

CATS-DEVELOPED GAMES

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CATS-Developed Games

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CATS-DEVELOPED GAMES

Center for Advanced Technology in Schools

This document contains an overview of a series of educational games developed by the Center for Advanced Technology in Schools (CATS) at UCLA's National Center for Research on Evaluation, Standards, and Student Testing (CRESST). Funded by the U.S. Department of Education's Institute of Educational Sciences, CATS combines research on cognitive psychology, instruction, assessment, and new technologies including gaming to improve the understanding of fundamental math concepts of underperforming middle school students.

For each CATS game, this document provides a brief game description, and describes the key features and math learning goals, the user interface, the typical game play sequence, game components, links to classroom learning, and the platform requirements.

CATS includes partners from the University of Southern California, UC Santa Barbara, Arizona State University, and ETS, in addition to a national advisory faculty including several dozen technology and game experts, cognitive psychologists, and noted researchers in mathematics, science teaching, and learning. We especially thank the University of Southern California's Game Innovation Lab for their contributions to the early development of several of the games described in this document. For more information about this document or to obtain access to the educational games described, please contact Dr. Gregory Chung at greg@ucla.edu or 310-794-4392.

The screenshot shows the 'Scribblenauts' game interface. On the left is the 'Path Options' menu, which includes a scrollable list of path types (e.g., '1' with a triangle, '1' with a square, '1' with a circle) and a 'RESET' button. The main game area displays 'Level 16' with a score of 0 and a key icon. The level itself is a green field with a blue path leading from a 'START' sign to a goal (a yellow circle with a black outline). The path is composed of several segments, some of which are marked with question marks and arrows, indicating a puzzle or a sequence of actions. A small blue character is visible on the path. At the bottom, there is a 'GO' button and a small icon of a blue character.

- Single-player game with 56 levels covering 10 math topics
- Stand-alone application that does not use the Web or require network connectivity
- Math learning goals integrated with game mechanics
- Individualized feedback system
- Research-based design
- Achievements in the form of coin accumulation leading to avatar choice
- Video tutorials on game play
- Puzzle-adventure genre

- Improve students' understanding of the idea of a unit.

- Improve students' understanding of the idea that addition of fractions involves adding equal-sized pieces.
- Improve students' understanding of the meaning of the numerator.
- Improve students' understanding of the meaning of the denominator.

About the Game

In the rational number addition video game *Save Patch*, the goal is to reach a cat statue across an archeological dig site. The challenge lies in only being able to travel on a one- or two-dimensional grid by determining the correct length of rope to travel between posts. In addition, on some levels, the student is required to stop at prescribed points (denoted by signposts labeled with a gold key). Students are given a set number of rope pieces to build the instructions for the explorer; rope pieces are added to signposts to prescribe the distance the character will walk. For example, if you add a one-unit rope piece to a signpost, the character will walk exactly one unit. In *Save Patch*, one whole unit is always the distance between two large gray posts. Rope pieces can be added to a signpost to increase the distance the character will walk; however, only identical rope pieces can be added together. While any size rope piece can be placed on the signpost initially, subsequent rope pieces can only be added to the signpost if they are the same size. Whole unit (integer) rope pieces are also added one at a time to signposts, reinforcing the meaning of addition with integers.

The game exploits the fact that real numbers can be broken into smaller, identical parts if necessary to facilitate addition, and that this process is similar in both integer and fractional addition. The intent is to make explicit connections between integer addition (with which many students have confidence) and fractional addition (with which many students struggle). Moreover, the gameplay requires that players (students) be attentive to the size of a unit they are adding. Unlike many previous games designed to teach mathematics, however, fluency with the basic ideas (the learning goals as specified in the knowledge specifications) is integral, not ancillary, to gameplay.

As gameplay proceeds, however, the signposts are placed at distances along the grid that are fractional parts of the whole unit. Consequently, students must know how to break rope pieces into fractional units. As only identical units can be added together (in agreement with the foundational idea of addition), students must be attentive to what the rational number means, to what units are being added, to what units are already on the signpost, and to how they will break rope pieces into smaller parts. So while students could add a rope piece that is $\frac{1}{2}$ a unit to another rope piece that is $\frac{1}{2}$ a unit, they are not allowed to add a rope piece that is $\frac{1}{2}$ a unit to a rope piece that is a whole unit until the whole unit is broken into two $\frac{1}{2}$ -unit rope pieces. At the

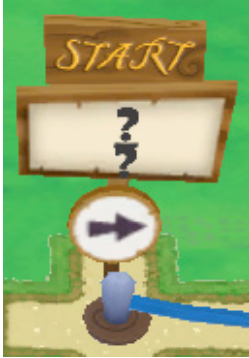

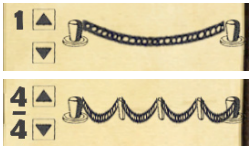
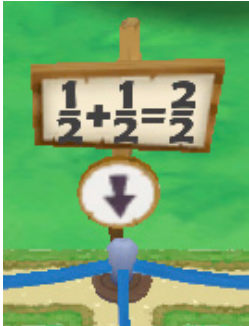
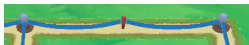
time all three of these rope pieces are added to the signpost, the signpost would show that it had $\frac{3}{2}$ (rather than $1\frac{1}{2}$) units of rope. As noted previously, this is intended to reinforce both the meaning of addition and to reinforce the player's understanding of the meaning of rational numbers.

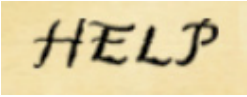

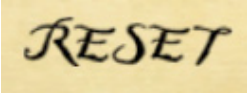
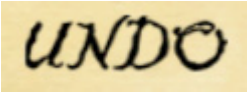

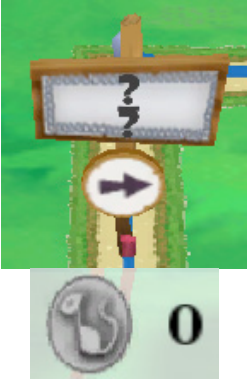
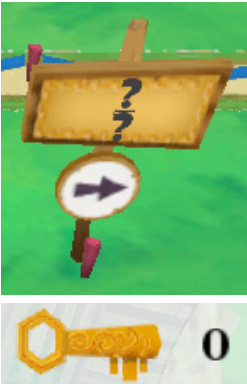
In *Save Patch*, the procedure for converting fractions of different sizes (i.e., fractions with different denominators) is not accomplished through multiplication since that was beyond the specified learning goals (knowledge specifications) around which the game was designed. Rather, students were shown how they could click on up and down arrows next to a rope piece and break it into more pieces (each smaller in size) or fewer pieces (each larger in size), respectively. The fractional representation of the rope piece was shown next to each rope as the student clicked on the arrows. For example, if a student clicked up on a rope piece that was one whole unit in length, the rope broke into two halves, then three thirds, etc. If the student used the same procedure with a $\frac{1}{2}$ rope piece, then the coil broke into two fourths, three sixths, and so on. Students could also click down on these same rope pieces to make fewer pieces that were larger in size.

Game Components

Table 1

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Start		The character must walk from the Start signpost to the goal.
Goal		The goal is to help the character reach the cat statue by leaving directions for how to move between the signposts placed on the grid.
Rope pieces		<p>Rope pieces are located on the left side of the screen. Rope pieces are used to identify the rope path to the statue. Players must use the grid size as a guide for determining both the size and the number of rope pieces to use.</p> <p>The number and size of available rope pieces change across levels.</p> <p>The up and down arrow buttons to the left of the rope pieces are used to change the size of rope pieces.</p>
Signpost		<p>Rope pieces are added to signposts. Only rope pieces of the same size can be added together. After a rope piece has been added to a signpost, the sign first displays for a few seconds the addition that just occurred and then the display only shows the current value of the sign post (in this case, $2/2$).</p> <p>The button with an arrow below the sign shows the direction the character will walk after reaching that signpost. Clicking on the arrow will change the direction.</p>
Unit		<p>The space between the two gray posts is one unit.</p> <p>Red posts divide the unit into smaller pieces. This also indicates what size (denominator) and how many (numerator) rope pieces to place on signposts.</p>

Game element	User interface element	Description
Help		Clicking the <i>Help</i> button launches a help menu with basic level help. Located along the bottom left of the screen.
Go		Clicking the <i>Go</i> button sets the character in motion on the designated rope path. If the correct number of rope pieces is placed on the signposts, the character will successfully reach the end. The character will turn into a puff of smoke if there are too many or too few rope pieces on the signposts.
Reset		Clicking the <i>Reset</i> button resets the level.
Undo		Clicking on the <i>Undo</i> button will undo the last action performed.
Zoom		Zoom control allows for zooming in and out of the grid.
Silver posts and coins		<p>Silver signposts indicate a coin can be picked up at that signpost if the character stops at that post.</p> <p>The coin counter at the top of the screen tells you how many coins you have collected in that level. Coins collected throughout the game can be used to unlock avatars. The avatar selection screen appears after login before the level selection screen.</p>
Gold posts and keys		<p>Gold signposts indicate a key can be picked up at that signpost if the character stops at that post.</p> <p>The key counter at the top of the screen tells you how many keys you have collected in that level. All available keys in the level must be collected to pass the level.</p>

Typical Game Sequence

1. Determine number and type of resources available for the level.
2. Define the unit.
3. Determine number of pieces the unit is broken into.

