Mathematics Assessment Project

Formative Assessment Lesson Materials

Solving Quadratic Equations: Cutting Corners

MARS Shell Center
University of Nottingham & UC Berkeley
Alpha Version

Please Note:

These materials are still at the “alpha” stage and are not expected to be perfect. The revision process concentrated on addressing any major issues that came to light during the first round of school trials of these early attempts to introduce this style of lesson to US classrooms. In many cases, there have been very substantial changes from the first drafts and new, untried, material has been added.

We suggest that you check with the Nottingham team before releasing any of this material outside of the core project team.

If you encounter errors or other issues in this version, please send details to the MAP team c/o map.feedback@mathshell.org.
Solving Quadratic Equations: Cutting Corners

Mathematical goals
This lesson unit is intended to help you assess how well students are able to solve quadratics in one variable. In particular, the lesson will help you identify and help students who have the following difficulties:

- Solving quadratic equations by taking square roots, completing the square, using the quadratic formula, and factoring.
- Interpreting results in the context of a real life situation.

Common Core State Standards
This lesson relates to the following Standards for Mathematical Practice in the Common Core State Standards for Mathematics:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.

This lesson also relates to the following Standards for Mathematical Content in the CCSS:

A-REI  Solve quadratic equations and inequalities in one variable.
G-SRT  Define trigonometric ratios and solve problems involving right triangles.
G-MG   Apply geometric concepts in modeling situations.

Introduction
This lesson is structured in the following way:

- Before the lesson students attempt the problem individually. You then review their work and write questions for students to answer to help them improve their solutions.
- At the start of the lesson, students work alone, answering your questions.
- Students are then grouped, and work collaboratively on the same task.
- In the same small groups, students are given some sample solutions to comment on and evaluate.
- In a whole-class discussion, students explain and compare the different solution strategies they have seen and used.
- Finally, students review what they have learned.

Materials required

- Each student will need a copy of the task, Cutting Corners, and the questionnaire, How Did You Work?
- Each small group of students will need an enlarged copy of the task, Cutting Corners, and a copy of each of the Sample Responses to Discuss.

There is also a projector resource to help with whole-class discussions.

Time needed
Approximately 15 minutes before the lesson, a one-hour lesson, and fifteen minutes in a follow-up lesson (or for homework). Exact timings will depend on the needs of the class.
Before the lesson

Assessment task: Cutting Corners (15 minutes)

Give this task, in class or for homework, a few days before the formative assessment lesson. This will give you an opportunity to assess the work, to find out the kinds of difficulties students have with it, and to see the mathematics they choose to use. You should then be able to target your help more effectively in the follow-up lesson.

Give each student a copy of the task, Cutting Corners.

Introduce the task, and help the class to understand the problem and its context.

Think about the wheels on a bus. What can you tell me about them? [Only the front ones turn. The rear wheels are fixed. The axle distance between each pair of wheels is fixed.]

The fixed distance between the hubs of the front and back wheel is called the wheelbase.

When the front wheels turn a corner, they describe a circle. What happens to the back wheel at the same time? [The back wheel cuts the corner because it doesn’t rotate].

You may like to show a short movie to help your introduction, such as: http://tinyurl.com/BusTurning.

Students may find the dynamic situation hard to visualize. A physical demonstration using, for example, a bicycle could be helpful. If the wheels don’t slip sideways, they will always point tangentially to the circle they describe. The back wheel changes direction as soon as the front wheel does, a wheelbase length behind the front wheel. The back wheel is pulled forwards and inwards, turning a smaller circle than the front wheel.

The diagram below shows the geometry of this situation.

The diagram on your sheet uses math to represent the bus scenario.

Read through the task. Read the diagram carefully. Try to answer the questions as carefully as you can.

Show all your working so that I can understand your reasoning.

It is important that students are allowed to answer the questions without assistance, as far as possible.

Students should not worry too much if they cannot understand or do everything, because in the next lesson they will engage in a similar task, which should help them. Explain to students that by the end of the next lesson, they should expect to answer questions such as these confidently. This is their goal.

Students who sit together often produce similar answers, and then when they come to compare their work they have little to discuss. For this reason, we suggest that when students do the task individually, you ask them to move to different seats. Then at the beginning of the formative assessment lesson, allow them to return to their usual seats. Experience has shown that this produces more profitable discussions.

