = Disagree – 3 = No Opinion – 4 = Agree – 5 = Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

One thing I liked about this club was:

Rachel is really nice.

One thing I would change about this club is:

I would like more time to work on the bridge.
Engineering Club Survey 2

Name: Cloria Neutu

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.

1 2 3 4 5

I know what an engineer might do every day.

1 2 3 4 5

I could be an engineer when I grow up if I wanted to.

1 2 3 4 5

One thing I liked about this club was:

Almost everything! Especially the building process.

One thing I would change about this club is:

I wish the field trip was longer. It was super fun!
Engineering Club Survey 2

Name: Ellie Bomberg

Circle a number in response to each statement.
1 = Strongly Disagree – 2 = Disagree – 3 = No Opinion – 4 = Agree – 5 = Strongly Agree

I know what engineering is.
1  2  3  4  5

I know what an engineer might do every day.
1  2  3  4  5

I could be an engineer when I grow up if I wanted to.
1  2  3  4  5

One thing I liked about this club was:
I got to learn about engineering and I got to build a bridge.

One thing I would change about this club is:
I would have more days to work and make the field trip longer.
Engineering Club Survey 2

Name: Joel

First

Last

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

One thing I liked about this club was:
that we got food and got to build a bridge

One thing I would change about this club is:
to give us more wood and time
Engineering Club Survey 2

Name: Ethan

First

Last

Circle a number in response to each statement.
1 = Strongly Disagree – 2=Disagree – 3=No Opinion – 4=Agree – 5=Strongly Agree

I know what engineering is.
1 2 3 4 5

I know what an engineer might do every day.
1 2 3 4 5

I could be an engineer when I grow up if I wanted to.
1 2 3 4 5

One thing I liked about this club was:
THE ENGINEERING TOUR

One thing I would change about this club is:
bad wood i love 6 9 15
Appendix B

The following pages include samples of completed skeletal notes. The first set of notes are Jimmie’s and the second set is Anna’s.
The Special Equation That Engineers Use Everyday
and
How They Use It

Pre-questions

1. What is a right triangle? Tell me what you know about its sides and angles.
   
   A right triangle is a triangle with a (1, one) right angle with all sides different and all angles different.

2. What formula would you use to find the side lengths of a right triangle? How do you use it?
   
   \[ a^2 + b^2 = c^2 \]
   
   You use it with \( \frac{c}{b} \) using opposite, adjacent, and the hypotenuse sides.

3. If you had to use a calculator to find the side lengths of a right triangle, could you? Explain.
   
   Yes. Just do \((a)^2 + (b)^2\), then you will get an answer, and you have to do the square root of it.

4. How much room is needed to unload the truck using the ramp? Do you recognize this triangle?

   \[ 3^2 + b^2 = 5^2 \]
   
   \[ 9 + b^2 = 25 \]
   
   \[ -9 -9 \]
   
   \[ a^2 = 16 \]
   
   \[ b = \sqrt{16} \]
   
   \[ b = 4 \]

5. Have you learned about the Pythagorean Theorem before?

   Yes
Pythagorean Theorem is used to find the unknown side lengths of right triangles.

It can be used whenever two side lengths of a right triangle are known.

The formula is: \( a^2 + b^2 = c^2 \).

The side \( a \) is the side length next to the 90° angle of the triangle, or the side length of a leg of the triangle.

The side \( b \) is the side length next to the 90° angle of the triangle, or the side length of the other leg of the triangle.

The side \( c \) is the side length opposite to the 90° angle of the triangle, or the side length of the hypotenuse of the triangle.

Label the sides of the triangle: \( a, b, c \)

Label the names of each side of the triangle: leg, leg, hypotenuse
An easy way to remember the hypotenuse is:

\[ a \]

\[ \text{hypotenuse} \]

\[ b \]

How to Use the Pythagorean Theorem – Part 2

Sequence of steps to do when using the Pythagorean Theorem

1. Label
2. Known Sides
3. Unknown Sides
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

Find the unknown side length of this triangle:

\[ \begin{align*}
3^2 + 4^2 &= c^2 \\
9 + 16 &= c^2 \\
25 &= c^2 \\
\sqrt{25} &= c \\
5 &= c
\end{align*} \]

1. Label the legs and \( x'de \) of the triangle.

2. Identify the \( \text{Known} \) sides.

Known: \( a = 3, b = 4 \)

3. Identify the unknown side lengths

Unknown: \( c = ? \)

4. Plug the \( \text{Known} \) side lengths into the Pythagorean theorem:
5. Simplify the known squares:

\[ 3^2 + 4^2 = c^2 \Rightarrow a + 16 = c^2 \]

6. Add the squares:

\[ 25 = c^2 \]

7. Take the square root of both sides:

\[ \sqrt{25} = \sqrt{c^2} \]

8. Simplify for the final answer of side length:

\[ 5 = c \]

As you can see, it saves time to know your perfect squares really well! Here is a sequence that has the example problem below it for you to follow:

Sequence of steps to do when using the Pythagorean Theorem with Example

1. Label
2. Known Sides
3. Unknown Sides
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

\[ b = 4 \]
\[ a = 3 \]
\[ c = ? \]

Known: \[ a = 3, b = 4 \]
Unknown: \[ c = ? \]

\[ a^2 + b^2 = c^2 \Rightarrow 3^2 + 4^2 = c^2 \]
\[ a^2 + b^2 = c^2 \Rightarrow 9 + 16 = c^2 \]
\[ 25 = c^2 \]
\[ \sqrt{25} = \sqrt{c^2} \]
\[ 5 = c \]
How to Use the Pythagorean Theorem with a Calculator – Part 3

Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a calculator when using the Pythagorean Theorem.

Find the unknown side length of this triangle:

\[ 5^2 + 8^2 = c^2 \]
\[ 25 + 64 = c^2 \]
\[ 89 = c^2 \]
\[ \sqrt{89} = c \]

Steps 1-4 are the same:
1. Label the sides
2. Known sides \( a = 5, b = 8 \)
3. Unknown side \( c = ? \)
4. Plug in unknown lengths into formula

5c. Use the ^ button on your calculator to find the square.

\[ 8^2 + 5^2 = c^2 \]

6c. Use \( \sqrt{} \) for adding squares on your calculator.

\[ ((8^2) + (5^2)) = c^2 \]

7c. Use the sqrt button and ANS key to find the square root of both sides.

\[ \text{sqrt( ANS )} = c \]
The unknown side length (round to 2 decimal places) = ________

Solution Summary

Sometimes you have to find the side length of a triangle that is not the __hypotenuse__, it's a __leg__.

You can find an __equation__ for the unknown side length using __algebra__.

It is the same equation for either __leg__. The 'a' or 'b' only depends on how you labelled the triangle at the beginning.

Matrix organizing the different ways to use the Pythagorean Theorem with Examples

<table>
<thead>
<tr>
<th>Triangle:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unknown Side:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>hypotenuse</strong></td>
</tr>
<tr>
<td><strong>leg</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a^2 + b^2 = c^2$</td>
</tr>
<tr>
<td>$b^2 = c^2 - a^2$</td>
</tr>
<tr>
<td>$a^2 = c^2 - b^2$</td>
</tr>
</tbody>
</table>

When solving a Pythagorean Theorem problem, you can use the __leg__ equation during __step 4__, and all the other steps will the same!
Example Problems

Now, we will do two practice Pythagorean Theorem problems together.

