OLIMPICO LEARNING

LEARN 3D DESIGN & PRINTING

GRADES 6-12

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Olimpico Learning

CHAPTER 1

An Introduction to 3D Printing and Design

Manual Highlights

1. Introduction to 3D Printing, Computer Aided Design (CAD), 3D Space, Visualization and Design Principles
2. Teacher background concepts and information.
3. An introduction to Tinkercad, a simple, free online CAD program geared towards students of all ages and abilities.
4. 12 weeks of lesson plans, supplementary materials and resources
5. Resource and recommended reading for further study on 3D printing and design concepts.

A Brief Overview of this Manual

Olimpico Learning strives to be the best in innovative STEAM curriculum and professional development opportunities for teachers, serving the Bay Area and beyond. We have developed this manual to give teachers a basis for introducing fundamental 3D printing and design concepts.

Olimpico summer STEAM program students learn about 3D printing

This manual comprises a learning base for beginners to designing in 3D space and 3D printing, geared towards students from grades six through twelve, as well as a number of resources and recommendations for teachers in instructing these concepts.

These lessons serve as a useful primer to a basic Computer Aided Design (CAD) course utilizing programs such as Tinker CAD. The content and lessons contained within this manual are suitable for after-school and summer STEAM programs, or as an enrichment project.

Included within this manual is instruction and lessons that will teach 3D concepts and design to students, as well as aiding students as they work on improving their math and English Language skills, through a variety of activities.

This manual also provides references and reading links to aid the teacher in further study and learning on 3D printing and conceptualization of 3D space and design, as well as suggested CAD programs.

The curriculum included is laid out in one-hour long lessons, as well as supplementary materials and presentation slides to accompany each lesson. A suggested course materials list, with links to several applicable 3D models is also provided.

Within the lesson content, the essential vocabulary words students must know are highlighted at the beginning of each lesson, as well as sentence stems/discussion questions for student reflection at the conclusion of each lesson. Each lesson is broken into an 'Attention Getter,' accompanied by 1-2 activities and/or applicable Tinkercad projects students will work on.

Olimpico Learning inspires students to prepare for higher education and ultimately the pursuit of careers in science, technology, engineering, arts, and math

Course Benefits

1. 3D printing is a great tool for encouraging STEAM learning in students, as well as opening up possibilities for new educational avenues in the classroom
2. 3D printing is a relatively new technology. Students can become early-adopters, with future advantages as 3D printing and manufacturing become more widespread.
3. Students experiment with creativity, design and engineering concepts. Furthermore, 3D printing can provide students with a meaningful learning experience, as they conceive, design and create their own 3D objects, and end up with a tangible item they can take home.

Why Learn 3D Printing?

3D printing is a great tool for encouraging STEAM learning in students, as well as opening up possibilities for new educational avenues in the classroom. 3D printers allow students to experience the modeling stages of the design process and understand its additive manufacturing process, where objects are built layer-by-layer. By allowing students to rapid-prototype their designs in real-time, 3D printing provides a new template for engineering design and manufacturing right in the classroom.

As 3D printing is a relatively new technology, when students can become early-

Students from Olimpico's innovative 3D printing class get up close with a 3D printer to learn how they work.

adopters, they will have future advantages as 3D printing and manufacturing become more widespread.

New educational considerations are beginning to see the use of tools such as 3D printers and modeling programs to allow students to experiment with creativity, design and engineering concepts. 3D printing can provide students with a meaningful learning experience, as they conceive, design and create their own 3D objects, and end up with a tangible item they can take home.

There is room for creativity and trouble-shooting in every aspect of the design project, teaching students persistence and how to deal with model failure, and learning to develop creative solutions. Students begin at the conceptual stage, and use their skills and creativity to troubleshoot common design problems, such as material breakage or print failure, in order to create a successful model. By allowing students to create their own 3D models, 3D printers and printing can be used to personalize lessons, and motivate students to invest in their own learning experiences.

STEAM Learning for All Ages

As a hands-on technology, 3D Printing can be used as a teaching tool for students from Kindergarten through to High School.

Younger students can engage with 3D printing technology by simply learning about 3D space, and experimenting with craft supplies such as cardboard, glue and markers to create 3D objects from 2D conceptual drawings.

Older students can learn about Computer Aided Design (CAD), and the 3D printing process. This process includes learning about materials - their strengths, weaknesses and suitability to different prints, as well entrepreneurship and product development

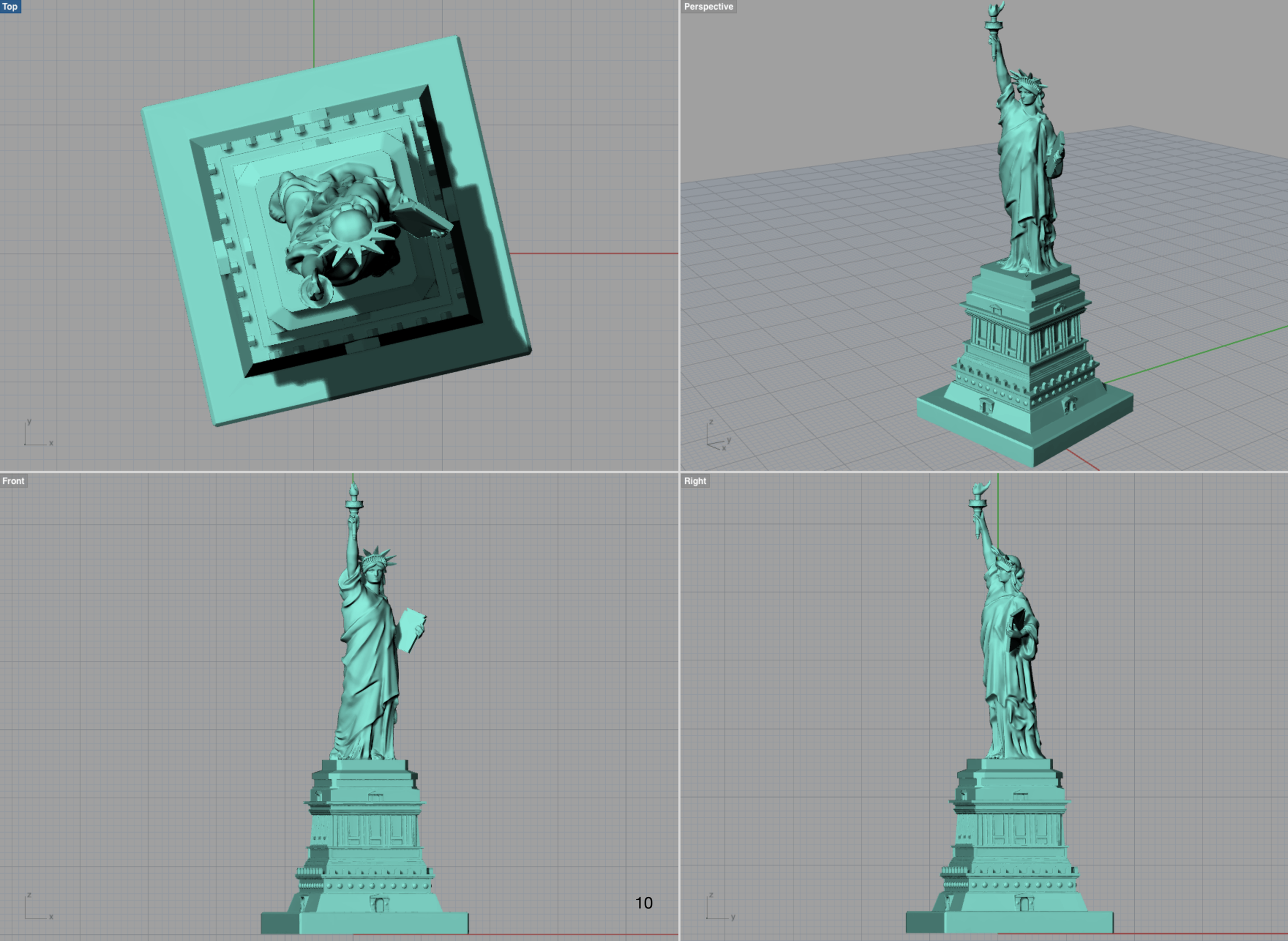
A 3D printed model of the Eiffel Tower 3D printed for student engagement and interaction.

through creating different 3D outputs and custom designs, from conception to the print stage.

Lesson Objectives

Student lessons can include design concepts, and activities geared around the need for structural creativity in 3D printing, technical communication essentials, and the process of taking a 2D design and translating it to a successful 3D print. These objectives can be achieved without necessarily needing access to a computer in the beginning stages, depending on the computer literacy of the class. As student proficiency in the course content progresses, and students learn to master 3D design and space conceptualization, they will be able to utilize these skills in the beginner CAD program Tinkercad.

Due to its ease of use and flexibility across multiple platforms, Tinkercad is an excellent starter program for students. Tinkercad is one of the most functional programs for beginners to CAD technology. In addition, Tinkercad can be used on a variety of platforms, including most operating systems, Chromebooks and even iPads and other tablets.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CHAPTER 2

Readings and Resources

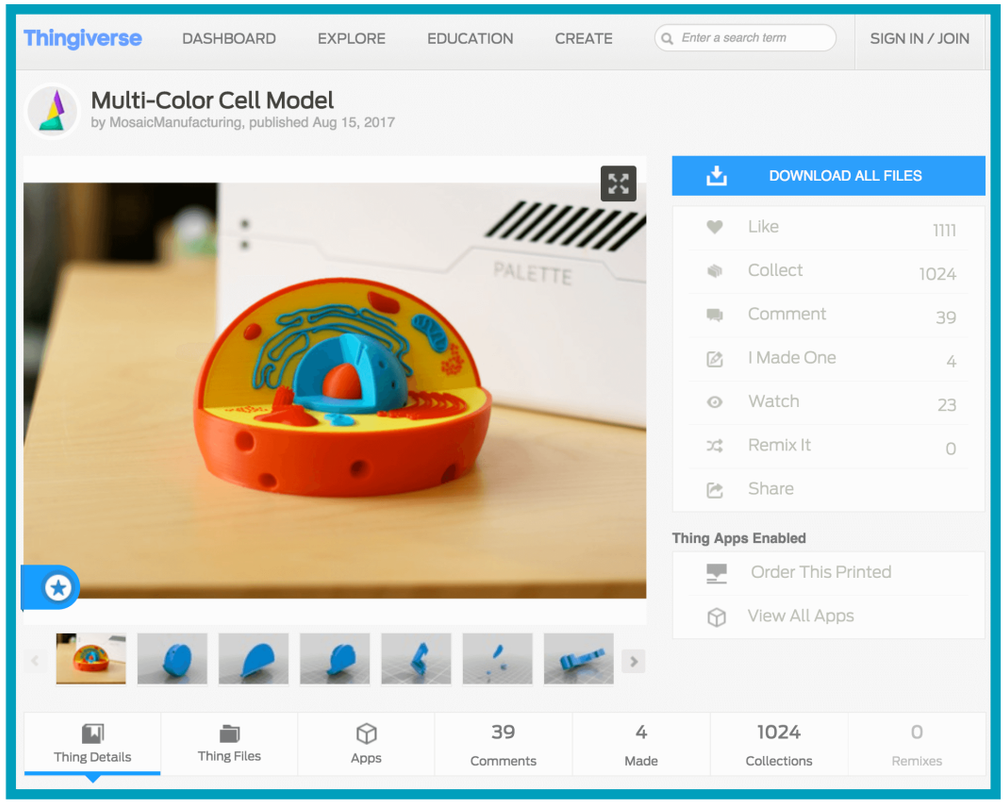
Manual Resources

1. Background Reading: there is a treasure trove of information, both highly technical, and more anecdotal, available on the internet from multiple sources.
2. CAD Programs: These run the gamut from simple drag-and-drop to more complicated software.
3. There is a wealth of online resources and tutorials available for increased proficiency in CAD and 3D printing technology.

Recommended Resources

There is a great deal of information available for information and tutorials on 3D printing, Computer Aided Design (CAD) and design, from the very basics to more technical and detailed levels as your skill level with 3D printing and CAD improve.