4. Place appropriate size and number of rope pieces on signposts.
5. Click *Go*.

Links to Classroom Instruction

Unit

One whole unit is always the distance between paths that are worn into the sodden field. Many students mistakenly believe that the whole screen is always the whole unit. Emphasize that they must identify the whole before they decide what rope(s) to use.

Denominator

In the game, the denominator is represented by spaces between the posts and pieces of rope. Many students mistakenly figure out the denominator by counting the posts instead of the spaces between the posts. Emphasize that they figure out the denominator by counting the spaces or the pieces of rope along the edge of the paths for each whole unit. Students should understand that the denominator tells you the number of pieces of rope that would make one whole unit of rope.

Numerator

As its name suggests, the numerator represents the number of a specific size of rope pieces a student has. So the three in $\frac{3}{4}$ just means that they have three pieces of rope, each one fourth of a whole rope in length. Students should understand that, even though both the numerator and denominator are integers, they represent very different things. The denominator tells us about the size of the unit and the numerator tells us how many of those size pieces we have.

Adding Fractions

Adding allows us to combine two things into a single sum; however, to do so, the two things must be identical. You can add miles to miles and yards to yards, but you can't add miles to yards unless you make the units identical. In the same way, you can't add fourths to thirds. To add fractions with different denominators, we have to make equivalent fractions with a common denominator (see converting fractions below). Then we add numerators and keep (write) the common denominator. Ask students WHY the denominators don't change when adding (or subtracting) fractions with common denominators. They should be able to tell you that, just like adding seven ones and two ones make nine ones, or adding 3 tenths and 4 tenths would be 7 tenths, the units don't change, so in adding fractions, the units don't change.

Converting Fractions

In *Save Patch*, it is not important for students to understand equivalent fractions or the math behind equivalent fractions. It is important that they see a pattern in converting from a rope piece of one size to another. For example, when one half of a rope is cut into half (i.e., two equal pieces), each piece is now a fourth (because it would take four of these pieces to make a whole) AND there are two of these in one half (because you cut the half rope into two equal pieces). This will help them determine common multiples (denominators), and will provide a conceptual base for understanding multiplication / division of fractions in future games. We hope that such an understanding also helps them begin to understand why multiplication of fractions does change the denominator.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

TLALOC'S BOOK



Key Features

- Single-player game with 45 levels
- Stand-alone application that does not use the Web or require network connectivity
- Achievements in the form of treasure chest accumulation
- Research-based game design
- Puzzle-platformer genre

Math Learning Goals

- Improve students' understanding of the effects of the operations of multiplication and division on quantities.
- Improve students' understanding of certain multiplicative relationships:
 - the inverse relationship between multiplication and division
 - If $a \times b = c$, then $\frac{c}{b} = a$ and $\frac{c}{a} = b$
 - $a \div b \times b = a$ or $a \times b \div b = a$
 - the relationship between a number and its reciprocal
 - $a \div b = a \times \frac{1}{b}$

- $b \times \frac{1}{b} = 1$
- Improve students' understanding of the relationships between whole numbers and fractions.

About the Game

The game *Tlaloc's Book* challenges players to overcome barriers they encounter during their adventurous journey through a mysterious jungle. Players move through the jungle by choosing to move left, right, or jump. Players encounter barriers which prevent them from moving forward or reaching valuable items. By using the numbers and operations they collect and store in their backpack, players can change the height of platforms. The player uses the platforms to overcome barriers.

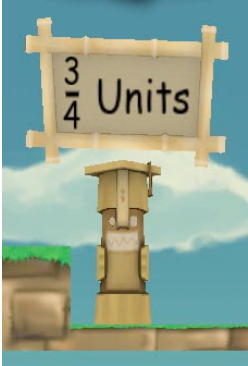



All tasks in *Tlaloc's Book* involve using a multiplicative comparison to change the platform height to a target height. The platform height is denoted on the platform, and the target height is denoted on the signpost. The height of the base of the signpost is to scale with the height denoted on the platform. The height on the platform is updated with each player action, which is composed of the choice of an available operator, either multiplication or division, and the choice of a scalar from the backpack.

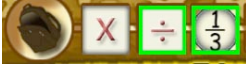
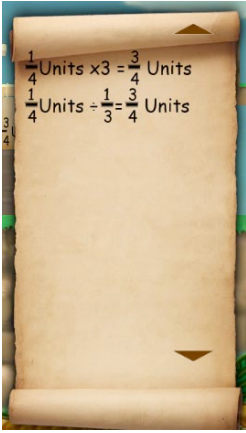


Each action players perform is recorded as math notations on the scroll and the players can use this information whenever they want to. For example, they can track their action history and undo their actions by choosing the appropriate operation and scalar. When the players solve the problem correctly, the pertinent math equations appear on the signpost. The signpost flashes for a second to attract the players' attention and the numbers used to solve the problem are stored in the treasure box. The numbers used to solve the problem go into the treasure box so that if there is another platform task on the same level, the player must solve it using a different strategy than s/he used on the first platform.

Game Components

Table 2

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Goal		The player needs to match the <i>platform</i> height to match the measure listed on the <i>signpost</i> .
Platform		Platforms are always represented as the same color and labeled with the current height.
Signpost		At the beginning of a level, each signpost on the screen shows a target height. If the player solves the task by matching the exact target height, the signpost changes to show an equation using the start height, the operations and numbers the player chose, and the target height.
Obstacles		Obstacles take the form of mountains, cliffs, or crevasses, which are accompanied by a signpost labeled with the target height for the task.

Game element	User interface element	Description
Backpack		As the player travels through the jungle, s/he collects numbers and operations to use to alter the size of platforms. The items the player collects are stored in the player's backpack, and the inventory is shown across the top of the screen.
Scroll		A scroll shows the history of the player's actions on a particular screen. The scroll shows all player actions as separate equations.
Treasure	 	The reward system for the game is treasure which is released when the player achieves an exact match to the signpost. When the exact match is obtained, the operations and numbers used to make the match are moved into a treasure chest which is dropped near the signpost. The player must walk past the treasure to collect it. Another function of the treasure is for resetting a level. The player may reset the level at the cost of one treasure.

Typical Game Sequence

1. Notice the start height and target height of the platform. The platform is labeled with the start height, and the signpost tells the target height.
2. Gather inventory (scalars and operators) as player approaches the platform. Inventory will be stored in the backpack.
3. Choose a scalar and operator to transform the platform by clicking on one of each.
4. Click on the platform to activate the transformation.
5. If the platform height matches the target height, the signpost will spin and reveal an equation which includes the start height, the operation(s) and scalar(s) used, and the target height.
6. If the platform height does not match the target height, the player may choose to apply the same operator and scalar or choose a different combination from the inventory.
7. In levels with more than one platform task, subsequent platforms are "locked" and cannot be activated until the previous platform heights match the target heights exactly.

Links to Classroom Instruction

Relationships Between Fractions and Whole Numbers

The game begins with whole numbers and moves to the use of fractions when a fraction results from the division of two whole numbers. So, fractions result from divisions and can describe quantities just as whole numbers do. Further, fractions can be used as scalars, just as whole numbers can be.

Inverse Operations

The game uses known multiplication and division facts to emphasize the inverse relationship of the operations. For instance, $24 \div 8 = 3$ because $3 \times 8 = 24$. The two statements are inextricably related, and this relationship is maintained after fractions are introduced.

Opposite Effects of Inverse Operations

Multiplying by 8 can be “undone” by dividing by 8. Multiplying by 8 makes a pillar 8 times taller in the game, and dividing by 8 makes it 8 times shorter (or more familiarly “ $1/8$ as tall”).

Unit Fractions

A unit fraction is a fraction with a numerator of 1. The unit fraction $1/5$ tells us that a unit or whole has been divided into 5 equal pieces, each piece being $1/5$ of the whole unit.

Reciprocals

Multiplication and division have the same effect if we use reciprocals. The product of two reciprocals is 1. Multiplying by any rational number has the same effect as dividing by its reciprocal. So, multiplying by $1/3$ has the same effect as dividing by 3. This can be extended to non-unit fractions, as well. Multiplying by $2/5$ has the same effect as dividing by $5/2$.

Scaling

To make a quantity larger or smaller, we must consider both the scaling operation and the scale factor. In this game, multiplying a positive integer by a number greater than 1 increases the quantity, and multiplying a positive integer by a number less than 1 decreases the quantity. Dividing a positive integer by a number greater than 1 decreases the quantity, and dividing a positive integer by a number less than 1 increases the quantity.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

ROSIE'S RATES



Key Features

- Single-player game with multiple practice levels in each of 5 stages
- Stand-alone application that does not use the Web or require network connectivity
- Tutorials offered at the beginning of each stage
- Puzzle-arcade genre

Math Learning Goals

- Improve students' understanding of independent and dependent variables as inputs/outputs of a function.
- Improve students' fluency with data tables showing the output of a function for a given input value.
- Improve students' understanding of the relationship between x and y values and rate of change in a linear function.
- Improve students' fluency with finding the y value for any given x value in a linear relationship.

About the Game

Rosie's Rates is a game that takes students through the initial steps of slope derivation given a table of x and y values. The goal of the game is to help Rosie the robot exchange

currency for her customers by first finding the change in y and change in x and eventually completing the equation $y = mx$. Players are challenged to be as speedy as possible or face unhappy alien customers. Each level brings a new customer with a new table of numbers, and each new planet brings students one step closer to completing the equation. Students help build Rosie's storefront when they complete the level successfully. Additionally, students may earn bonuses at each planet.