Assessing students’ responses

Collect students’ responses to the task. Make some notes on what their work reveals about their current levels of understanding and their different problem solving approaches.

We suggest that you do not score students’ work. The research shows that this will be counterproductive, as it will encourage students to compare their scores, and will distract their attention from what they can do to
improve their mathematics. Instead, help students to make further progress by summarizing their difficulties as a series of questions. Some suggestions for these are given on the next page. These have been drawn from common difficulties observed in trials of this unit.

We suggest that you write a selection of these questions on each student’s work. If you do not have time, select a few questions that will be of help to the majority of students. These can be written on the board at the beginning of the lesson.

<table>
<thead>
<tr>
<th>Common issues</th>
<th>Suggested questions and prompts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student has difficulty getting started</strong></td>
<td>• What do you know? What do you need to find out?</td>
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<tr>
<td></td>
<td>• Try labeling the diagram.</td>
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<tr>
<td></td>
<td>• Is there a shape there that you can see?</td>
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<td></td>
<td>• How do you know this is a right triangle?</td>
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<tr>
<td><strong>Student does not identify relevant mathematics</strong></td>
<td>• What mathematics have you studied that connects with the situation?</td>
</tr>
<tr>
<td>For example: The student does not refer to the</td>
<td>• What shape can you see in the diagram?</td>
</tr>
<tr>
<td>Pythagorean Theorem (Q1).</td>
<td>• What kind of equation are you given?</td>
</tr>
<tr>
<td>**Student labels the diagram with incorrect</td>
<td>• What does ( r ) represent? What does ( x ) represent?</td>
</tr>
<tr>
<td>lengths (Q1)</td>
<td>• What is the connection between ( r ) and ( x )?</td>
</tr>
<tr>
<td>For example: In labeling the radius of the circle</td>
<td>• Check your answer.</td>
</tr>
<tr>
<td>produced by the back wheel, the student adds ( x</td>
<td>• Suppose someone in another class is reading your work to figure out the solution. Would she be able to understand your work?</td>
</tr>
<tr>
<td>) rather than subtracting ( x ) from ( r ),</td>
<td></td>
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<tr>
<td>producing the equation ( r^2 = (r + x)^2 + w^2</td>
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<td></td>
<td>• Read the question again. How do the numbers you have found help you to answer that question?</td>
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<tr>
<td><strong>Student makes algebraic errors</strong></td>
<td>• Can you think of a more efficient method?</td>
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<tr>
<td>For example: The student mistakenly changes the</td>
<td>• What kind of equation are you working with? Can you think of other ways of solving that equation?</td>
</tr>
<tr>
<td>sign of a term when clearing brackets: ( w^2+(x-r)^2 ) ( =r^2 ) ( \Rightarrow ) ( w^2+x^2+2xr+r^2 ) ( =r^2 ).</td>
<td></td>
</tr>
<tr>
<td><strong>Student explanation is unclear or incomplete</strong></td>
<td>• Check your solution to the quadratic. Could ( x ) be any other value?</td>
</tr>
<tr>
<td>For example: The student has not labeled the</td>
<td>• What lengths do you already know?</td>
</tr>
<tr>
<td>diagram, or the student has not explained the</td>
<td>• The values of ( w ) and ( r ) have not changed, but what will the value of ( x ) be now?</td>
</tr>
<tr>
<td>math used.</td>
<td>• Can you use those lengths to figure out the length of the radius of the front wheel’s circle?</td>
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<tr>
<td><strong>Student does not interpret findings in context</strong></td>
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<tr>
<td>For example: The student does not explain which</td>
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<tr>
<td>solution to the quadratic is relevant given the</td>
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<tr>
<td>context (Q2).</td>
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<tr>
<td><strong>Student uses an inefficient method</strong></td>
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<tr>
<td>For example: The student tries to use guess and</td>
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<tr>
<td>check to solve a quadratic (Q2).</td>
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<tr>
<td>**Student only takes account of the positive</td>
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<tr>
<td>square root of a number</td>
<td></td>
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<tr>
<td><strong>Student does not answer Q2b</strong></td>
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</table>
Suggested lesson outline

Individual work (10 minutes)

Give students back their scripts. If you did not add questions to individual pieces of work, write your list of questions on the board. Students are to select questions appropriate to their own work, and spend a few minutes answering them.

