You’ve learned how to replace values for variables into equations to see if they are true. Take a look at this problem.

A grocery store is giving a reusable bag to every person who donates more than $5 to charity. Let $x$ equal the amount that a person donates. Use words and symbols to solve all of the following problems about this situation.

Explore It

Use the math you already know to solve these problems.

- Ella donates $5.50. Will she get a bag? Explain how you know.
- Daniel donates $5. Will he get a bag? Explain how you know.
- Courtney donates $1.25. Will she get a bag? Explain how you know.
- Name 2 other amounts people could contribute and get a bag.
- To get a bag, are the amounts greater than or less than $5?
- Use the symbols $>$ or $<$ to show $x$ is greater than $5$.
- Explain how you know when any person should receive a free bag.
Find Out More

A sentence such as \( x > 5 \) is called an **inequality**. On the previous page you identified values for \( x \) that make \( x > 5 \) true, like 5.50 or 10, but there are too many possible values for \( x \) to be counted. Unlike an equation that has one solution, an inequality has infinitely many solutions.

Here are some symbols and words to describe an inequality:

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( &gt; )</td>
<td>( \geq )</td>
<td>( &lt; )</td>
<td>( \leq )</td>
<td></td>
</tr>
<tr>
<td>is more than</td>
<td>greater than or equal to</td>
<td>is less than</td>
<td>less than or equal to</td>
<td></td>
</tr>
<tr>
<td>is greater than</td>
<td>at least</td>
<td>below</td>
<td>at most</td>
<td></td>
</tr>
<tr>
<td>above</td>
<td>no less than</td>
<td>no greater than</td>
<td>no more than</td>
<td></td>
</tr>
<tr>
<td>( x ) is greater than 5</td>
<td>( x ) is at least 5</td>
<td>( x ) is below 5</td>
<td>( x ) is at most 5</td>
<td></td>
</tr>
<tr>
<td>( x &gt; 5 )</td>
<td>( x \geq 5 )</td>
<td>( x &lt; 5 )</td>
<td>( x \leq 5 )</td>
<td></td>
</tr>
</tbody>
</table>

Reflect

1. Explain the difference between an equation, like \( x = 5 \), and an inequality, like \( x \geq 5 \).
Read the problem below. Then explore how to write and solve an inequality.

When the temperature drops below 15°C in a building, the heater turns on. At what temperatures will the heater turn on? Write an inequality to represent this situation, and graph the solution on a number line.

**Model It**

You can use words and symbols to represent the problem.

Let \( x \) equal the temperature in a building. When \( x \) is less than 15, the heater turns on.

\[
 x < 15
\]

**Graph It**

You can graph the inequality on a number line to show all solutions.

Shading the line to the LEFT represents all the numbers LESS THAN 15. The arrow means the shaded line extends indefinitely.

15 is NOT a solution to \( x < 15 \), so there is an open circle here.

A closed or shaded circle on the above graph would show the solutions for \( x \leq 15 \).

**Check It**

You can substitute values for \( x \) to check your solution.

The graph shows that \(-5\)°C is a possible solution. You can replace \( x \) with \(-5\) to check.

\[
 x < 15
\]

\[
 -5 < 15 \quad \text{TRUE}
\]

The graph shows that 16°C is not a solution. You can replace \( x \) with 16 to check.

\[
 16 < 15 \quad \text{FALSE}
\]
Part 2: Guided Instruction

Connect It

Now you will solve the problem using the model and graph.

2 What words in the problem help you know which inequality symbol to use?

3 Look at the graph. Why is there an open circle at 15? What does it mean?

4 Explain the meaning of the shaded line and arrow to the left of 15.

5 Would the heater turn on if the temperature was 2.5°C? Explain how you know.

6 Suppose the heater turns on when the temperature is at 15°C or below.
Write an inequality for this new situation.
Graph the solution on the number line below.

7 Explain when to use an open or closed circle when graphing an inequality.

Try It

Use what you just learned about graphing inequalities to solve this problem.

8 This graph shows the solution of what inequality?
Read the problem below. Then explore how to write and solve an inequality.

Cooper spent at least $25 at a music concert. What are some possible amounts of money Cooper could have spent? Write an inequality to represent the amount of money Cooper spent, and graph the solution on a number line.