There are several websites available for a beginner to 3D printing. If you do not know how to use any CAD programs, but still want to be able to print 3D objects, websites such as the popular **MyMiniFactory** or **Thingiverse** have thousands of

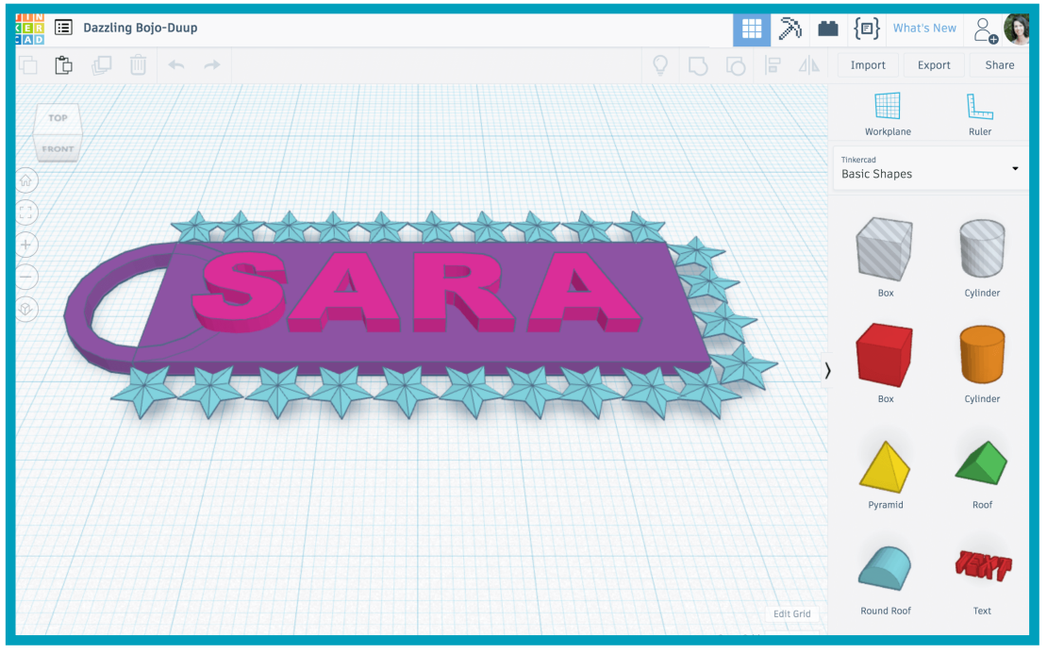


Sample cell model from Thingiverse

objects, from classical statue replicas to educational toys. These objects can be easily downloaded, and printed for free, either at home, or by third-party printing services, which are readily available.

The models available from websites such as Thingiverse or MyMiniFactory can be used as a part of a 3D printing program, or even in the general classroom space, to supplement and inspire student learning, with hands-on objects students can experiment with, and even take home.

Many CAD programs, utilized for creating and customizing 3D models, are available for free or reduced costs for educational institutions and teachers. These programs may be online browser-based or offline desktop-based programs - suited for a variety of



Sample student Tinkercad nameplate project

skill levels, from beginner to advanced.

On the beginner end of the spectrum; **Tinkercad**, a simple online 3D design and printing program, utilizes a simple interface, wherein users can drag-and-drop a menu of pre- defined shapes, in order to create custom objects. Tinkercad is an essential beginner program for teaching 3D printing to students. The teacher can administrate student accounts, both to moderate students, as well as for ease of access to student designs.

From a teaching and learning perspective, Tinkercad is easy for students to work with and understand, even if they have little grasp on the intricacies of math and 3D space that may be involved in more advanced CAD programs. Students can easily drag-and-drop Tinkercad's pre-set menu of shapes to create objects that may be simple, or surprisingly intricate as they gain more proficiency with the program and 3D conceptualization.

There are a number of on-demand 3D printing services that can be utilized for those that do not have access to a 3D printer, either at school or at home. For online ordering from local 3D printers, **3D Hubs**

is a great resource for competitive pricing. Another on-demand print site, **Shapeways**, provides professional 3D prints, in materials from plastic to solid gold, as well as its own 3D printed design marketplace.

The following pages list a sample of helpful websites and resources that can be used as you learn about 3D printing and CAD.

Where to Look...

1. Look to the various guides and knowledge bases. Get a good overview of 3D Printing technology and concepts by going through this material.
2. As you gain knowledge on these topics, investigate the various forums dedicated to all things 3D Printing. Connect with other designers and educators to troubleshoot and discuss ideas and concepts.

Essential Reading and Learning

You will find most of the best 3D printing resources online, with content from CAD tutorials, to trouble-shooting 3D printer issues. Below is a short compilation of resources that can be used to get started on 3D printing, as well as troubleshoot common printer issues.

1 **The Free Beginners Guide** by 3D Printing Industry: parse through this site for a good introductory set of articles on 3D Printing. It is easy to read and delve into the details of 3D printing technicalities.

2 **The 3D Hubs Knowledge Base:** Includes articles on 3D printing and design. This site is geared towards intermediate to advanced knowledge in 3D printing and CAD.

3 **3D Printing Troubleshooting: 33 Common 3D Printing Problems** from All3DP. This article provides picture references to compare with, and diagnose common 3D printing issues. A must-read for beginners to 3D printing.

4 **Instructable's Guide to 3D Printing:** A good introductory read on 3D printing concepts, printer types, and materials overview. This article is also suitable to be used for classroom reading for older students.

5 **CAD Software Tools** from All3DP. This article details and compares a variety of CAD programs, their skill levels, and available platforms. This is an essential read, to get an overview of the multitude of CAD programs, their required skills levels, and platform availability.

6 **Getting started With 3D Printing Tutorials** from Shapeways. Never 3D printed or used CAD before? There are several tutorials and material available to help you get started on your 3D printing journey.

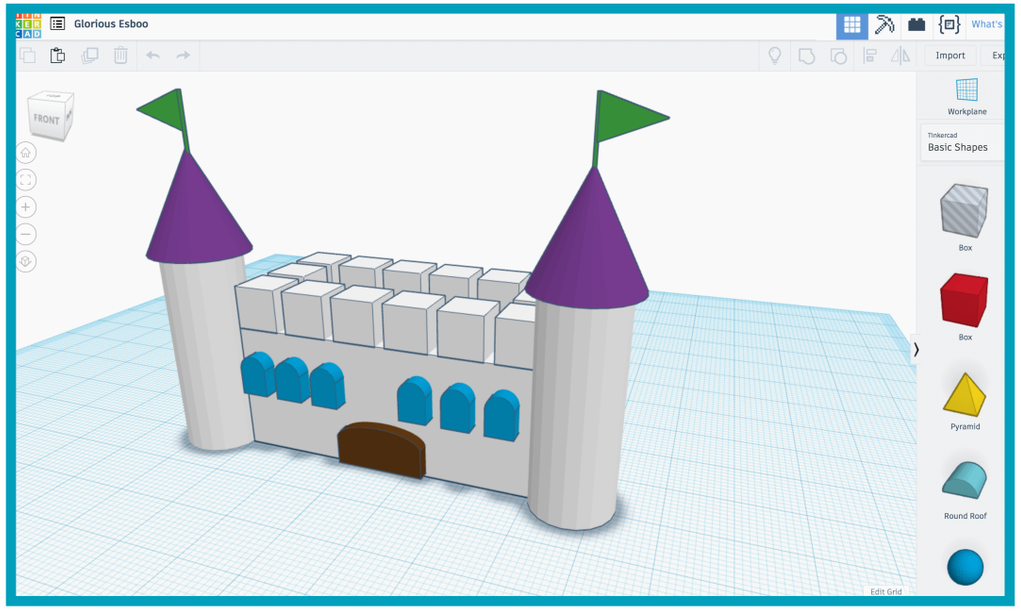
Drafting or Sculpting?

1. Begin your CAD education with Tinkercad. This simple drag-and-drop program will allow you to easily explore 3D concepts and design
2. When you are ready to explore more advanced programs, decide whether to work with CAD Drafting or Sculpting/ Model-based programs. Each type has several advantages and disadvantages, as detailed in this section.

CAD Programs

There are a number of different, free or low-cost Computer Aided Design (CAD) available, both online, as well as desktop based, and may be either CAD drafting or CAD modeling (sculpting) based. Here is a brief overview of some useful programs to get started with.

1 **Tinkercad** is an easy-to-use, drag-and-drop CAD program. Teachers can moderate students designs with ease. Students can use the program and design objects with minimum frustration as they learn.



Design custom objects with TInkercad's menu of shapes and forms.

What is the difference between CAD Drafting and Modeling/ Sculpting?

How do you decide between sculpting-based design versus modeling based design? Consider your needs...

Sculpting/Modeling based programs are better suited to creating organic shapes and forms. These programs may be best suited towards those looking to teach strictly design concepts.

Drafting based programs are best for creating precise models and complex moving parts that need a high level of accuracy in their output.

*For further insight, read through **this article** from Shapeways Magazine -an excellent resource for 3D Printing.*

2

Fusion 360: from the same parent company as Tinkercad (Autodesk), is a more advanced, cloud-based CAD program. There is a much steeper learning curve on advanced CAD programs such as Fusion 360, but also much more potential to create custom, intricate and complicated designs. Fusion 360 is free to students and educators, and suited to more advanced classes. Fusion 360 provides a number of introductory, in-depth tutorial videos to get started with and learn the basics of the program.

3

Sculptris is a free, intermediate-friendly 3D sculpting program. 3D sculpting uses a brush-based interface, and is suited to creating complex, flowing organic shapes and forms that are not easily created with modeling-based programs such as Fusion 360.

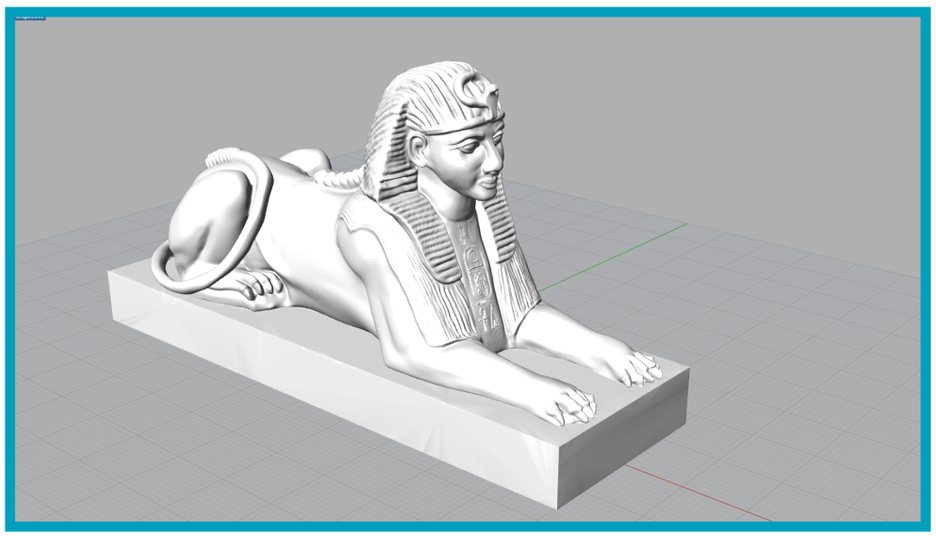
Engage Your Students

1. Print out your custom 3D designs. This is especially useful if you do not yet have a 3D printer available.
2. Learn and develop exciting new projects for your students.
3. Get 3D prints for your classroom. Almost anything you might want to print is available, most often for free!

Further Web Resources

From on-demand printing, to 3D design marketplaces, you can find a wealth of inspiration and services available online.

1 **MyMiniFactory**: A great source for thousands of 3D files to download and print at home. MyMiniFactory features the **Scan the World** initiative - using 3D scanning technologies to bring objects of cultural significance all. Works scanned come from famous sites across the world, including The Louvre and the British Museum. Use this website for your 3D printing class or even to bring tactile models for student engagement as part of history class.