1. **Label**

2. **Known sides**, $a = 9$, $c = 12$

3. **Unknown sides**, $b = ?$

4. **Plug in**, $9^2 + b^2 = 12^2$

5. **Simplify**, $81 + b^2 = 144$

6. **Simplify again**, $b^2 = 63$

7. **Square root**, $\sqrt{b^2} = \sqrt{63}$

8. $b = 7.137253933$

---

1. **Label**

2. **Known sides**, $a = 12$, $b = 5$

3. **Unknown sides**, $c = ?$

4. **Plug in**, $5^2 + 12^2 = c^2$

5. **Simplify**, $25 + 144 = c^2$

6. **Simplify again**, $169 = c^2$

7. **Square root**, $\sqrt{169} = c$

8. $c = 13$
Pythagorean Triangles – Part 4

As we saw in the last example, sometimes triangles don’t require a calculator to be solved if you learn your perfect squares.

This is a special type of right triangle that has side lengths that are all perfect squares. It’s called a Pythagorean Triangle.

Here are some common examples of Pythagorean Triangles you may encounter:

<table>
<thead>
<tr>
<th>3, 4, 5</th>
<th>5, 12, 13</th>
<th>8, 15, 17</th>
<th>7, 24, 25</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

If you know these triangles, then you can skip most of the procedure.

Do steps 1, 2, & 3.

1. **Label**
2. **Known side**: $a = 5$, $b = 12$
3. **Unknown side**: $c = ?$

3a. Is it a Pythagorean Triangle? **YES**  **NO**
If YES, go to step 8 and fill in values from memory. If NO, go to step 4.

The final answer would be:

\[
\begin{align*}
c &= 13 \\
12 &= a \\
5 &= c
\end{align*}
\]

Final Procedure

Using the final form of our procedure, we can solve any type of Pythagorean Theorem problem.
Practice Problems

Find the length of the unknown sides on the triangles shown.

\[
\begin{align*}
10^2 + 6^2 &= a^2 \\
100 + 36 &= a^2 \\
a^2 &= 136 \\
\sqrt{a^2} &= \sqrt{136} \\
a &= 8
\end{align*}
\]

\[
\begin{align*}
7.6^2 + 3.21^2 &= c^2 \\
57.76 + 10.2641 &= c^2 \\
c^2 &= 68.0241 \\
c &= 8.215
\end{align*}
\]
Applications of the Pythagorean Theorem

List three applications of the Pythagorean Theorem:

1. Designing machines
2. Modeling Electricity
3. Designing and analyzing trusses
The Special Equation That Engineers Use Everyday
and
How They Use It

Pre-questions

1. What is a right triangle? Tell me what you know about its sides and angles.
   A right triangle is a triangle that has 1 right angle.

2. What formula would you use to find the side lengths of a right triangle? How do you use it?
   You plug the numbers in.
   I don't know.

3. If you had to use a calculator to find the side lengths of a right triangle, could you? Explain.
   Yes?

4. How much room is needed to unload the truck using the ramp? Do you recognize this triangle?
   Yes it is a right triangle
   5 ft.

5. Have you learned about the Pythagorean Theorem before?
   No!!!
All About the Pythagorean Theorem – Part 1

Pythagorean Theorem is used to find the unknown side lengths of right triangles.

It can be used whenever two side lengths of a right triangle are known.

The formula is: \( a^2 + b^2 = c^2 \).

The side \( a \) is the side length next to the 90° angle of the triangle, or the side length of a leg of the triangle.

The side \( b \) is the side length next to the 90° angle of the triangle, or the side length of the other leg of the triangle.

The side \( c \) is the side length opposite to the 90° angle of the triangle, or the side length of the hypotenuse of the triangle.

Label the sides of the triangle:  

Label the names of each side of the triangle:
An easy way to remember the hypotenuse is:

As a hypotomuse.

How to Use the Pythagorean Theorem – Part 2

Sequence of steps to do when using the Pythagorean Theorem:

1. **Label**
2. **Known Sides**
3. **Unknown Sides**
4. **Plug in**
5. **Simplify**
6. **Add or Subtract**
7. **Square Root**
8. **Simplify Again**

Find the unknown side length of this triangle:

\[ a = 3 \]
\[ b = 4 \]

\[ c = ? \]

1. **Label the legs and** unknown **of the triangle.**

\[ \sqrt{a^2 + b^2} = c \]

2. **Identify the unknown sides.**

Known: \( b = 4, a = 3 \)

3. **Identify the unknown side lengths**

Unknown: \( c \)

4. **Plug the known side lengths into the Pythagorean theorem:**

\[ c^2 = a^2 + b^2 \]
5. Simplify the known **squared**:

\[ a^2 + b^2 = c^2 \rightarrow 3^2 + 4^2 = c^2 \]

\[ 9 + 16 = c^2 \]

6. Add the **square**:

\[ 25 = c^2 \]

7. Take the **square root** of both sides:

\[ \sqrt{25} = \sqrt{c^2} \]

8. Simplify for the final answer of side length:

\[ 5 = c \]

As you can see, it saves time to know your perfect squares really well! Here is a sequence that has the example problem below it for you to follow:

**Sequence of steps to do when using the Pythagorean Theorem with Example**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>b=4</td>
<td>c=?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a=3</td>
<td>Known: a=3, b=4</td>
<td>Unknown: c=?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a² + b² = c²</td>
<td>( a^2 \rightarrow c^2 )</td>
<td>3² + 4² = c²</td>
<td>( a^2 + b^2 = c^2 \rightarrow c^2 )</td>
<td>9 + 16 = c²</td>
<td>25 = c²</td>
<td>( \sqrt{25} = \sqrt{c^2} )</td>
</tr>
</tbody>
</table>

\[ \text{Known: } a=3, b=4 \]

\[ \text{Unknown: } c=? \]

\[ a^2 + b^2 = c^2 \rightarrow c^2 \]

\[ 3^2 + 4^2 = c^2 \]

\[ 9 + 16 = c^2 \]

\[ 25 = c^2 \]

\[ \sqrt{25} = \sqrt{c^2} \]

\[ 5 = c \]
How to Use the Pythagorean Theorem with a Calculator – Part 3

Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a calculator when using the Pythagorean Theorem.

Find the unknown side length of this triangle:

Steps 1-4 are the same:
1. Label sides.
2. Known sides.
   \[ a = 8 \quad b = 5 \]
3. Unknown sides.
4. Plug in numbers.
   \[ a^2 + b^2 = c^2 \]
   \[ 8^2 + 5^2 = c^2 \]
   \[ 64 + 25 = c^2 \]

5c. Use the ^ button on your calculator to find the square:

6c. Use calculator for adding squares on your calculator.

   \[ ((8^2) + (5^2)) = c^2 \]

7c. Use the sqrt button and ANS key to find the square root of both sides.

   \[ \sqrt{ANS} = c \]
   \[ a \approx 4.3 \]
The unknown side length (round to 2 decimal places) = \( a.43 \)

**Solution Summary**

Sometimes you have to find the side length of a triangle that is not the 

[Diagram: Hypotenuse, it's a leg]

You can find an equation for the unknown side length using ____________.

