Creating a T-Shaped Puzzle with CNC

Creating a T-Shaped Puzzle with CNC is designed to integrate mathematics (coordinates) and technology (**C**omputer **N**umerical **C**ontrol Laser machine) at a Grade 8/9 level. The T-shaped puzzle is a tangram that has four pieces and one solution. This task is a computational thinking activity in which students refine a code and create something new while engaging with math concepts and having fun in the math classroom.

> *"Both classes were engaged with the activity because it offered them the chance to use machinery in order to build the puzzle pieces."*
> (teacher comment, April 2018)

Description of Activity

Creating a T-Shaped Puzzle with CNC consists of four main sections which include an introductory presentation, G-code worksheet, Scratch guidelines, and printable puzzle pieces; all of which are provided with this activity (see 'Resources' at page 3). The class will need access to computers or laptops and a CNC Laser Machine. The CNC reads G-code to cut and engrave materials such as wood, metal, and acrylic.

Part one begins with a presentation which introduces the CNC machine and reviews coordinates in the Cartesian plane. It also introduces the CNC G-code which dictates what shape the machine will cut. Using printed puzzle pieces and a ruler, students determine the coordinates of the vertices of each puzzle piece and fill in the G-Code worksheet accordingly. Lastly, students look at use of ratios and proportions.

Part two focuses on Scratch using a guided worksheet to further explore ratios and proportions. Some completed codes are given to students to try out. Once they are comfortable with the codes students use similar commands to draw the four puzzle pieces in Scratch. The completed code worksheets are then used to familiarize students with the movements that the laser must make to cut the designs.

Part three is a hands-on activity in which the students use the CNC machine to cut the four puzzle pieces bringing together the content they have learned so far. In small groups students are guided through the CNC machine process by an instructor. Each student receives a T-shaped puzzle to bring home.

Part four again uses Scratch and can be done while students are either waiting to go cut their puzzle pieces or finished cutting their puzzle pieces. Students are asked to create multiple shapes using only two commands; move and rotate. These commands are different from commands in the first Scratch activity. This shows the students that there is more than one way to draw the same shape in Scratch.

Learning Objectives
- Math
    - Understanding and using the Cartesian plane
    - Understanding and using ratios and proportions
    - Measuring in imperial units
    - Converting improper fractions into decimals

- Technology
  - Communicating in G-Code
  - Understanding the basics of programming variables, commands, loops, etc.

Math Topic & Curriculum

The intended math topics in this activity are: the cartesian plane, imperial units, as well as ratios and proportions. *Creating a T-Shaped Puzzle with CNC* was originally designed for a grade 9 academic and grade 9 applied math class, therefore the following specific expectations from the grade 8 and grade 9 Ontario Ministry of Education Curriculum were referenced:

> *By the end of Grade 8 students will: represent transformations using the Cartesian coordinate plane, and make connections between transformations and the real world; graph the image of a point, or set of points, on the Cartesian coordinate plane after applying a transformation to the original point; identify, through investigation, real-world movements that are translations, reflections, and rotations.* (MoE, 2006)

> *By the end of [grade 9 applied mathematics] students will: represent, using equivalent ratios and proportions, directly proportional relationships arising from realistic situations.* (MoE, 2005)

These expectations are addressed throughout the task. Students learn about the cartesian plane through the introductory presentation in part one since the CNC machine uses the first quadrant to cut designs. To determine the coordinates of the puzzle pieces, students must measure scaled diagrams of the puzzle pieces in imperial units and convert the measurements into decimal form. Finally, students need to understand that ratios and proportions can be used to create shapes and objects at a larger scale.

Technology & Project type

Within this activity, there are two main forms of technology used: Scratch and the CNC machine. This activity follows an "understand, modify, create" model. The students use Scratch—a friendly coding interface that allows students to explore movements and commands of a sprite—to learn about the concepts necessary for drawing the T-shaped puzzle, modify the code to suit their needs, and transfer their learning to write the G-code to create their puzzles using the CNC machine.

Implementation

Creating a T-Shaped Puzzle with CNC includes a variety of traditional instruction, guided worksheets, individual exploration, and peer collaboration. It can be implemented into many mathematics classrooms in approximately two 75-minute periods. However, some portions of the activity, such as using the CNC machine, have to be modified to suit the technology that is available in the classroom. If students are not using the CNC machine the T-shaped puzzle and the mathematics behind drawing shapes in the Cartesian plane can still be explored using Scratch. An approximated timeline for implementation may include one period to explain the Cartesian plane and drawing coordinates in the positive quadrant, and a second period to allow the students to explore drawing similar shapes in Scratch. Another possibility is to only include the activity of drawing shapes in Scratch (part four of *Creating a T-Shaped Puzzle with CNC*). If this activity was the only portion being implemented into the classroom, one period would most likely allow enough time for students to explore drawing all the shapes.

It is recommended that the puzzle piece activity is given out first. This allows the students work on this activity until all groups have the coordinates of each puzzle piece. After this stage is completed, the *Completing the Code* worksheet can be introduced. Students do like to explore the attractive features of Scratch such as the sound functions and the appearance/background changes that can be made. It is recommended that the students have a small amount of time to do so. This time will allow the students to get familiar with the attractive features and hopefully create a more focused group of students for when it comes time to work in Scratch.

Mathematics Engagement

The main sections where mathematical engagement happens are in parts one and two of the activity. In part one, students determine the coordinates of the puzzle piece's vertices. To do this, students need to pull on their previous knowledge of working in Cartesian planes. Students will find the proper coordinates by measuring the side lengths of the shapes in imperial units. Additionally, students are engaging with real-life math through using the CNC machine to apply their learning. Lastly, in part four, students are able to explore geometry and shapes more deeply by writing their own code in Scratch.

There are several computational affordances for math learning in the T-Shaped Puzzle activity. First, at the end of the lesson each student can take home a T-Shaped puzzle that they cut. This gives students a tangible feel: the mathematics that they practiced and implemented is in the palm of their hand! Secondly, this activity has a low floor and high ceiling; students of all academic abilities can complete this activity. Additionally, both the mathematics and Scratch portions of the activity can be altered to suit the needs of the group of students, to make it either more attainable or more challenging. Another affordance is that students are agents of their own learning. In the scratch portion of the activity students use the Scratch interface to check the code that they made in part one. In this activity there is minimal teacher instruction so students guide their own learning experience. Finally, this activity has wide walls as seen in the two different Scratch activities. The purpose of the two different Scratch activities is to show the students that there is more than one way to arrive at the same end result.

Resources for this task:
Completing the G-Code (pdf)
T-Shaped Puzzle Complete Code – Answer sheet (pdf)
Puzzle Piece Handout (pdf)
Scratch Handout (pdf)
T-Shaped-Code-Presentation (pdf)
Programming files:
      Part A: Drawing a Square: https://scratch.mit.edu/projects/237145228/#editor
      Part B: Puzzle Pieces: https://scratch.mit.edu/projects/237146036/#editor
      Part B: Puzzle Pieces – Complete: https://scratch.mit.edu/projects/237146596/#editor

We would love to hear from you! If you try *Creating a T-Shaped Puzzle with CNC* in your classroom or for more information about this task contact **Marika Fowler** - mf14kl@gmail.com - *or **Tianxingjian (Aries) Wu*** – wtxj00789d@gmail.com