



MPACT

Math and Computational Thinking Through 3D Making

Teacher Notes: Grade 6 Module 1

Goals for the Module

Mathematics

Convert like measurement units within a given measurement system (cm to mm and mm to cm).
Use measurement conversions in solving real world problems.

Spatial reasoning

Rotate 3D objects mentally to decide if they are the same.
Interpret 2D drawings of 3D objects.

Computational Thinking (CT)

Identify and correct errors in designs (debugging).

Materials

- Computer
- Rulers

Timing

- Three to four 45-minute lessons
- Times may vary. Times given below are for phases of design (such as prototyping) and you can break those into lessons for what works best for you.

Introduction

10 min

Goals

Learn about the design process.

Learn about and use new vocabulary terms, such as prototype, iterate, sketch and the Computer Aided Design (CAD) tool.

Materials

- PPT slides
- Design process poster

Name _____ Date _____

Think Like a Designer

Designers **collect ideas** by doing research and talking to the people they are designing for.

They **make and remake prototypes**. Prototypes are models you make quickly with common materials to work out how things will look and fix things they hadn't thought about.

They **design on computer and paper**, using more precise measurements.

Finally, they **make the real thing**. They might use cardboard, wood or even a 3d printer.

All along, they **iterate** the designs. When you iterate, you go back to improve the design as you learn along the way.

We will follow the same **design process** as we learn to be designers!



Collect Ideas

You are going to use a Computer Aided Design (CAD) tool called Tinkercad™ to design a bookmark. Here is an example.

1. Describe the kind of bookmark you want to design. Who is it for?



Introduce the Module

10 min

Say: we are going to start some activities in which you will be designing and making things.

Have a brief discussion about what students think *design* means and what kinds of design they've heard of. *Accept all answers.*

Say: the whole of the human-made world has been designed: from pencils, chairs, tables, to phones, cars, and buildings. Even the most insignificant plastic fork: everything has been designed. You will all be designers.

Slide 2-3: Lead a whole group conversation, explaining the four steps in the design process and how iteration happens for the whole process and internal to each step. Clarify any vocabulary.

Slide 4: Say that there are many things that can be 3D printed and share the story of Kieran. Review the links before sharing any with the class.

Slide 5: Ask questions in slide. *Accept all answers.* Encourage them to think about the design process as they consider how the prosthetic hand gets made.



Collect Ideas

10 min

Goals

Learn about a bookmark and design requirements.

Materials

- Slides **Mod 1 teacher PPT**
- Bookmark How-to video (<https://vimeo.com/351285136>)
- Tinkercad keyboard shortcuts

Name _____ Date _____

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Collect Ideas

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1. Describe the kind of bookmark you want to design. Who is it for?

Jaxon

Write initial list of design requirements

10 min

Explain that designers think about a person or group that will be using their design.

Ask:

- Who are you making the bookmark for? (It could be for themselves or someone else.)
- How many letters are in the name?
- Do you think they would like all caps or a mixture of lower and upper case?

Explain that they are gathering ideas for their design. They are making a list of requirements just like designers do. These are the important things to keep in their design, even when they make quick sketches.



Make and Remake Prototypes

25 min

Goals

Make prototypes (sketches) of their bookmarks.

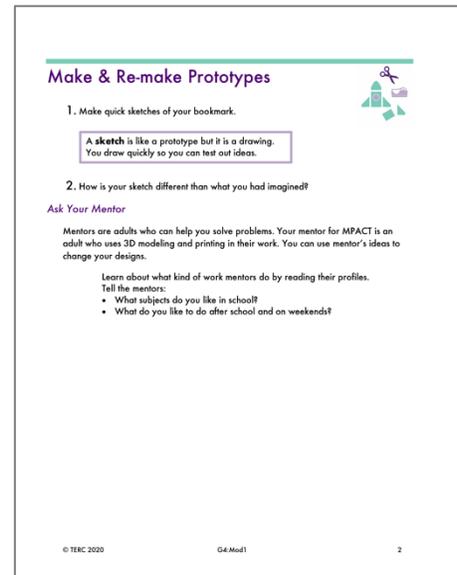
Communicate with mentors.

Computational Thinking

Students practice the CT skill of abstraction as they make a quick sketch of their bookmark and decide if the sketch is what they had imagined.

Materials

- Have a camera ready to record progress.
- Website and student logins for mpact3d.terc.edu.



Before the lesson

Make sure the MPACT team has your roster and you have student logins to the MPACT website. Then, test the process by which students will interact with the mentors: Go to mpact3d.terc.edu website and log in as a student. Make sure you have all the documentation you need for helping students get online, sign in, and write to mentors during class.