It is the same equation for either ____________. The ‘a’ or ‘b’ only depends on how you labelled the triangle at the beginning.

**Matrix organizing the different ways to use the Pythagorean Theorem with Examples**

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>Hypotenuse</th>
<th>Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td>a[Diagram]</td>
<td>c = ?</td>
<td>a[Diagram]</td>
</tr>
<tr>
<td>b</td>
<td>c = ?</td>
<td></td>
</tr>
<tr>
<td>Unknown Side:</td>
<td>Equation:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( a^2 + b^2 = c^2 )</td>
<td>( a^2 + c^2 = b^2 )</td>
</tr>
</tbody>
</table>

When solving a Pythagorean Theorem problem, you can use the ____________ equation during step ______, and all the other steps will the same!
Example Problems

Now, we will do two practice Pythagorean Theorem problems together.

1. **Label**
   - Known: \( a = 9 \), \( b = ? \), \( c = 12 \)
   - Unknown: \( b = ? \)
   - **Plug in**:
     \[ a^2 + b^2 = c^2 \]
     \[ 9^2 + b^2 = 12^2 \]
     \[ b^2 = 144 - 81 \]
     \[ b^2 = 63 \]
     \[ b = \sqrt{63} \]
     \[ b = 7.938 \]
   - **Answer**: \( b = 7.94 \)

2. **Label**
   - Known: \( a = 5 \), \( b = 12 \)
   - Unknown: \( c = ? \)
   - **Plug in**:
     \[ a^2 + b^2 = c^2 \]
     \[ 5^2 + 12^2 = c^2 \]
     \[ 25 + 144 = c^2 \]
     \[ c^2 = 169 \]
     \[ c = 13 \]
   - **Answer**: \( c = 13 \)
Pythagorean Triangles – Part 4

As we saw in the last example, sometimes triangles don’t require a calculator to be solved if you learn your perfect squares.

This is a special type of right triangle that has side lengths that are all perfect squares. It’s called a Pythagorean Triangle.

Here are some common examples of Pythagorean Triangles you may encounter:

Matrix organizing the different types of Pythagorean Triangles

<table>
<thead>
<tr>
<th>3-4-5</th>
<th>5-12-13</th>
<th>8-15-17</th>
<th>7-24-25</th>
</tr>
</thead>
</table>

If you know these triangles, then you can skip most of the procedure.

Do steps 5, 12 & 13.

1. Label
2. Known sides: \( a = 12 \), \( b = 5 \)
3. Unknown \( c \)

3a. Is it a Pythagorean Triangle? **YES** **NO**
If YES, go to step 8 and fill in values from memory. If NO, go to step 4.

The final answer would be:

![Triangle diagram]

Final Procedure

Final sequence of steps to use to solve any Pythagorean Theorem Problem

1. Label
2. Known Sides
3. Unknown Sides
3a. NO
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

Is it a Pythagorean Triangle?

- Use $a$
- Use $b$
- Use $\sqrt{ANS}$

Using the final form of our procedure, we can solve any type of Pythagorean Theorem problem.
Practice Problems

Find the length of the unknown sides on the triangles shown.

1. Table
2. Known: $c = 10$, $b = 6$
3. Unknown: $a = ?$
4. $a^2 = b^2 - c^2$
   $a^2 = 10^2 - 6^2$
   $a^2 = 100 - 36$
   $a^2 = 64$
   $a = \sqrt{64}$
   $a = 8$

5. $c = 7.6$
6. $a = 3.21$
7. $b = 7.6$
8. $c = ?$
9. $a^2 + b^2 = c^2$
10. $7.6^2 + 3.21^2 = c^2$
11. $55.376 + 10.297 = c^2$
12. $c = \sqrt{65.673}$
   $c = 8.096$
13. $c = 18.004102396$
14. $3.042 + 0.0301 = 0.0644$
15. $53.7680 + 10.3042 = 64.0722$
16. Is it a Pythagorean Triangle?
Applications of the Pythagorean Theorem

List three applications of the Pythagorean Theorem:

1. Mechanical Engineers use the Pythagorean Theorem when they design machines.
2. Electrical engineers use right triangles and Pythagorean Theorem to model electricity.
3. Civil engineering use the Pythagorean Theorem when they design and analyze trusses.
Appendix C

Included here are two complete engineering notebooks for reference. The first notebook is Joel’s and the second notebook is Ellie’s.
<table>
<thead>
<tr>
<th>Pages</th>
<th>Subject/Project</th>
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<td>3</td>
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<td>4-5</td>
<td>ratios</td>
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<td>bridge designs</td>
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<td>14</td>
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<td>pythagorean theorem and their triangles</td>
<td>3/20/17</td>
</tr>
</tbody>
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All About Engineering Notebooks

and

The Engineering Design Process

What are Engineering Notebooks?

Engineering notebooks are used by engineers to document their ideas and designs.

Engineers use engineering notebooks to protect their ownership of their work and inventions.

Engineering notebooks are legal documents.

Rules for Using Engineering Notebooks

9) Number each page as soon as you use it.

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15) Have a witness sign each page.

16) Never throw away old notebooks.
What is the Engineering Design Process?

The Engineering Design Process is a **frequency** of steps engineers use to create their projects.

Sometimes, many of the steps have to be repeated before a design is **finalized**.

This semester, you will use the engineering design process to design and build a **bridge**.

Steps of the Engineering Design Process

To build and design our bridge, we will follow these six engineering design process steps:

6. **Define the problem.**

   The bridge must span **one foot** and hold **fifteen pounds**.

   The bridge must be made of **balsa wood** and **glue**.

   It may only use **fourteen feet** of material.

Sketch __________________ potential bridge designs.

8. Analyze which solution is the best.

Pick the best bridge design, using engineering principles.

9. Plan how to make that solution.

Sketch the __________________ bridge design, to scale.

10. Test the solution.

Test your bridge designs in an online simulation.

11. Improve on the solution.

Repeat Steps ______ through ______ using what you learned from Step 5. Build and test the final bridge.

Define  Brainstorm  Analyze  Plan  Test  Improve
Engineering and Ratios

What are ratios?

A ratio is a \underline{comparison} that is represented by numbers.

In general, it means how many times the first number is \underline{contained} by the second for a given example.

Ratios can be expressed with \underline{words, percentages, slashes, colors, and fractions}.

Some Examples of Ratios

There are many examples of ratios you come across every day:

- Speed limits are a special type of ratio called a \underline{rate}. They are between miles and hours. In fraction form, this ratio would be \underline{35 miles} \underline{per hour} \underline{mph}. Because the denominator is always one, we often write speed limits as \underline{35 miles per hour} or \underline{mph}. The “per hour” signifies the 1 hour in the denominator of the fraction.

- Percentages are \underline{ratios} out of 100. The ratio ninety-nine out of one hundred, or \underline{99/100} can be written with a \underline{percentage signs} and not as a fraction. Like with rates, we often ignore the denominator and write percentages as \underline{99%}. 
- When cooking, all **measurements** are ratios. The measurement ½ cup of flour is an example of a ratio written as a **fractions**. It means there is one out of two halves of a cup of flour in the recipe.

