**High School: Geometry**

***Congruence***

This learning progression will be taught in a high school sophomore geometry classroom. The common core standards that this learning progression aligns with are HSG.CO.A.3, HSG.CO.A.4, and HSG.CO.A.5. This progression also makes use of the following three mathematical practices: MP1: Make sense of problems and persevere in solving them, MP5: Use appropriate tools strategically, and MP6: Attend to precision.

Prior to this learning progression, students will have been introduced to basic geometric shapes. Students will be familiar with much of the vocabulary surrounding this lesson. They will know the definitions of each of the following terms: line, line segment, ray, quadrant, angle, etc. This particular learning segment will introduce students to rigid transformations within the plane. This learning progression will begin be students learning the concepts and procedures necessary to complete each of the rigid transformations: translations, reflections, and rotations. Following each of these lessons, students will learn how to combine transformations and whether or not the order of transformations matters. The final lesson of the progression will assess whether or not students can perform compositional transformations on a figure. The order of the progression will allow students to build on their knowledge of geometric vocabulary and previous lessons. This progression will provide students with new conceptual understanding and will prepare them for future learning segments.

To support the learning of all students in the class, students will spend a lot of time working in small groups during this progression. Working in groups will provide a great opportunity for students who understand the material to teach their peers who might be falling behind. Peer teaching will not only help those being taught, but will reinforce concepts for the gifted students. Throughout the progression students will receive direct instruction, and then will have an opportunity to learn in groups while working on assignments. While they work in groups students will receive further instruction in small groups as they explore the activity for each particular lesson. Students will be assessed daily and will receive quick and informative feedback as well.

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**Experiment with transformations in the plane**

Each lesson in this progression will begin by assessing what students already know. For example, at the beginning of the reflection lesson, students will be asked “what does it mean to reflect something?” Then the lessons will build upon what students already know. In each lesson, students will be given several definitions

and theorems for each transformation. For reflections, students will learn the definition of a reflection, and how to reflect figures such as line segments, rectangles, and parallelograms. After students have gained a complete conceptual understanding and procedural fluency of reflections they will move on to rotations. In the lesson on rotations, students will be introduced to definitions for rotations, angle of rotation, etc. Students will also learn the set of procedures necessary to rotate a figure. Finally, after students have been assessed and have succeeded in gaining an understanding of rotations, students will learn how to translate figures. During each of these lessons, especially the lesson on rotations, students will learn how to use the proper tools to complete the transformation. They must learn how to properly use a protractor and a compass to complete rotational transformations MP5.

In each lesson, after students have been introduced to key vocabulary, students will begin to think more deeply about the concepts surrounding each transformation. After completing several examples for each transformation, students will learn about transformational symmetries. Each transformation has a specific procedure that will map a figure onto itself. Students will be asked to think about what kinds of reflections, rotations, and translations will map figures onto themselves. Students will be given several figures and must tell which transformational symmetry it has MP1.

After students have gained conceptual understanding of each transformation, students will be given the opportunity to work in groups to practice procedural fluency. In groups, students will complete an assignment for each lesson. They will have the opportunity to peer teach each other and will be assessed on how well they understand the concepts that were taught for that day.

**HSG.CO.A.4-** Develop definitions of rotations, reflections, and translations in terms of angles, circles, perpendicular lines, parallel lines, and line segments.

**Benchmark:** Given segment AB, reflect segment AB across the x-axis.

**MP5-** Use appropriate tools strategically

**HSG.CO.A.3-** Given a rectangle, parallelogram, trapezoid, or regular polygon, describe the rotations and reflections that carry it onto itself.

**MP1-** Make sense of problems and persevere in solving them

**Benchmark:** Does a regular hexagon have rotational symmetry? If yes, what is it? What about other regular polygons?

Each day students will be assessed on how well they know the concepts and procedures for each individual transformation. The goal of this learning progression will be realized in the final lesson. In the final lesson students will learn how to perform several different transformations on a figure in a row. Students will learn that this is called a composition, and will learn several definitions needed to be precise in performing compositions. Through doing several examples, students will learn that for some compositions, the order of transformations matters while for others the order does not. In this students must have mathematical precision and must build on their conceptual understanding of the previous lessons MP6. During this lesson students will also learn how to complete compositions in the coordinate plane and will use graph paper to complete practice problems.

In a final assessment for the entire progression, students will be assessed on their ability to complete compositions. This will assess their understanding of each of the previous lessons as will. For this assessment, students will be given a figure in the coordinate plane, and will be asked to perform a list of many transformations on the object. If students can do this well, this will show great conceptual understanding and procedural fluency for the entire learning segment.

**HSG.CO.A.5-** Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another.

**MP6-** Attend to precision.

**Benchmark:** For which compositional transformations does the order matter? For these compositions why does the order matter?