Make prototypes

Q1. Read the prompt. Ask the class what they think a sketch is. Have the students read the description of a sketch in the box. Then they draw their sketches. The sketch does not have to be accurate or to scale. It should give a rough idea of what the students have in mind. Students may label their drawing with estimated measurements.

Q2. Ask students to share how their sketch is different from what they had imagined before drawing it. They may not know what to say, so you can model that you had a different idea of how big the bookmark would be when you imagined it in your head. The actual size requirements will be given in the Design activity.

Ask your Mentor

This is the first time students are asked to communicate with mentors. Explain who the mentors are—professionals that use design and 3D printers—and how they'll be communicating with them via the mpact3d.terc.edu website.

Tell students what they should share (questions about their project and questions about the professionals' work), and what they should definitely not share (e.g., personal information).

Let the class know that in this project, they will have opportunities to communicate with an assigned mentor and ask questions. The mentors will write back to the students in a few days.

10 min



15 min



Goals

Create a drawing that is based on the prototypes and prepares them to design in the CAD.

Math

Measure or estimate parts in centimeters.

Understand the relationship between millimeters and centimeters.

Convert measurements between millimeters and centimeters to make a model.

Spatial reasoning

Envision an object from all sides.

Computational Thinking

Make an accurate model of their design.

Test and refine the design.

The screenshot shows a worksheet with the following content:

- Design**
- Measurement Check Up**
Before you use Tinkercad to design your bookmark, do this activity to understand the relationship between millimeters (mm) and centimeters (cm).
1. How many millimeters (mm) are in 1 cm? Use the ruler to count.
1 cm = _____ mm
An image of a ruler is shown below the question.
- 2. If you know a length in cm, how do you calculate the length in mm?
3. If you know a length in mm, how do you calculate the length in cm? (try this without the ruler)
- Design on Computer and Paper**
- 4. The design requirements for the bookmark are given. The design requirements for the bookmark are:
 Length: less than 120 mm
 Width: less than 50 mm
 Height: less than 3 mm
- 5. Convert the measurements from millimeters to centimeters.
 Length: less than 120 mm → _____ cm
 Width: less than 50 mm → _____ cm
 Height: less than 3 mm → _____ cm
- © TERC 2020 GS.Mod1.Think Like a Designer 3

Materials

- Rulers with cm and mm markings
- 1 cm by 1 cm dot paper
- Tinkercad Keyboard Shortcuts handout.
- How to make a bookmark tutorial video: <https://vimeo.com/351285136>

Before the lesson

Make sure students have access to Tinkercad, through your classroom.

Measurement Check Up

Read the introduction to this section together.

Discuss as a whole class that in meeting the printing requirements, students will convert from millimeter on the Tinkercad screen to centimeter. The following measurement activities are designed to help students in understanding the relationship between mm and cm.

Do Q1 together. Then, students do Q2-3 in pairs. Then, discuss Q2 and Q3 as whole class.

Q1. Encourage students to use a ruler or rulers to count how many mm are in 1 cm.

This insight, 10 mm in every cm, leads to the multiplicative rule for Q2 and Q3:

Answer: 10 mm

15 min



Q2. Have students explain to their classmate that when given a length in cm, how they calculated the length in mm.

Potential answer: Because there are 10 mm in 1 cm, I can calculate mm by multiplying cm by 10.

Q3. Challenge students to explain (without using the ruler) how they could calculate a length in cm, if they know the length in mm.

Potential answer: Because I know 1 mm is the same as 0.1 cm, I can calculate cm by multiplying mm by 0.1. Or, because I know 1cm is 1/10 of a mm, I can find cm by taking 1/10 of mm.

Q5. Encourage students to discuss the patterns they noticed when going from mm to cm. Pair work.

Answer: 12 cm, 5 cm, 0.3 cm

Discuss the take-aways:

Multiply the number of cm by 10 to get the same length in mm.

Divide the number of mm by 10 to get the same length in cm.

Design requirements revisited: maximum measurements

Ask students what their original design requirements are: from the Collect Ideas activity: the words, the color, the font they had.

Q4. Now, say that they have additional design requirements that include the measurements of the bookmark. Have students read the design requirements and show you how much each measurement is.

Designing the bookmarks in Tinkercad

Let students know that they will be using Computer Aided Design (or CAD), a tool that designers use to increase productivity, improve the quality of their design, and help them in communicating their work to others. The students will use a tool called Tinkercad to design their bookmark.

Provide the Tinkercad Keyboard Shortcuts handout.

Q6. Show students the how-to video (<https://vimeo.com/351285136>), which shows the steps laid out in Q6.

Circulate and help students follow the steps shown, while encouraging independent problem solving. Students are now in the design phase, where accuracy counts.