Recall what we were looking at in a previous lesson. What was the task about?

Today we are going to work together trying to improve on these initial attempts.

I have read your solutions and I have some questions about your work.

I would like you to work on your own to answer my questions for about ten minutes.

Collaborative activity (15 minutes)

Organize the class into small groups of three students.

Give each group an enlarged copy of the task Cutting Corners.

Deciding on a Strategy

Ask students to share their ideas about the task, and plan a joint solution.

I want you to share your work with your group.

Take it in turns to explain how you did the task and how you now think it could be improved.

Listen carefully to any explanation. Ask questions if you don't understand or agree with the method.

You may want to use some of the questions I have written on the board/on your scripts.

I want you to plan a joint method that is better than your separate solutions.

Everyone in the group must agree on the method.

To remind students while they work, these instructions are shown on the slide, Planning a Joint Solution.

Implementing the Strategy

Students are now to write their joint solution on the handout.

While students work in small groups, you have two tasks: to note different student approaches to the task, and to support student problem solving.

Note different approaches to the task. Notice how students talk about the context, and whether and how they link this to the diagram. Notice the math students choose to use on the problem. Do they notice that the lengths given form a right triangle? Do they then realize that the Pythagorean theorem is relevant? What method are students using to solve the quadratic equations?

Attend also to students’ mathematical decisions. Do they talk about their own progress? Do they notice if they have chosen a strategy that does not seem to be productive? If so, what do they do?

Note if and how students use algebra. What errors do students make when manipulating equations? Are there any errors in their numerical calculations? Do they find both solutions when solving a quadratic?

Notice whether students reinterpret their numerical solutions in terms of the context. Do they notice when one solution does not make sense, given the question?

You can use the information you find out about students to focus the whole-class discussion towards the end of the lesson.

Support student problem solving. Try not to make suggestions that move students towards a particular approach to this task. Instead, ask questions that help students clarify their own thinking and promote further progress. Encourage students to check their work and detect errors. Encourage them to explain their answers to
each other, and question each other’s explanations. You may find it helpful to use some of the questions in the
Common issues table.

If the whole class is struggling on the same issue, you could write a couple of relevant questions on the board, or
hold a brief whole-class discussion. You could also give any students really struggling to get started one of the
Sample Responses to Discuss.

Review of strategy As students finish working on the problem; give them the questionnaire How Did You
Work? Ask students to answer Questions 1 and 2 of the questionnaire.

Collaborative analysis of Sample Responses to Discuss (20 minutes)
This task gives students an opportunity to evaluate a variety of possible approaches to the task, without
providing a complete solution strategy.

After students have had enough time to solve the problem, give each group copies of all Sample Responses to
Discuss. If there is not time for all groups to look at all solutions, be selective about what you give out. For
example, groups that have successfully completed the task using one method will benefit from looking at
different approaches. Groups that have struggled with a particular approach may benefit from seeing a student
version of the same strategy.

Here are some solutions to the Cutting Corners task produced by students in another class.
I would like you to choose one of the solutions and read it together, carefully.
Try to understand the method the student has chosen, and any errors he or she has made.
Answer the questions on the sheet, to correct the work and comment on the accuracy of the work.
Then choose the next response to work on. Work your way through the responses one by one.

The questions on each Sample Response should encourage students to do more than check to see if the answer is
correct.

During the small group work, support the students as before. Encourage students to focus on the math of the
student work, rather than surface features such as neatness and spelling. Check to see which of the explanations
students find more difficult to understand. Note similarities and differences between the Sample Responses and
those methods the students used in the group work.

Extension Task. If any students complete the task quickly, ask them to write about practical changes that the
bus driver could adopt to help prevent the bus cutting into the cycle lane. Students could write this report on the
reverse side of the handout.

Whole-class discussion: comparing different approaches (15 minutes)
Organize a whole-class discussion to consider the different approaches used in the Sample Responses. Focus the
discussion on parts of the small groups tasks students found difficult. Ask the students to compare the different
solution methods.

Which approach did you find difficult to understand? Why?
How could the work be improved?
Which of the student’s methods did you think the most effective? Why?