There are five stages in *Rosie's Rates*. The first stage helps students learn how to find the change in y and the change in x . A screen shot of the first stage is shown in Figure 1.



Figure 1. Screen shot of Stage 1 of *Rosie's Rates*.

Stage 2 of *Rosie's Rates* helps students learn how to find the next row's value in the table. Students must attempt to correctly solve the row with the "??". A screen shot of Stage 2 is shown in Figure 2.



Figure 2. Screen shot of Stage 2 of *Rosie's Rates*.

Stage 3 of *Rosie's Rates* helps students learn how to find the slope given a set of values. A screen shot of Stage 3 is shown in Figure 3.



Figure 3. Screen shot of Stage 3 of *Rosie's Rates*.

Stage 4 of *Rosie's Rates* helps students learn how to find the missing y value given the change in y , the change in x , and the x value. A screen shot of Stage 4 is shown in Figure 4.



Figure 4. Screen shot of Stage 4 of *Rosie's Rates*.

In Stage 5 students learn how to complete the equation to find the value of y given x . A screen shot of Stage 5 is shown in Figure 5.






Figure 5. Screen shot of Stage 5 of *Rosie's Rates*.

Game Components

Table 3

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Function table		The function table lists the x and y values for each level. Players should drag these numbers as needed.
Help		The <i>Help</i> button allows players to access help screens.
Unknown row		In some levels there are unknown rows. In these levels, players must attempt to solve these rows.

Typical Game Sequence

1. Drag numbers from columns in the table to the equations on the right.
2. Drag values calculated by the equations on the right back to the table on the left.

Links to Classroom Instruction

Finding the change in x and change in y

In the game, students learn to find the change in y and change in x given a table of data. Knowing how to find the change for the input (x) and output (y) will allow students to see the relationship between x and y (e.g., for a slope of $2/3$; every time y changes by 2, x changes by 3). To find the change in y and change in x , students first select two consecutive rows in the data table, from which they will find the difference between the two y values in the y column and the difference between the two x values in the x column. Emphasize that using consecutive rows to

find the change in x and change in y is important in the game. This method will help students in later levels of the game when they are asked to find the x and y values of missing rows in a data table. However, you might want to point out that the use of consecutive rows is not the only way to find the change in x and change in y . What is important is that you use the corresponding y values to the x values from any two rows.

Finding the x and y values in the missing rows

Now that students know the relationship (or rule) of y and x in the data table, they can find the x and y values of a missing row. Although students can do that by counting, the game emphasizes that they can calculate the values mathematically. It is important to point out that the missing x can be found by adding the change in x to the x value that directly precedes the missing x in the data table. Similarly, the missing y can be found by adding the change in y to the y value that directly precedes the missing y in the data table.

Finding the missing y value given x

In the game, students are asked to complete the equation $y = (\text{change in } y) / (\text{change in } x)(x)$ given a data table. The value of y will be calculated by the game after the equation is completed by the student. Students don't have to do the actual calculation in the game to compute y —the key concept to emphasize is the importance of setting up the equation correctly to find y . Emphasize that knowing this equation can help determine any y value in a data table with (x,y) pairs.

Points in the table must satisfy the equation

Give students sets of x and y values that are not included in the data table and ask if those sets belong in the table. You might want to ask, will $(0,0)$ work in the table? In their rule? This question is asked to reinforce the idea that the table can include values above as well as values below the given entries, to prepare students to discuss domain and range of functions at a later date, and to begin the thinking that (a) points that satisfy the equation must be in the table, and (b) points in the table must satisfy the equation that accurately represents the data set.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

ZOOPLES IN SPACE



Key Features

- Single-player game with multiple levels over four math topics
- Stand-alone application that does not use the Web or require network connectivity
- Tutorials offered throughout the game
- Puzzle-arcade genre

Math Learning Goals

- Improve students' understanding of the equals sign in an equation.
- Improve students' understanding of the additive inverse.
- Improve students' understanding of the idea that an equation needs to be balanced on both sides when solving for the unknown.



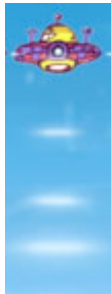

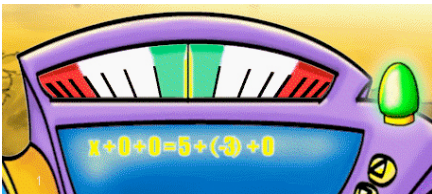
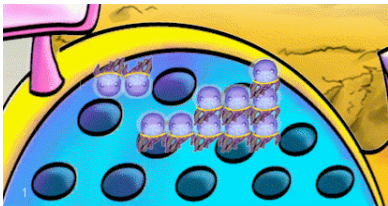
About the Game

Zooples in Space is a game in the domain of solving equations. The player is presented with a spaceship that is carrying creatures called Zooples. Also on the spaceship are containers called Zarples, which carry an unknown number of Zooples. To pass the level, the student must (a) isolate the Zarples on the top side of the wing on one side of the ship and (b) group all the Zooples on the other side of the ship either on the top of the wing (representing a positive value) or underneath the wing (representing a negative value). An equation that maps onto the current state of the ship is displayed at the bottom of the screen.

Early levels of the game require the player to make only a few moves (e.g., remove one Zoople from each side of the ship). As the game progresses, the player is taught that the tractor beams that hold the Zooples and Zarples in place on the ship can be used to simplify the equation. A positive tractor beam and a negative tractor beam holding the same number of Zooples or Zarples can be lined up and then, because of the additive inverse, the Zooples/Zarples disappear from the ship but the ship still remains balanced. In later levels, students must make more moves to reduce the number of Zooples on the ship to find out how many Zooples are in one Zarples. A time limit is imposed for each game level; when the ship is unbalanced, the timer starts to count down, but when the ship is balanced again, the timer resets. If the ship remains unbalanced and the timer runs out, a “try again” screen comes up that shows the ship has crashed, and the ship is reset to the beginning of the level.

Game Components

Table 4
Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Zoople		A right-side-up Zoople represents +1, and an upside-down Zoople represents -1. Zooples can be added or taken away from the wings of the ship to isolate the Zarple and determine its value.
Zarple		The Zarple is a container that holds an unknown quantity of Zooples. Like Zooples, an upside-down Zarple is a negative quantity. However, a right-side-up Zarple can be equal to a negative number of Zooples.
Tractor beam		Tractor beams hold Zooples and Zarples in place on the ship. Each tractor beam is one term in the equation shown at the bottom of the screen. Some tractor beams are “locked”—Zooples and Zarples can’t be added or removed from them. When there is an equal number of Zooples or Zarples in a tractor beam on top of the ship and a tractor beam on the bottom of the ship, the player can align the tractor beams and the contents of the tractor beams will disappear, demonstrating the additive inverse.
Ship		The ship smiles when both wings are balanced, regardless of whether the Zarple has been isolated. When the wings are unbalanced, the ship starts to tilt, and the face on the ship grows more and more agitated. The ship starts to smile again when the wings are balanced. If the ship is unbalanced and the timer runs out, the ship crashes and a “Try Again” screen appears.
Dashboard		The meter at the bottom of the screen indicates whether the ship is balanced. When the ship is balanced, the light bulb on the right is green and the yellow indicator is centered. When the ship is unbalanced, the yellow indicator moves either to the right or the left depending on which wing has fewer Zooples on it, and when the yellow indicator is in the red part of the meter, the light turns red and starts flashing. The equation reflects the current state of the ship; each tractor beam is one term in the equation.
Resource bin		Zooples and Zarples in the resource bin can be added to the ship, or they can be dragged to the resource bin from the ship. If Zooples and Zarples have been zeroed out using the additive inverse feature of the tractor beams, they disappear and do not appear in the resource bin.

Typical Game Sequence

1. Isolate the Zarple on the positive side of the wing.
2. Add or remove Zooples evenly on both sides.
3. Align tractor beams (use the additive inverse) to simplify the equation and remove excess Zooples/Zarples.
4. Simplify the Zooples on the side opposite the Zarple so the Zooples are either all on the top or all on the bottom of the wing.

Links to Classroom Instruction

Equality

The smiling face on the ship represents equality. As long as both wings have the same mathematical value—that is, the two sides of the ship are balanced—the face is happy. This has the same meaning as the equals sign in a mathematical equation.

Addition and Subtraction

In the game, addition means that something is added to a wing, whereas subtraction means that something has been taken away from a wing. Just like in math, addition and subtraction are operators. They should not be confused with positive and negative numbers. While subtraction will produce the same value as adding the opposite, subtraction is not the same as negation and the two are very distinct in the game.

Division

Division can be interpreted as partitive (how many groups should be made) or measurement (how many items should be put into each group). In Zooples, the partitive meaning of division is stressed. In other words, when both sides of the equation $3x = 12$ is divided into three groups, each of the three groups on the left side will have an x and each of the three groups on the right side will have four ones. The goal is to have students see that in this case: (a) each x is the same as four ones; and (b) as a consequence, removing an x from one side and four ones from the other will keep the ship in balance. This is slightly different from solving the equation symbolically where the remaining, equivalent groups are ignored since they exactly duplicate the solution.

