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| **Lesson 2 : Connecting Tunnels to Functions** | **Unit #: 1** | **Lesson #: 2** | **Activity #: 4** |
| **Activity 1.2.4: Let’s Build a Tunnel** |

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| **Estimated Lesson Duration:** | **6-7 days** |
| **Estimated Activity Duration:** | **4 days** |

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| **Setting:** | **classroom** |

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| **Activity Objectives:**   * **Students will work in teams of 3-4 to design a road for the given toy cars.** * **Students will write a mathematical model for a tunnel using linear, quadratic, and/or semi-circle equations based on their road.** * **Students will graph their mathematical models.** * **They will explain why and how they chose the equations used.** * **They will find the area under the curve and the length of the curve.** * **Students will refine their mathematical model, graph it, explain it, and build a physical model with clay.** * **Students will test tunnels for load bearing.** * **Students will present a 3-5 minute demonstration or PPT about their process and decision making for the tunnel.** * **Students will reflect on the EDP and the Challenge and whether they increased students’ knowledge and understanding of piecewise functions.** |

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| **Activity Guiding Questions:**   * **What do I need to know to design a road?** * **What do I need to know to design a tunnel?** * **Do I have to use a piecewise function to model my tunnel?** * **What criteria do I use to develop my tunnel?** * **What are the constraints for my tunnel?** * **How do I graph my mathematical model?** * **How can I modify and refine my model?** * **What kind of test can we use to check our tunnel’s strength?** * **What things does my team need to say in our presentation?** * **How can we be sure that everyone speaks during the presentation?** |

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☒ Developing and using models | ☐ Cause and effect |
| ☐ Planning and carrying out investigations | ☒ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☒ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☒ Constructing explanations (for science) and designing solutions (for engineering) | ☒ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☐ Obtaining, evaluating, and communicating information |  |

| **Ohio’s Learning Standards for Science (OLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| ☐ Demonstrating Science Knowledge **(D)** |
| ☐ Interpreting and Communicating Science Concepts **(C)** |
| ☐ Recalling Accurate Science **(R)** |

| **Ohio’s Learning Standards for Math (OLS) and/or**  **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| ☒ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☒ Attendto precision |
| ☒ Construct viable arguments and critique the reasoning of others | ☒ Look for and make use of structure |
| ☒ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, OLS and/or CCSS):**   * F-IF.8 Write a function * F-BF.1 Build a function that models a relationship between 2 quantities * G-GPE.1 Derive the equation of a circle or given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation. * G-GPE.7 Use coordinates to compute the perimeters of polygons and areas of triangles and rectangles, e.g. using the distance formula. * G-MG.1 Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder.) * G-SRT.5 Use congruence and similarity criteria for triangles to solve problems and prove relationships in geometric figures. |

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies)   * Larson, R., *College Algebra: A Graphing Approach, 5th ed.,* * Challenge description with flow EDP chart * Suggested outline for presentation * Peer review sheet for students to evaluate each other’s presentations * Clay and tools for making physical model |

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| **Teacher Advance Preparation:**   * Prepare worksheets * Prepare “mountains” out of clay * Make sure computers are charged so teams can work on presentations. |

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| **Activity Procedures:**   * Day 1: Student groups will receive instructions for the Challenge. They will discuss criteria and constraints for the tunnel. They will discuss what they will include in their models based on ideas from the various real tunnels they have watched in videos. * They will use toy cars to design a road and then use the road to design a mathematical model for a cross-section of a tunnel. They will graph the tunnel and find the area under the curve and the length of the curve. * Student groups will communicate with the teacher about their decisions and choices for the first model. They will document their discussion about possible revisions. Revisions may be based on the shape of their tunnel, the area under the curve, or length of the curve. Area and length might be decreased. After graphing their curve, groups may decide that a different shape would be better. * Student groups will refine their mathematical models. * Day 2: After choosing their best mathematical model, each team will make tunnel with clay, test it with their road and cars, and let it dry. Hopefully this will be a Friday so tunnels can dry over the weekend. * Students will begin work on their presentation. * Students will discuss as a class what type of testing can be done for load-bearing. * Day 3: Students will test tunnels for load-bearing capacity. * Students will finish presentations. * Students will take the post-test. * Day 4: Students will do their presentations and reflection of EDP and Challenge. |

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

* Verbal checks on progress of models
* Feedback on student work
* Students will turn in diagrams of their tunnels and the graphs they produce with annotations justifying their revisions.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

* Post-test
* Final team report – includes final mathematical model with justifications and graphs, physical model, written outline of presentation
* Presentation – including student evaluations of each team’s presentation.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners. Refer to Activity Template for details.  I realized from the previous lesson that students were still having difficulties with graphing and restricted domain/range. I did a tutorial about using DESMOS, an on-line graphing tool. This allowed students to graph equations and modify them to immediately see how changing the equations changed the graphs. It also gave them much more freedom in their choices for equations. The different groups chose different equation designs based on their level of sophistication in understanding.  As the groups started building, I realized they might need other materials to supplement the clay. I allowed them to suggest other materials and provided some of them. I also provided on-going feedback about their designs and helped them make modifications that would be simpler to build. |

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson.  DESMOS worked very well and allowed the students to use more creativity in their tunnel designs. In the future it needs to be introduced earlier in the unit so students are more comfortable using it. Some of the students had a better background in art and found the building to be easier. The students who were used to math being pencil on paper struggled at first and needed a lot of encouragement. The group presentations were interesting and mostly well done. I will provide a template next time so the students have a clear understanding of what I expect from their presentations. |