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Using Mathematical Games to Align Classroom Materials with the Common Core State Standards

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Mathematics is a subject often dreaded by students in American classrooms. Students often say that they do not enjoy math in school, but when it comes to math in the real world, their answers differ (Boaler, 2008). The disconnect between school mathematics and everyday mathematics causes many students to develop a negative disposition toward math in school. This could be part of why American mathematics achievement pales in comparison to other countries. In an international assessment of forty developed countries, the United States ranked 28th in terms of student mathematical performance and sank to the bottom of the list when spending on education was factored into the calculations (Boaler, 2008).

In order to address this issue, mathematics curricula must attempt to bring aspects of everyday math into school math and help students see how math is evident in the world around us (Boaler, 2008). One method is using game-play to help students see how mathematical concepts are used in more than just the classroom. Additionally, the Common Core State Standards (CCSS) call for more conceptual understanding of mathematics content as opposed to learning the rules. In exploring game-play in mathematics classrooms, the Common Core State Standards, as well as the issue of textbook alignment with the standards, we will attempt to gain a better understanding of how to use games in order to supplement classroom materials and adhere to the Common Core, thus helping students reach a more conceptual, realistic view of mathematics.

Many studies have shown that game-play is an important aspect of the development of children. According to Rieber (1996), play is an integral part of the psychological, social, and intellectual development of a child. Chan, Chen, Cheng, Liao, and Yeh (2012) found that game-based learning facilitated the participation of students in the classroom as well as kept them more engaged in the learning process. Additionally, the study showed that students were more willing

to undertake the activities and had more enjoyable experiences with the lessons when structured in a game-based manner (Chan et al., 2012). Despite these findings, passive learning, where the students primarily listen to the teacher and takes notes on the lecture, is still very common in classrooms (Boaler, 2008).

Passive learning is particularly common in mathematics classrooms, notwithstanding numerous studies showing the effectiveness of game-play in mathematics learning (Boaler, 2008). Giving children puzzles to solve can help encourage them to get into mathematics by making the math more enjoyable and hands-on (Boaler, 2008). Game-based learning can give students the opportunity to deepen their understanding of mathematics (Rutherford, 2015). Two important aspects of mathematics are creativity and guessing, and these concepts are ones that students are often find discomforting (Boaler, 2008). Typical mathematics lessons do not leave much room for guessing or being creative with numbers, so these parts of mathematics are left under-developed. Using a game-based approach could help students become more comfortable with these aspects and develop their understanding of how guessing and creativity are involved in math.

Additionally, playing games involves strategic thinking, which can help students develop the ability to find different approaches to solve problems (Rutherford, 2015). Some games can also support computational fluency with repeated play (Rutherford, 2015). One study found that giving young students from low-income backgrounds the opportunity to play a board game involving counting results in significant, lasting gains in their understanding of numbers (Cavanagh, 2008). Mathematical games can address an array of concepts and help deepen students' understanding. A study by Ke and Grabowski (2007) showed that using mathematical games in the classroom promoted test-based learning achievement. Using mathematical games

also allows for students to practice using their skills and knowledge without necessarily needing a teacher guiding them; this gives the teacher the opportunity to observe students or possibly work with small groups of students while the rest of the class is practicing in an engaged manner (Rutherford, 2015).

Since students are able to play mathematical games without necessitating a teacher to preside over the game, this means that they are also capable of playing these games at home with their families. Many great mathematicians became interested in mathematics due to puzzles and games given to them by family members, which showcases how influential the family can be in student mathematics achievement (Boaler, 2008). Research has shown that parents' beliefs and expectations can greatly affect the children's attitudes towards mathematics and subsequent achievement in the subject (Kessinger, 2014). Therefore, getting parents involved in the children's learning of mathematics can help develop positive dispositions toward the subject and encourage academic achievement (Kessinger, 2014). Using games as a way to get parents involved in student learning creates a school-to-home connection in which parents can help students apply the knowledge learned in school in an interactive way (Rutherford, 2015). Additionally, parents can learn about their children's thinking and help them progress by targeting areas in which their children need support.

Researchers and educators have been trying to address the issue of a lack of conceptual understanding among students in mathematics classrooms. One possible solution is through the implementation of the Common Core State Standards (CCSS). The CCSS were created to focus more on understanding concepts and relationships, as opposed to practicing skills (Confrey & Krupa, 2010). The goal was for proficient students to be able to apply mathematics to everyday problems they might encounter, with less emphasis on memorizing and calculating using

algorithms (Mayes & Koballa, 2012). The CCSS require a student to be able to determine the meaning of a problem and analyze the relationships, goals, and constraints within the problem in order to develop a strategy for finding the solution (Mayes & Koballa, 2012). There is a much greater focus on learning how to problem solve as opposed to learning how to apply algorithms in the hopes that students will not only develop a greater understanding of different relationships within mathematics but also learn how to persevere in mathematics and to enjoy challenges instead of finding challenges discouraging.