Positive and Negative Numbers

The game reinforces that positive and negative numbers are opposites by using Zooples and Zarples oriented in opposite directions and allowing students to attach different types of Zooples and Zarples to one side of the wing. Positive Zooples and Zarples can only be attached on the top of the wing; negative Zooples and Zarples can only be attached on the bottom of the

wing. Just like in math, the sign of Zooples and Zarples should not be confused with the operations of addition and subtraction; however, students may begin to see that subtraction of a negative Zoople or Zarple is mathematically equivalent to adding a positive Zoople or Zarple, respectively, or that subtraction of a positive Zoople or Zarple is mathematically equivalent to adding a negative Zoople or Zarple, respectively.

The Additive Inverse and Additive Identity

A key idea developed in Zooples is that adding a number and its opposite is equivalent to zero (additive inverse) and adding zero to any value does not change that value (additive identity). These concepts can be combined in the game so that one can add a positive Zoople and a negative Zoople to one side of the ship and not change the balance. This understanding is critical to the game and in understanding how to transform algebraic equations. Students will have to use these concepts, along with addition and subtraction, to complete various levels in the game.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

EXPRESSO



Key Features

- Single-player game with 43 levels
- Stand-alone application that does not use the Web or require network connectivity
- Option for player selection of levels
- Puzzle genre

Math Learning Goals

- Provide students with practice applying different operations (addition, subtraction, multiplication, and division) and order of operations to form complex expressions.

About the Game

Espresso is a puzzle game about the manipulation of expressions. The student is presented with a limited set of ingredients and tools. They must use these resources to fill a given order in a specific format. Each ingredient, or element, represents a small expression and may contain any


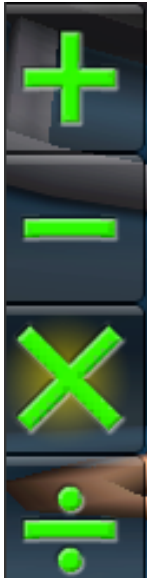



combination of positive or negative whole numbers and variables. The tools provided to the player come in the form of machines and represent the arithmetic operators. Each machine may require one or two elements to be placed on the machine's locators before it can be operated. The order is represented as a mathematical expression, and the format of the order is restricted by the number of answer balls the player is required to fill.


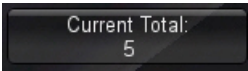

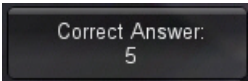
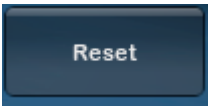
Early levels of the game require the player to manipulate a small number of elements with only one or two machines to create simple expressions. As the game progresses, new mathematical concepts and techniques are introduced and practiced. In later levels, the orders become more complex and require creative manipulations of the elements. This challenging problem-solving environment requires the player to explore the meaning of each operator and the rules governing the order of operations.

Game Components

Table 5

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Elements		Elements are the green balls with smaller objects orbiting them. The elements can represent a combination of numbers and variables. Small bright green spheres orbiting an element represent a one. Bright green spheres that grow larger and smaller while orbiting an element represent an x variable. Orbiting cubes that scale in size represent a y variable. If the orbiting object is black, then it represents a negative. Touching an element will reveal the value of that element.
Machine Selection		The Machine Selection is where the player selects which machine is currently active. The four green symbols on the left show which machines are available. The active machine's symbol has a yellow highlight behind it. Symbols for machines that are unavailable are gray. The "Uses" field below each machine displays the number of times the machine can be used in the current level. Once the "Uses" count reaches zero, the machine breaks and can no longer be used.
Addition Machine		The Addition Machine has two platforms that can be filled with elements. When both platforms are occupied, touching the machine will combine the two elements into a single element with a value equal to the total value of the two input elements.
Subtraction Machine		The Subtraction Machine has two platforms that can be filled with elements. When one or both platforms are occupied, touching the machine will result in a single element with a value equal to the value of the left element minus the value of the right element. Touching the machine while leaving the left platform empty subtracts the right element from zero and makes the element negative.
Multiplication Machine		The Multiplication Machine has one platform that can be filled with an element. It also has an up and down arrow. These arrows control the "Parameter" value displayed at the machine's center. When the platform is occupied, touching the machine will create a number of copies of the input element. The number of copies is specified by the Parameter value.

Game element	User interface element	Description
Division Machine		The Division Machine has one platform that can be filled with an element. It also has an up and down arrow. These arrows control the “Parameter” value displayed at the machine’s center. When the platform is occupied, touching the machine will transform the input element into an element with a value equal to the initial value divided by the Parameter. The machine will not work if the answer is not an integer.
Current Total button		The <i>Current Total</i> button shows the player how many x’s, y’s and ones are currently present in all the elements on screen. Pressing the <i>Current Total</i> button submits the current answer. A correct answer results in a victory effect and lets the player advance to the next level. An incorrect answer flashes any unoccupied answer balls, and any elements not occupying an answer ball.
Answer Balls		The Answer Balls are the green and gold spheres on the right of the screen. When the player has finished transforming an element, the element can be dragged onto the answer ball. This covers the answer ball and informs the player that an answer is in place.
Correct Answer button		The <i>Correct Answer</i> button in a level tells the player the required total value in all the elements. For a correct order to be accepted, all of the elements must be placed on the Answer Balls with no extra elements left over. Pressing the <i>Correct Answer</i> button also submits the current answer.
Reset button		The <i>Reset</i> button allows the player to put the level back in its initial configuration. This is a useful option if the player gets stuck or makes a mistake.

Typical Game Sequence

1. Determine number and type of resources available for the level.
2. Determine the number of pieces the answer is broken into.
3. Define the operations needed and the order of operations.
4. Place the elements on the machine (addition, subtraction, multiplication, or division machines) and activate the machine by touching it. Review the descriptions in Table 5 for the different machines and how to specify machine inputs.
5. When the correct answer is created, place the elements on the answer balls.
6. Press the order button.

Links to Classroom Instruction

Addition

Addition allows us to combine things together. If the things are identical, the result of adding can be expressed as a single term. For example, two ones plus five ones is seven ones, but

$2 + x$ can't be expressed as a single term. While these ideas can be expressed as “combine like terms” we feel it is important for students to understand the reason behind such a statement and relate this idea to the way addition is used throughout the domain of mathematics (e.g., miles and miles per hour cannot be combined into a single term unless one or both are “converted” into equivalent quantities with like units). Addition is commutative so the order two things are added does not matter. Addition is associative so when three or more numbers are added, the sum is the same regardless of the grouping of the addends. For example, $(2 + 3) + 4 = 2 + (3 + 4)$; in both expressions, the result is 9.

Subtraction

Subtraction allows us to take one quantity away from another, or to find the difference between two quantities. The subtraction of two quantities can be rewritten as an equivalent addition using the additive identity and additive inverse properties. In the game, a quantity can be made negative by subtracting the quantity from zero. Subtraction can be used to undo an addition but is not commutative. Consequently, the order things are subtracted is important.

Multiplication

Multiplication can be thought of as representing a certain number of groups with the same number of things in each group. While this can be represented as repeated addition when the multiplier is an integer, the repeated addition model can have shortcomings when the multiplier is a fraction. Among these shortcomings is that a repeated addition model can lead to the belief that multiplication always makes a quantity larger. Students should realize that, even in the case of integer multiplication, multiplication of a negative number by a positive multiplier can make the result (product) smaller than either the multiplier or multiplicand. Multiplication is commutative so the order things are multiplied will not affect the result.

Division

Division has two meanings. In partitive division, the divisor tells one how many groups to divide some quantity (dividend) into; in measurement division, the divisor tells one how many things to put in each group and the result (quotient) represents how many whole groups will result. In part, these two meanings result from the fact that division can undo multiplication and the fact that multiplication is commutative (three groups of four produces the same result as four groups of three, so when reversing the process it can be difficult to tell which order was originally used). Unlike multiplication, division is not commutative so the order things are divided is important. Because of limitations in how the results of division are represented, *Expresso* only represents partitive division. Moreover, because of the desire to integrate previous student understanding, only a single identical group remains after division. For example, when

students divide the quantity $3x + 6$ by 3, three groups of $x + 2$ are shown (partitive division); however, because students expect that the division $(3x + 6) / 3$ should produce $x + 2$, the other two groups of $x + 2$ disappear from the screen after a few seconds.