- Parts-to-whole comparisons and part-to-part comparisons are examples of ratios that are represented by **colons**. A tip to spot colon ratios is that they usually use the word **1:0** when the ratio is expressed by words.

For example, there is one oranges to the five strawberries.

Or, the ratio of oranges to strawberries is **1:5**.

There are five strawberries out of six total fruits. Or, the ratio of strawberries to all fruits is **5:6**.

Write these ratios in terms of numbers, using colons and fractions. Make sure to include units.

1. For every five dogs, there are four cats. (Use a colon) 5:4 dogs to cats

2. There 2.54 cm per inch. (Use a fraction) 2.54 cm / 1 in

3. Six of the eggs are brown out of the dozen. (Use a fraction) 6/12 brown eggs to a dozen

4. There are 5280 feet in a mile (Use a colon) 5280:1 feet to miles
Ratios are very important for Engineers

Engineers use ratios for many, many parts of their

projects, calculations, and designs.

Some of these uses for ratios are in chemistry, in physics, triangle relationships, statistics, probabilities, formulas, and models.

One of the most important topics engineers use ratios for is **dimensional analysis**. Dimensional analysis is the use of conversion factors to find units of numbers. Engineers use dimension analysis to convert the **units** of their terms.

A **conversion factor** is a ratio that is equivalent to one in the physical world. It changes the units of whatever it is multiplied by without changing its **physical value**.

Some examples of conversion factors are:

- **24 hours per day** \(\frac{24 \text{ hours}}{1 \text{ day}}\): 24 hours and 1 day represent the same length of time, but the ratio is a conversion factor because it can convert hours to days or days to hours.

- **There are 2.2 pounds in 1 kilogram** \(\frac{2.2 \text{ lb}}{1 \text{ kg}}\): They represent the same mass, but the numbers are different for the different measurements.

Another example is in 2. above. There are 2.54 cm in an inch, but they are the same length.
The last use of ratios we will talk about today is ratios in **scale** drawings. Scale drawings are accurate representations of engineering projects, just drawn in reduced or enlarged sizes.

Engineers use scale drawings as _instructions_ for how their projects can be built or made. They include dimensions, notes, and clear pictures on their scale drawings.

In order to distinguish scale drawings from **sketches**, engineers say that a drawing is **1:0-scale**.

Making notes of what scale that the drawing is done at is VERY important. Engineers write this important ratio using a **colon**, like this example:

```
SCALE= 1:4
```

This means for every one unit on the **drawing**, the actual part is 4 times bigger.

Some common scales engineers use are: 1:1, 1:2, 1:4, 1:5, 1:10

---

**Brainstorming for the Bridge Project**

Now, it is your turn to brainstorm some sketches of your bridge. Remember sketches are not to scale. When you pick your favorite design, we will draw it to scale. The rules of brainstorming are:

1. No idea is a **bad** idea.
2. More ideas are **better**.
BRIDGE TERMINOLOGY

- Stress: a structure composed of members connected together to form a bridged framework.

- Member: a component of a bridge. It is the most basic unit of a bridge.

- Node: a connection between two or more members.

- Load: the weight the bridge must hold.

- Fixed and rolling nodes: corners of the bridge that rest on support.

- Doesn't matter which side which.
The Special Equation That Engineers Use Everyday
and
How They Use It

Pre-questions

1. What is a right triangle? Tell me what you know about its sides and angles.
   a triangle with one rightangle and two acute
   angles

2. What formula would you use to find the side lengths of a right triangle? How do you use it?
   don't know

3. If you had to use a calculator to find the side lengths of a right triangle, could you? Explain.
   don't know

4. How much room is needed to unload the truck using the ramp? Do you recognize this triangle?
   yes

5. Have you learned about the Pythagorean Theorem before?
   No I haven't
All About the Pythagorean Theorem – Part

The Pythagorean theorem is used to find the unknown side lengths of right triangles.

It can be used whenever two side lengths of a right triangle are known.

The formula is: $a^2 + b^2 = c^2$.

The side $a$ is the side length next to the 90° angle of the triangle, or the side length of a leg of the triangle.

The side $b$ is the side length next to the 90° angle of the triangle, or the side length of the other leg of the triangle.

The side $c$ is the side length opposite to the 90° angle of the triangle, or the side length of the hypotenuse of the triangle.

Label the sides of the triangle: $a$, $b$, $c$.

Label the names of each side of the triangle: legs, hypotenuse.
An easy way to remember the hypotenuse is:

It sounds like a hippopotamus which are long animals.

How to Use the Pythagorean Theorem – Part 2

Sequence of steps to do when using the Pythagorean Theorem

1. Label
2. Known Sides
3. Unknown Sides
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify

Find the unknown side length of this triangle:

1. Label the legs and hypotenuse of the triangle.
2. Identify the known sides.
3. Identify the unknown side lengths
4. Plug the known side lengths into the Pythagorean theorem:
5. Simplify the known squares:

\[ 3^2 + 4^2 = c^2 \rightarrow 9 + 16 = c^2 \]

6. Add the squares:

\[ 25 = c^2 \]

7. Take the square root of both sides:

\[ \sqrt{25} = \sqrt{c^2} \]

8. Simplify for the final answer of side length:

\[ 5 = c \]

As you can see, it saves time to know your perfect squares really well! Here is a sequence that has the example problem below it for you to follow:

Sequence of steps to do when using the Pythagorean Theorem with Example

1. Label
2. Known Sides
3. Unknown Sides
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

\[ b=4 \]
\[ a=3 \]

Known: \[ a=3, b=4 \]
Unknown: \[ c=? \]

\[ a^2 + b^2 = c^2 \]
\[ 3^2 + 4^2 = c^2 \]
\[ 9 + 16 = c^2 \]
\[ 25 = c^2 \]
\[ \sqrt{25} = \sqrt{c^2} \]
\[ 5 = c \]
How to Use the Pythagorean Theorem with a Calculator – Part 3

Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a **calculator** when using the Pythagorean Theorem.

Find the unknown side length of this triangle:

\[ a = 8 \]
\[ b = 5 \]
\[ c = ? \]

Steps 1-4 are the same:

1. **Label**
2. **Unknown**
3. **Known**
   \[ a = 5 \]
   \[ b = 8 \]
4. \[ 15 + 64 = c^2 \]

5c. Use the ^ button on your calculator to find the **square root**.

\[ 8^2 + 5^2 = c^2 \rightarrow 25 + 64 = c^2 \]

6c. Use **button** for adding squares on your calculator.

\[ ((8^2) + (5^2)) = c^2 \]

7c. Use the sqrt button and ANS key to find the **square root** of both sides.

\[ \text{sqrt(ANS)} = c \]
Solution Summary

Sometimes you have to find the side length of a triangle that is not the hypotenuse, it’s a leg.

You can find an equation for the unknown side length using algebra.

It is the same equation for either leg. The ‘a’ or ‘b’ only depends on how you labelled the triangle at the beginning.