The Sphinx at Cleopatra's Needle
from MyMiniFactory

2 **Thingiverse:** A popular website for downloading and printing 3D objects. Thingiverse also has a number of project files designed to work within Tinkercad that can be used for inspiration, or for incorporation into lessons to aid student development in 3D concepts.

3 **Shapeways:** A popular 3D printing service and digital marketplace. This site is a great source of inspiration for advanced 3D projects. Shapeways provides a wealth of information on various 3D printing materials, available **here.**

4 **3D Hubs:** An online 3D printing service platform. Connect with local 3D printers. to get on-demand 3D prints in a variety of materials. 3D Hubs also provides a number of detailed articles to help you learn more 3D printing and CAD design concepts.

5 **3D Printer Product Chart:** An interactive map of 3D printers and specs. Use the metrics and filters to customize your search to find the perfect 3D printer to fit your needs.

Essential Items

1. 3D Printed Objects: Print a variety of 3D objects and forms for students to interact and experiment with.
2. Modeling Clay: Use modeling clay to teach students about visualization and concepts regarding 3D space.
3. Technological Resources: student computers and internet access are essential.

Recommended Course Materials

Included in this section is a list of recommended materials and resources that can be implemented in this course. While not all materials are strictly necessary to teach the course -for example, it is not required to bring in 3D objects - doing so will help create a rich, engaging and exciting learning experience for your students.

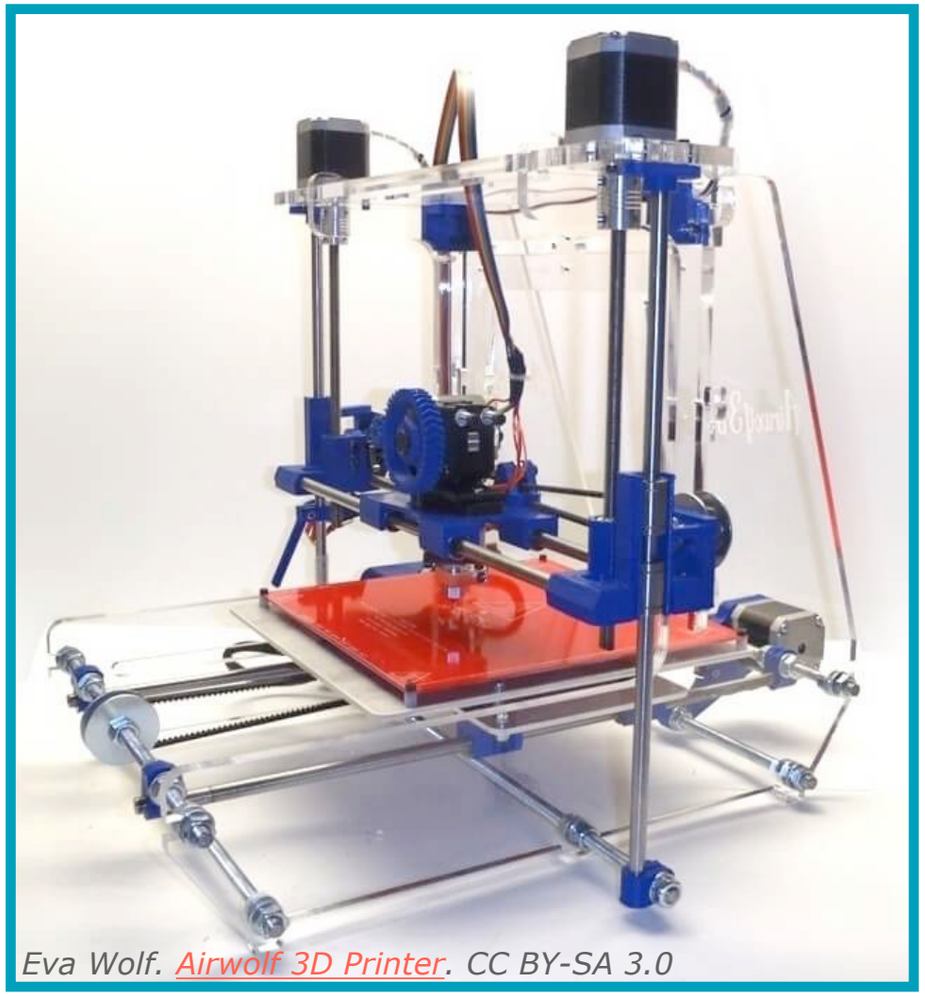
Technology Resources:

Teacher Computer: It is necessary to show slide presentations and videos to aid student learning. In later course lessons, it will be essential to demonstrate to students the processes used to design objects in Tinkercad.

Projector/Screen: Ensure access to a projector and an adequately sized screen is available. When demonstrating Tinkercad operations, students must be able to visualize the process, and some of the commands and property input boxes may be quite small.

Powerpoint/Keynote Access: Slides and presentation materials are provided in this manual, accompanying the provided lesson plans in PDF format for ease of use across all formats. However, as you move through the course, you may want to customize and add your own slides, depending on student engagement and progress with the course materials.

3D Printer: For printing supplemental materials, as well as for student demonstrations in class. There are a number of suitable printer options available. Printers run the gamut from smaller, less expensive units, to larger, production-based models. In general, the prices for a 3D printer run from approximately $500.00 to upwards of $5000.00 depending on the make and model. The larger the print



Eva Wolf. Airwolf 3D Printer. CC BY-SA 3.0

Sample picture of an FDM-type 3D printer. Refer to the Interactive 3D Printer Comparison Chart for a comprehensive overview of suitable options.

capacity (bed size) and features, the greater the price.

However, if you are willing to do some DIY and put the printer together yourself, there are a number of lower priced options to work with. See the **Interactive 3D Printer Comparison Chart** in the Web Resources section for further information and insight.

3D Printer Filament: You will most likely be using a Fused Deposition Modeling type 3D printer. This is a type of additive manufacturing in which the 3D printer lays down material layer by layer from the bottom up, in order to create a solid object. The filament will most often take the form of a spool or coil that is fed into the printer, heated up and extruded.[1]

3D Printed Resources:

3D Printed Objects: Bringing in a variety of 3D printed objects for students to interact and experiment with is essential. If you are proficient in CAD programs and design, create your own models for classroom demonstration and student experimentation. If not, you have several options to provide 3D printed objects for the classroom. Download one of the thousands of available options from websites such as MyMiniFactory or Thingiverse.

A sample 3D printed replica of a T-Rex fossil head from ***Thingiverse.***

3D Printed Mishaps: When creating 3D printed objects for this course, it is inevitable mistakes will happen, either due to a design error, or the 3D misprints. DO NOT throw these mistakes out! They make a valuable learning tool. Students love seeing half-finished objects, or objects that have turned to filament 'spaghetti.' Keeping these objects is valuable, as it allows students to see the interior structure of a 3D printed object. Furthermore, these objects serve as a tangible reminder and example of the processes of troubleshooting 3D printing and design require.

A 3D model of a mouse that misprinted shows the internal structure of the print.

Physical Materials

Writing/Drawing Materials (pencils, pens, markers, pencil crayons, crayons): As part of the coursework in this series, students will create concept drawings and sketches in their notebooks.

Student notebooks/workbooks: For students to create 2D concept drawings, complete sentence stems and other class work.

Chart Paper: Students will have the opportunity for group work and brainstorming. Have the groups use chart-paper where appropriate, to share their ideas with the class.

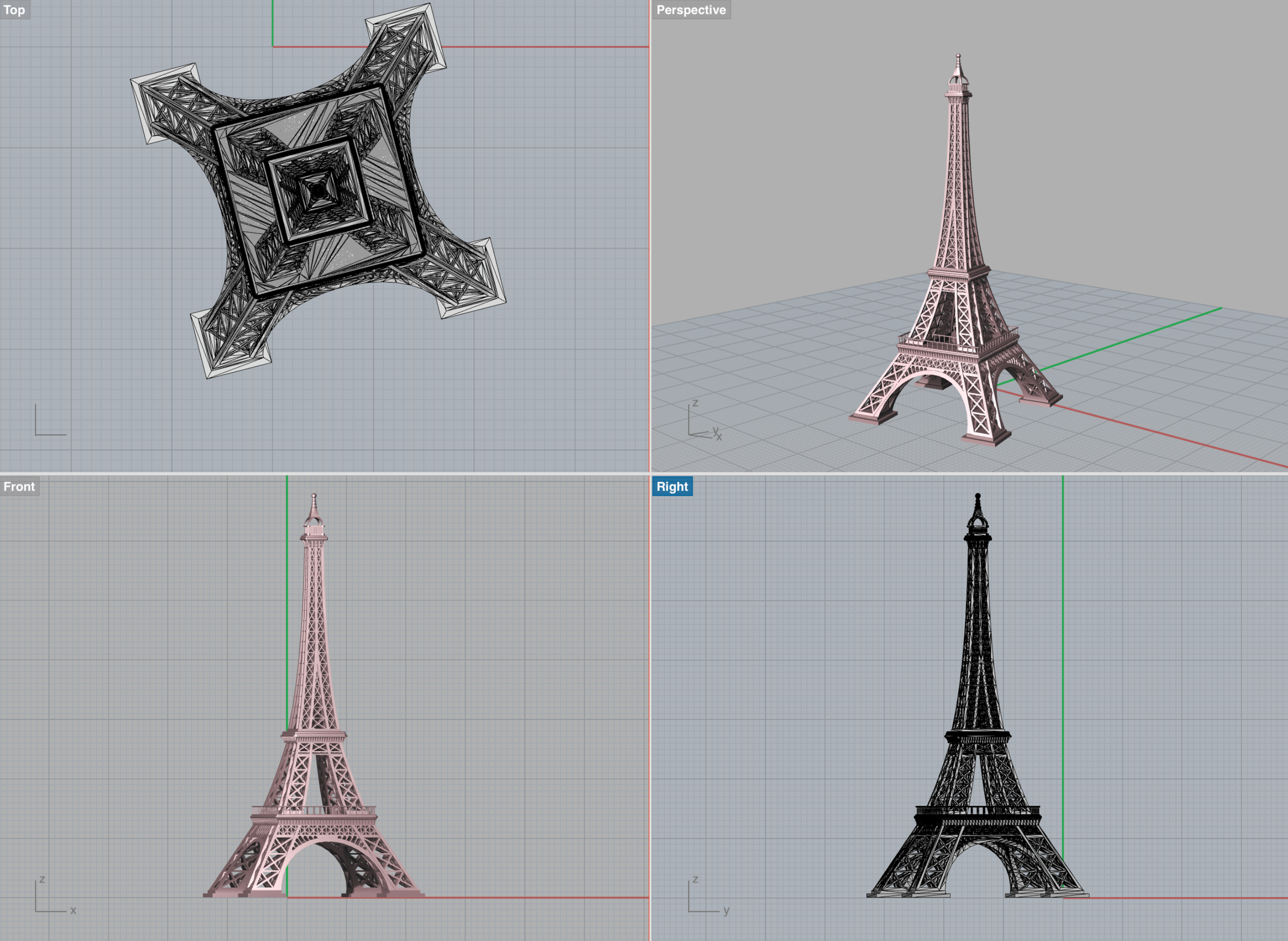
Construction Materials: Cardboard/Pipe cleaners/Popsicle Sticks: Use these construction materials to teach students about creating 3D concepts, and how to create 3D objects from 2D drawings. These materials may be useful in helping students visualize their projects.

Modeling Clay: Use modeling clay such as Model Magic or Plasticine to teach students about 1 packet can serve 2-3 students. Use the Modeling Clay to help students visualize their projects, and process working on and in 3D space -internalizing 3D design concepts.

Other Materials: as necessary, such as glue, tape, scissors and rulers.

End Notes

[1] "FDM Technology. 3D print durable parts with real thermoplastic" Stratasys. Accessed December 13, 2017.http://www.stratasys.com/3d-printers/technologies/fdm-technology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CHAPTER 3

Lesson 1: Introducing 3D Concepts

Lesson Highlights

1. Students will be introduced to basic 3D concepts and 3D printed objects.
2. Students will investigate how 3D printing can be used to help others through a variety of games and group-based activities.
3. Students will explore concepts related to 3D printing, and the myriad ways 3D printing can be used to create everyday objects.