The CCSS have now been adopted by 46 states and the District of Columbia (Kohler, Christensen, & Kilgo, 2014). The CCSS outline the concepts that should be taught in each grade and subject of mathematics. However, the CCSS are not a curriculum; they are a set of high points or benchmarks that students should reach in a given year, but the way they are achieved is not mandated (Confrey & Krupa, 2010). Each grade level's standards were written to assume complete mastery of the previous grade level's standards, thus making it very important that those who have adopted the CCSS follow the progression of the standards as they are written (Confrey & Krupa, 2010). The standards were written to be rigorous, internationally competitive standards that narrows the focus of the mathematics taught in schools and are based on evidence from mathematics education research (Confrey & Krupa, 2010). An analysis of the CCSS, previous state standards, and test scores seems to support this notion. States whose previous standards closely aligned with the CCSS tended to have students with higher mathematical achievement and higher test scores on national exams such as the National Assessment of Educational Progress (Robelen, 2012). This shows that states with rigorous, focused standards similar to the CCSS were more successful in mathematics education, which leads to the assumption that the CCSS will have similar results.

As noted previously, the CCSS are not a curriculum. This means that the way a teacher decides to implement the standards is not stated and materials to be used in the classroom are not specified or supplied. Teachers and districts will have to evaluate textbooks in light of the new standards. Textbooks are used in virtually all mathematics classrooms in some form, so it is crucial that these materials be aligned with the standards being implemented. In order to be aligned perfectly, textbooks need to address all of the content in the standards in the specified grade level and no additional material not listed in the standards (Polikoff, 2015). The effects textbooks have on student achievement vary substantially depending on the degree of alignment to the standards, which means that the most effective textbooks are ones aligned with the standards and assessments (Polikoff, 2015). In order for the CCSS to be implemented effectively and raise student achievement, the materials must be high quality and well aligned (Polikoff, 2015). The issue with finding aligned textbooks is that publishers are not required to have their materials systematically evaluated to determine whether they align with the standards or not; publishers can claim their textbooks are Common Core aligned even if the books do not effectively address the standards (Polikoff, 2015).

An analysis by Polikoff (2015) attempted to evaluate some of the commonly used textbooks to determine if they were aligned with the Common Core, as their publishers claimed. In her analysis, she found that the textbooks generally fail to cover conceptual skills. Polikoff (2015) determined that the textbooks emphasized procedures and memorization roughly 30% more than the CCSS, and the textbooks asked students to demonstrate their understanding about 20% less than the CCSS. Additionally, the CCSS call for higher order thinking in approximately 11% of the standards, according to Polikoff (2015), and the textbooks analyzed had zero coverage of these levels of thinking. She also noted that the textbooks were very repetitive

between chapters, thus making the textbooks longer than necessary. This analysis shows how the textbooks that claim to be Common Core aligned aren't necessarily the best materials to be using in the classroom. Teachers must be able to supplement the textbooks with other materials that align with the Common Core and aid in the development of a conceptual understanding of mathematics.

One solution to this issue of the misalignment of classroom materials to the CCSS is to use games that support the standards to supplement the textbooks. Most of the textbooks in the market focus on mastering basic skills instead of understanding, which is a major focus of the CCSS (Devlin, 2013). As previously discussed, games can be used in mathematics to help students better understand the material and the relationships in math, so games could be used to supplement the textbooks in order to reach that goal of the CCSS. Additionally, computational fluency is an expectation of the CCSS, and games can be used as tools for practicing these skills (Rutherford, 2015). Research has shown that the drill techniques used frequently in textbooks are not as effective as mathematical games in this area, so math games could be used as an additional tool to better achieve the CCSS (Rutherford, 2015). There has also been some critique of the CCSS being too rigorous for young learners and disregarding the necessary play-based learning for children (Kohler et al., 2014). Using games in the classroom that address the standards could be beneficial for student development while still addressing the content outlined by the CCSS (Kohler et al., 2014).

In order to effectively use games as supplemental material in the classroom, teachers must be able to look at textbooks with a critical eye and determine the areas that need additional support. This involves looking through the sections of the textbook, classifying the types of problems, and determining whether the problems align with the standards. Once this has been

completed, it should become evident which concepts the textbook addressed well and which concepts need additional coverage. Then, the teacher must be able to determine which educational games would effectively supplement the material and help achieve the CCSS. This process can be a challenge and may be time consuming, but the end product is a curriculum that addresses the concepts and adheres to the CCSS, thus better preparing students for any national examinations and helping them to understand the mathematics.

For example, I went through the process of examining textbooks and determining mathematical games to be used as supplemental material. I assessed *Glencoe Math: Your Common Core Edition*, an eighth grade mathematics textbook (Carter, Cuevas, Malloy, & Day, 2013). I focused on the chapters on transformational geometry (chapters 6 and 7), for this is a relatively new topic for eighth grade that is prevalent in the CCSS. I evaluated the textbook on types of problems, concepts the problems addressed, and whether the problems were Common Core aligned.

