Unit: 3D Printing- Tinkercad

Standards:

NGSS

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

METS

3-5.TC.1. use basic input and output devices (e.g., printers, scanners, digital cameras, video recorders, projectors)

3-5.TC.2. describe ways technology has changed life at school and at home

3-5.TC.5. know how to exchange files with other students using technology (e.g., network file sharing, flash drives)

Lesson 1: Keychain (3 sessions of 45 minutes to finish and upload the design, 1 optional 45 minute session to evaluate the printed project and make improvements)

Objective: Students will apply the engineering design process to design and print a keychain with the following criteria/constraints:

- print time is less than 10 minute
- grams of PLA are less than 10 for a single keychain
- it must have a usable area for use in attaching it to a backpack

Materials and Resources:
3D printer   PLA   website: tinkercad.com   Chromebooks   Overhead projector for modeling
Tutorial found at https://vimeo.com/159227901

** Prior to starting this lesson run your 3D printer a few times so they see what it does. It greatly assists in the anticipation and fascination with this project!

Procedure:

Note: Day 1 is setting up the accounts, and showing students a few basics. Then provide 20 minutes or so to let them play with it, and answer questions. Then on session 2 introduce the parameters of the project, and demonstrate the needed skills. Tinkercad has tutorials, and if you do a Youtube search you can also find tutorials intended for the classroom there. Here is a tutorial that is designed specific to this project, and outlines all steps needed to complete a keychain (or alternative option). This was created to show students who were absent from the instruction so they may view it at an alternative time.

1. Introduce the project and connect it to the engineering design process. (See image of the poster I use to reference for this near the end of the document.) Define:
    a. constraints
    b. what PLA is
    c. review metric measurement
    d. CAD (computer assisted design)
2. Warn students that this objective and project will not be completed in one session, and will be challenging. Be patient with oneself and each other during this process!
3. If needed, have students register their account. This is done quickly by students logging into Google Drive first, and then using the Google registration feature on Tinkercad.
4. Introduce Tinkercad, and just a few basic tools. Show students how to start a new design, place geometric objects onto the workspace, resize objects, and delete objects. To resize, select the object and drag from the boxes. I connect this to prior learning by it being similar to resizing an object when making a Powerpoint or slideshow. They understand it immediately then. To delete, select the object and hit the backspace button. To raise the object above or below the grid, drag the black cone up or down, noting the changes in the value. A value of 0 places it directly on the grid-emphasize this!. Explain at this time why the object must be on the grid for printing purposes, and the consequences of having “floating” objects or objects that are below the grid. Allow students to play with this for a few minutes and assist each other. Reassure them that it is free play with the purpose being to just acclimate to Tinkercad. Watch for students showing signs of stress and assist. It is a little overwhelming for an occasional student here and there, but with a little 1:1 guidance that quickly resolves.
5. Next introduce how to use letters. Show them how to place them onto the workspace. Model how to align and group them. (Hint: have students align and then group the letters before resizing if they goal is to have the same sized lettering.) Model how to stack objects-use of the cone to raise the object and place on top, or adjust the height by making one object taller than the other and then layering the objects on top of each other. Model how to view the object from the top, bottom, and side and explain it is important to check the design from all perspectives. Model what a design looks like if it is below the grid. Model how to make a hole. By this time students will figure out that the right navigation panel offers more than just geometric shapes and letters. Allow time to play with these features.
6. Model a design that has parts that require “rafting”. I do not demonstrate how to do this at the elementary level, but explain to students that if parts of their design has an portions that overhang the base area, it will have nothing to support it and the print will not work. (For example, if printing the letter “T” vertically, the horizontal portion of the letter will not print correctly. By laying the letter down on the grid, it will print correctly.) This is the most common mistake when students create their first design.
7. With at least 5 minutes left demonstrate how to name and save the file to their account.
8. Generate a rubric for scoring as a class. Allow students who need to make design changes the opportunity. Students who finished may go back into the file and use scale tool to explore how it impacts their design. Remind students not to save changes if they do not want to alter their original design, or to start a new file to experiment with. My students general opt for a score of 1-4. 4 requires application beyond what was explicitly taught in the design, 3 meets all requirements, 2 is missing a constraint or only partially printed correctly, 1 is a file that did not print correctly and needs to be redone.)

9. Students will have misprints. I always ensure that I have enough time in the school year to print everything, and then provide time in class for students who need to redo the project. The remaining class members work on coding during this time..
10. Model how to save and logout. (Design tab, "properties", save as, rename the file, save.)