Lesson 1: Introducing 3D Concepts

In this first lesson, students will be introduced to concepts of 3D printing and design. Students will begin the lesson by completing a pre-assessment designed to gauge their understanding of the subject material, and compare with the post-assessment to judge student knowledge gained during the course.

Before students are able to create and design their own objects in Tinkercad, it may be useful to print 3D objects for them from MyMiniFactory or Thingiverse. This is a cost-effective and easy way to both reward student participation, as well as further provoke their interest in 3D printing. For example, as part of the ‘empathy games’ later on in the lesson, reward student groups with their choice of 3D object to be given in the next lesson. Allow students to pick from a predetermined set of easily printable objects.

Consider 3D printing student name tags. as shown in the image below. This can be easily done even by using Tinkercad, and will, in fact, serve as a later project in the course, and inspiring future student projects. The name tags can be printed in white filament to allow students to color and customize their items.

Sample 3D printed name tag

A regular (paper) printer prints in 2 dimensions - the drawing or type only has **Length** and **Width**. A 3D printer prints objects in 3 dimensions -the objects have **Length**, **Width** and **Depth/ Height**.

Lesson Objectives (Students will learn...)

1. Introductory 3D printing concepts and the basics of how a 3D printer works.
2. How to interact with 3D objects.
3. How 3D printing can be used to help others, and evoke their empathy in ways relevant to themselves/their communities.

Lesson Outcomes (Students will be able to...)

1. Describe how a 3D printer is different from a regular (paper) printer.
2. Identify and name the materials 3D printers use to print objects (filament).
3. Explain how 3D printing can be used to help others.

Materials

- Computer
- Projector
- Prepared Slide Presentation
- 3D Printed Objects

- 3D printed glasses, hands, prosthesis, grasper 3 buckets with a variety of objects (plates, cutlery etc.)
- Soft Blindfolds
- A medium-sized stuffed animal (approximately 12 inches in height). Preferably a dog or cat.
- Student notebooks
- Chart Paper
- Writing Materials (pencils, pencil crayons, markers etc.)

Setup

1. Setup the prepared slide presentation. Ensure that the teacher computer, projector and slides are in working order.
2. Pre-print and bring in a set of 3D objects for students to interact with. These objects should include fossils (such as MakerBot's 3D T-Rex skull), as well as more practical or household items (such as a toothbrush holder). Students should be shown a wide range of 3D printed objects to interact with, to gain insight into the potential applications of 3D Printing
3. Prepare chart paper for student groups of 4-5 students, and markers for each group

4. Write class details on the board before class, including sentence stems and key vocabulary.

Vocabulary List

- 3-Dimensional (3D)
- 2-Dimensional (2D)
- 3D Printing
- 3D Printer
- Filament
- Computer Aided Design (CAD)

Sentence Stems

1. A 3D Printer is different from a regular printer because:

_____

Answers: it prints objects, it prints in 3 dimensions, it does not use paper etc.

I think 3D printing can change the world because:

_____

Pre-Assessment: (10 minutes)

Materials:

Handout: **3D Printing Pre-Assessment**

- Handout: Pre-Assessment
- Student writing materials

Process:

1. Instruct students to fill out the answers to the best of their knowledge.
2. Instruct students to leave blank or write 'I don't know' if they cannot answer a question.
3. Use this pre-assessment to gauge student knowledge of the course content, and as a good comparison for student learning with the final course post-assessment (from lesson 12).

Attention Getter: (5 minutes)

Materials:

- Teacher computer
- Projector
- Prepared slides 1-4

Process:

1. State to students: "Today we will be learning about, and introducing 3D Printing. Do any of you know what 3D Printing is and what you can do with this technology?"
2. Check for understanding to gauge student knowledge of 3D printing and concepts before reading through the student pre-assessments.
3. Begin Slide Presentation. Work through slides 1-4
4. Play the video from slide 4: 'What is 3D Printing and how does it work?"

Activity 1: Introduction and Interaction with 3D Objects (10 minutes)

Materials:

- Computer
- Projector
- Prepared Slides 4-8

Process:

1. Pass 3D objects around the room for students to interact with. Engage students with questions regarding the objects. Instruct students to investigate and interact with the objects.
2. State: "These objects were printed on a 3D printer. Let's take a look at this video: can anyone guess what is being printed?"
3. Play the video from slide 5: "3D Printer in Action: Pokeball"
4. After the videos, ask students the following questions

Question 1: "How is a 3D Printer different than a normal printer?"

Answer(s): A 3D Printer does not use paper. It uses filament made of plastic, rubber, or wood to print 3 Dimensional objects. A normal printer uses paper and prints 'flat,' or 2-Dimensional images.

Question 2: "What kind of objects can be 3D Printed?"

Answer(s): Toys, bracelets, phone cases, body parts/organs, a moon base in space, or another 3D Printer.

Activity 2: How are 3D Printers Used? (25 minutes)

Materials

- Computer
- Projector
- Slides 8-21
- Chart paper
- Writing materials (pencils, pencil crayons, crayons, markers etc.)
- Graspers, hands, glasses and prosthetics

- Buckets with assorted objects inside
- Blindfold

Process:

1. Students will interact with 3D printed objects used to help others: A 3D printed hand from enabling the future, 3D printed prosthesis for dogs, 3D printed glasses and 3D printed graspers will be used. Students will explore how 3D printing can be used to help others, and help engage students in empathy. Show students the hand from enabling the future and stuffed animal/dog prosthesis.
2. Students will play the grasper game. State: “These graspers were 3D printed for those with trouble picking up objects from the floor. What injuries or disabilities might a person have where they would need to use one?”
3. Students will break into 3 groups. Students will have 1 minute (timed) to try and pick all objects out of a bucket. The group that wins the challenge will pick the 3D printed objects for the following week at the end of class.
4. Students will play the orientation game. State: “What if we need help seeing? How could we use 3D printing to help?” Lead the class in a discussion about 3D printing glasses or visual aids.

5. Choose one student to be a direction leader. State “Let’s pretend I lost my glasses and can’t see, lead me to find my glasses.” Place on a blindfold and students will provide directions for the teacher to ‘find’ the glasses. Once found, the teacher will put on the glasses, and be able to ‘see again.’
6. Work through slides 8 - 21
7. Split students into small groups of 3-4. Give each group a piece of chart paper.
8. Draw **Chart 1.1 -***3D Printing Ideas* (see lesson Supplementary Materials) on the board. Instruct students to copy the chart on chart paper. Encourage groups to both write and draw their answers. Students should begin to conceptualize and think about 3D printing possibilities and ways to use 3D printing for those in need.
9. When groups have completed their charts, they will present their work to the class.

Recap and Wrap Up: (10 minutes)

Materials

- Computer
- Projector

- Slides 22 -24
- Student notebooks
- Writing materials (pencils, pencil crayons, crayons, markers etc.)

Process:

1. Work through slides 22 -24
2. Take a student survey to see which item they would like to see printed for the class for the following lesson. The winner of the Activity 1 game gets to choose the next lesson's 3D objects.
3. Discuss the following questions with the class to tie back into the lesson: "Why is 3D Printing important? How can 3D Printing be used to help others?"
4. Students will complete the Sentence Stems written on the board at the beginning of class in their notebooks. Encourage students to draw accompaniments to their answers, time permitting.

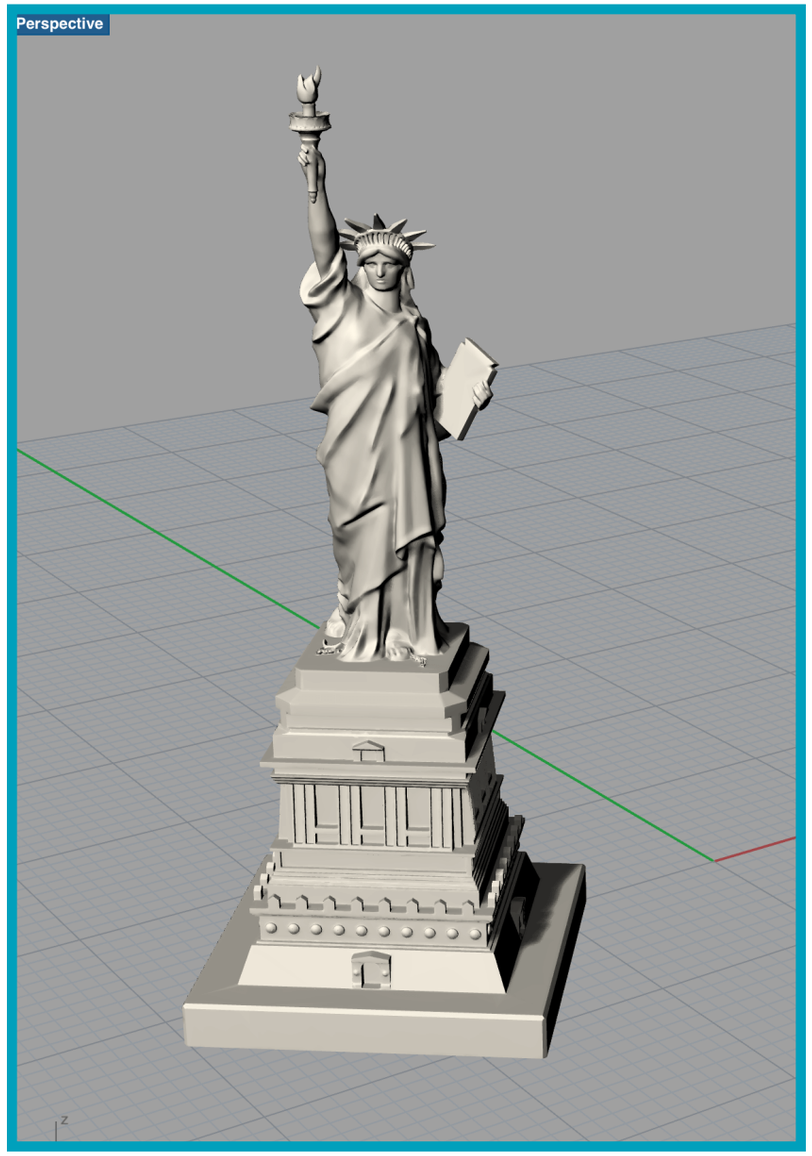
Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