**Model It**

You can use words and symbols to represent this problem.
The amount Cooper spent, $x$, is greater than or equal to $25$.

$x \geq 25$

Another way to think about this problem is that $25$ is less than or equal to the amount Cooper spent, so $25 \leq x$.

**Model It**

You can graph the inequality on a number line to solve the problem.

![Number Line Graph](image)

**Check It**

You can substitute values for $x$ to check your solution.
The graph shows that $25.50$ is a possible solution. You can replace $x$ with $25.5$ to check.

$x \geq 25$

$25.5 \geq 25 \quad \text{TRUE}$

The graph shows that $30$ is a possible solution. You can replace $x$ with $30$ to check.

$25 \leq x$

$25 \leq 30 \quad \text{TRUE}$
**Part 3: Guided Instruction**

**Connect It**

Now you will solve the problem using the model and graph.

9 Explain how $x \geq 25$ and $25 \leq x$ both represent the amount Cooper spent at the concert.

10 Look at the graph of $x \geq 25$. What does the closed circle at 25 mean?

11 What is a possible amount of money Cooper could have spent? Check your solution.

12 How would the inequality be different if the problem said that Cooper spent more than $25? Write and graph the inequality on the number line below.

13 Explain how a shaded line means that fractions, decimals, and numbers not labeled on a number line can be part of the solution to an inequality.

**Try It**

Use what you just learned about writing and graphing inequalities to solve this problem.

14 The Earth’s atmosphere does not exist above $30\frac{1}{2}$ km. Write an inequality to represent this situation. ____________________________

Now graph the solution on the number line below.
Study the student model below. Then solve problems 15–17.

Which of the following values is not a solution of $x - 4 < 15$?

- $0$, $19$, $18.9$, $15 \frac{1}{4}$

**Look at how you can show your work using a model.**

<table>
<thead>
<tr>
<th>Value</th>
<th>Expression</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 - 4 &lt; 15$</td>
<td>$-4 &lt; 15$</td>
<td>TRUE</td>
</tr>
<tr>
<td>$19 - 4 &lt; 15$</td>
<td>$15 &lt; 15$</td>
<td>FALSE</td>
</tr>
<tr>
<td>$18.9 - 4 &lt; 15$</td>
<td>$14.9 &lt; 15$</td>
<td>TRUE</td>
</tr>
<tr>
<td>$15 \frac{1}{4} - 4 &lt; 15$</td>
<td>$11 \frac{1}{4} &lt; 15$</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

**Solution:** 19 is not a solution of $x - 4 < 15$

15 Which of the following values is a solution of $12.6 \leq 3x$?

- $4$, $4.2$, $3$, $10$

**Show your work.**

**Solution:**
16 Algae cannot survive at depths greater than 300 meters below sea level. The inequality to represent this situation is $x \leq -300$. Graph the solution on a number line.

*Show your work.*

![Number line diagram]

*Solution:*

-500 -400 -300 -200 -100 0 100

17 Which inequality represents the situation: Hailey has at most $500 in her bank account?

A $x > 500$

B $x \geq 500$

C $x < 500$

D $x \leq 500$

Tessa chose C as the correct answer. How did she get that answer?

Will your graph have an open or a closed circle?

*Pair/Share*

How could you use substitution to check your graph?

Does “at most 500” include 500 as a possible solution?

*Pair/Share*

What are some words that help you know when to use < and when to use \(\leq\)?
Solve the problems. Mark your answers to problems 1–4 on the Answer Form to the right. Be sure to show your work.

1. Which is a correct graph of $x \leq -\frac{1}{4}$?
   - A
   - B
   - C
   - D

2. Mark cannot read traffic signs that are more than 50 meters away. Which inequality represents distances at which Mark cannot read signs?
   - A $x > 50$
   - B $x \geq 50$
   - C $x < 50$
   - D $x \leq 50$

3. Which inequality does this graph represent?
   - A $x > -2.5$
   - B $x \geq -2.5$
   - C $x < -2.5$
   - D $x \leq -2.5$
4 Which of the following is not a possible solution of $5x \geq 35$?

A 7
B $7\frac{1}{5}$
C 6
D 8

5 Eric has practiced more than 40 hours with his band.

Write an inequality to express this situation. ________________________________

On the graph below, graph Eric's situation.