Through my analysis, I discovered that out of 414 author examples or student problems, only 14 directly stated CCSS that the problem was addressing. Of the 14 specific Common Core problems, only two problems ask students to describe, analyze, explain, or justify their answers. This shows that the majority of the problems that claimed to be Common Core aligned only skimmed the surface of the mathematics and focused on the procedures as opposed to focusing on conceptual understanding of the mathematics. These 14 problems were specifically chosen by the publishers to be representative of the content in the CCSS, yet the problems do not develop the conceptual aspects of the mathematics. While there were more problems in the textbook that align to some of the standards, these problems were primarily procedural and were not emphasized by the publishers. Approximately 37% of the problems in the textbook asked

students to describe, explain, or analyze the mathematics. These problems asked for more than just numerical or symbolic answers, which shows the textbook is striving to obtain a more conceptual understanding of mathematics. However, a majority of these problems were not Common Core aligned.

Additionally, 59 of the problems and examples, or approximately 14%, stated Standards for Mathematical Practice (SMP), which is a section of the CCSS that lists general mathematics skills and practices that students should develop. Of these 59 problems, 36 call for students to provide descriptions or explanations of their work. Furthermore, there are four CCSS dealing with transformational geometry in the eighth grade curriculum, yet only three of these are mentioned in the textbook. Also, there is one seventh grade CCSS mentioned on multiple occasions, which shows that the textbook is not correctly aligned because it contains standards from a different grade. Overall, the *Glencoe Math: Your Common Core Edition* textbook was not very aligned with the Common Core, despite its claims, because it failed to develop a conceptual understanding of the content, only dealt with the procedural aspects of the standards, and did not address all of the related standards in the appropriate grade level.

In order to enhance this textbook, games from the *Adventures with Mathematics* books can be used. For instance, lesson 2 of chapter 6 of the text focuses on reflections and briefly mentions the concept of a line of symmetry. In the book, the students are asked to draw an Easter egg that has symmetry, which is followed by a definition of “line of symmetry.” The concept is not very well developed since the students are merely told what the term means. Instead of using the Easter egg activity, a teacher could use the activity “Knot Your Average Geometry” from *Adventures with Mathematics* (Beckmann, 2010). In this activity, students are given various images of Celtic Knots. They are asked to make copies of one of the knots and

create new patterns in which there are one, two, three, or four lines of symmetry, in addition to finding various rotational symmetries. Then, students are asked to find a relationship between lines of symmetry and rotational symmetry. This activity allows students to explore the concepts of line and rotational symmetry and see connections in the mathematics, instead of being told the definitions. This activity would better align the lesson with the SMPs of "Model with Mathematics" and "Look for and Make Use of Structure" due to it's use of the structure of Celtic knots and finding mathematical relationships within the knots. It also builds upon CCSS 8.G.A.1 by using exploratory methods to find properties of rotations and relationships with symmetry ("CCSS," 2010).

Lessons 1, 2, and 3 in chapter 6 of *Glencoe Math: Your Common Core Edition* focus on translations, rotations, and reflections, respectively. While these lessons have many problems for students to understand the procedure of the transformations, the problems all look very similar and most are used in the same context. There is little opportunity to apply any of the knowledge gained through the author examples and numerous student problems. Using the games "Toto's Tornado" and "The Ultimate Transformer" from *Adventures with Mathematics* gives the students the opportunity to use their knowledge of translations, rotations, and reflections in a different setting in order to obtain a goal (Stapert, 2010; Novotny & Beckmann, 2012). These games have different objectives, but both involve moving pieces about a game board in order to reach a certain finishing point using translations, rotations, and reflections. Therefore, there is some strategy involved in addition to performing the transformations correctly. Students must predict and visualize where certain transformations would bring them in order to determine which route to take. These games would help develop SMPs "Model with Mathematics" and "Attend to Precision" because the students are required to use their mathematical knowledge in board games

and they must carefully transform their pieces. Additionally, the activities further progress the CCSS 8.G.A.1 by having students use reflections, translations, and rotations strategically to reach a finishing point (“CCSS,” 2010).

The concepts of dilations and scale factors are found in lesson 4 of chapter 6 of the textbook. In this section, the focus is primarily on applying the rule for finding the coordinates of the dilated image using the scale factor and drawing the figures in grids. There is little emphasis on how dilations can be used in the real world and very few discovery-based problems in this lesson. The activity “Set Designs for Hagrid” from *Adventures with Mathematics* can help students recognize how to use dilations in a setting other than a mathematics classroom (Churchill, Burdick, & Beckmann, 2011). In this activity, students are asked to find various measurements of household items and scale them so that the items could be used in a movie scene to make the actor who plays Hagrid, a giant from the *Harry Potter* series, appear to be larger than his surroundings. The questions in the activity help students develop the concept of scale factors and explore how some dilations make objects larger, whereas other dilations make objects smaller. It also asks questions about patterns and relationships in the data collected and discovered by the student, which helps build a conceptual understanding of the mathematics involved in dilations. This activity supports the SMPs of “Reason Abstractly and Quantitatively” and “Attend to Precision,” since it involves finding relationships in quantitative data and contextualizing the data and the students must be accurate in their measurements. In terms of CCSS, this activity addresses 8.G.A.3 and 8.G.A.4 by building foundational knowledge about how dilations and scale factors function (“CCSS,” 2010).