1. A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

2. Presentation Slides. In PDF format. **Available here:**

3. Student pre-assessment worksheet. **Available here:**

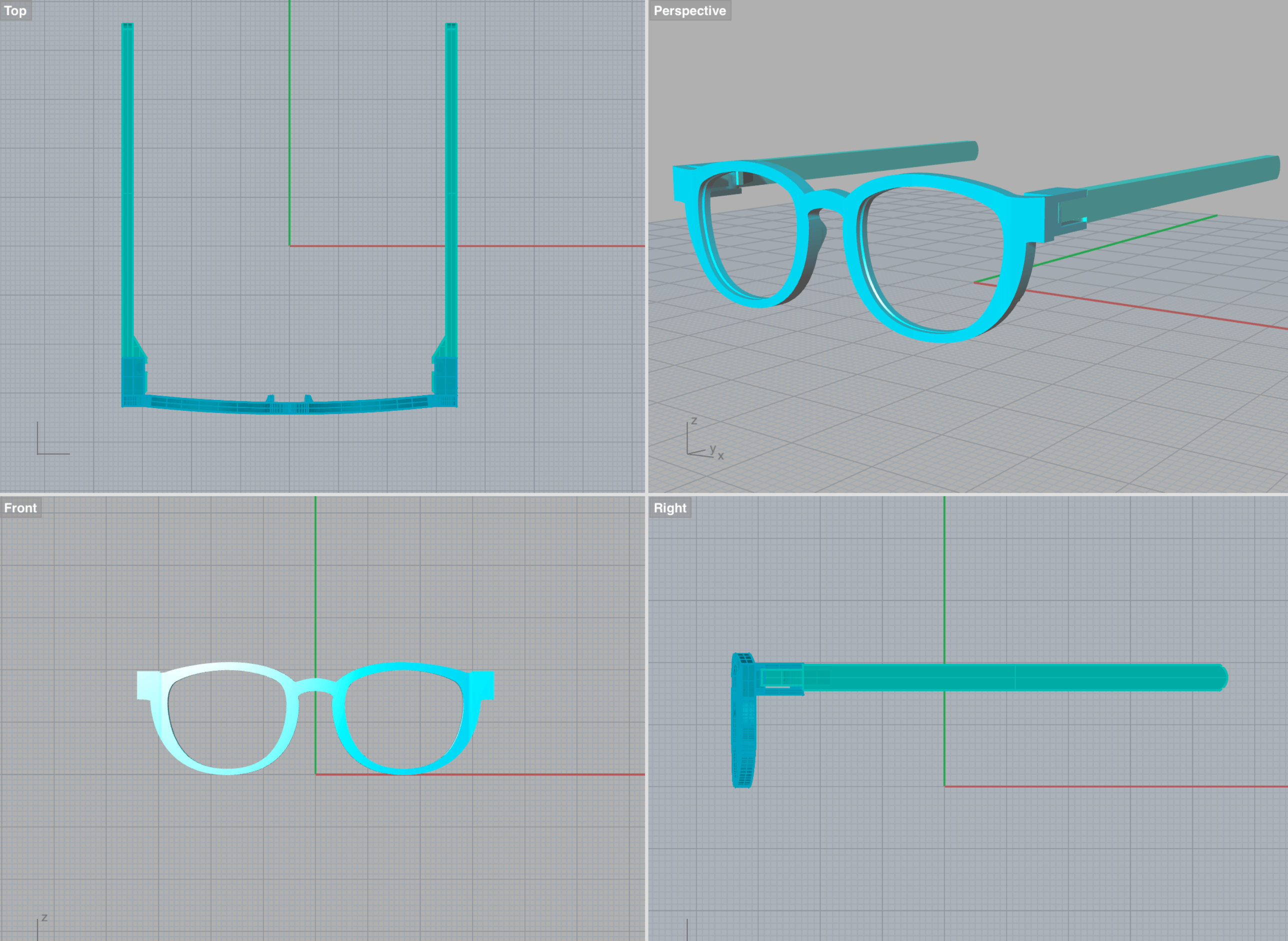


*A rendered version of the Statue of Liberty from the **Scan the World** project.*

4 Navigate to **MyMiniFactory** and **Thingiverse** for downloadable 3D designs to introduce students to 3D printed objects. The **Scan the World Project** objects at MyMiniFactory are of particular interest and relevance to student learning.

5 **Chart 1.1:** *3D Printing Ideas*

Materials to Use for 3D Printing	How to Use 3D Printing to Help Others	What Would You 3D Print? Sketch it Out
PLA Filament	Create a cast	A robot arm


Top
Perspective
Front
Right

CHAPTER 4

Lesson 2: 3D Concepts and Designs

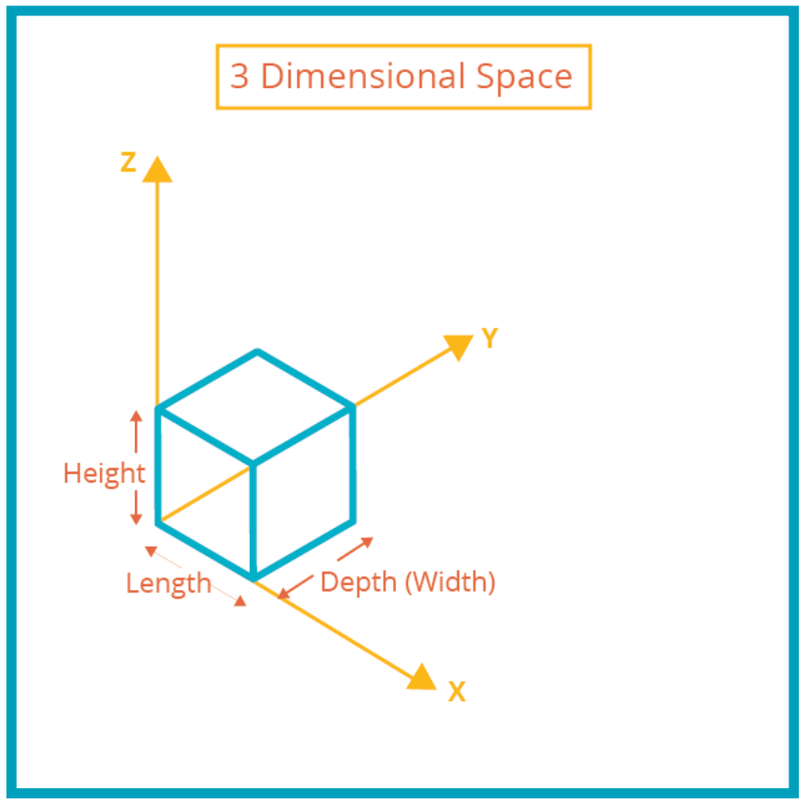
Lesson Highlights

1. Students will learn the difference between 2D and 3D.
2. Students will learn to create 3D objects from 2D drawings and concepts.
3. Students will get a brief introduction to Tinkercad to further reinforce the ideas introduced in this lesson.

Lesson 2: 3D Concepts and Designs

In this second lesson, students will be introduced 3D forms and objects through basic design work. The main focus of this second lesson is for students to conceptualize and visualize how 3D forms are created from 2D designs. Students will work with modeling clay in order to create their own, custom 3D forms. This lesson is designed to apply to a variety of different student learning styles. Students will go through a teacher lecture (aural), with slides (visual), explore lesson concepts through group activities and discussion (auditory) and experiment with building their own forms (kinesthetic).

During this lesson, students will be introduced to working in Tinkercad to create 3D objects to be printed. Tinkercad has several excellent tools for teacher moderation of student projects. Once you have created student accounts and assigned passwords, you can easily access and print student designs. You can then easily create custom shapes for student projects and upload them to student accounts.



A cube represented in 3 Dimensional Space

Lesson Objectives (Students will learn...)

1. The difference between 2 Dimensions and 3 Dimensions.
2. To conceptualize basic designs in 2D, and learn to transform those designs into 3D objects.
3. What and how Computer Aided Design (CAD) programs are and how they work.
4. How to get started on the CAD program for this lesson series: Tinkercad.

Lesson Outcomes (Students will be able to...)

1. Identify and explain the difference between 2D and 3D, and how to create designs in each space.
2. Create 3D objects from 2D designs.
3. Perform basic interaction with the Tinkercad interface.

Materials

- Computer
- Prepared Slide Presentation

- Projector
- T-Rex Head
- Handout: From 2D to 3D
- Modeling Clay packets
- Student notebooks
- Writing materials (pencils, pencil crayons, crayons, markers etc.)
- Student Chromebooks

Setup

1. Prepared Slide Presentation
2. Bring in 3D printed T-Rex head from Lesson One
3. Print the T-Rex Head Photo
4. Get a box of Modeling Clay packets. Link located in Supplementary Materials
5. Prepared Handout: *From 2D to 3D*. Print out 6-8 copies of each shape.
6. Pre-prepare all student Tinkercad accounts with unique usernames and passwords.

Handout: **From 2D to 3D**

Vocabulary List

- 3D
- 2D
- Computer Aided Design (CAD)

Sentence Stems

1. A (1) _____ is 2D, because (2) _____.

Answers: (1) Drawing, print out, words on paper (2) it is flat, you can only measure its length and width, it does not project out into space

2. A (1) _____ is 3D, because (2) _____.

Answers: (1) object, 3D, everyday object examples (chair, person, pencil etc) (2) You can measure its length, width, and length, it projects out into space, it is solid.

Attention Getter: (5 minutes)

Materials:

- Computer
- Projector
- Slides 1-3
- 3D printed T-Rex Head
- Student notebooks
- Writing materials (pencils, pencil crayons, crayons, markers etc.)

Process:

1. Project slide 1 and state "Today we will be continuing our lessons on 3D printing. We will learn about the difference between 2D versus 3D, and how to make a 3D object from a 2D drawing. When we have something that is 2-Dimensional, it is flat, like a drawing, or what you print from a regular paper printer. When we have something that is 3-Dimensional, it is an object, like a chair, or something you can print from a 3D Printer."

2. Project slide 2 and state: "When we draw something, it is 2-Dimensional -we measure it by width and length -it's 2 Dimensions." Project slide 3, and hold up the T-Rex skull.
3. State "When we have a 3D object, there are 3 Dimensions projecting into space: width, length AND depth (thickness). When we want to create a 3D object to print out on a 3D printer, we use a program called Computer Aided Design (CAD). Often, we will create a 2D drawing of our model, and then create the 3D object from the flat, 2D drawing."
4. State: "Let's do a scavenger hunt! Get out your notebooks, and you must locate around the room 3 items that are flat -or 2-Dimensional, and 3 objects."
5. Students will draw or write the items from the scavenger hunt in their notebooks.

Activity 1: Working in 2 and 3 Dimensions (20 minutes)

Materials

- Computer
- Projector

- Slides 4-8
- Modeling Clay
- Handout: From 2D to 3D
- Student notebooks
- Writing materials (pencils, pencil crayons, crayons, markers etc.)

Process:

1. State: "When we create an object, for example using Computer Aided Design, or CAD, we first create a 2D drawing of that object. 2D drawings are flat, while 3D objects project out into space - they have depth."
2. Show slides 8-9 to demonstrate to students 2D drawings and their 3D counterpart objects.
3. Break students into groups of 3.
4. Give each group a 2D drawing: A) Rectangle, B) Triangle, C) Pentagon, D) Circle.
5. Pass out Modeling Clay and assigned shape paper. 1 pack of Modeling Clay can serve 2-3 students.
6. Each student will use materials to create a 3D object from their assigned 2D drawing, referring to the paper handout. For example,

students will use Modeling Clay to build a sphere by creating a circle then rolling it into a sphere.

7. Students will compare their models with their group.
8. Optional: If students are done early, they will use the modeling clay to create each shape option A-D.

Challenge

1. Students will create a simple drawing in their notebook (such as a flower, tree, dog, house etc.)
2. Students will use their 2D drawing to create a 3D object using Modeling Clay.
3. Students will share their designs with the student next to them.
4. Choose 2-3 students to share their drawings and counterpart objects with the class.
5. Instruct students to wrap up their modeling clay for re-use next class.

Activity 2: Introducing Tinkercad (30 minutes)

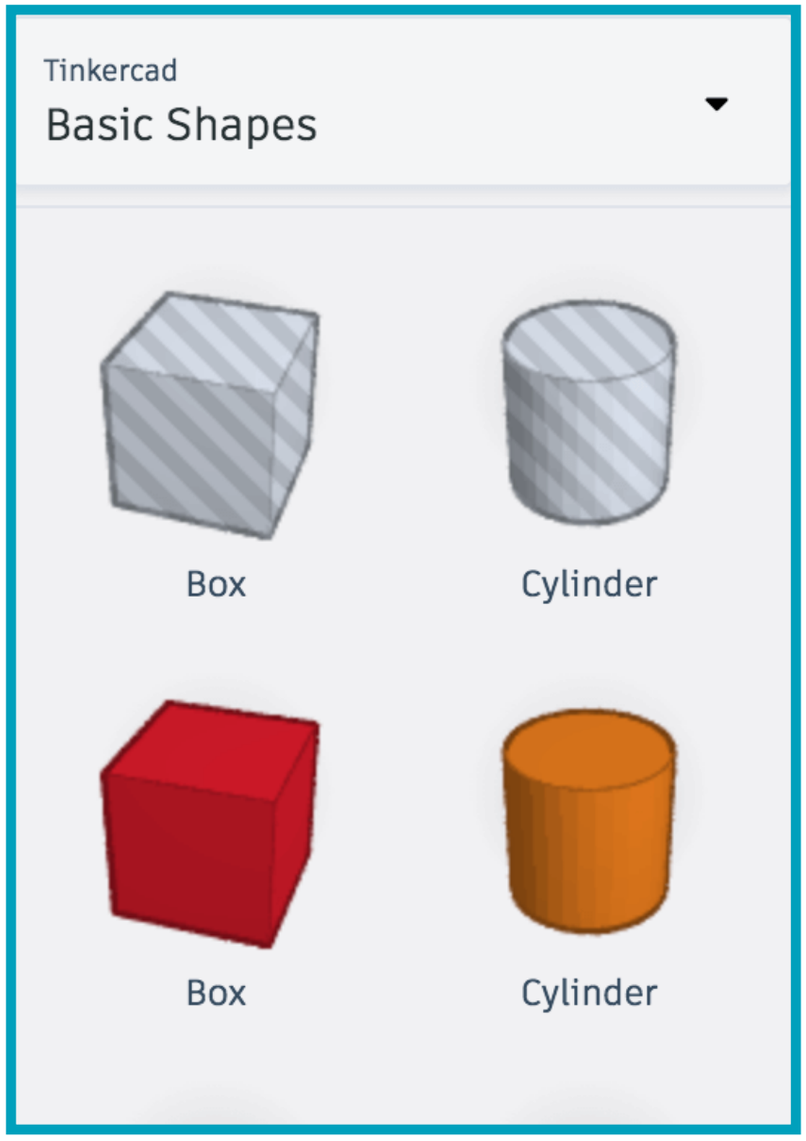
Materials

- Student Chrome-Books
- Teacher computer
- Projector and screen

Process:

1. State: “Let’s get started with some Computer Aided Design (CAD) practice!”
2. Instruct students on the process to log into Tinkercad, with their provided usernames and passwords.
3. Instruct students to open Tinkercad by

Introducing the CAD program Tinkercad...