6 Judah’s family wants to ride the bumper boats at a water park.

- There are 4 children ($c$) and 2 adults ($a$) in Judah’s family.
- The boats are safe if $40c + 120a \leq 500$.

Can Judah’s family ride the bumper boats safely? Explain.

Show your work.

Answer ____________________________________________
Lesson 20 (Student Book pages 196–205)

Solving Inequalities

LESSON OBJECTIVES

• Write an inequality that represents real-world mathematical problems containing a constraint or a condition (<, >).
• Recognize that a variable can stand for an infinite number of solutions when used in inequalities.
• Use substitution to determine whether a given number in a specified set makes an equation or inequality true.
• Represent inequalities on a number line.

THE LEARNING PROGRESSION

In earlier grades, students gained an understanding of simple inequalities such as 3 < 5. They also understand the concept of algebraic equations having a solution.

In this lesson, students begin the organized study of algebraic inequalities. They learn that variables can represent infinitely many solutions when used in inequalities, and they learn how to graph those solutions. They use key word phrases such as “at most” and “no less than” to help them write symbolic inequality representations of real-world situations. They increase their mathematical proficiency through using different methods to check their answers.

PREREQUISITE SKILLS

• Understand the meanings of equality and inequality.
• Recognize that a variable can stand for a number.
• Substitute values for given variables.
• Write an inequality of the form x > c or c > x where x and c are rational numbers.

VOCABULARY

inequality: two unequal values that are compared using less than (<) and greater than (>) signs

CCLS Focus

6.EE.5 Understand solving an equation or inequality as a process of answering a question: which values from a specified set, if any, make the equation or inequality true? Use substitution to determine whether a given number in a specified set makes an equation or inequality true.

6.EE.8 Write an inequality of the form x > c or x < c to represent a constraint or condition in a real-world or mathematical problem. Recognize that inequalities of the form x > c or x < c have infinitely many solutions; represent solutions of such inequalities on number line diagrams.

ADDITIONAL STANDARDS: 6.NS.7a, 6.EE.6 (see page A32 for full text)

STANDARDS FOR MATHEMATICAL PRACTICE: SMP 1–4, 6, 7 (see page A9 for full text)
Part 1: Introduction

AT A GLANCE

Students study a real-world situation involving a simple inequality. They use algebraic symbols to represent it.

STEP BY STEP

• Tell students that this page models mathematical representations of real-world inequalities.
• Have students read the problem at the top of the page.
• Work through Explore It as a class.
• Ask student pairs or groups to explain their answers for the last four questions.

ELL Support

• Point out that “greater than” is a mathematical way to say “more than.” It does not refer to being better or more important, but simply a larger quantity.

Mathematical Discourse

• How do you think inequalities are different from equations you’ve worked with before?

Students at this point may think that inequalities don’t involve any operations. Listen for answers that talk about how the two sides of an inequality aren’t equal, or don’t balance, unlike the equations in the previous lesson.

• How do you think inequality sentences could be useful?

Some students may think they are not, and mathematical inequality sentences aren’t commonly used in simple real-world situations. However, some students may see that they are an efficient way to communicate meaning and could be helpful in problems that don’t have one definite answer.
**Part 1: Introduction**

### AT A GLANCE

Students learn about inequalities and their solutions. They review inequality symbols.

### STEP BY STEP

- **Read** Find Out More as a class.
- **Ask,** What does “infinitely many solutions” mean? [It is impossible to list every solution individually because there is no end to how many there are.]
- **Review** the word expressions given in the table. You may want to especially focus on “is at least” and “is at most” because these can be the most challenging.

### ELL Support

English learners may be confused by the “small words” in the comparison phrases. Discuss each phrase. Have students repeat them and use them with examples. Have students copy and add to the chart in Find Out More for reference.

### SMP Tip: The phrases in the chart let students communicate precisely when comparing quantities (SMP 6). Regularly call attention to students’ use of the phrases in discussion and to their meaning in real-world situations.