To critique the different strategies, you can use the questions on the sheets Sample Responses to Discuss, and the
slides of them in the projector resource.
Guy’s Solution

Guy correctly substitutes into the equation \( x^2 - 2rx + w^2 = 0 \) the values for \( r \) and \( w \). He initially tries to factorize the quadratic. After three attempts Guy realizes this method is not suitable so he changes to ‘completing the square’ to figure out a value for \( x \).

The last line of Guy’s solution is incorrect. It should be:

\[
x - 17 = 13.75 \text{ or } x - 17 = -13.75
\]

Therefore \( x = 30.75 \) feet \text{ or } x = 3.25 \) feet.

Guy has not considered the practical implications of \( x = 30.75 \) feet. The radius of the outside edge of the cycle lane is only 17 feet. Therefore the bus cuts the cycle lane by 3.25 feet or 3 feet 3 inches.

Where has Guy made a mistake? What does he need to do to correct this mistake?

Ryan’s Solution

Ryan correctly substitutes into the equation \( x^2 - 2rx + w^2 = 0 \) the values for \( r \) and \( w \). He uses the ‘quadratic formula’ to figure out values for \( x \). However he makes a mistake when substituting into this formula. The correct solution for \( x \) is:

\[
x = \frac{34 \pm \sqrt{34^2 - 4 \times 1 \times 100}}{2 \times 1} = \frac{34 \pm \sqrt{756}}{2}
\]

\[
x = 30.75 \text{ or } x = 3.25
\]

Ryan has not considered the practical implications of a negative value for \( x \).

Does Ryan’s results make practical sense? Why/Why not?

Donna’s Solution

Donna uses guess and check. Her method is not very efficient and her answer is not very accurate. Donna could organize her work into a table. Donna has not considered the practical implications of \( x = 31 \) feet. The radius of the outside edge of the cycle lane is only 17 feet.

There is another value for \( x \) that fits into the equation.

Does Donna’s results make practical sense? Why/Why not?

Sketch the graph from \( x = 0 \) to \( x = 50 \).

What value of \( x \) should Donna try?
Liam’s Solution

Liam has used an efficient method, however he has not labeled the diagram. Liam makes a mistake in his manipulation of the equation. The solution should be:

\[ a^2 = 289 - 100 = 189 \]

\[ a = 13.75 \text{ or } a = -13.75 \]

A negative value for \( a \) is not possible in this context, therefore

\[ x = 17 - 13.75 = 3.25. \]

The bus cuts into the cycle lane by 3.25 feet (3 feet 3 inches.)

Follow-up lesson: Review solutions to Cutting Corners (10 minutes)

Give each student a copy of the questionnaire, How Did You Work? along with their original solutions to the Cutting Corners task. The questionnaire is intended to help students monitor and review their progress during and at the end of an activity.

Read through your first solution. Think about all the work you’ve done on this problem: the first time you tried it, when you used my questions working alone, when you worked with your partner.

Fill in the questions as you reflect on your experience.

Some teachers set this task as homework.
Solutions

1. The radius of the circle formed by the back wheel is $r - x$. This radius is perpendicular to the tangent to the circle, the line segment formed by the wheelbase. Thus $r, r - x$ and $w$ form a right-angled triangle.

Using the Pythagorean Theorem:

$$ r^2 = (r - x)^2 + w^2 $$

$$ r^2 = r^2 - 2rx + x^2 + w^2 $$

$$ x^2 - 2rx + w^2 = 0 $$

2a. If we take $w = 10$ and $r = 17$, and substitute into the equation:

$$ x^2 - 34x + 100 = 0 $$

There is a range of methods students might use to figure out the value for $x$.

Completing the square:

$$(x - 17)^2 - 17^2 + 100 = 0$$

$$(x - 17)^2 - 189 = 0$$

$$ x - 17 = 13.75 \text{ or } x - 17 = -13.75 \text{ (Taking the square root of both sides.)} $$

$$ x = 30.75 \text{ or } x = 3.25. $$

The outside edge of the cycle lane is a circle of radius only 17 feet, therefore $x = 30.75$ feet is not a possible solution in this context. (See page 9 for a discussion of this issue.)

The bus cuts into the cycle lane by 3.25 feet (3 feet 3 inches.)

Using the quadratic formula:

$$ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} $$

$$ a = 1, b = -34, \text{ and } c = 100 $$

$$ x = \frac{34 \pm \sqrt{34^2 - 4 \cdot 1 \cdot 100}}{2 \cdot 1} $$

$$ x = 30.75 \text{ or } x = 3.25 $$

The radius of the outside edge of the cycle lane is only 17 feet, therefore $x = 30.75$ feet is impossible.