Throughout both chapters 6 and 7 of the *Glencoe Math: Your Common Core Edition* textbook, the concepts of congruence and similarity are developed through the use of

translations, rotations, reflections, and dilations. At the culmination of these chapters, the students should have a firm grasp on what it means for figures to be congruent or similar, and how to determine whether figures are congruent or similar by using various transformations accurately. In order to get students thinking about these relationships and testing their knowledge, they can play the game “You Don’t Say” from *Adventures in Mathematics* (Beckmann, Thompson, & Hollenbeck, 2010). In “You Don’t Say,” students have to describe different words dealing with transformational geometry without saying the most commonly used words related to that topic. This forces the students to think of other relationships and connections within the topic in order for their partner to be able to guess the word. “You Don’t Say” would help students recognize how interrelated the concepts are and help them explore other ways to use the mathematics. This game can address any of the CCSS based on what words or phrases are used, and it also helps develop the SMP “Construct Viable Arguments and Critique the Reasoning of Others” because students have to use results, definitions, and assumptions they know about the topic in order to construct logical statements and phrases that will be beneficial for their partners.

Another game that can be used to address the concepts from both chapters 6 and 7 is “Destination Transformation,” which is a game I constructed for this topic (see Appendix). In this game, students must be able to accurately perform various transformations, as well as answer questions about different relationships within the content area of transformational geometry in order to reach a finishing point. This game includes translations, rotations, and reflections, as well as questions about dilations, isometries, congruence, and similarity. “Destination Transformation” supports the SMPs “Make Sense of Problems and Persevere in Solving Them” and “Attend to Precision” because students must be able to determine the appropriate

transformation and complete it correctly. Also, this activity would supplement the textbook in CCSS 8.G.A.1-8.G.A.4 because it involves various transformations and the connections they have to similarity and congruence ("CCSS," 2010). Thus, this game would enhance the textbook because students would have opportunities to put the procedures they learned to use and to discover connections between the concepts.

As the Common Core State Standards continue to be implemented into American classrooms, the need for aligned classroom materials grows. The CCSS strive for students to obtain a conceptual understanding of the mathematical content in order to improve our country's mathematical performance. However, the textbooks in circulation do not adhere to this aspect of the standards and remain primarily procedural. Teachers must be able to supplement the textbooks used in the classroom in order to achieve a deeper understanding of mathematics, and one way to accomplish this goal is through the use of mathematical games. There have been numerous studies done to show the benefits of using games in the classroom and at home to help further learning, thus making the use of mathematical games a viable option for supplementing a classroom curriculum that is Common Core aligned.

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APPENDIX

Destination Transformation

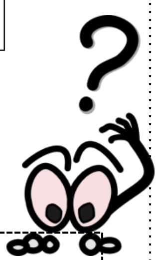
Flip, turn, and slide your way to the finish! Use your knowledge of transformations to reach your destination

Why:

Strand:

Number & Quantity	
Algebra	
Functions	
Geometry	x
Statistics & Probability	

How:



What:

Materials Needed:
- Scissors
- Glue/Tape
- Game board
- Question cards
- Player pieces
- 1 die

Where:

Outside	
Inside	X
On-line	
On-site	

Set-Up:
- Print and assemble game board and player pieces
- Print and cut out question cards

Object of the Activity: Reach the "FINISH" area by successfully completing transformations and answering questions

Playing the Game:
1. The player whose birthday is closest goes first.
2. Begin on "START" with your piece "Heads" side up.
3. Roll the die, then move your piece forward however many spaces you rolled.
4. When you land on a space, you must complete the transformation stated or answer a question from the question card pile.
   a. Reflection and Rotation spaces: Follow the directions stated on the space.
   b. Translation Spaces: After you translate your piece, you must state the translation (i.e., 3 spaces right and 2 spaces up).
   c. Question spaces: The other players decide if your answer is correct. If it is, you get to move ahead 2 more spaces. If it is not, you have to move back 1 space. (Do not perform the transformation on the space landed on after answering the question.)
5. The first player to reach the "FINISH" area wins!

If you do not transform the piece correctly:
- The other players should determine in which space the piece would land.
- If the transformation would move you farther in the game, you do not move.
- If the transformation would move you backward in the game, you should move to the space that the transformation would bring you to.

If you cannot move:
- If you roll the die and do not have enough spaces to move your piece, you must remain on that space and wait for your next turn to roll the die again.