### Visual Model

**Study unbalanced inequalities.**

**Materials:** pan balance scale, lightweight opaque bag, several blocks

Before class, put 4 blocks in the bag labeled $x$. Place the bag in one pan of the balance scale. Ask students to direct you in putting blocks in the other pan to find the value of $x$. Write the inequality for each suggestion; for example, write $x > 1$ if they suggest 1 block. Continue until the value of $x$ is known. Then write $x > 4$. Ask students to discuss how many values, including fractional values, there can be. Guide them to see that there are infinitely many. Then ask whether 2 or 0 could be solutions. Point out that while $x$ can equal infinitely many numbers, not all numbers will be solutions to $x > 4$.

### Real-World Connection

Ask students to think of real-world situations where multiple solutions can satisfy a constraint. The problem on page 196 is a good example where people who donated more than a certain amount get a reward. Budgets are usually constrained by being able to spend no more than a certain amount. Athletes might need to have at least a certain number of practices or grade-point average to be able to compete in a game. Students must have fewer than a certain number of absences to get credit for a class.

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L20: Solving Inequalities

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Students learn how to use words, inequalities, and graphs to represent solutions to a problem. They learn to check graphical answers by substituting values into the inequality.

**STEP BY STEP**

- Read the problem at the top of the page as a class.
- In Model It, point out that part of modeling with words involves specifying what the variable represents.
- Make sure to note the open circle used in Graph It. Ask, *Why is an arrow used on this number line? Why not just a segment?* [to represent that the answers do not end but continue to infinity]
- Read Check It. Remind students to always check the reasonableness of their answers.

**SMP Tip:** Students become mathematically proficient by learning to think about whether their answers are reasonable (SMP 1). Tell students to use different methods to check answers.

---

**Mathematical Discourse**

- **How is this graphing similar to other graphing you have done? How is it different?**

  Students may note that they first find a number on a number line, something they have done before. Listen for answers that talk about using open circles and shading lines as being differences.

- **How would you explain the differences between graphing \( x > 4 \) and \( x \geq 4 \) to a student who missed this lesson?**

  Students will probably mention using open circles for \( > \) and closed circles for \( \geq \). Listen for them to talk about shading the number line and how to know which side to shade on. Listen for them to explain using an arrow and what that represents.
Lesson 20

Part 2: Guided Instruction

AT A GLANCE

Students revisit the problem on page 198. They discuss inequalities, how to represent them algebraically, and how to graph them.

STEP BY STEP

• Be sure students understand Connect It refers to the problem on page 198.
• Read Connect It as a class.
• Have students work through Try It on their own.

Hands-On Activity

Graph an inequality.

Materials: masking tape, a large arrow made of poster board for each group

• Divide the class into groups of 4–6 students and direct each group to a separate space. Have each group model a number line on the floor using masking tape.
• Use a 10-foot strip for the line and use 4-inch strips to make tick marks about every foot from one end to the other. Label these from −5 to 5, perhaps using a longer strip for 0.
• Tell students they are going to model inequalities that you put on the board.
• One person is to model the boundary point. They are to either stand on it with arms to their sides for a ≥ or ≤ situation or stand just in front of it with their arms in a big circle over it for a > or < situation.
• The other students should line up as points on the side that satisfies the inequality, with the student farthest out holding an arrow pointed in the direction that the solutions continue.
• Display several inequalities, including both positive and negative values. Direct students to rotate their roles.

TRY IT SOLUTION

8 Solution: Check students’ work. Values for x include anything greater than or equal to −4.5.

ERROR ALERT: Students who did not interpret the closed circle correctly do not understand the difference between > and ≥.
AT A GLANCE
Students explore how to write and solve an inequality involving an “at least.” They check their solutions.

STEP BY STEP
• Read the problem at the top of the page as a class.
• In the first Model It, point out that \( x \geq 25 \) can be read left to right, as “\( x \) is greater than or equal to 25,” or right to left, as “25 is less than or equal to \( x \).”
• In the second Model It, point out use of the closed circle on the graph.
• Read Check It. Tell students to make sure that the solutions proposed (25.5 and 30) both appear on the correct side of the graph.

ELL Support
Be careful about using the terms “correct” and “right” interchangeably in situations where the words “right” and “left” refer to direction or position.

SMP Tip: Students model the amount of money spent both symbolically and contextually (SMP 4). Point out the cue words “at least” and review other key word phrases frequently.