The bus cuts into the cycle lane by 3.25 feet (3 feet 3 inches.)

Replacing $r - x$ with the variable $a$:

$$ r^2 = a^2 + w^2 $$

$$ 17^2 = a^2 + 10^2 $$

$$ a^2 = 289 - 100 = 189 $$

$$ a = 13.75 \text{ or } a = -13.75. $$

$$ x = r - a \Rightarrow x = 17 - 13.75 \text{ or } x = 17 + 13.75 $$

$$ x = 3.25 \text{ or } x = 30.75 $$

The radius of the outside edge of the cycle lane is only 17 feet, therefore $x = 30.75$ feet is impossible.

The bus cuts into the cycle lane by 3.25 feet (3 feet 3 inches.)
The student now needs to reinterpret the situation, to find the value of $r$ when $x = 0$.

Using the Pythagorean Theorem:

$$b^2 = 17^2 + 10^2$$

$$= 389$$

$$b = 19.72 \text{ or } b = -19.72.$$  

A negative value for $b$ is impossible given the context, therefore the front wheel is:

$$19.72 - 17 = 2.72 \text{ feet (2 feet and 8.6 inches) from the outside edge of the cycle lane.}$$

Students may also solve the quadratic equation:

$$(17 + y)^2 = 17^2 + 10^2$$

$$289 + 34y + y^2 = 289 + 100$$

$$y^2 + 34y - 100 = 0.$$  

They could do this by either completing the square or using the quadratic formula.

Alternatively, students could start with the equation from Q1 and, instead of substituting in $r = 17$, substitute $r = 17 + x$.

Simplifying this leads to the same quadratic equation as above.

**Completing the square:**

$$(y + 17)^2 - 289 - 100 = 0$$

$$(y + 17)^2 = 389$$

$$y + 17 = 19.72 \text{ or } y + 17 = -19.72$$

$$y = 19.72 - 17 = 2.72 \text{ or } y = -19.72 - 17 = -36.72$$

A negative value for $y$ is impossible, therefore the front wheel is 2.72 feet (2 feet and 8.6 inches) from the outside edge of the cycle lane.

**Using the quadratic formula:**

$$y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$a = 1, \ b = 34, \text{ and } c = -100$$

$$y = \frac{-34 \pm \sqrt{34^2 - 4 \times 1 \times -100}}{2 \times 1}$$

$$y = \frac{-34 \pm \sqrt{1556}}{2}$$

$$y = 2.72 \text{ or } y = -36.72$$

A negative value for $y$ is impossible, therefore the front wheel is 2.72 feet (2 feet and 8.6 inches) from the outside edge of the cycle lane.
Note: What does the ‘impossible’ solution mean?

If you extend the cycle path into a complete circle, you’ll see that there are two ways you could measure the distance from the rear wheel of the bus to the circle representing outside of the cycle path. The solution you threw away was actually the distance from the rear wheel to the far side of the circle:

\[ x_1 = 3.25' \]

\[ x_2 = 2 \times 17' - 3.25' = 30.75' \]

It is clear from the description of the problem that this is not the distance we’re interested in.
When a bus turns a corner, it must swing out so that its rear wheels don’t go into the cycle lane.

In this picture, as the bus goes round the corner, the front wheel is on the edge of the cycle lane, but the rear wheel cuts into the cycle lane.

The diagram below shows the geometry of this situation.

The distance between the front and rear wheel is called the wheelbase, \( w \).

Let \( r \) represent the radius of the outside edge of the cycle lane.

The distance marked \( x \) shows the amount by which the rear wheels cuts into the cycle lane.
Questions on Cutting Corners

1. Use the diagram to show that $x^2 - 2xr + w^2 = 0$.

2. Let $w = 10$ feet and $r = 17$ feet.
   (a) Figure out how much the rear wheel cuts into the cycle lane.

   (b) Figure out how far the front wheel must be from the outside edge of the cycle lane for the rear wheel not to cut into the cycle lane.
# Sample Responses to Discuss: Guy

Check Guy's work carefully and correct any errors you find.

What methods has Guy used?

Why has Guy changed his method?