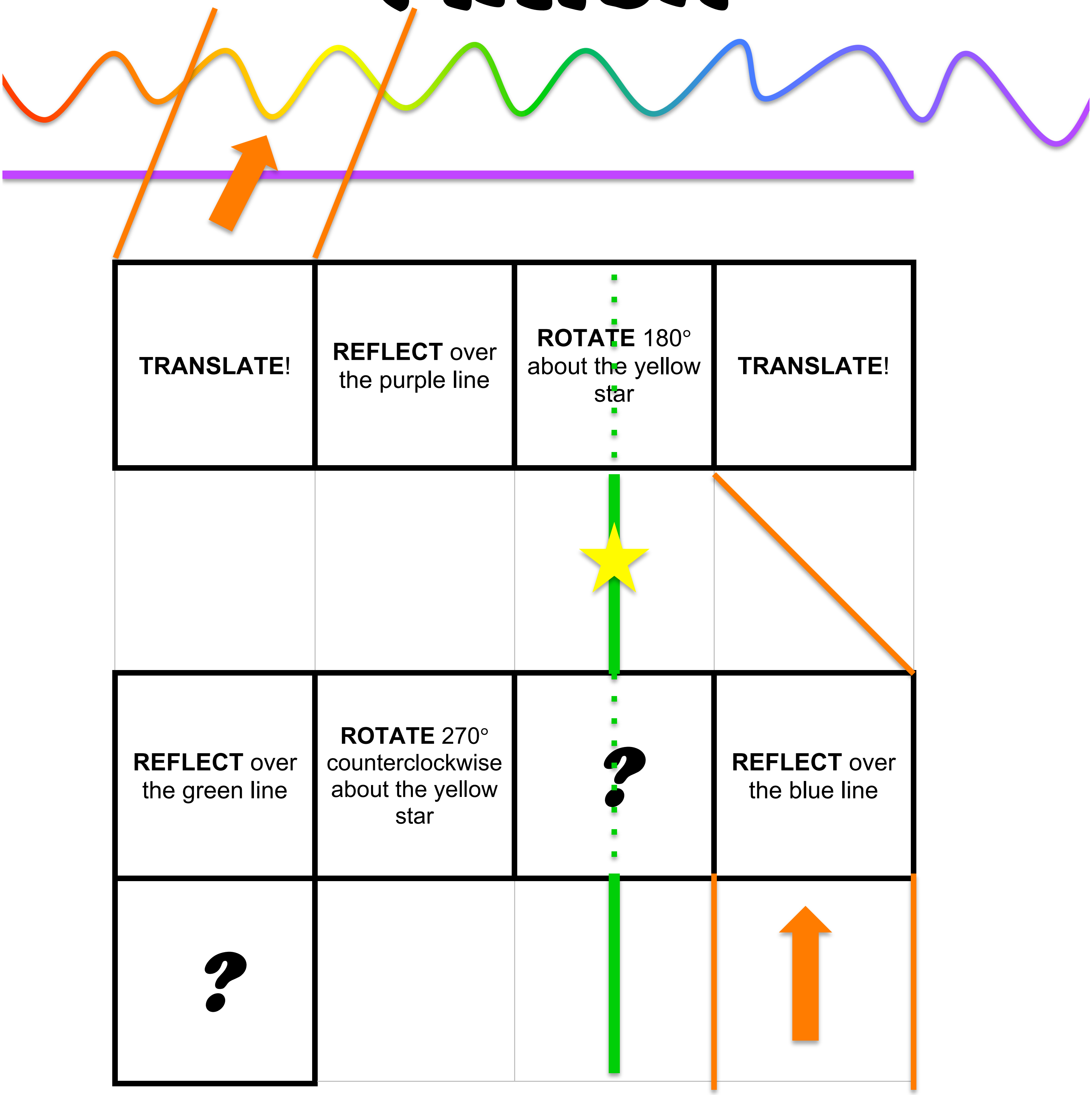
Think About It:
- Why is it important to pay attention to where the corners are?
- Why does the orientation of the game piece matter?
- Why aren't there any dilation spaces in the game?

Variations
- **To win:**
  - **Player must have piece in "FINISH" area with the "Heads" side up.**
  - **Player must have piece in "FINISH" area with corners 1 and 2 on top.**
  - **Player must have piece in "FINISH" area with the "Heads" side up and corners 1 and 2 on top.**
- **Players are allowed to move backward or forward on any turn**

Helpful Hints:
- Always pay attention to where the corners of the pieces are and which side is facing up.
- Watch the other players do their transformations to make sure they are correct and to help you better understand how the pieces are moved.