Mathematical Discourse
• Which is easier for you to understand: the symbol inequality \( x \geq 25 \), or looking at the graph?
  Students who are comfortable reasoning abstractly may prefer \( x \geq 25 \). They may think interpreting the inequality is faster and easier than drawing a graph. Students who are visual learners may prefer seeing which side of 25 is shaded on a graph.

• How might you use a graph to represent a variable that must be bigger than 0 but less than 10?
  Listen for students to talk about using open circles. Let students present their thinking visually on a whiteboard. While there is a definite standard for how to do this, you may want to let students just explore it for now.
Students revisit the problem on page 200. They discuss meanings of inequality representations, both symbolically and graphically.

**STEP BY STEP**

- Point out that Connect It refers to the problem on page 200.
- Have students work through Try It on their own.

**Concept Extension**

**Graph inequalities with two bounds.**

- Tell students that there are problem situations where a range of solutions can be bounded on two ends. For example, a B grade might be given to a student whose percentage points are greater than or equal to 79.5 and less than 89.5. How do you represent this?
- First make a graph. Draw a section of a number line from about 75 to 93. Look at the boundary points.
- Ask, Would 79.5 receive a B grade? How would you represent that on the graph? [Yes; the problem said greater than or equal to. Put a closed circle there.]
- Ask, Would 89.5 get a B? [No. Put an open circle there.]
- Ask, What other points would receive a B? How do we graph to show all the solutions? [Test some values and find that values between the two boundary circles would be solutions. Shade the line between the circles.]
- Ask, Without an arrow are there still infinitely many solutions? [Yes, there are infinitely many decimal values that could receive a B grade.]
- If you have time, you may discuss how to represent this situation symbolically. Designate a variable, $x$, that represents the possible range of percentage points to receive a B grade. Working from left to right, translate the graph to an inequality, first in words, then symbols. 79.5 is less than or equal to $x$, which is less than 89.5. Or $79.5 \leq x < 89.5$.

**TRY IT SOLUTION**

**14 Solution:** $x$ is the altitude above Earth’s surface; $x \leq 30\frac{1}{2}$. Check students’ work for the graph.

**ERROR ALERT:** Students who wrote $x < 30\frac{1}{2}$ may not understand that the cue words “not exist above” includes the value $30\frac{1}{2}$. 

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Students work to solve problems involving inequalities represented symbolically and graphically.

**STEP BY STEP**

- Ask students to solve the problems individually.
- When students have completed each problem, have them Pair/Share to discuss their solutions with a partner or in a group.

**SOLUTIONS**

15 *Solution:* 4.2 and 10 are solutions; Students could solve the problem by replacing each possible solution in the inequality to see which ones result in true statements.

16 *Solution:* See solution on student book page; Students could solve the problem by using a closed circle at \(-300\) and shading to the left.

17 *Solution:* D; Tessa could have $500 or less in her account.

Ex Check each possible solution by substituting it for \(x\) in the inequality. Because 15 is not less than 15, 19 is not a solution.
Part 5: Common Core Practice

Solve the problems. Mark your answers to problems 1–4 on the Answer Form to the right. Be sure to show your work.

1. Which is a correct graph of \( x \leq -1 \frac{1}{4} \)?
   - A
   - B
   - C
   - D

2. Mark cannot read traffic signs that are more than 50 meters away. Which inequality represents distances at which Mark cannot read signs?
   - A \( x > 50 \)
   - B \( x \geq 50 \)
   - C \( x < 50 \)
   - D \( x \leq 50 \)

3. Which inequality does this graph represent?
   - A \( x > -2.5 \)
   - B \( x \geq -2.5 \)
   - C \( x < -2.5 \)
   - D \( x \leq -2.5 \)

4. Which of the following is not a possible solution of \( 5x \geq 35 \)?
   - A 7
   - B \( \frac{1}{5} \)
   - C 6
   - D 8

5. Eric has practiced more than 40 hours with his band. Write an inequality to express this situation. On the graph below, graph Eric’s situation.

6. Judah’s family wants to ride the bumper boats at a water park.
   - There are 4 children (c) and 2 adults (a) in Judah’s family.
   - The boats are safe if \( 4c + 11a \geq 500 \).
   - Can Judah’s family ride the bumper boats safely? Explain. Show your work.