3D object representations in Tinkercad

clicking on “New Design”

4. Go over the interface with students. Instruct students on the basics of the Tinkercad interface: the workplane, the viewport controls, and tool panels.
5. Demonstrate how to drag shapes onto the workplane, and move them around.
6. Write a list of the following shapes on the board: Circle, square/ rectangle, triangle
7. Students will create Chart 2.1 in their notebooks.
8. Instruct students to draw a quick sketch in their notebook of the different shapes listed.
9. Students will then locate the 3-Dimensional object counterpart of the object they just sketched in the Basic Shapes section of the Tinkercad interface. Instruct students to drag the object onto the workplane and sketch to fill in and complete their chart. Demonstrate to students as necessary.
10. Allow students to interact and experiment with the Tinkercad interface as time permits. More formal instruction will form the greater part of the next lesson.

Recap and Wrap Up: (5 minutes)

Materials

- Student notebooks
- Student writing materials

Process:

1. Ask students to reflect on the lesson
2. Recap: 2D refers to a flat drawing or representation of an object.
3. 3D refers to an object with depth/thickness that projects into space
4. Instruct students to complete sentence stems.

Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

1. A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

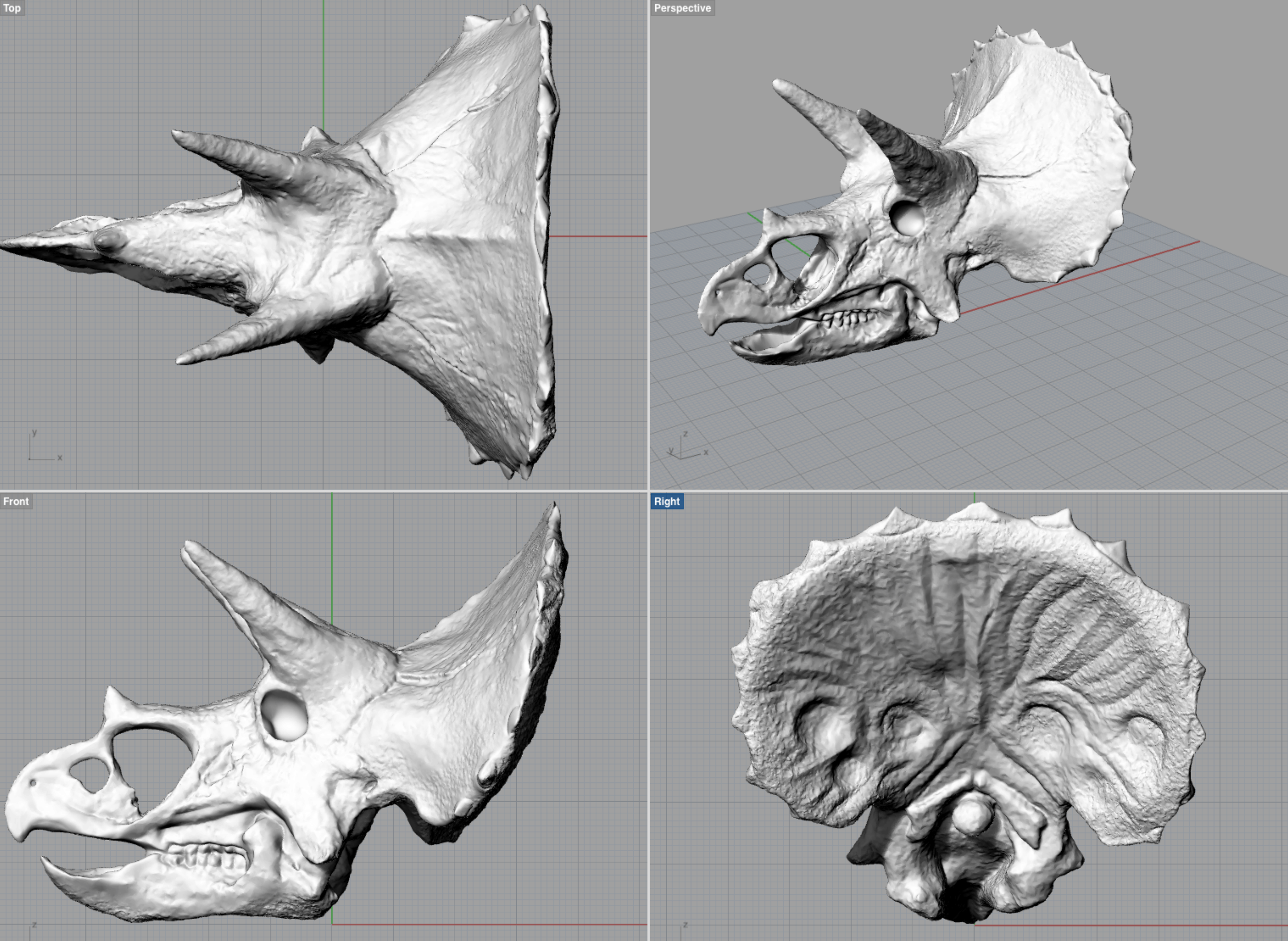
2. Presentation Slides. In PDF format. **Available here:**

3. Handout -*From 2D to 3D*. **Available here:**

4 **Tinkercad for Teachers.** This resource from Tinkercad gives an overview on how to use the program for educational purposes, and moderate students.

5 **Chart 2.1:** Sample **2D to 3D Sketch Chart** to be drawn

2-Dimensional Shape Name	2-Dimensional Sketch	3-Dimensional Shape Name	3-Dimensional Sketch


Top
Perspective
Front
Right

CHAPTER 5

Lesson 3: Points of View **in 3D Space**

Lesson Highlights

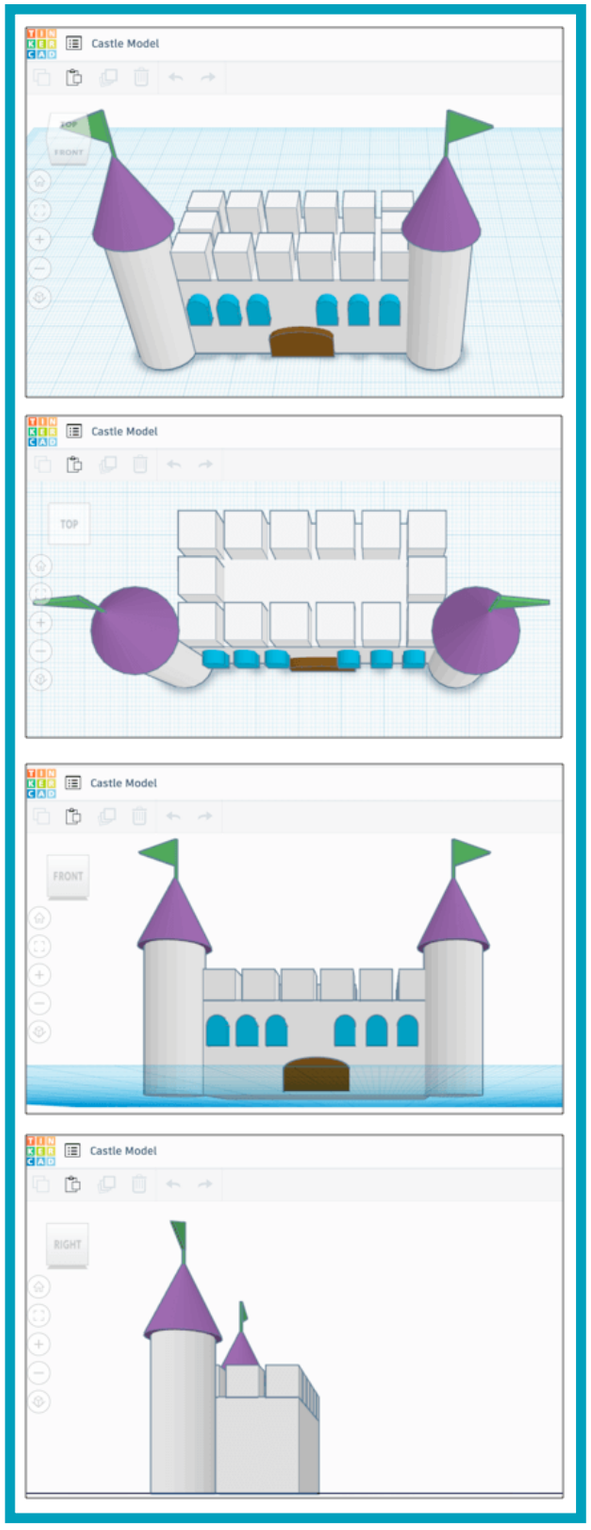
1. Students will learn about the different views in 3D space: Perspective (World), Top, Front and Right (Side).
2. Students will learn how to view an object from different views as well as draw the object from each view.
3. Students will begin to internalize the concepts of 3D space, and how objects can be viewed from different perspectives.
4. Students will continue their introduction to Tinkercad, as they experiment with the different viewports, and creating simple objects.

Lesson 3: Points of View in 3D Space

An essential aspect of learning to work with CAD programs is how to manipulate the different viewports. When creating custom objects and designs, it is necessary to work in the main views: **Perspective (World), Top, Front and Right (Side)**. Each view provides a different perspective of a model, allowing designers to accurately and quickly place object parts.

However, learning to work with, and manipulate objects in the different viewports is a very difficult concept, especially for students. Tinkercad allows for ease of manipulation of the different views with a 'view cube.'

You may find that working with, and manipulating viewports will be one of the largest hurdles students face in this course. By working through this process, students will be able to carry these skills into more advanced and complicated CAD and design programs, providing them with a solid background in 3D design concepts.



Viewports: Perspective (World), Top, Front, Right

Lesson Objectives (Students will learn…)

1. The different views of 3D space.
2. How to view objects in each view.
3. How to draw objects in each view.
4. Tinkercad view controls.