Matrix organizing the different ways to use the Pythagorean Theorem with Examples

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>[ a^2 + b^2 = c^2 ]</th>
<th>[ a^2 = c^2 - b^2 ]</th>
<th>[ b^2 = c^2 - a^2 ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown Side:</td>
<td>hypotenuse</td>
<td>leg</td>
<td></td>
</tr>
<tr>
<td>Equation:</td>
<td>[ a^2 + b^2 = c^2 ]</td>
<td>[ a^2 = c^2 - b^2 ]</td>
<td>[ b^2 = c^2 - a^2 ]</td>
</tr>
</tbody>
</table>

When solving a Pythagorean Theorem problem, you can use the leg equation during step 4, and all the other steps will the same!
Example Problems

Now, we will do two practice Pythagorean Theorem problems together.

1. Label

2. Known sides
   \( a = 9 \), \( c = 12 \)

3. Unknown
   \( b = ? \)

4. Plug in
   \( a^2 + b^2 = c^2 \)
   \( 9^2 + b^2 = 12^2 \)

5. Simplify
   \( b^2 = 144 - 81 \)

6. \( b^2 = 63 \)

7. \( b = \sqrt{63} \)

8. \( b = 7.9372 \)
   \( b = 7.94 \)

1. Label

2. Known sides
   \( a = 5 \), \( 12 \pm b \)

3. Unknown sides
   \( c = ? \)

4. Plug in
   \( a^2 + b^2 = c^2 \)
   \( 5^2 + (12 \pm b)^2 = c^2 \)

5. Simplify
   \( 25 + 144 = c^2 \)
   \( 169 = c^2 \)

6. \( c = 13 \)
Pythagorean Triangles – Part 3

As we saw in the last example, sometimes triangles don’t require a calculator to be solved if you learn your perfect squares.

This is a special type of right triangle that has side lengths that are all perfect squares. It’s called a Pythagorean triangle.

Here are some common examples of Pythagorean Triangles you may encounter:

Matrix organizing the different types of Pythagorean Triangles

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3-45</td>
<td>5-12-13</td>
<td>8-15-17</td>
<td>24-25</td>
</tr>
<tr>
<td><img src="3-45.png" alt="Triangle" /></td>
<td><img src="5-12-13.png" alt="Triangle" /></td>
<td><img src="8-15-17.png" alt="Triangle" /></td>
<td><img src="24-25.png" alt="Triangle" /></td>
</tr>
</tbody>
</table>

If you know these triangles, then you can skip most of the procedure.

Do steps 1, 2, and 3.

1. Label
2. Known
3. Unknown

3a. Is it a Pythagorean Triangle? **YES** **NO**
If YES, go to step 8 and fill in values from memory. If NO, go to step 4.

The final answer would be: $\sqrt{13}$

Final Procedure

Final sequence of steps to use to solve any Pythagorean Theorem Problem


Is it a Pythagorean Triangle? YES

Using the final form of our procedure, we can solve any type of Pythagorean Theorem problem.
Practice Problems

Find the length of the unknown sides on the triangles shown.

\[ a = 10, \quad 6 = b, \quad a = 7.6, \quad 3.21 = c \]

\[ \alpha = 8 \]

\[ 100 + 36 = 64 \]

\[ 10.3041 + 57.76 = 68.0641 \]

\[ c = 8.25 \]
Applications of the Pythagorean Theorem

List three applications of the Pythagorean Theorem:

1. To design machines
2. To model electricity
3. To design and analyze trusses

\[ 25 + 144 = 1569 \]

\[ \frac{13}{69} = \frac{13}{13} - \frac{99}{69} - \frac{39}{0} \]
<table>
<thead>
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<th>Pages</th>
<th>Subject/Project</th>
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<tr>
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<td>7</td>
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<tr>
<td>8</td>
<td>Engineering and Ratios continued</td>
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<tr>
<td>9</td>
<td>Ratios are very important for engineers</td>
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<td>10</td>
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<td>11</td>
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<td>bride terminology</td>
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<td>The special equation that engineers use everyday and how they use it</td>
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<td>14</td>
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<td>15</td>
<td>Pythagorean theorem part 2</td>
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<td>16</td>
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<td>Pythagorean theorem part 3</td>
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<tr>
<td>18</td>
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<tr>
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<td>-------</td>
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<td>23</td>
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<td>2/30</td>
</tr>
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What is the Engineering Design Process?

The Engineering Design Process is a sequence of steps engineers use to create their projects.

Sometimes, many of the steps have to be repeated before a design is finalized.

This semester, you will use the engineering design process to design and build a bridge.

Steps of the Engineering Design Process

To build and design our bridge, we will follow these six engineering design process steps:

6. Define the problem.

The bridge must span one foot and hold fifteen pounds.

The bridge must be made of balsa wood and glue.

It may only use fourteen feet of material.

   **Engineering and Ratios**

   Sketch three potential bridge designs.

8. Analyze which solution is the best.

   Pick the best bridge design, using engineering principles.

9. Plan how to make that solution.

   Sketch the best bridge design, to scale.

10. Test the solution.

    Test your bridge designs in an online simulation.

11. Improve on the solution.

    Repeat Steps 1 through 4 using what you learned from Step 5. Build and test the final bridge.
Engineering and Ratios

What are ratios?

A ratio is a comparison that is represented by numbers.

In general, it means how many times the first number is contained by the second for a given example.

Ratios can be expressed with words, percentages, slashes, colons, and fractions.

Some Examples of Ratios

There are many examples of ratios you come across every day:

- Speed limits are a special type of ratio called a rate. They are between miles and hours. In fraction form, this ratio would be \[
\frac{35 \text{ miles}}{1 \text{ hour}}.
\]
  Because the denominator is always one, we often write speed limits as 35 miles per hour or \( \text{mph} \). The "per hour" signifies the 1 hour in the denominator of the fraction.

- Percentages are ratios out of 100. The ratio ninety-nine out of one hundred, or \( \frac{99}{100} \) can be written with a percentage sign and not as a fraction. Like with rates, we often ignore the denominator and write percentages as 99%. 
• When cooking, all measurements are ratios. The measurement ½ cup of flour is an example of a ratio written as a fraction. It means there is one out of two halves of a cup of flour in the recipe.

• Parts-to-whole comparisons and part-to-part comparisons are examples of ratios that are represented by colons. A tip to spot colon ratios is that they usually use the word "to" when the ratio is expressed by words.

For example, there is one orange to five strawberries.

Or, the ratio of oranges to strawberries is 1 to 5.

There are five strawberries out of six total fruits. Or, the ratio of strawberries to all fruits is 5 to 6.

Write these ratios in terms of numbers, using colons and fractions. Make sure to include units.

1. For every five dogs, there are four cats. (Use a colon) 5dogs : 4cats

2. There 2.54 cm per inch. (Use a fraction) \( \frac{2.54 \text{ cm}}{\text{inch}} \)

3. Six of the eggs are brown out of the dozen. (Use a fraction) \( \frac{6 \text{ brown eggs}}{12 \text{ eggs}} \)

4. There are 5280 feet in a mile (Use a colon) 5280ft : 1mile
Ratios are very important for Engineers

Engineers use ratios for many, many parts of their

projects, calculations, and designs.