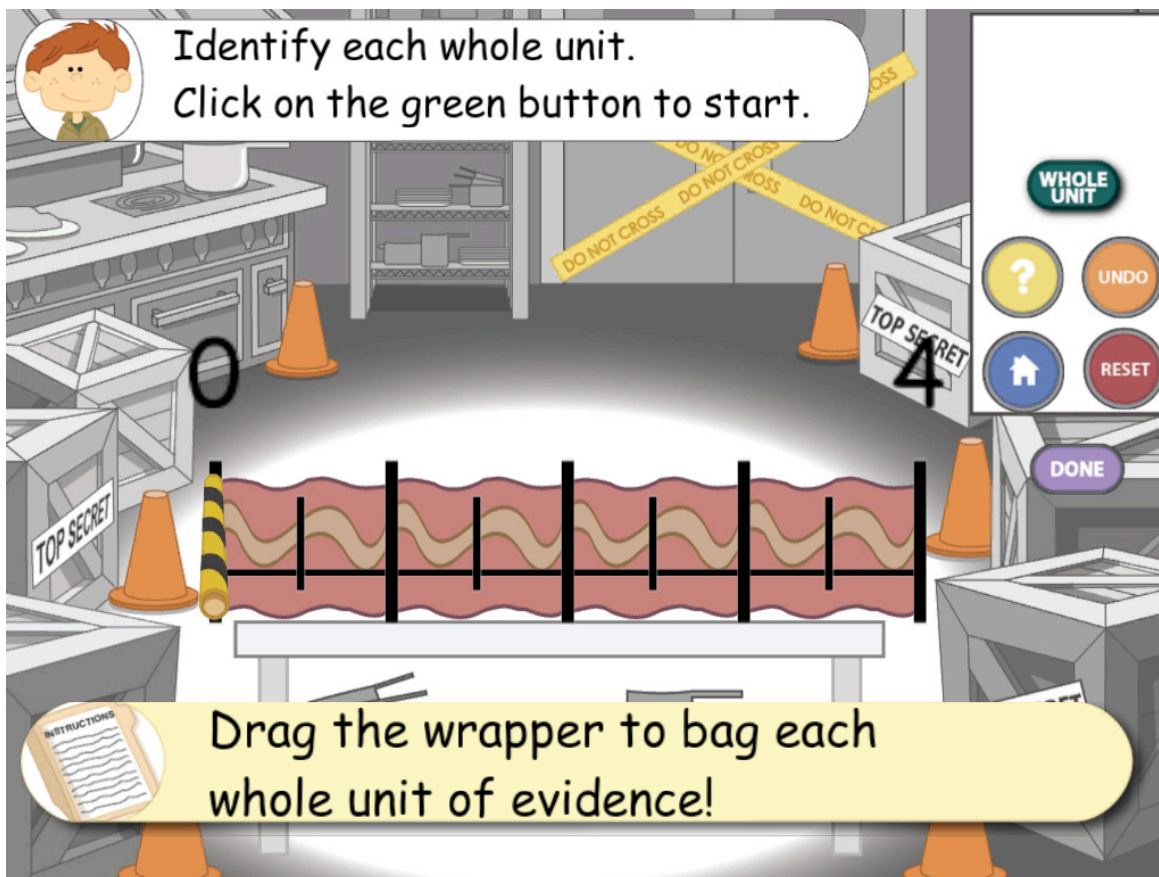
Order of Operations

Students should see that the order they choose to perform operations in the game is important. For example, adding $1 + x$ and then multiplying by 2 will result in two groups of $1 + x$ (a total of $2 + 2x$), but multiplying 2 times x and then adding one will result in two groups of x plus one more (a total of $2x + 1$). The order of the four operations—multiply or divide before adding or subtracting, but add (subtract) or multiply (divide) in order from left to right—can be reinforced as a gaming strategy.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

WIKI JONES



Key Features

- Single-player game with multiple practice levels over five stages
- Stand-alone application that does not use the Web or require network connectivity
- Individualized task sequence within levels based on player performance
- Adventure genre

Math Learning Goals

- Improve students' understanding of the idea of a unit.
- Improve students' understanding of the concepts of the numerator and denominator of a fraction.

About the Game

In the narrative, a detective named Wiki Jones is investigating a mystery in the school cafeteria. Players help Wiki Jones find the perpetrator by performing actions on the number line. The narrative is split into five scenes, with each scene requiring the student to perform a different

task that builds towards writing the fraction represented by the number line. In the first scene, the student must identify the whole unit by bagging each unit of evidence. In the second scene, the student must use a laser to cut each unit of evidence into equal pieces (the denominator) for analysis. In the third scene, the student must follow a recipe that requires a certain number of equal pieces (the numerator). In the fourth scene, the student has tracked the crooks and found they have placed firecrackers in the sprinkler pipes and must therefore locate and defuse the firecrackers given a fraction. In the fifth scene, the crooks are hiding in a library so the student must input a fraction that matches the shaded portion of the number line, so a crane can locate and hoist each crook to be apprehended.

In the first scene, the player only needs to identify the whole unit. In later scenes, the task order is adapted to the player's performance. If players are having trouble with dividing the whole unit or locating the fraction, they are directed to identify each whole unit on the number line first, and then continue with the task in the scene. Detailed descriptions of each scene follow.

In Scene 1 (see Figure 6), students must identify each whole unit by clicking and dragging the black-and-yellow wrapper located at zero. Students must drag all the way to the end of a whole unit and release the mouse—if they stop and start midway through a unit, or double click at the whole unit, they should press the Undo button or Reset button and drag the wrapper again.

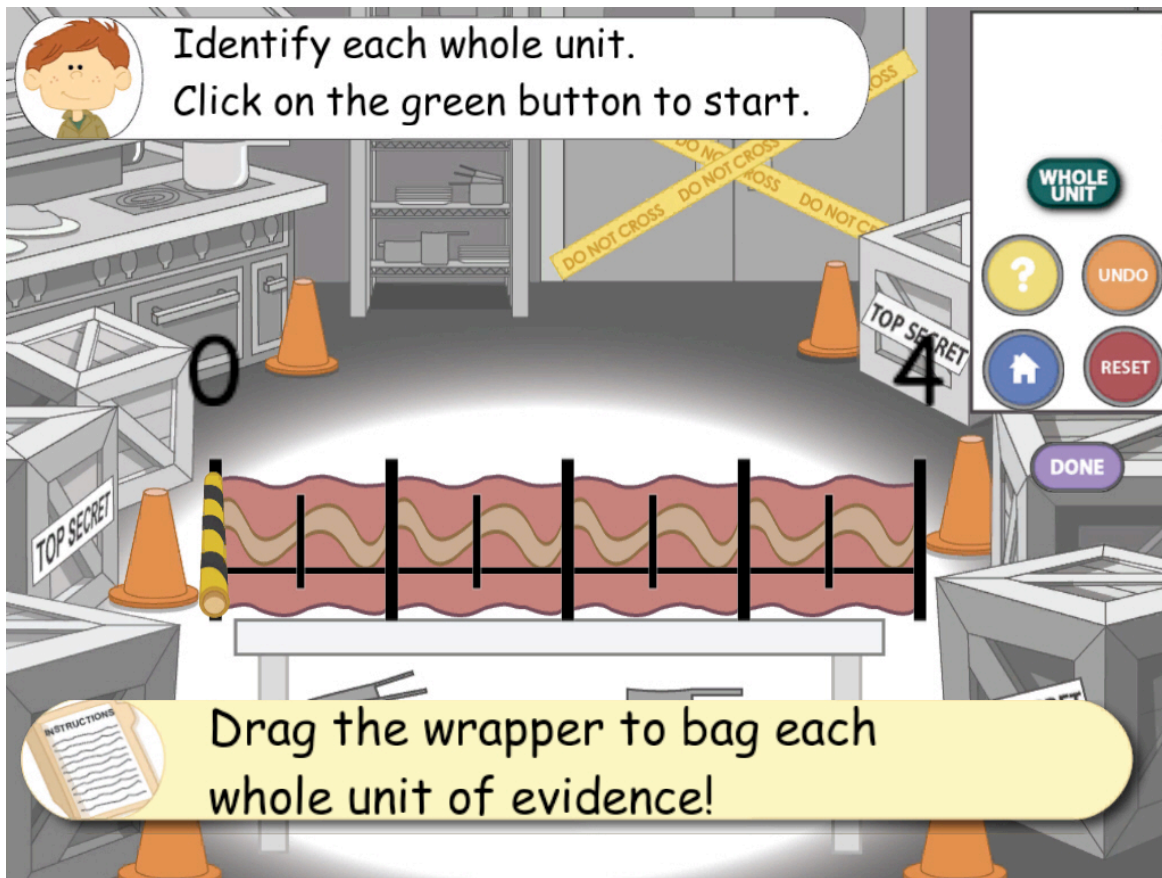


Figure 6. Screen shot of Scene 1 of *Wiki Jones*.

In Scene 2 (see Figure 7), students draw vertical lines to slice the bacon into equal pieces. If the pieces are too unequal, they will be asked to redraw the lines.