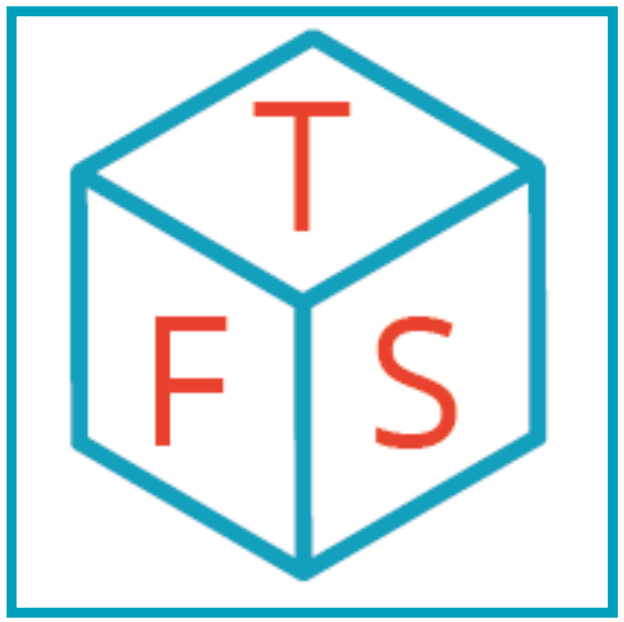
Lesson Outcomes (Students will be able to…)

1. Identify the different views of 3D space.
2. Draw objects in each view of 3D space.
3. Manipulate the Tinkercad view controls.

Materials

- Computer
- Prepared Slide Presentation
- Projector
- Modeling Clay packets

- Student notebook
- Writing materials (pencils, pencil crayons, crayons, markers etc.)
- Student Chrome Books



Sample box to be created out of modeling clay

Setup

1. Prepared Slide Presentation
2. Modeling clay for students, separated as necessary
3. Prepare a simple box-shape made out of modeling clay, with a T, S, and F
   engraved on the sides. Reference the image to the left.
4. Prepare a simple object made out of Modeling Clay (such as a house or car).

Vocabulary List

- Viewpoints
- 3D Space
- Perspective (World) View
- Top View
- Front View

- Side View

Sentence Stems

1. Looking at an object from _____ view is the easiest way to see and identify an object because: _____.
2. Drawing an object from _____ view is the easiest way because: _____.

Attention Getter: (5 minutes)

Materials:

- Computer
- Prepared Slides 1-3
- Projector

Process:

1. Project slide 1. State: "Today we will be continuing our lessons on 3D printing. We will be learning about the different views of 3D space."

2. Project slide 2. State: "Can anyone tell me what it is?"
3. Project slide 3. Answer: "It is a Triceratops head! We are looking at it from top view -imagine you were a bird, looking down: this is how the Triceratops head would appear to you."

Activity 1: **Points of View** in 3D Space (15 minutes)

Students will work on investigating how different views work in 3D space. Using modeling clay, students will examine and draw objects from each view: Perspective (World), Top, Front and Right (Side).

Materials

- Computer
- Projector
- Slides 4-8
- Modeling Clay
- Prepared Modeling Clay box
- Student notebooks
- Writing materials (pencils, pencil crayons, crayons, markers etc.)

Process:

1. Work through slides 4-5
   Instruct students to get out their Modeling Clay and mold it into a triangle shape. Instruct students to engrave, using their fingernail, an 'F' on the front, a 'T' on the top, and an 'S' on each side to represent the different views. The box should be approximate to the image here:
2. State: "You are going to have a completely different perspective on this simple triangle!"
3. Show slides 6-9 to go through the different views.
4. Use your prepared box made of Modeling Clay to show students what they will be making.
5. Instruct students to place their triangle model on their desks, with the 'F' engraving facing them.
6. State: When we look at an object from Top View, we are looking down on an object. Imagine you are a bird in the sky, looking down at the tops of trees, buildings and people's heads." Instruct students to get up and look at their triangle from above, so they can see the engraved 'T.'
7. State: "When we look at an object from Front View, we are looking head-on at an object, at eye-level." Instruct students to kneel on the

ground with their field of view to be level with the object, in order to easily see the engraved 'F.'

8. State: "When we look at an object from Side View, we can see how it looks from Side View." Instruct students to move to the side of their desk, and kneel down so their field of view is level with the object and they can see the engraved 'S.'
9. State: "When looking at an object from Perspective, or Worldview, we can see all sides where we engraved the letters." Instruct students to hold up the object in such a way that they can see all engraved letters.
10. Instruct students to create **Chart 3.1** *-3D Views Sketch Chart* in their notebooks, and draw each view they just examined in their notebook.
11. Instruct students to create an object of their choosing, and draw each view of that object in their notebook

Activity 2: Guess the Object (5 minutes)

Students will work through a slide set of 3D objects shown in different viewports. Encourage students to work together to guess which object is being shown.

Materials

- Computer
- Projector
- Slides 10-29

Process:

1. State: "Let's play a game! Try to guess what we are looking at."
2. Work through the slides, ensuring that you state and reinforce with the class what viewpoint the first slide is representing, allowing students to guess the object, then moving to the next slide with the object revealed.
3. The purpose of this activity is to get students familiar with looking at objects from different **Points of View**, and eventually to work with objects in each. Working in different viewports and utilizing different views is one of the more difficult concepts students will need to learn when using CAD programs.

Activity 3: Different Views in Tinkercad (25 minutes)

Students will experiment with different views in Tinkercad, furthering their learning in the program, and getting a feel for how the controls work.

Materials

- Computer
- Projector
- Student notebooks
- Writing instruments (pens, pencils, markers, crayons, etc) • Student
- Chromebooks
- Projector
- Slides 10-29

Process:

1. Instruct students to open Tinkercad, and go to “Create a design”
2. Instruct students to drag a cylinder onto the workplane.
3. Demonstrate how the viewport tool works. Show students how to switch views, and demonstrate top, front, side and bottom views. Show students how to go to perspective view by clicking on the home button.
4. Instruct students to open the Tinkercad learning tutorials **available here:** and go to the camera controls tutorial.
5. Have students work through the tutorial, and learn about manipulating the camera controls.
6. Instruct students to open a new project file, and create a quick build of their choice using up to 5 different shapes. Students will have 2 minutes to create their object. Show students how to resize and move objects up and down on the workplane.
7. Instruct students to create **Chart 3.2:** *Tinkercad Viewport Drawing Chart* in their notebooks. Students will then view the object just created in each viewport, and draw a quick sketch of the object in each view.

Recap and Wrap Up: (5 minutes)

Materials

- Student notebooks
- Writing instruments (pens, pencils etc)

Process:

1. Instruct students to think about which of the viewpoints is the easiest way to see and identify an object, and why.
2. Instruct students to think about which of the viewpoints is the easiest way to draw an object and why.
3. Instruct students to work through the Sentence Stems written on the board and write their answers in their notebooks.
4. Encourage students to think about and write down the hardest viewpoints for seeing and drawing objects, time permitting.

Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

1. A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

2. Presentation Slides. In PDF format. **Available here:**

3

Chart 3.1: *3D Views Sketch Chart*

Object:_____

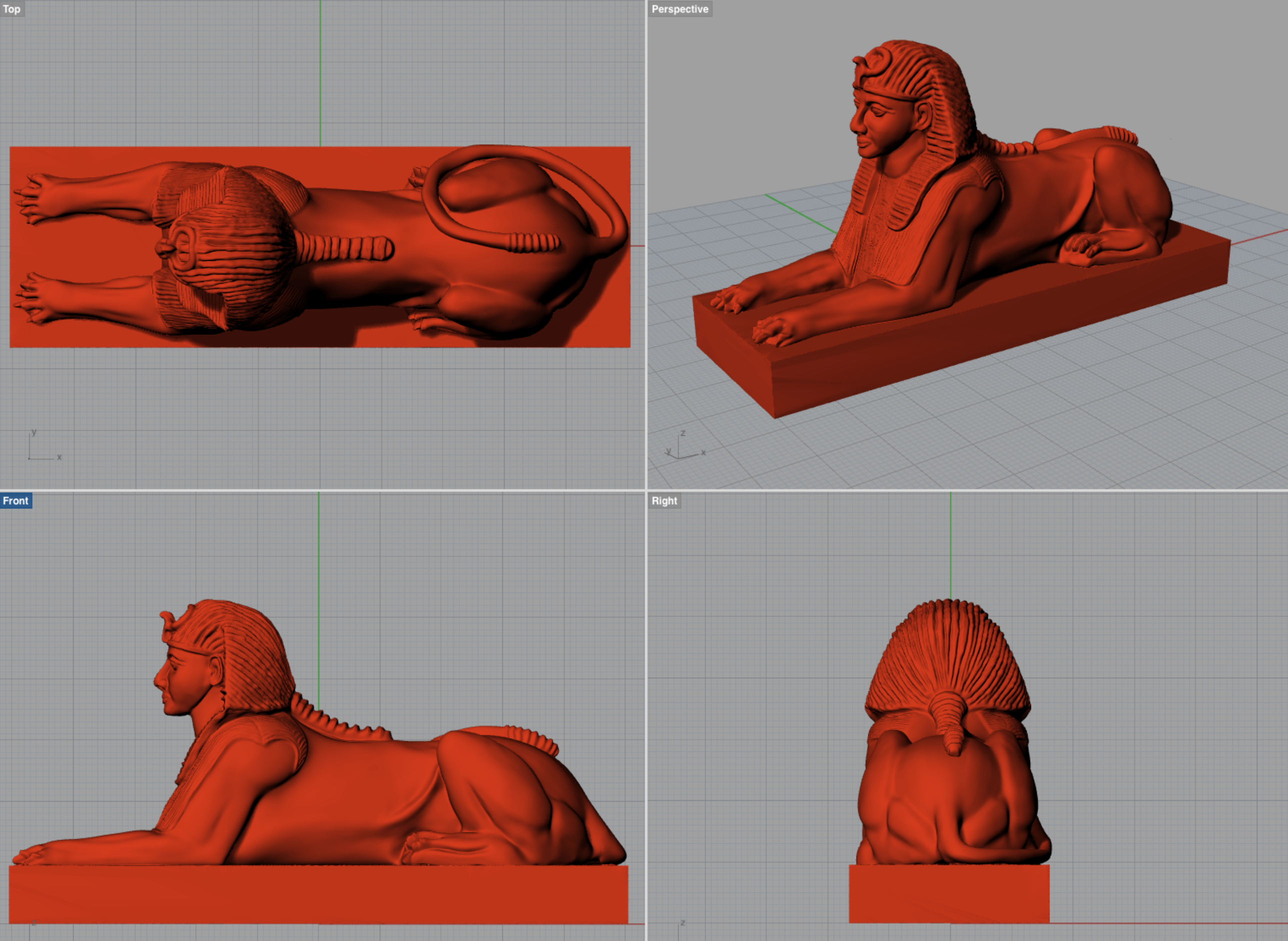
View	**Drawing**

4

Chart 3.2: *CAD Viewport Drawing Chart*

Object:_____

Viewport	**Drawing**


Top
Perspective
Front
Right

CHAPTER 6

Lesson Four: Beginning Skills in Tinkercad

Lesson Highlights

1. Students will be introduced in-depth to the Tinkercad interface and controls.
2. Students will learn how to manipulate the Tinkercad interface and controls in order to create custom 3 Dimensional objects.
3. Students will learn these basic skills in Tinkercad as they work with shape manipulation and transformation.

Lesson 4: Beginning Skills in Tinkercad

Students have spent the three previous lessons learning about 3D printing technology, 3 Dimensional design concepts, and an introduction to working in 3D space, as they learned about the different views: Perspective (World), Top, Side and Front -and how these different views shape how an object is represented and seen by the viewer.

In this lesson, students will draw from the skills learned in the first three introductory lessons in order to begin creating custom objects using the Tinkercad interface. Students will receive an overview of key Tinkercad commands and controls, in order to master program basics. Students may take the whole lesson to experiment with, and properly learn how to use the Tinkercad controls. Some, such as the **Move** and **Rotate** tools require more finesse, and will prove difficult for students to use with ease.

Lesson Objectives (Students will learn…)

1. The Tinkercad interface and controls.
2. Basic shape manipulation and commands.
3. Basic design concepts in Tinkercad.
4. How to use the Tinkercad view controls.

Lesson Outcomes (Students will be able to…)

1. Identify the basic controls and interface elements used in Tinkercad.
2. Transform basic shapes.
3. Manipulate and work with **Points of View** in 3D space, and apply these concepts (from Lesson 3) to object manipulation in Tinkercad.