Some of these uses for ratios are in chemistry, in physics, triangle relationships, statistics, probabilities, formulas, and models.

One of the most important topics engineers use ratios for is dimensional analysis. Dimensional analysis is the use of conversion factors to find units of numbers. Engineers use dimension analysis to convert the units of their terms.

A conversion factor is a ratio that is equivalent to one in the physical world. It changes the units of whatever it is multiplied by without changing its physical value.

Some examples of conversion factors are:

24 hours per day

24 hours per day: 24 hours and 1 day represent the same length of time, but the ratio is a conversion factor because it can convert hours to days or days to hours.

There are 2.2 pounds in 1 kilogram 22 lbs/1 kg: They represent the same mass, but the numbers are different for the different measurements.

Another example is in 2. above. There are 2.54 cm in an inch, but they are the same length.
The last use of ratios we will talk about today is ratios in **scale drawings**. Scale drawings are accurate representations of engineering projects, just drawn in reduced or enlarged sizes.

Engineers use scale drawings as **instruction** for how their projects can be built or made. They include dimensions, notes, and clear pictures on their scale drawings.

In order to distinguish scale drawings from **sketches**, engineers say that a drawing is **"to scale"**.

Making notes of what scale that the drawing is done at is **VERY** important. Engineers write this important ratio using a **colon**, like this example:

```
SCALE = 1:4
```

This means for every one unit on the **drawing**, the actual part is 4 times bigger.

Some common scales engineers use are: 1:1, 1:2, 1:4, 1:5, 1:10

---

**Brainstorming for the Bridge Project**

Now, it is your turn to brainstorm some sketches of your bridge. Remember sketches are not to scale.

When you pick your favorite design, we will draw it to scale. The rules of brainstorming are:

1. No idea is a **bad idea**
2. More ideas are **better**
Truss: A structure composed of MEMBERS connected together to form a rigid framework

Member: a component of a bridge. It is the most basic unit of a bridge

Node: Connection between two or more members

Load: The weight the bridge must hold

Fixed and rolling Nodes: corners of the bridge that rest on support

Continued on page
Pre-questions

1. What is a right triangle? Tell me what you know about its sides and angles.
   A right triangle has one right angle.

2. What formula would you use to find the side lengths of a right triangle? How do you use it?

3. If you had to use a calculator to find the side lengths of a right triangle, could you? Explain.

4. How much room is needed to unload the truck using the ramp? Do you recognize this triangle?

5. Have you learned about the Pythagorean Theorem before?
   No
All About the Pythagorean Theorem – Part

The Pythagorean Theorem is used to find the unknown side lengths of right triangles.

It can be used whenever two side lengths of a right triangle are known.

The formula is: \( a^2 + b^2 = c^2 \).

The side \( a \) is the side length next to the 90° angle of the triangle, or the side length of a leg of the triangle.

The side \( b \) is the side length next to the 90° angle of the triangle, or the side length of the other leg of the triangle.

The side \( c \) is the side length opposite to the 90° angle of the triangle, or the side length of the hypotenuse of the triangle.

Label the sides of the triangle: \( a \), \( b \), \( c \)

Label the names of each side of the triangle: hypotenuse, leg, leg.
An easy way to remember the hypotenuse is:

How to Use the Pythagorean Theorem – Part 2

Sequence of steps to do when using the Pythagorean Theorem

1. Label
2. Known Sides
3. Unknown Sides
4. Plug in
5. Simplify
6. Add or Subtract
7. Square Root
8. Simplify Again

Find the unknown side length of this triangle:

\[ a^2 + b^2 = c^2 \]

1. Label the legs and sides of the triangle.

2. Identify the known sides.

Known:

\[ a = 3, \quad b = 4 \]

3. Identify the unknown side lengths

Unknown:

\[ c = ? \]

4. Plug the side lengths into the Pythagorean theorem:
5. Simplify the known \(3^2 + 4^2 = c^2\):

\[3^2 + 4^2 = c^2\]

6. Add the \(9 + 16 = c^2\):

\[25 = c^2\]

7. Take the \(\sqrt{25} = \sqrt{c^2}\) of both sides:

\[\sqrt{25} = \sqrt{c^2}\]

8. Simplify for the final answer of side length:

\[5 = c\]

As you can see, it saves time to know your perfect squares really well! Here is a sequence that has the example problem below it for you to follow:

| Sequence of steps to do when using the Pythagorean Theorem with Example |
|---|---|---|---|---|---|---|---|
| \(b=4\) | \(a=3, b=4\) | \(c=?\) | \(a^2 + b^2 = c^2\) | \(3^2 + 4^2 = c^2\) | \(a^2 + b^2 = c^2\) | \(25 = c^2\) | \(\sqrt{25} = \sqrt{c^2}\) | \(5 = c\) |
How to Use the Pythagorean Theorem with a Calculator – Part 3

Most of the time, the triangles that you will be analyzing will not be so easy to do in your head.

This is how to use a calculator when using the Pythagorean Theorem.

Find the unknown side length of this triangle:

Steps 1-4 are the same:

1. Label
2. Know
   \[ a = 5 \]
   \[ b = 8 \]

3. Unknown
   \[ c = ? \]

4. \[ a^2 + b^2 = c^2 \]

5c. Use the ^ button on your calculator to find the square.

\[ 8^2 + 5^2 = c^2 \]

6c. Use calculator for adding squares on your calculator.

\[ ((8^2) + (5^2)) = c^2 \]

7c. Use the sqrt button and ANS key to find the square root of both sides.

\[ \sqrt{\text{ANS}} = c \]
Solution Summary

Sometimes you have to find the side length of a triangle that is not the hypotenuse, it's a leg.

You can find an equation for the unknown side length using algebra.

It is the same equation for either leg. The ‘a’ or ‘b’ only depends on how you labelled the triangle at the beginning.

<table>
<thead>
<tr>
<th>Triangle:</th>
<th>a</th>
<th>c = ?</th>
<th>a</th>
<th>c</th>
<th>a = ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td></td>
<td></td>
<td>b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unknown Side:</th>
<th>Hypotenuse</th>
<th>Leg</th>
</tr>
</thead>
</table>

| Equation: | \( a^2 + b^2 = c^2 \) | \( b^2 = c^2 - a^2 \) |

When solving a Pythagorean Theorem problem, you can use the leg equation during step 4, and all the other steps will be the same!
Example Problems

Now, we will do two practice Pythagorean Theorem problems together.

1. \[ a = 9 \]
   \[ c = 12 \]
   \[ b = ? \]

1. \[ a = 5 \]
   \[ b = 12 \]
   \[ c = ? \]

2. Known
   \[ a = 9 \]
   \[ b = 12 \]

3. unknown
   \[ b = ? \]

4. plug in
   \[ b^2 = c^2 - a^2 \]
   \[ a^2 + b^2 = c^2 \]
   \[ 9^2 + 12^2 = c^2 \]

5. \[ b^2 = 144 - 81 \]

6. \[ b^2 = 63 \]

7. \[ \sqrt{b^2} = \sqrt{63} \]

8. \[ b = 7.9372 \]

   \[ b = 7.94 \]

4. \[ a^2 + b^2 = c \]
   \[ 5^2 + 12^2 = c^2 \]

5. \[ 25 + 144 = c^2 \]

6. \[ c^2 = 169 \]

7. \[ \sqrt{c^2} = \sqrt{169} \]

8. \[ c = 13 \]
Pythagorean Triangles – Part 4

As we saw in the last example, sometimes triangles don’t require a calculator to be solved if you learn your perfect squares.