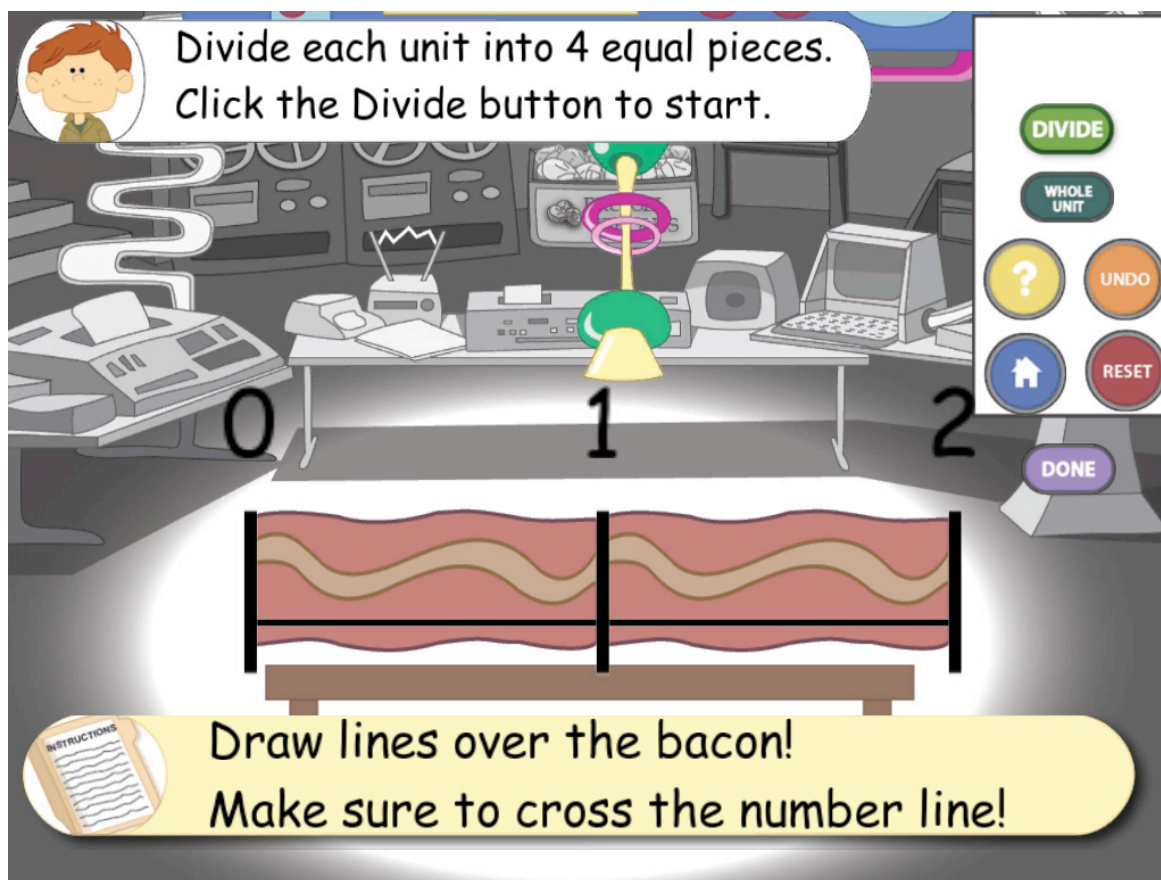


Figure 7. Screen shot of Scene 2 of *Wiki Jones*.

In Scene 3 (see Figure 8), students drag the handle of the machine to the location specified. Each whole unit is correctly divided for the student; this scene provides practice on the meaning of the numerator.

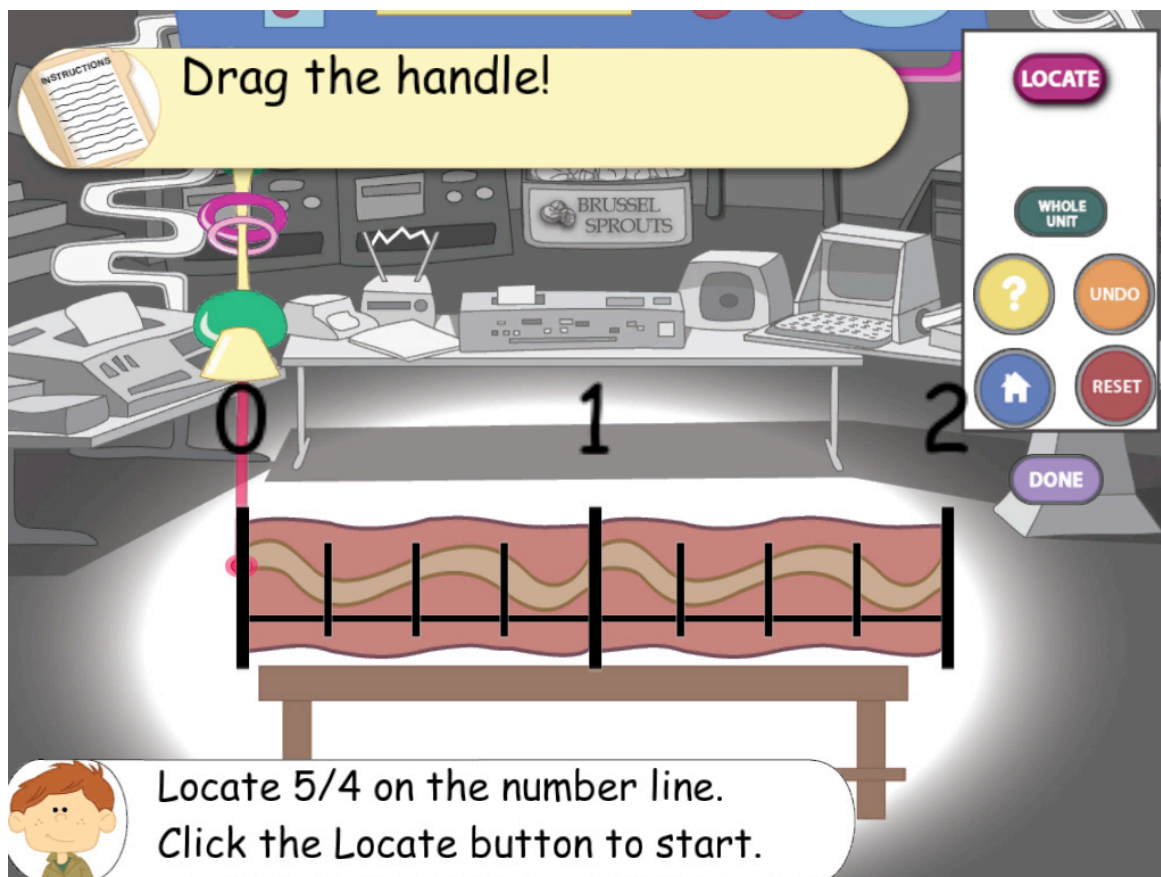


Figure 8. Screen shot of Scene 3 of *Wiki Jones*.

In Scene 4 (see Figure 9), students must perform two actions: first divide each whole unit, and then drag the handle of the defuser to the location specified.

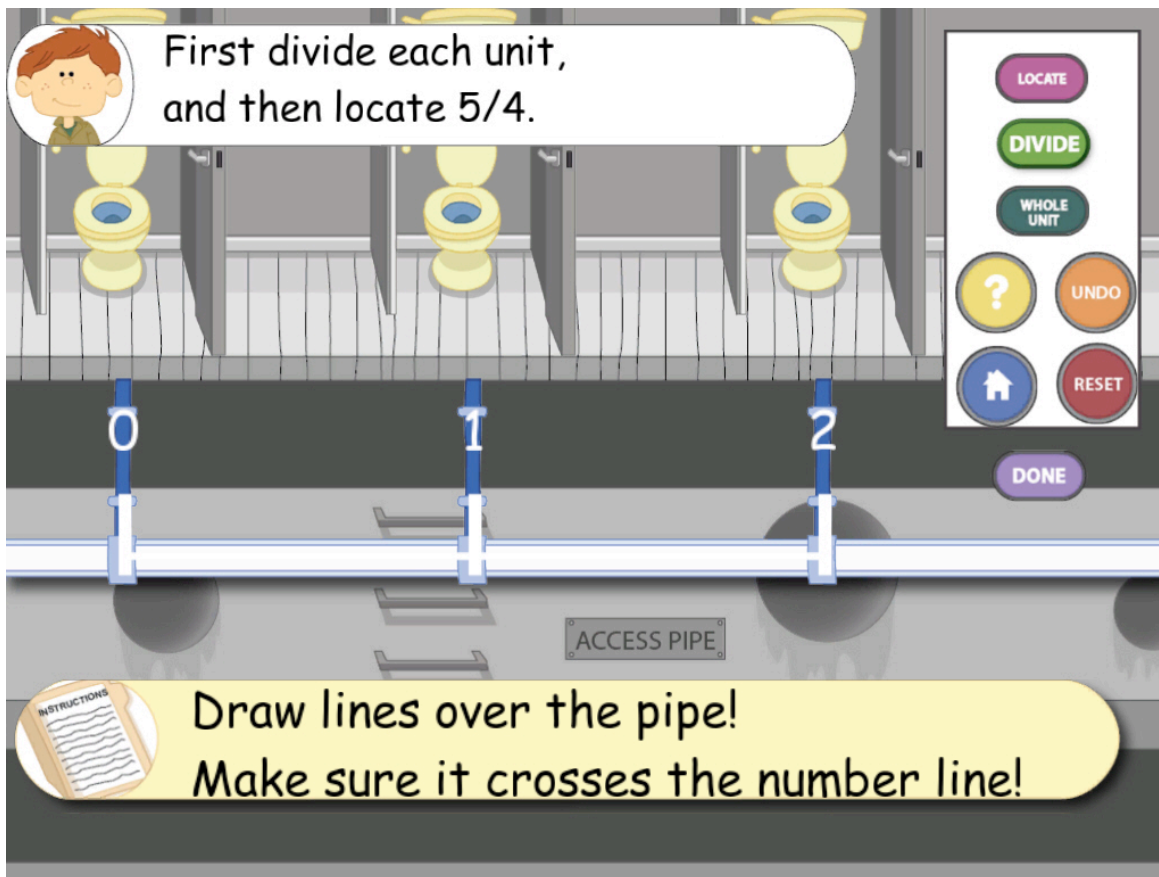


Figure 9. Screen shot of Scene 4 of *Wiki Jones*.

In Scene 5 (see Figure 10), students must enter the fraction depicted by the highlighted part of the number line. The crane moves to whatever fraction the student has entered and attempts to grab the crook. Students must enter the fraction exactly as depicted in the number line, and not an equivalent fraction (e.g., must enter $\frac{4}{6}$ instead of $\frac{2}{3}$ if the whole unit is divided into sixths).