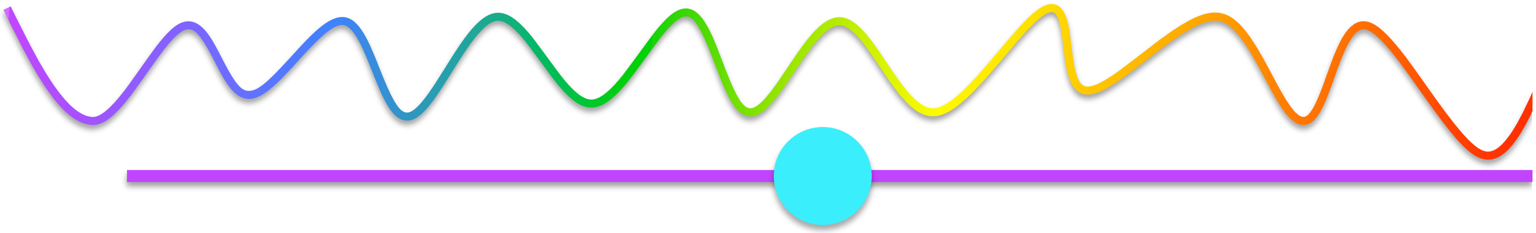
FINISH

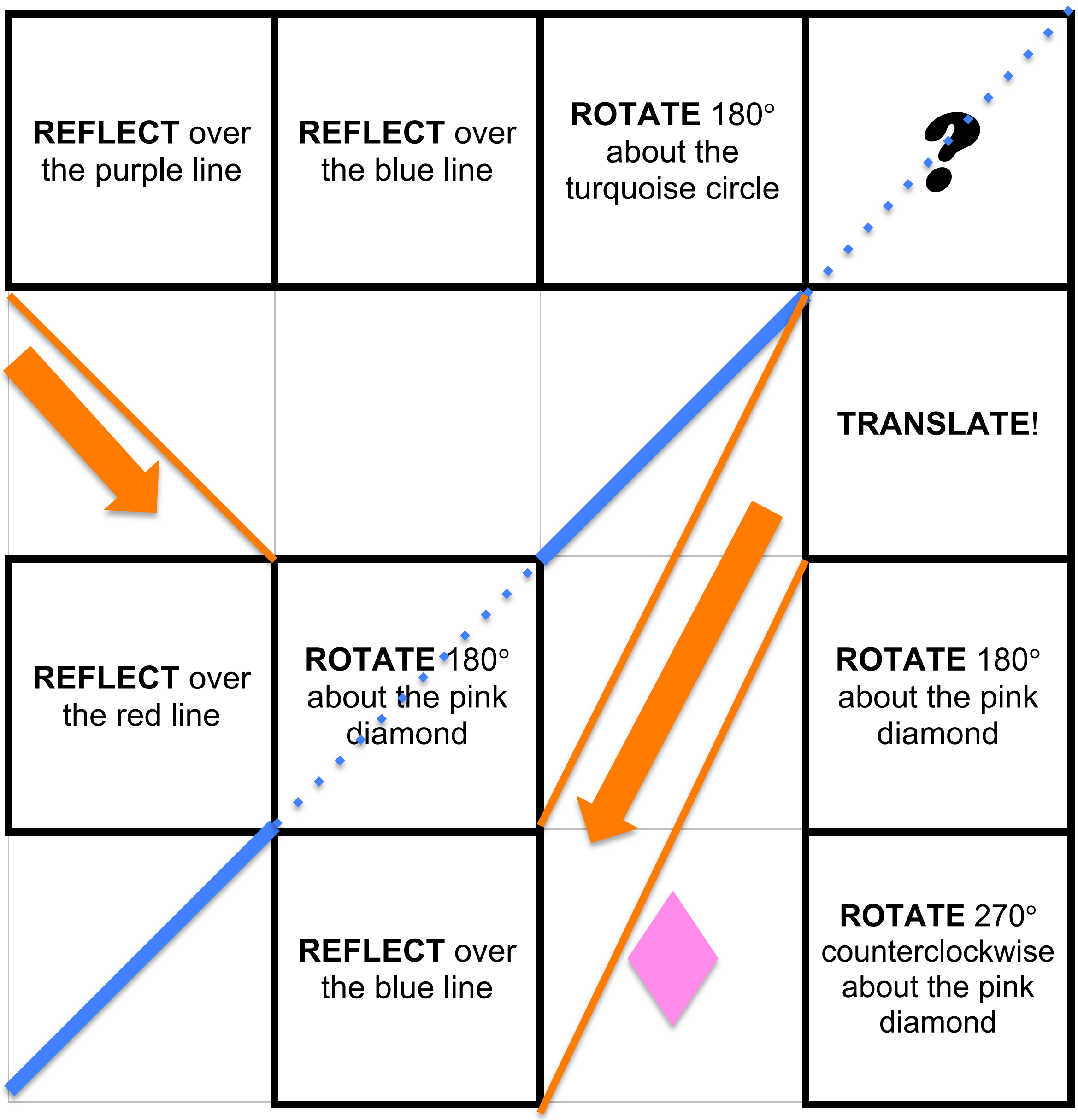
(Top Left)