Do you think Guy has chosen a good method? Explain your answer.

How can Guy improve his explanations?
Sample Responses to Discuss: Ryan

Check Ryan's work carefully and correct any errors you find.
What method has Ryan used?

Do you think Ryan has chosen a good method? Explain your answer.

How can Ryan improve his explanation?
Sample Responses to Discuss - Donna

Check Donna's work carefully and correct any errors you find.

What method has Donna used?

Why do you think Donna has sketched a graph?

How could Donna improve her work?
Check Liam’s work carefully and correct any errors you find.

What method has Liam used?

-------------------------------------------------------------

Do you think Liam has chosen a good method? Explain your answer

-------------------------------------------------------------

What isn’t clear about the work?

-------------------------------------------------------------

-------------------------------------------------------------

-------------------------------------------------------------

-------------------------------------------------------------

-------------------------------------------------------------

Why is Liam’s work incomplete?

-------------------------------------------------------------

-------------------------------------------------------------

-------------------------------------------------------------

-------------------------------------------------------------

-------------------------------------------------------------
How Did You Work?

Tick the boxes and complete the sentences that apply to your work.

1. Our group solution was better than my own work □

   Our group solution was better because ___________________________________________

2. We checked our solution: □

   We checked our solution by ______________________________________________________

3. a. Our solution is similar to one of the sample responses □

   Our method is similar to ___________________________ (add name of the student)

   OR Our solution is different from all of the sample responses □

   I prefer our solution □ OR I prefer the solution of ___________________________ (add name of the student)

   b. I prefer our solution / the student’s sample response (circle)

   This is because ...........................................................................................................

   .................................................................................................................................

   .................................................................................................................................

4. Which approach would you now use to answer Question 2b? __________________________ (add name of the student or your own name)

   I prefer this approach because ....................................................................................

5. If you taught this lesson to another class, what advice would you give them about potential pitfalls?

   ........................................................................................................................................

   ........................................................................................................................................

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Buses cut corners...beware!

Link to online movie: http://tinyurl.com/BusTurning
Planning a Joint Solution

1. Take it in turns to explain how you did the task and how you now think it could be improved.

2. Listen carefully to explanations.
   - Ask questions if you don't understand.
   - Discuss with your partners:
     • What you like/dislike about your partners’ math.
     • How clear their work is.
     • How their work could be improved.

3. Once everyone in the group has explained their solution, plan a joint method that is better than each of the separate solutions.

4. Everyone in the group must agree on the method.
Sample Response to Discuss: Guy

\[ r = 17 \quad w = 10 \]
\[ x^2 - 34x + 100 = 0 \]
\[ (x - 10)(x - 10) \]
\[ (x - 20)(x - 5) \]
\[ (x - 25)(x - 4) \]
\[ x^2 - 34x + 100 = 0 \]
\[ (x - 17)^2 - 289 + 100 = 0 \]
\[ (x - 17)^2 = 189 \]
\[ x - 17 = 13.75 \]
\[ x = 30.75 \]
Sample Response to Discuss: Ryan

\[x^2 - 2x + \omega^2 = 0\]
\[r = 17, \omega = 10\]
\[x^2 - 34x + 100 = 0\]
\[x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\]
\[= \frac{-34 \pm \sqrt{34^2 - 4 \cdot 100}}{2}\]
\[= \frac{-34 \pm \sqrt{756}}{2}\]
\[x = -30.75 \text{ or } x = -3.25\]
Sample Response to Discuss: Donna

Try

Try

$x = 10$

$a^2 - 34.10 + 100 = -140$

$x = 20$

$2a^2 - 34.20 + 100 = -180$

$x = 30$

$3a^2 - 34.30 + 100 = -20$

between

$x = 40$

$4a^2 - 34.40 + 100 = 340$

$x = 50$

$35^2 - 34.35 + 100 = 135$

$35^2 - 34.35 + 100 = 135$

$x = 32$

$32^2 - 34.32 + 100 = 36$

$x = 31$

$31^2 - 34.31 + 100 = 7$

$x = 31$

Bus

Wheelbase

Radius of outside edge of cycle lane.
Sample Response to Discuss: Liam

\[ 17^2 = a^2 + 10^2 \]
\[ a^2 = 289 + 100 \]
\[ = 389 \]
\[ a = 19.72 \]