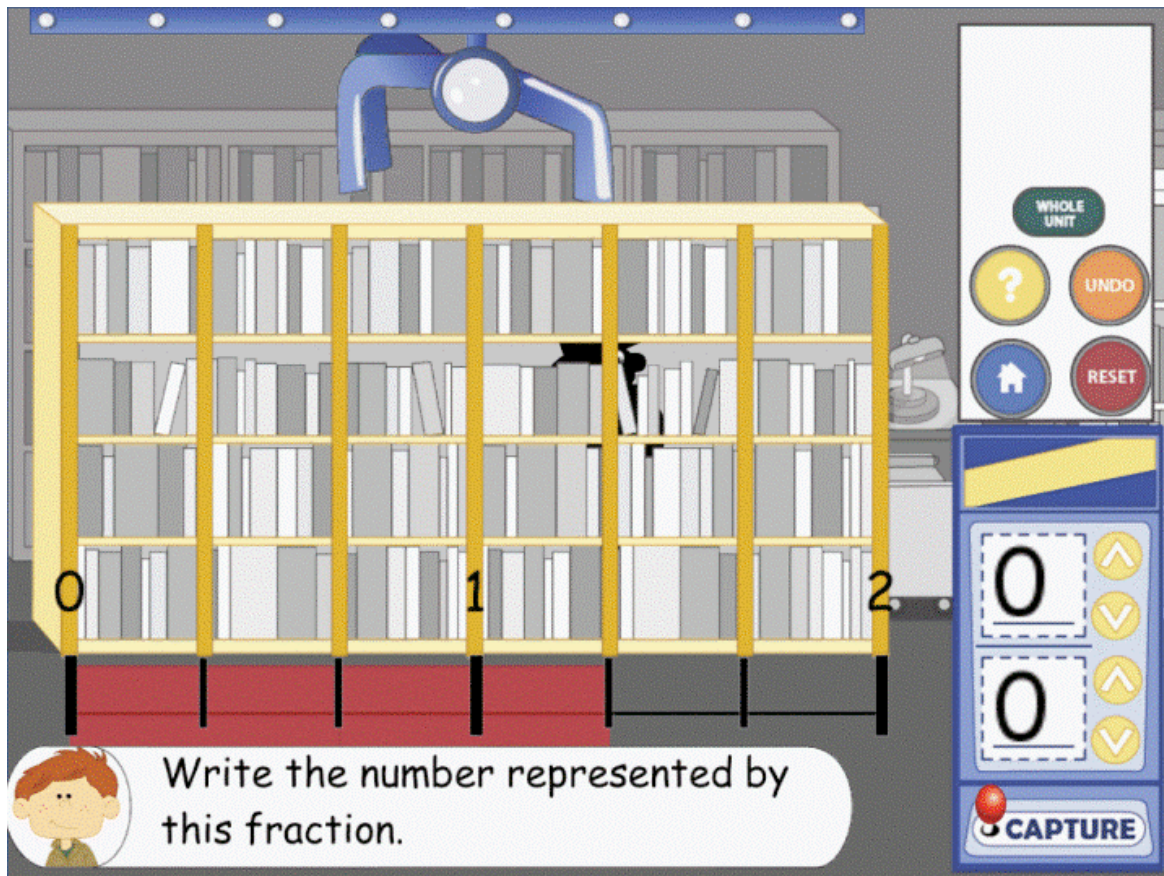







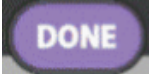


Figure 10. Screen shot of Scene 5 of Wiki Jones.

Game Components

Table 6

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Whole Unit		The <i>Whole Unit</i> button allows the player to identify each whole unit on the number line.
Divide		The <i>Divide</i> button allows the player to divide each unit into the appropriate number of fractional pieces.
Locate		The <i>Locate</i> button allows the player to locate a specific number on the number line.
Undo		The <i>Undo</i> button allows the player to undo the most recent move.
Reset		The <i>Reset</i> button allows the player to reset the current level.
Help		If the <i>Help</i> button is pressed, the player will be taken to a help screen.
Home		The <i>Home</i> button allows the player to return to the main menu. In the menu, the player may return to a previously achieved level.
Done		The <i>Done</i> button should be pressed when the player completes a level and is ready to submit an answer.

Typical Game Sequence

1. Identify the whole unit.
2. Divide each whole unit into the required number of pieces (denominator of the fraction).
3. Identify the location of the numerator of the fraction.
4. Generate a fraction that is depicted by the highlighted portion of a number line.

Links to Classroom Instruction

Fractions

This game uses the idea of fractions as measures or lengths. Divisions of the number line are used to emphasize that a point on a number line is named for its distance from zero measured in units. For instance, the number “2” is located 2 units from zero, and $\frac{1}{3}$ is located $\frac{1}{3}$ of 1 unit from zero. The big idea here is that students must understand what one whole unit is before they understand how each of these whole units is divided up.

Whole Units as Fractions

When identifying a fraction greater than or equal to a whole unit, the whole unit means that the number of equal pieces shaded, by definition, matches the number of equal pieces in the unit. For example, the whole unit 1 is equivalent to $\frac{4}{4}$ because if the denominator indicates that each whole unit is divided into four equal pieces and the numerator indicates there are four of these pieces, then that must be equivalent to one whole unit. Each of the integers can be written in exactly the same way.

Locating Numbers

When locating a number on a number line, students must use the length from 0 to 1 to identify the length of one unit. In early levels, the number 1 is shown; in later levels it is implied. When locating a fraction, divide each unit into the number of equal segments denoted by the denominator. For example, a denominator of 3 means to divide each whole unit into 3 equal segments. Each of the segments is a length of $\frac{1}{3}$ of the whole unit, and there are three of them in each whole unit. Note that the only point named $\frac{1}{3}$ is the point that is this length from 0. After dividing the unit appropriately, look at the numerator to know how many of these segments to include in the length from 0. For instance, to locate $\frac{2}{3}$, we need to start at 0 and move to the right by 2 of the $\frac{1}{3}$ segments. If the number line displays more than one whole unit, the denominator applies to each unit on the number line. For example, a number line that displays 4 units with a denominator of 3 will have 12 equal $\frac{1}{3}$ segments.

Naming Numbers

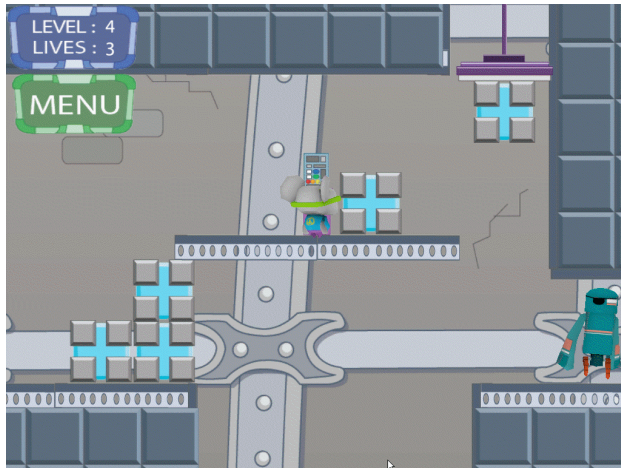
When using a number line it is important to notice which numbers are already labeled. If 0 and 1 are labeled and the point to be named is located between them, look at the number of equal sized segments between 0 and 1. The name of the point is based on how many segments the unit has been divided into (the denominator) and how many of those segments are included in the length (the numerator) from 0 to the particular point. Sometimes more equal divisions need to be created in order to determine the name of the point. Note that it is not necessary for 0 and 1 to be

labeled (any two numbers could be labeled), but it is important for students to be able to identify what one whole unit is in order to correctly identify fractional pieces on any number line.

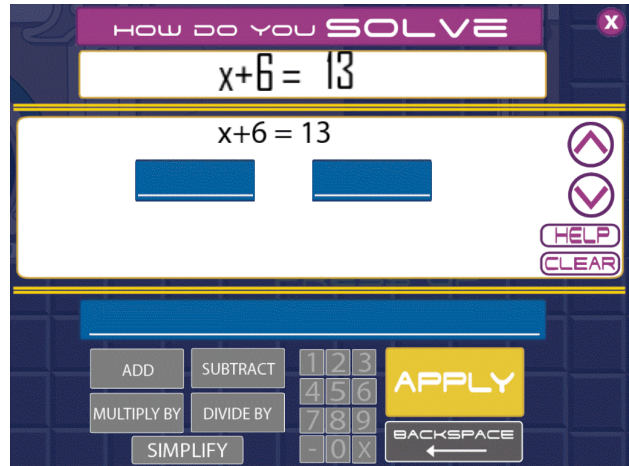
Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

ALGEBROCK



Example level screen



Example equation screen

Key Features

- Single-player game with 8 levels with multiple problems per level
- Stand-alone application that does not use the Web or require network connectivity
- Puzzle-platformer genre

Math Learning Goals

- Improve students' understanding of solving equations.

About the Game

AlgebROCK is a platform game in the domain of solving equations. As students encounter barriers or treasure chests, they are required to correctly solve an equation before proceeding.

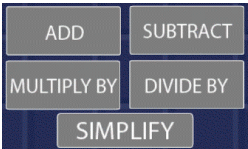




The goal of this game is to collect the band's musical instruments that have been hidden by evil robots. Students run and jump through levels using the keyboard. As students complete the levels, they amass the instruments needed for the band. Students solve algebraic equations in order to pass blockades, collect keys, and recover instruments.