Lesson continued in session 2 & 3:

1. Model how to locate the file created in session one. They will need to be shown that they have to click on "tinker this" to get started again.
2. If possible, have a student use the computer to model how to create the keychain while you guide the example by the whiteboard. Demonstrate the entire process from start to finish highlighting common errors or challenges. Common errors: forgetting to allow for a way to affix it to a backpack, making a part so thin that it breaks easily (especially a ring for the keychain to thread a chain or string through, letters that are not joined or parts that will print out separately due to no overlap, floating above the grid, design components beneath the grid (negative y value), and parts of the design not having the support it needs to print (overhang). Keep this to less than 10 minutes. Alert students that they will not remember all steps or tools, and that they will help one another during this process. If you do not have a student able to assist, just ensure that students are able to easily see what you are clicking on. An alternative is to show the video tutorial linked above as an instructional support or to post the link so a student may view it for additional support.
3. Remind students of the constraints. Explain that the grams/print time will be difficult for them to judge. Give them some general guidelines on size. (50mm x 5mm x 50 mm in general will meet the constraints, but it is dependent on how intricate the design is and other factors. You will scale it when slicing to Gcode to ensure it is not too large or too small.)
4. Students begin. Allow them to assist one another.
5. Once a student is finished, check the design to ensure it is centered on the grid, laying flat, and that it will print correctly.. Hint: make this a "job" and that each student is responsible for checking at least one other design. You will notice that some students excel and are better at troubleshooting. Have these students pair with your struggling students. This will greatly reduce the number of misprints and develop critical thinking skills.
6. Students who finish early may begin a new design of choice, and select which project will be submitted for printing.
7. Review the engineering design process and connect each part of the project to it.
8. Once all students are finished model how to save the file to the harddrive of the Chomebook. (Note: this will be much easier if you demonstrate it using a Chromebook connected to the projector. Don't forget to set it to "mirror" (lower right corner of the screen click and look for this option). Go to the "Design" tab, "properties", " save as", rename the file (I have them put their first name, first letter of their last name, and the classroom code due to working with 700+ students- this is greatly helpful in keeping projects organized!). Next, download as an "stl" file to the Chromebook. I then have them upload this file to Google Classroom, but you could use a flashdrive or other option to collect files.

If possible, prior to session 4 print out all keychains. I highly recommend that you train a few trusted students on how to do this and allow them to come in before school and during lunch to assist.

Session 4 (optional):

1. Pass out keychains if possible.
2. Open Cura and demonstrate how the constraints were met by loading a stl file and splicing it to gcode.
    a. Use this opportunity to complete a mini lesson on scale factors. Students should recognize after the lesson that a scale factor of greater than one increases the original size and a conversely a scale factor less than one decreases the original size.
    b. Experiment with changing the scale factor. Have students suggest and predict the outcome of applying a scale factor.
    c. Apply a scale factor to only 1 or 2 of the planes. Have students predict prior what will occur. Take suggestions on altering the scale factor and have students predict the impact.
    d. Ensure during the manipulation of the model that students note the changes in the length, width, and height. Connect the conversion of the metric system (mm to cm, compare to inches) to the changing models. Have rulers available for students to reference during this phase.
    e. Connect manipulations of the scale to meeting or exceeding constraints, or being so small as to not be practical to print.
3. Class determines a scale factor and then model how to slice to GCODE. Print this during the session if possible so students may connect the CAD model to the physical piece. Assess the final prints together with each student and determine if adjustments needs to be made to the file in order to meet the constraints of the project. Connect this to the standard 3-5-ETS1-2 (multiple possible solutions that meet constraints).

Extensions:

1. Students may be shown how to scale and use this and scale the piece prior to sending the teacher the file. Another option could be to have students upload the file. Then, teach them how to go back into the file and use the scale feature. Compare what they did to the final results of the print, but be sure to note what scale factor you set in Cura so students may compare. More advanced students could elect to design anything that may be attached to the backpack and skip the following of the steps in creating the keychain. Additionally, the students could independently view the tutorials found on the website (under the lessons tab) to learn additional skills and then design a more advanced project.
2. More time may be spent closely examining the accessible math of this design. Students may experiment with scale factors, converting metric units from mm to cm or metric to inches, geometry concepts such as differing between flips and rotations, right angles, etc. and the coordinate plane including the z axis. More specific constraints could then be given requiring students to set coordinate points to specific values, flip, etc. I have found that after they experienced designing the project, when they view the 3D printer working they are FASCINATED with watching the x, y, and z coordinates change- as it now starts to make sense how the printer is working.
3. More advanced students could be provided with simple objects such as a doorstop, a wand used to blow bubbles out of, etc. and replicate the product.

Lesson 2: Create an object based on an exemplar model.

Objective: Students will backwards-design a bubble wand.
Resources:
Tinkercad   Bubble wands (download and print designs found on Thingiverse)

Bubble Solution   Chromebooks   Pla/3D Printer   Digital Calipers

Form mixed-ability groups of no more than 4 per group, but ideally group in pairs. Each group should receive at least 1 bubble wand model to reconstruct. Students then precisely measure the exemplar wand, and create an identical design using Tinkercad. Students will need a lesson in how to use the digital caliper in order to measure the wand accurately. If possible, have the printer available in class to run test prints for groups as needed. Students who finish early may design a container to hold bubble solution that works with the wand, or create an alternative and improved design for the wand. After prints are finished, mix up a batch of bubble solution, students try their wands, and compare the results to the exemplar wand.