This is a special type of right triangles that has side lengths that are all perfect squares. It’s called a Pythagorean Triangle.

Here are some common examples of Pythagorean Triangles you may encounter:

| Matrix organizing the different types of Pythagorean Triangles |
|-------------------|-----------------|-----------------|-----------------|
| 3-4-5             | 5-12-13         | 8-15-17         | 7-24-25         |
| ![Triangle 3-4-5](triangle_3-4-5.png) | ![Triangle 5-12-13](triangle_5-12-13.png) | ![Triangle 8-15-17](triangle_8-15-17.png) | ![Triangle 7-24-25](triangle_7-24-25.png) |

If you know these triangles, then you can skip most of the procedure.

Do steps 1, 2 & 3.

1. Label
2. Known \( a = 12 \), \( b = 5 \)
3. Unknown \( c = ? \)

3a. Is it a Pythagorean Triangle? [YES] [NO]
If YES, go to step _____ and fill in values from memory. If NO, go to step 4.

The final answer would be:

![Diagram of a right triangle with sides labeled 5, 12, and c]  

\[ c = 13 \]

Final Procedure

Final sequence of steps to use to solve any Pythagorean Theorem Problem

1. Label  
2. Known Sides  
3. Unknown Sides  
3a. NO Plug in  
4. Simplify  
5. Add or Subtract  
6. Square Root  
7. Simplify Again

Is it a Pythagorean Triangle?  

- Use \( \)  
- Use \( \sqrt{\text{ANS}} \)

Using the final form of our procedure, we can solve any type of Pythagorean Theorem problem.
Practice Problems

Find the length of the unknown sides on the triangles shown.

1. Label
   \[ A = 8 \]

2. Known
   \[ c = 10 \]
   \[ b = 6 \]


\[ a^2 + b^2 = c^2 \]
\[ 57.76 + 10.3641 = c^2 \]
\[ c^2 = 68.1241 \]
\[ c = 8.25 \]
Applications of the Pythagorean Theorem

List three applications of the Pythagorean Theorem:

1. Mechanical engineers - use Pythagorean theorem when they design machines
2. Electrical engineers - use right triangles and Pythagorean theorem to model electricity
3. Civil engineers - use the Pythagorean theorem when they design and analyze trusses
Bridge Sketch for Test

New Bridge Design Based on Analysis

SCALE: 1:2
Bridge Test 1 Analysis

What part of your bridge failed? The part of my bridge that failed was the center and bottom.

List three ways you could reinforce your bridge to prevent your bridge failing in that way in the future:

1. smaller & more triangle
2. 
3. 

Pick at least one of these solutions and sketch your new bridge design in your engineering notebook.
Appendix D

This appendix contains scans of my weekly reflections over the duration of the semester.
Resolution of Engineering Club Meeting #1

I used a story to tell the importance of engineering notebooks (Alexander Graham Bell) and it really hit home; the kids were really amazed by the importance of engineering notebooks.

I think the paper bridge activity went well. I liked the group that remained. At that point we had a lot of fun.

I think that they got the memo of the importance of sketching notes; I think I will really try to nit it home next time (after lesson maybe) again for reinforcing (nervous at beginning) but I gave them a pretty accurate idea of what to expect every week so they came back next week with correct perception of club.

Concerned about BBall kids; need theme to know to be respectful listeners from the beginning.

Go through and learn all names again.

Hopefully we can sort through using a projector every week they can get it for me to worry about it.
I think combo of PPT + notes is good; especially if I add extra info verbally. Wane them off mental notes slowly.

Powerpoints don't necessarily follow EAN format, but it's not really a presentation, it's a lesson. VERY IMPORTANT to not put too much info on their once so they are forced to listen to every slide.

Try to build relationships w/them. Talk about different disciplines in depth to give them more solid idea of what they're doing. More on the math idea explanations: best way to state not lousy math etc...
Overall, I think it went pretty well. It was a more boring week than others, because we talked about ratios all the time. I do think that they did learn the information, however (or they already knew it). I think the club is just about the right level for 7th graders, the 8th graders are finding it a little easy. So maybe I will target them in the future. I will say they were pretty chatty, it could be a problem.

I think that it was helpful to go over the dimensional analysis stuff; it was more challenging than the other ratios, so it could be good to talk about it more.
This week was pretty crazy. The website to test the bridges didn’t work on the chromebooks, so I had to improvise. It is good that I could recover decently, even though I didn’t have time to plan adequately. I think that in general they are still too chatty, so the hand raising thing helped a lot. I will continue to do that in the future. It is hard to do because they all work at different paces, but we all need to be the same to move on (i.e. Ricardo not done early), have them be on topic (and quiet, I think). I did better handling them, with all the interrupting topics all week. The time, than last week. Not listening to him when he’s not respectful works.
Reflection of Engineering Club Meeting #4

I think it didn't go so hot from a tech standpoint. The bridge program didn't work too well with a lot of their bridge designs. I wish I could have picked up on it to alert sooner... but I think that there's nothing we could have done for their bridge designs w/o testing them.

I think that it was good that a lot of the kids were well-behaved despite the large amount of lead time. I feel bad for Joel; he was trying to be a good sport. So, I'm going to be sure to do a good job this bridge eval. I don't know how I'm going to do the bridge designs. I'll have to do a hard stories review or maybe input into program myself? I don't know. However, I know for next time to not test the bridges like this.

For next time, we will do the Pythagorean theorem get (hopefully) analysis time for the bridge designs to start drafting. I think we will have to mix the final lesson week just given them time to work on their bridge.

I will have to talk to dad about how to do the bridge drafting in more detail for the following weeks.
Reflection of Engineering Club Meeting #5

This week we covered the Pythagorean theorem Presentation. Overall I think it went pretty well. It was a little slow for the eighth graders, a good review for the seventh graders (they didn't really remember it then well). The sixth graders had never learned it before. I didn't quite have enough time to get through everything, I had to skip one example problem, some kids didn't finish the second example problem. That might have been due to them being too chatty.

In terms of what they learned, I was very impressed by Joel (the sixth grader there) because he had never seen it before but he picked it up very quickly. Needed to understand what was going on, did the practice problems himself. As for the seventh graders, some where still confused, some knew it pretty well. Some didn't follow some knew it pretty well. Some 7th graders think it helped them. Some 7th graders think it helped them. Some didn't follow the steps (mostly the girls) and they did pretty well I think. (There were some rounding errors on one).
I was surprised that an eighth grader, Aiden, messed up when working on an example problem. It was just a calculation error, he definitely understood it, but he also didn't follow the sequence I gave. I think that the majority of the students understood the example of the matrix was a scalar multiple of the vector — I didn't explain Pythagorean theorem. I didn't explain Pythagorean theorem at much but when I went around 7 on people (including you, Taur Paru) noticed.