Students use the arrow keys to run and the space bar to jump. To solve equations, students must supply the next steps of the equation to correctly isolate x .

Game Components

Table 7

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Operators		The Operators allow the player to select an operation to use when solving the equation.
Keypad		The keypad buttons allow the player to select a number or variable to use when solving the equation
Apply button		The <i>Apply</i> button allows the player to apply both an operation and a number to both sides of the equation, and to submit the answer.
Backspace button		The <i>Backspace</i> button allows the player to delete text while solving equations.
Help		The <i>Help</i> button allows the player to access help screens.

Typical Game Sequence

1. Find equation access points.
2. Open equation screen.
3. Solve for x .
4. Continue through the level until the next equation access point.

Links to Classroom Instruction

Equality

The equation displays for students to solve. The equality sign signifies that the problem is an equation, and not just an expression. After choosing an operator and a number, students

“apply” these to the equation. The operation is automatically applied to both sides of the equals sign. It is important that students understand why the operation is applied to both sides of the equals sign. For example, with the equation $2x + 2 = 14$, when the “subtract” operator and “2” are selected and the “apply” button is clicked, students will automatically see that 2 is being subtracted on both sides of the equals sign. This built-in feature reinforces the concept that performing the same operation on both sides of the equals sign keeps the equation balanced. To complete the problem and solve for x , students can choose the “divide” operator and “2” and click “apply.” The automated feature will show that 2 is being divided on both sides of the equals sign.

Operators

Students choose the operations (adding, subtracting, multiplying, and dividing) to perform on the equation. Students will automatically see the effects of the order in which these operations are chosen. For example, dividing $3x + 3 = 9$ by 3 will display each component as being divided by 3 rather than just the $3x$.

Inverse Operations

The game uses inverse operations of addition, subtraction, multiplication, and division to emphasize the inverse relationship of the operations. For instance, $24 \div 8 = 3$ because $3 \times 8 = 24$; $20 - 5 = 15$ because $15 + 5 = 20$. The two pairs of statements are inextricably related.

Opposite Effects of Inverse Operations

Adding by 3 can be “undone” by subtracting by 3. Multiplying by 8 can be “undone” by dividing by 8. For example, the equation $5x + 10 = 15$ can be solved several ways. One of the ways is to choose the subtract operator and 10. Since the operation in the given equation is to add 10, to undo the addition of 10 (and work your way toward solving for x), the inverse operation would be to subtract 10. The game’s built-in feature that reinforces the concept of equality will display 10 being subtracted on both sides of the equals sign. Another way to solve the equation is to choose the divide operator and 5. Since the operation in the given equation is to multiply 5 and the unknown x , to undo the operation of multiplying 5, the inverse would be to divide by 5 on both sides of the equals sign.

Getting x by itself

In order to get x by itself in an equation such as $x + 3 = 6$, a student must subtract 3 from both sides. In doing so, the student “makes a zero” with the number 3 on the left side of the equation, leaving x by itself. In multiplication or division equations, the number next to the x must be made into a one. For example, in an equation such as $2x + 2 = 6$, after students subtract 2

from both sides, students must divide each side by 2. Since any number divided by itself makes a one, students are left with $1x$ (or x) on the left side.

Components of an equation

The operation that can be done to a number in the equation can also be done to the variable. For example, in the problem $2 - x = 3$, the variable x may be added to both sides. The problem then becomes $2 = 3 + x$. The variable may appear on either the right side or the left side of the equation.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.

MONSTER LINE



Key Features

- Single-player game with 28 levels
- Stand-alone application that does not use the Web or require network connectivity
- Arcade genre

Math Learning Goals

- Improve students' understanding of negative and positive integer addition, subtraction, and multiplication.

About the Game

In *Monster Line*, various monsters are attacking a city. Their goal is to reach and destroy the tall building which has its location on the number line denoted by a number at the bottom of the screen. In a round, the student fires one or more pie launchers at the monsters. Each pie launcher has an integer (its location on the number line) and an operation associated with it. The student can supply either a positive or negative integer for each pie launcher, with the intent that the resulting sum, difference, product, or quotient will equal the location of one of the monsters on the number line.


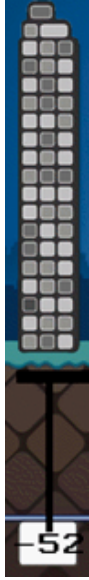
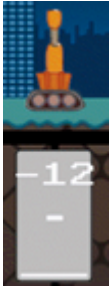
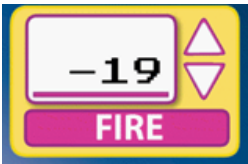

Each round, if a monster is not destroyed by a pie, it moves a certain number of spaces along the number line. Each monster moves a different number of spaces, so some of them will advance more quickly toward the target building. Monsters can also destroy pie launchers if they are allowed to advance along the number line to the location of the launcher.



Each monster may require more than one pie to hit it before being defeated, so depending on the number of pie launchers and monsters in the level, the student may need to go through multiple rounds. Pie launchers with either division or multiplication operators may not be able to be used in every round, but pies launched by these operators will destroy a monster in one hit, so they are more powerful than the subtraction and addition pie launchers, which take three pies before a monster is destroyed.

Game Components

Table 8

Description of Game Elements and User Interface Elements

Game element	User interface element	Description
Monsters		There are one or more monsters in each level. Monsters move towards a target. The goal of the game is to stop the monster(s) from reaching their target.
Tower		The monster's target is the tower. Each level has one tower located at a fixed positive or negative integer on the number line.
Launcher		Pie launchers are used in this game to shoot pies at monsters. To hit a monster, the player must solve the equation and enter the appropriate positive or negative integer to hit the monster. The monsters move after each attempt, therefore, the correct number to input into a launcher will change for each round. Each time the player hits a monster with a pie, it loses a life.
Number selector		The number selector box is used to enter numbers into each launcher equation. Players may enter the number with their keypad or use the up and down arrows to scroll through numbers. Once the desired number is displayed in the number selector box, the player should press "FIRE."
Number of lives		Each monster begins the level with three lives. Each time a monster is hit with a pie from an addition or subtraction launcher, it loses one life. Monsters hit with a division or multiplication launcher are destroyed immediately. A player can display the number of remaining lives for each monster by clicking on the monster.

Game element	User interface element	Description
Menu		The <i>Menu</i> button will return the player to the main menu where levels can be selected.
Score		The player's score is displayed in the score box. The score box is located in the upper left corner of the screen.

Typical Game Sequence

1. Identify correct integer to solve the equation and hit the monster.
2. Enter integer in appropriate space.
3. Repeat for each launcher.
4. Press “FIRE” when complete.

Links to Classroom Instruction

An Unknown

In the game, the unknown is represented by the blank space beneath the integer in the gray box. An unknown represents one or more quantities that allow the expression to be evaluated, but the value of which is, at present, unknown. Since the unknown is a blank in this game, you can suggest to your students to use a symbol or a variable to represent the unknown quantity.

Positive and Negative Numbers

The game reinforces that positive and negative numbers are opposites by positioning the launchers, building, and monsters accordingly on the number line. In the game, most levels do not display the location of zero on the number line. To make sure students are not confused, if both positive and negative numbers are displayed, point out that the positive numbers are always positioned to the right of negative numbers on the number line. It is also important for students to see that numbers get larger as you move farther along to the right on the number line (for example, -9 is located to the right of -19 and so -9 is larger than -19). Students should not confuse the subtraction sign in each gray box with a negative sign; however, students may begin to see that subtraction and negation are related. For example, subtraction of a negative number is mathematically equivalent to adding the opposite of that number or that subtraction of a positive number is mathematically equivalent to adding the opposite of that number.

Addition and Subtraction

In the game, just like in math, addition and subtraction are operators. They should not be confused with positive and negative numbers. While subtraction will produce the same value as adding the opposite, subtraction is not the same as negation.

Division

Division can be interpreted as partitive (how many groups should be made) or measurement (how many items should be put into each group). It may be easier for students to conceptualize different meanings in different situations. For example, in the division $-12 \div -3$, students may find it easier to think about forming groups of -3 (measurement division) rather than forming -3 groups (partitive).

Multiplication

Multiplication can be thought of as the number of groups of a quantity of things. For example, $(2)(5)$ can be thought of as two groups of five. Because multiplication is commutative, this expression can also be seen as five groups of two. It can, at times, be easier for students to see one interpretation more easily than the other.

Expressions and Equations

Simple expressions can be represented using diagrams, number lines, symbols, manipulatives, words, or in other concrete ways. If students are having trouble seeing that the integer, operator, and blank space inside each gray box represent an expression, suggest that they write it another way that makes sense to them (perhaps horizontally). You may also want to point out that the integer for each monster is an expression in itself. For example, the expressions for the screen shot below (see Figure 11) are $-21 - \underline{\hspace{1cm}}$, $3 - \underline{\hspace{1cm}}$, and 48 . Have students rewrite the expressions using variables for the blanks.



Figure 11. Screen shot of sample level in *Monster Line*.

Platform Requirements

Windows XP or later or Mac OS X 10.5 or later, 2GB of RAM, 1GB of hard disk space, screen resolution of at least 1024×768 , and 3D graphics card designed for gaming applications. Machines with lower specifications may experience slow or unstable performance.