Remind students that when they move the text and solid shape together, to check the bookmark. The two objects may appear to sit on top of each other, but they may be separate. And printing them will not work.

10 min



20 min



Make the Real Thing

45 min

Goals

Check their design to make sure it will print and then 3D print their bookmark.

Math

Understand that volume can be a set of infinite areas layered one on top of the other.

Spatial Reasoning

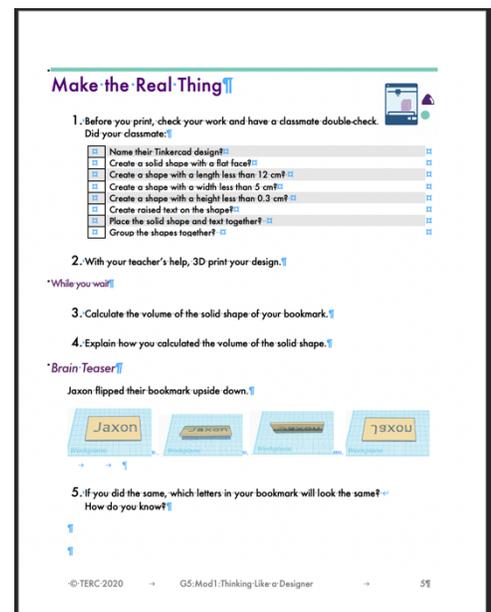
Rotate an 3D object mentally.

Computational Thinking

Debug a problem and improve their bookmark designs.

Materials

- Ruler
- 3D printer
- Printer software (at least on teacher machine)



Before the lesson

For partner check:

- Confirm that you have all the students' bookmarks in your Tinkercad classroom.

For printing:

- Export the Tinkercad designs as .STL to your desktop and then import these files into the printer software to check the length of time they will each take to print. This will allow you to set a schedule for printing.
- If there is time, you can print a smaller version of some of the bookmarks to check if they will print properly and come out as students expected.

Partner check on Tinkercad

Q1. Put students in pairs and have them check each other's designs. Emphasize that if the file isn't properly assembled, the files will not print.

15 min



Seeing the 3D printer in action

This will take time, perhaps several days. We have included the Brain Teaser to do while they wait, but you can get back to your regular curriculum after that.

5 min



Q2. Demonstrate the process of importing a CAD file to the print software. Start printing one of the bookmarks.

If you can, let students see the printing in action. This is where they can see the layers being printed on top of each other, supporting their developing sense of volume as a set of infinite layered areas.

Leave extra time in your print schedule. Students may make models that cannot be printed, or the printer could mess up. Show students what happened, and have them correct their Tinkercad file or troubleshoot the 3D printer.

Printing can be done while students work on other math problems from their regular curriculum. You or students can start and monitor the printing process.

While you wait

Q3. Possible answer: if students used 12cm by 5cm by 0.3cm for the solid base, the volume is 18 cubic cm (or 18000 cubic mm)

Q4. Possible answer: Students might say they found the volume by multiplying the length, width, and height.

5 min



Brain Teaser

This activity affords students the opportunity to use and enhance their spatial reasoning skills. They can flip the bookmark by rotating it mentally, or physically rotate it around its vertical and horizontal axes.

Q5. Give students 5 minutes to answer individually or in pairs. Then, discuss their answers together as a whole class.

There may be multiple answers. It depends on how students interpret the words in the question – which in itself may be a very productive conversation.

Intended answers: Most letters do not look the same when you flip the bookmark upside down. The capitals of the following letters will look the same (for certain fonts): B, C D, E, H, I, O, X, and maybe K depending on font styles. These are the letters that have horizontal symmetry so they look the same upside down. Lowercase letters are less likely to look the same upside down depending on the font and some will look like other letters when viewed upside down (e.g., w, u, n, m, p, q, d, b). If time allows, students can check their answer using Tinkercad.

Q6. Answer: the two designs have the same volume.

Q7. Answer: Option 2 needs more paint. Possible explanations include: the two-piece bookmark has two more sides that need to be painted so it will take more paint.

10 min



Reflect and Celebrate

Encourage students to share challenges and the strategies they used to overcome these challenges. The goal of this sharing is not to evaluate their designs but to find ways to iterate and refine and to share what has been learned with the classroom community.

They have used algorithmic thinking, estimated, measured and converted mm to cm, compared measurements and areas, and used spatial reasoning.

Reflection questions can help students in developing a systematic approach to debugging a problem and to improving their bookmark designs (CT practices).

Additional questions to ask:

- What do you like about designing with Tinkercad?
- What was successful about designing with Tinkercad?
- What challenges did you have with Tinkercad?
- Any strategies that worked well?

10 min