   **Answer:**
   
   Judah’s family can ride the bumper boats safely.

AT A GLANCE

Students use their knowledge of inequalities to solve problems that might appear on a mathematics test.

STEP BY STEP

- First, tell students that they will use their knowledge of inequalities to solve problems. Then have students read the directions and answer the questions independently. Remind students to fill in the correct answer choices on the Answer Form.
- After students have completed the Common Core Practice problems, review and discuss correct answers. Have students record the number of correct answers in the box provided.

SOLUTIONS

1. **Solution:** B; The graph needs a closed circle at \(-1 \frac{1}{4}\) with shading to the left.

2. **Solution:** A; The words “more than” indicate a > symbol.

3. **Solution:** C; Shading to the left with an open circle indicates the < symbol.

4. **Solution:** C; \( 5 \cdot 6 = 30 \); 30 is not greater than or equal to 35.

5. **Solution:** \( x > 40 \), see student book page for the graph

6. **Solution:** The ride is safe for Judah’s family. Substitute 4 for \( c \) and 2 for \( a \) in both inequalities. Simplify and check that both inequalities are true.
Assessment and Remediation

- Ask students to write and graph an inequality to represent the following situation: Martin has written at least 70 words of his essay. \([x \geq 70]\); student number lines should have a closed circle at 70 and an arrow extending to the right.

- For students who are struggling, use the chart below to guide remediation.

- After providing remediation, check students’ understanding. Ask students to write and graph an inequality to represent the following situation: There are fewer than 30 students in the algebra class. \([x < 30]\); student number lines should have an open circle at 30 and an arrow extending to the left.

<table>
<thead>
<tr>
<th>If the error is . . .</th>
<th>Students may . . .</th>
<th>To remediate . . .</th>
</tr>
</thead>
<tbody>
<tr>
<td>(x &gt; 70)</td>
<td>not understand that “at least” includes the given value as well as greater values.</td>
<td>Ask questions about specific values. Could he have written 120 words? Could he have written 70? Yes, 70 is at least 70. Help them to see that “at least” includes “more than” but also “equal to.”</td>
</tr>
<tr>
<td>(x \leq 70, x &lt; 70)</td>
<td>have difficulty translating words to symbols.</td>
<td>Remind students to test specific values in both the problem and the inequality they write. Is 80 words at least 70? It is, but if you put it in the inequality (80 \leq 70), you see that isn’t true.</td>
</tr>
<tr>
<td>(x \leq 70, x &lt; 70)</td>
<td>confuse (\leq) with (&gt;) and (&lt;) with (\geq).</td>
<td>Review the meanings of the symbols and how to read them. Use some examples with specific numbers such as (3 &lt; 7) and (9 \geq 8). Point out that the pointed end points to the smaller value while the larger, open end faces the larger value.</td>
</tr>
<tr>
<td>graph has an open circle at 70.</td>
<td>not understand the difference between closed and open circles.</td>
<td>Review how to plot points on a number line. Tell students that when an inequality is (\leq) or (\geq), it includes the number and the number must be plotted with a closed circle. An open circle excludes that value.</td>
</tr>
<tr>
<td>graph is shaded on the wrong side.</td>
<td>have difficulty translating symbols to the graph.</td>
<td>Remind students to check their answers. Tell them to pick a value in the section they’ve shaded and put it back in the inequality to test whether it works or not.</td>
</tr>
</tbody>
</table>

Hands-On Activity

**Model inequalities on a floor number line.**

**Materials:** approximately 2-foot long number line marked from –12 to 12; black checkers or bingo markers; a small triangle to be used as an arrow head; two black circles with one-inch diameters, one with the inside cut out to make a ring.

Give students simple inequalities such as \(x < 6\). Have students model the inequality on the number line. Use either the closed black circle or the ring to model the boundary point. Use checkers to plot several points that satisfy the inequality. Then place the triangle to indicate the direction the solutions continue in.

Alternatively, have students make a graph and then find the symbolic inequality.

Challenge Activity

**Create word problems from a given inequality.**

Ask students to write a real-world situation that is represented by the inequality \(x > 35\), or for more difficulty, \(-5 \leq x \leq 30\). Have them graph their solutions.