Lesson 3 Students design a part that is useful in the school environment and fills a need.

Objective: Students will create a useful product using 3D printing technology

Form mixed-ability groups of no more than 4 per group. Show a part designed for use in the building (i.e. I made a door stop and explained that this is useful due to my door having a gap from the floor that is much greater than what a doorstop purchased at a store can accommodate.) The part needs to have a use and not simply created for decoration. It also cannot be a version of the keychain project from lesson 1. Prior to starting the work on this project, the week before explain to students about the project and ask them to look for ideas as they go about their regular school day. Their "homework" is to come up with ideas for the project. Alternatively, the teacher could provide a group of projects and students select a topic of choice. Students should sketch out the idea from multiple perspectives (orthographic projection for older students) using graph paper. Students then create, design, test, and adjust the part until it fulfills the intended need. A few ideas that you could offer as the teacher are:

- A product that fits over the classroom door that may quickly be removed. This allows the teacher to keep the door locked, and this part would prevent the lock from engaging. Then during a lockdown, the teacher simply removes the part and no longer needs to locate a key to lock the door.
- Doorstops
- Containers for organization (i.e. boxes to hold Makey Makey parts, a class set of flashdrives, etc.)
- Toys/games for indoor recess
- Hooks to go over the door or other area. (I hang hooks over my charging cart for a makeshift classroom lost and found for when students leave their jackets behind. They all know to look there if they need to return to my classroom later in the day and do not need to interrupt instruction to retrieve their items.)

Extensions for the Unit:

- Have a class design a part for a fundraiser including the marketing and sales of the product.
- Create a tangram set complete with sketches for use when playing
- Design a car challenge and race the final products. Launch the cars from a ramp with awards for aesthetics, speed, and distance.
- Cookie Cutters

Options for more advanced students:

- Form groups of 3-4 students. The group determines a problem that needs to be solved and designs a part for the solution. Example: the doors in my building have a gap from the floor that is greater than average, and door stops that are purchased many times do not work well. Design a custom door stop that will work in the building. For older students, a project solved the problem of snow coming into the car and landing on the seat. A part was designed to prevent this (and it actually worked!). Students then could develop a sales presentation marketing the part.

General Resources for 3D Printing:

Project Ignite Teachers may sign up for an account, create a classroom, and students sign-up using a generated code. Tinkercad tutorials may then be assigned, with the first three lessons being particularly helpful for this project.

Kathy Schrock's Guide to Everything: 3D Printing This site offers a multitude of resources gathered in one conveinent location including tutorials, project and lesson ideas, resources, etc.

UMassAmherst Google Spreadsheet (Public) This spreadsheet is open for anyone to use and add resources too. There are tabs (see the bottom of the spreadsheet) for lesson plans, 3D models, ideas and activities, guides, and 3D modeling tools and tutorials, articles, videos, purchasing, and filament.

Appendix A: Directions if using 3dtin.com instead of Tinkercad.

1. Students should be logged into 3Dtin.com
2. Select the text template tool (icon is the letter A).
   a. Select the text void option, as it does not require a base to attach the letters to
   b. On the right side of the screen enter the text for the keychain and click add
3. The cursor now shows the base when moved. Center the cursor on the grid and click, and this drops the base onto the workspace.
4. Click on the select tool to clear the object from the cursor.
5. Click on the rotate (or pan) tool.
   a. Click on the base, click on the pop up menu (bottom of workspace) and click on the rotate tool.
   b. Click on the "X" (for the x axis), and change the degrees to 90 (small print on right side of pop up menu). Click apply.
6. Rotate/Pan to view if the object is sitting on the grid (it probably isn't). You have two methods of moving the object:
   a. Close the pop up menu. Then click on and grab the object. This allows you to move the position. OR
   b. Close the pop up menu. Click on the object. Notice that the coordinates now appear at the bottom of the work space. Set the Y MIN = 0 and apply. This guarantees the object to be perfectly flush. When checking student designs use this to confirm the object is set correctly on the grid!
7. Click on the Toroidal template tool (to the left of the text template tool)
   a. Select the semicircle pipe band
   b. Set the radius=1, outer radius = .5, and the inner radius= .2, click apply

c. Drop the semi circle on the grid.

8. Click on the select tool. Click on the rotate (or pan) tool and move the semicircle into position.
    a. Students may grab the pipe band and move it into position.
    b. Pan and rotate through all views to confirm the proper placement (NOT offset, incorrect y MIN value, joined to the base (look for the yellow line to appear if joined correctly), etc. This is the most common time for students to make a mistake so model what it should look like, and what the mistakes look like so that students understand better what to look for. It will save you a bunch of PLA and bad prints!
9. As an option, at this point you may use the select tool and group the objects together. This is useful if you plan to have students use 3Dtin to scale the chain, as the scale factor will automatically be applied to both the base and the pipe band.
10. Model how to save the file and log out.