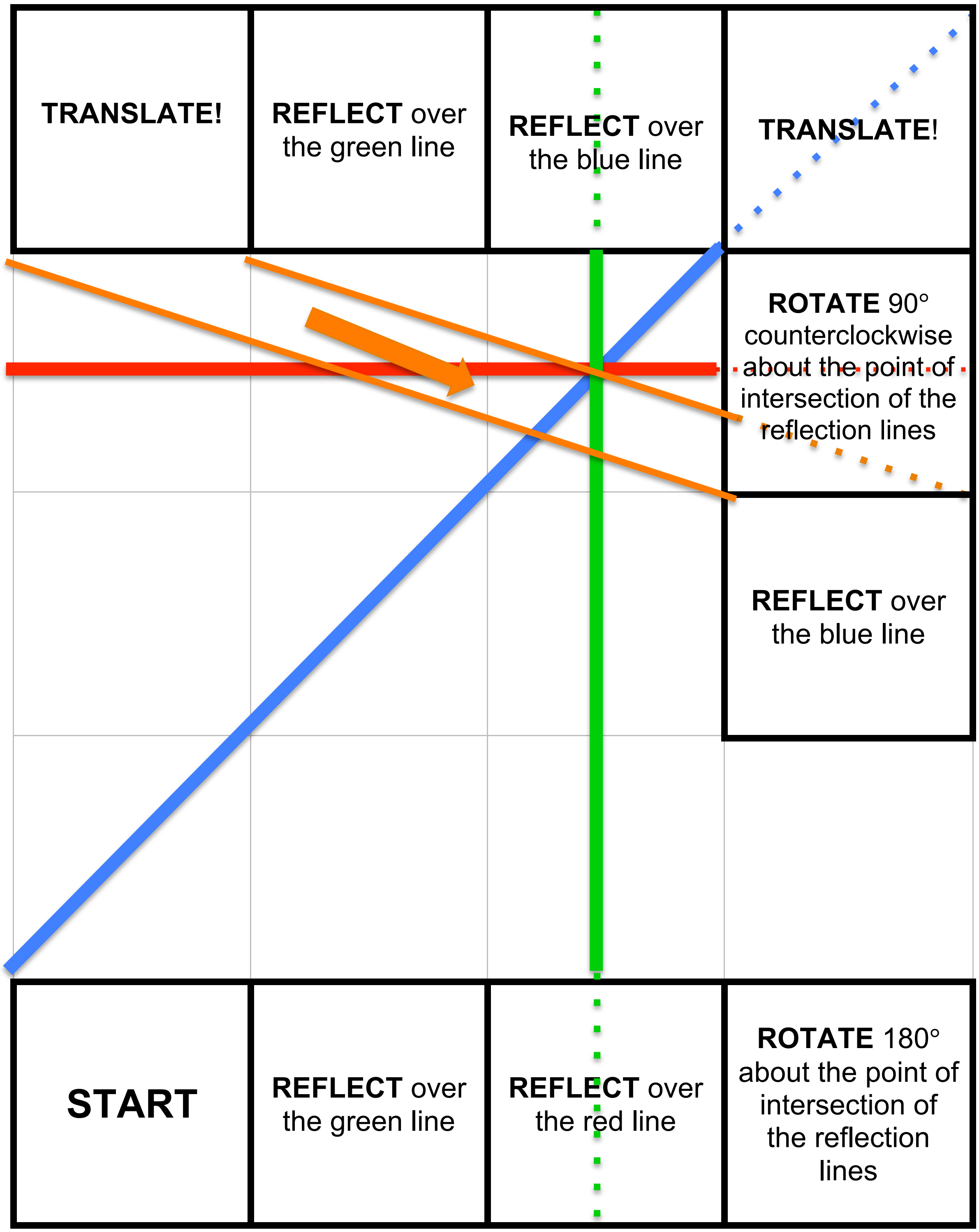


FINISH

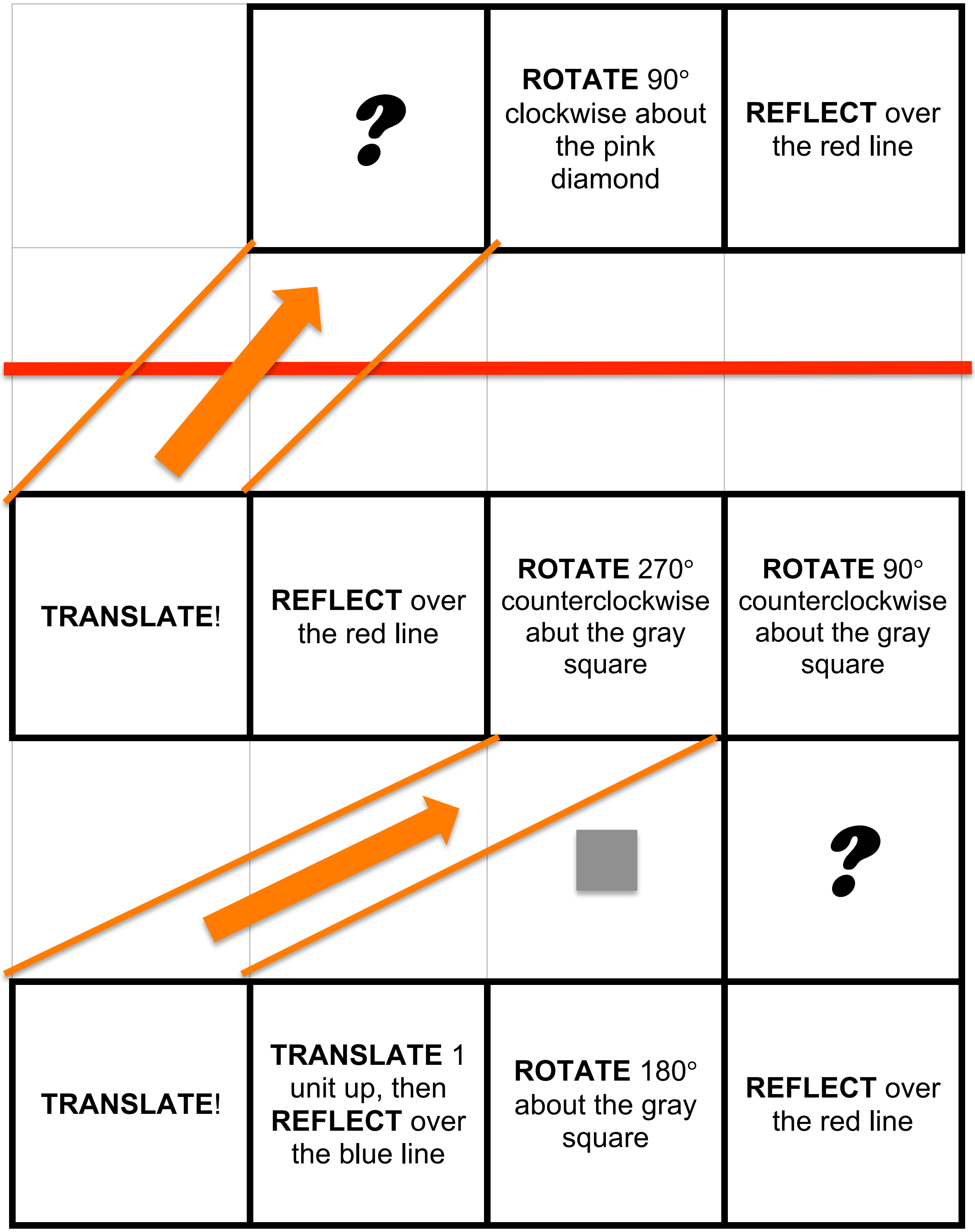
(Top Right)






TRANSLATE!
REFLECT over the green line
REFLECT over the blue line
TRANSLATE!
ROTATE 90° counterclockwise about the point of intersection of the reflection lines
REFLECT over the blue line
START
REFLECT over the green line
REFLECT over the red line
ROTATE 180° about the point of intersection of the reflection lines

(Bottom Left)



(Bottom Right)

What transformation is not an isometry?	Dilation produces what kind of figures?	Isometric transformations produce what kind of figures?
What does it mean if a transformation is an isometry?	When rotating 180°, why don't we have to specify whether the rotation is clockwise or counterclockwise?	A 90° rotation counterclockwise is the same as what clockwise rotation?
Reflecting a figure twice over parallel lines will produce the same image as what single transformation?	In a reflection, the image and preimage are _______ from the line of reflection.	What happens to a figure that is dilated with a scale factor greater than 1?
What happens to a figure that is dilated with a scale factor less than 1?	What measures are preserved in dilations?	How can we use transformations to determine if two figures are congruent?

Demonstrate a half-turn using your body.	What would a 360° turn look like? Demonstrate with your body.	Describe informally what a rotation is/looks like.
Describe informally what a translation is/looks like.	Describe informally what a reflection is/looks like.	Using your hands, can you show what the result of a reflection looks like?
How does a dilation change a figure?	Demonstrate a slide using your body.	Demonstrate a quarter-turn with your body.
What would a 180° turn look like? Demonstrate with your body.	What would a 90° turn look like? Demonstrate with your body.	Demonstrate a three quarter turn with your body.

Front of Player Pieces

1 Heads 2 4 3	1 Heads 2 4 3	1 Heads 2 4 3
1 Heads 2 4 3	1 Heads 2 4 3	1 Heads 2 4 3

Back of Player Pieces (glue or tape to attach)

2 Tails 1 3 4	2 Tails 1 3 4	2 Tails 1 3 4
2 Tails 1 3 4	2 Tails 1 3 4	2 Tails 1 3 4