Finally, I asked the following week about Pythagorean theorem and no one could remember the name. I could remember the name: I should create a memory tool to help students remember that for next time.
Reflection of Engineering Club Meeting #6

I tried to have the students get more work done by keeping them quiet and having quiet time. Did get work as well as I was hoping, but it was still nice. I think I might do it again next time. They might be motivated more by the fact that they have a tight deadline - only 4 more weeks!! I think that they do understand the Pythagorean Theorem well - I was particularly impressed w/ Joel who seemingly understands it having never learned it before! It is somewhat frustrating that some students don't follow the steps, however some still do, so I don't know. I think that Ricardo goofing off is pretty annoying and distracting. Maybe have to figure out plan to deal w/ that. Additionally, had to send Will to the computer bc he was causing problems. I guess I should send him there again to "earn" it back (dad's idea). Finally, I think it worked pretty good to let everyone work at their own pace and for me to check on them.
I'm kinda worried about late: I think she was a little frustrated by not being able to learn the Pythagorean theorem stuff. I think that will just allow her to not have to worry about it since she was gone. I also have to figure out a way to have them check to make sure they have enough building material using the Pythagorean theorem. I think that if I should have them do that one-on-one. I wonder if I should demo how to use the saws/etc. right away this week if most people won't be ready for it. I think I should, but make it quick.

Yeah.
Reflection of Engineering Club Meeting # 7

This week went fairly well— it was good that everyone got to start working at their own pace. It was helpful that I could have some kids help out others. I think for next week, I'll have to ask the kids that were gone to gather around for ailee though. I do think that most kids are a little behind the curve on building, but hopefully once they get going we can get some momentum up. The longer class periods. I think that as the faster kids finish their bridges, they could maybe help out the kids who are further behind. I also have to tell them that they only have two real work days left. I could maybe hold a come-in-after-school work day for them on a Tuesday or Thursday? Sometime. I'll have to really emphasize the need to work very hard to get things done. Next week. I'm proud of Ethan & Jimmie, who are much further ahead of some kids and are doing an awesome job. I'll likely
use theirs as examples for everyone again.
Next time, I need to make sure I learn how to do the pins well - teepee style - because Mom Tee didn't get it to stuck her pins through her wood. As well, there's hoping.
I think that a majority of my students made some good progress on their bridges—at least on building either the top front of them. I’m concerned that they will not have enough material to build their bridges. I think that even than B, whose bridge isn’t too complicated, won’t have enough. I think I might give them two more feet each to get them halfway done or so up their bridge. Additionally, I’m concerned about the kids being able to finish their bridges on time. I offered them a way to come after school next Tuesday to get some extra work done, however, not everyone will be able to make it and it concerns me. I want everyone to get an opportunity to work on this at home, however, I don’t know how to deal with the saws (or loaning them). I’ll have to ask Dad.
Reflection of Engineering Club Meeting #9

This week was only an extra work week and not an official meeting. I didn't remind any of the students to attend because it would be difficult to contact all of them and ask them if they all have any random contact info for them. Next time, hopefully I can get a contact list from their database. Because of this, only two kids came. Many others stopped by, but they had archery club and couldn't attend. It was pretty fun working with the girls that came. We just chatted and got some progress made on their bridges. Next semester I should allow more time for students to work on their bridges. Next week for the trip, I am going to remember to bring the notebooks to help.

Also, I need to make sure that I can keep the kids well behaved and that we can follow the schedule between the two organizations be on time.
This week was the field trip to UNL. It went really well, I believe. We started by getting everyone together to ride in the vans to UNL. That was fine, but I screw up & I told Alixia to go when she and Ellie were wanting to go together. It should have been all girls & all guys in each van. Oh well; Ellie was a good sport & we switched on the way home. Then, it was fun to tour the buildings. Trekking of went great and they met us right at the door.

Unfortunately, Liz (tour guide) was more than a little boastful, which didn't keep their attention. Luckily, they still asked good questions and were polite. They were interested in the CHEM1 car and the boat (current) thing. Then, they wanted to tour the aerospace lab so I called Nate quick — which turned out awesome — Nate did a good job & they enjoyed & remembered what he talked about. I'm glad I did that too because it ate up time as well which worked it.
our favor. (as you will see next). Earthquake presentation went really well except for Shelly—however, I can tell they were a little rusty. The kids still enjoyed the presentation, paid attention & were interested, and asked questions (I think), hopefully learned something.

At the end, we were going to have a Q&A on engineering but, no one asked many questions. So, it was good they came late & that there wasn’t much dead time. I think I wasn’t much help in that regard so it wasn’t helpful fill the time decently so it wasn’t awkward for the ambassadors etc.

Then we came home. The vans shared up just as we got to the door. It worked out well, coming home was fine. It worked out well, coming home was fine. Also, Aidan had to leave early, but that worked pretty well too—ok now—but Aidan handled it.

Also, I think having heard them all talk about it bunches in the past meetings they really did enjoy it & did learn stuff. I’m glad we did it. We may want to go again earlier in the semester next time.
Reflection of Engineering Club Meeting #77

The next engineering club meeting (this next) is another work week: this we met on Thursday & we tried to have people get further on their bridges. A few girls (Alivia, Alex, Anna & Ellies) showed up & I think they made good progress. We had fun talking too. After it was done, I think they probably got caught up & thank Summer. It's good to offer extra time to coursework if they need it. I think...
this week was purely a work week. I think the 1/2 dogging time contributes to that because they can really sit and work for a long while. I gave them good instructions about building their bridges and stuff that they had to cut everything and glue later. A lot of people are really close to being done now. I feel bad because Alex's bridge is less than perfect, partially because I rushed her a little. I definitely think the bridge building itself is a good fit for 8th graders. The other grades went super detailed and sitting down yet. I think that I definitely could do a better job explaining why they need to make 2 sides of their bridge than the sides end up going together. Many struggle to understand that I think most people will be ready for that next week. Hopefully we can do that quick before we bridge test. Also, I'm worried that the glue won't be dry — hopefully everything works out!
Reflection of Final Engineering Club Meeting

→ Everyone was pretty excited for the last meeting, snacks/etc. helped. I got there early to set up the bridge tester & equipment which worked great to do in 2 trips from dad's class. In terms of testing the bridges, we did spend too long explaining & defining how to test the bridges for everyone to go in time. I think next time I would explain how to use the bridge tester in a previous week (how to test bridges) to save time. Next, I would help them prep the calculation for efficiency better on the sheet because they struggled w/ the differing units.

I was impressed w/ the bridges—some held over 40 lbs! We also had some good efficiencies. I think the prizes are good, but I want to come up w/ cool ones for this semester too.

I stacked my stuff in the closet for the fall, hopefully it's still there. Overall, I think the kids had a good →
Time based on their surveys + the fact that so many wanted to come back for this semester. I don't know if we will actually let them do that but it's very sweet. I forgot to mention another problem that occurs—the 5 gallon bucket broke! With all the weight put in it, the bottom fell out. So we had another delay in testing while it got fixed. This time, hopefully we can rig the bucket better so it doesn't fail.

I also want to include adding safety glasses for the person tilling the bucket + wetting the gravel.