Materials

- Teacher Computer
- Prepared Slide Presentation
- Projector

Handout: **The Tinkercad Interface**

Handout: **Tinkercad Object Controls**

- Student Chromebooks
- Handout: *The Tinkercad Interface*
- Handout: *Tinkercad Object Controls*
- Modeling Clay
- Student Notebooks
- Student Writing instruments (pens, pencils etc)

Setup

- Provide Students with the handouts, key Tinkercad vocabulary/ terms/tools and accompanying diagrams. This lesson will utilize numerous vocabulary terms that are essential for student knowledge.
- Prepared Slide Presentation
- Pre-prepared model plans for students to emulate and practice with.
- Tinkercad account pre-prepared for each student, with the appropriate username and password, for ease of student access, and ease of teacher moderation.

Vocabulary List

Tinkercad Interface Terms

- The Workplane
- Edit Controls -Copy, Paste, Delete, Duplicate
- Transform Controls -Group, Align, Flip
- View Controls -Perspective (World), Top, Front, Side
- Grid Controls
- Design Tools
- Shape Controls
- Zoom Controls -Zoom In/Zoom Out

Tinkercad Object Controls Terms

- Rotation
- Property Input
- Anchor Point
- X, Y, Z-axes

Sentence Stems

1. In Tinkercad, the Workplane is where we create...

   _____

   Answers: 3D designs, objects, shapes

2. In Tinkercad, the CAD stands for...

   _____

   Answer: Computer Aided Design

3. In Tinkercad, and 3D programs we work with, we use 4 Viewports.
   Name 2: _____

   Answers: Perspective (World), Top, Front, Side

Attention Getter: (5 minutes)

Materials:

- Modeling Clay
- Student notebooks
- Writing instruments (pens, pencils etc)

It is essential that students internalize the fundamental concepts on 3D **Points of View** to gain proper working knowledge of how to manipulate and use viewports in CAD.

These concepts are fundamental knowledge for further study in CAD and 3D Printing.

Handout: **The Tinkercad Interface**

Process

1. State: "In the previous lesson, you practiced working with the different **Points of View** in 3D Space. Let's review what they are."
2. Ask students to name the four views: Perspective (World), Top, Front and Side.
3. Instruct students to quickly create a 3D object using modeling clay, such as a letter, flower or car.
4. Instruct students to draw **Chart 3.1** *-3D Views Sketch Chart* in their notebooks, and fill in each **Points of View** section, referencing the object they created with modeling clay.

Activity 1: Introducing the Tinkercad Interface (10 minutes)

Materials:

- Handout: *The Tinkercad Interface*
- Student Chromebooks
- Prepared Slide Presentation, slides 1-23
- Writing instruments (pens, pencils etc)

Students should review the worksheet prior to each future lesson, and ensure they have a mastery of the interface controls and terms. Tinkercad controls can be easily transferred to more advanced CAD programs in future courses.

Handout: **Tinkercad Object Controls**

Process

1. Instruct students to open their Chromebooks, and navigate to **www.Tinkercad.com**
2. Walk students through the log-in process, using pre-prepared usernames and passwords for each student. Most students will have no experience with the program.
3. Work with students through the handout *The Tinkercad Interface*. Work through slides 1-23.
4. Instruct students to label and match the appropriate Tinkercad control/interface label to the appropriate section on the diagram.

Activity 2: Tinkercad Object Controls (10 minutes)

Materials:

- Handout: *Tinkercad Object Controls*
- Student Chromebooks
- Prepared Slide Presentation, slides 24-39
- Writing instruments (pens, pencils etc)

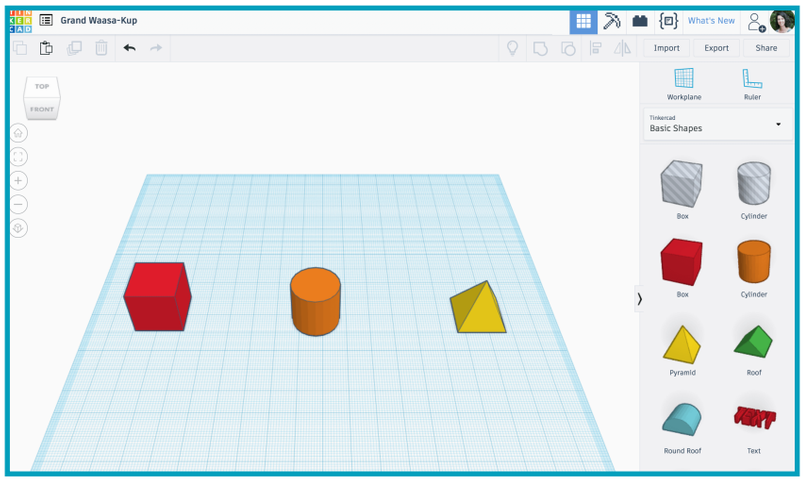
Process

1. Work with students through the handout *Tinkercad Object Controls*. Work through slides 24-39.
2. Drag a number of objects onto the Tinkercad workplane, and demonstrate to students object manipulation and transformation controls as the class works through the worksheet.
3. Instruct students to match the Tinkercad object control label to the appropriate section on the diagram.

Activity 3: Manipulating Tinkercad Objects (30 minutes)

Materials:

- Student Chromebooks
- Prepared Slide Presentation
- Student notebooks
- Writing instruments (pens, pencils etc)



Drag a box, cylinder and pyramid onto the workplane, as shown in the image above.

Process

1. The slide presentation for the activity will demonstrate to students how objects can be manipulated and transformed in Tinkercad, priming students for their first project in the next lesson.
2. Navigate to Tinkercad. Drag three objects onto the workplane in a horizontal row: A box, a cylinder and a pyramid. Ensure each object is a different color. Ensure adequate space between each object (they will be resized larger at some point).
3. Work through the slide presentation. After each slide, demonstrate the appropriate command in Tinkercad.
4. Instruct students to complete each command/work with each tool along with the teacher.
5. Once all slides have been worked through, allow students to interact with the Tinkercad interface.
6. Instruct students to use each command and control from the worksheets completed at the beginning of the lesson.
7. Instruct students to take brief notes on the function of each command and tool in Tinkercad.

Recap and Wrap Up: (5 minutes)

Materials

- Student notebooks
- Writing instruments (pens, pencils etc)

Process:

1. Instruct students to think about which commands were the easiest to work with in Tinkercad, and which were the most difficult.
2. Instruct students to work through the Sentence Stems written on the board and write their answers in their notebooks.

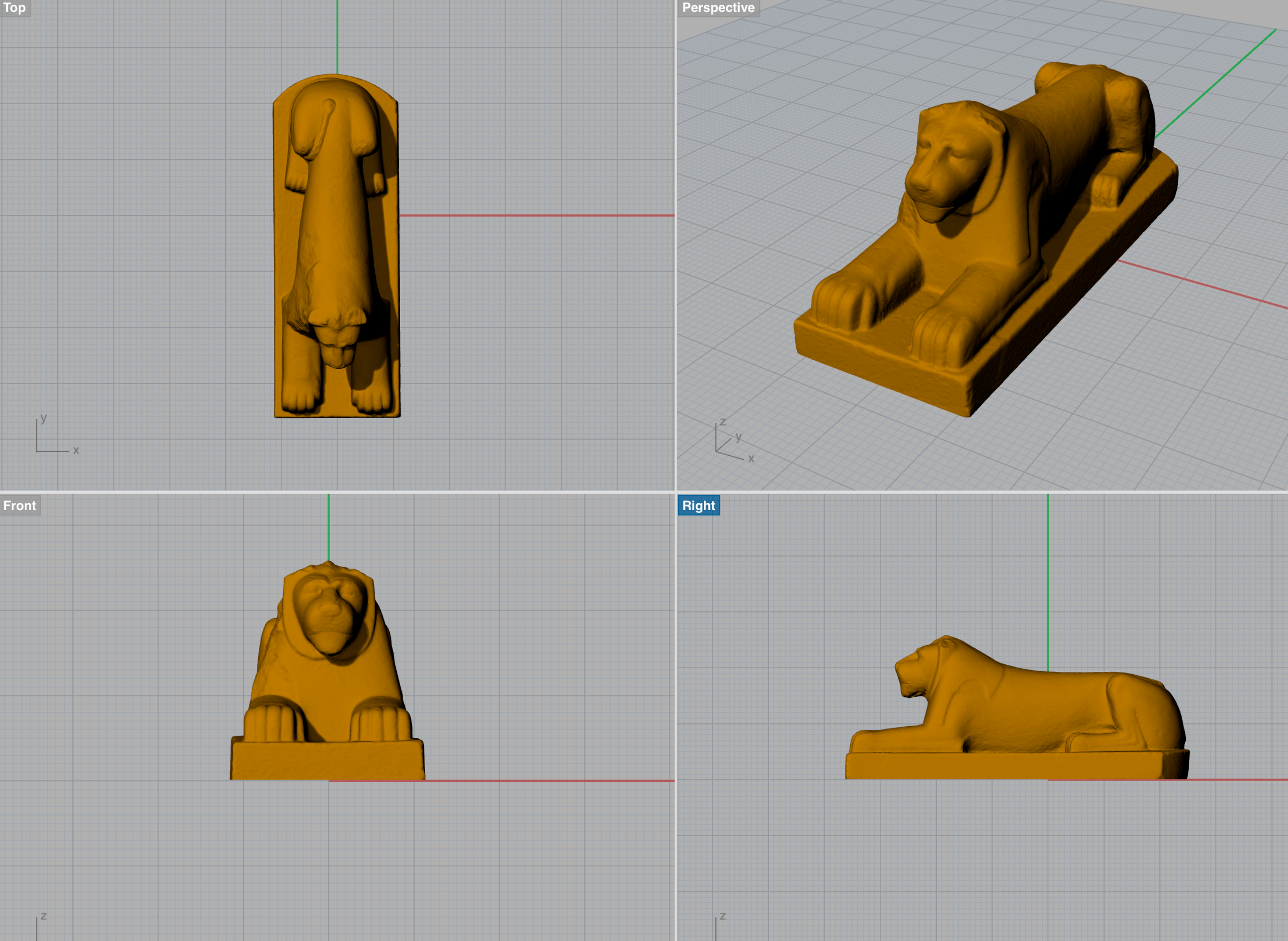
Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

1. A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

2. Presentation Slides. In PDF format. **Available here:**

3. Handout -*Tinkercad Object Controls*. **Available here:**


Top
y
x
Perspective
z
y
x
Front
z
Right
z

CHAPTER 7

Lessons 5: Create a custom nameplate keychain in Tinkercad

Lesson Highlights

1. Students will build on skills learned in the previous lessons to design and create their own, personalized nameplate keychain.
2. Students will output a printable object.
3. Students will learn to write and create a short **Design Brief** describing their project. Students will make use of technical communication concepts, while further working on and improving their English Language skills.

Lesson 5: Create A Custom Nameplate Keychain in Tinkercad

In the previous lesson, students were introduced to the Tinkercad interface, as they worked through a guided lesson to learn the commands of the program. Students also practiced object manipulation and control, as they experimented with design and 3D principles in Tinkercad.

In this lesson, students will begin with an introduction to **Design Briefs**. Students will learn the importance of planning out their designs, and working through the **Design Process** in order to create successful, well-thought-out projects.

Students will be introduced to two new basic Tinkercad concepts in this lesson -as they learn Tinkercad's **Hole**, **Align** and **Group Tools**. Learning these new, simple commands will set students up for success in further lessons. Students will further practice and refine the core concepts of object resize and movement learned and practiced in the previous lesson.

Lesson Objectives (Students will learn…)

1. How to create custom objects in Tinkercad.
2. Tinkercad's **Hole Tool.**
3. Tinkercad's **Align Tool.**
4. Tinkercad's **Group Tool.**
5. Design Brief concepts and the creative process of a write-up detailing design objectives.

Lesson Outcomes (Students will be able to…)

1. Create a custom nameplate keychain.
2. Manipulate and transform objects using key Tinkercad controls and commands.
3. Create a custom Design Brief detailing their project and design objectives.

Materials

- Computer
- Prepared Slide Presentation

Handout: **Design Brief**

Handout: **Tinkercad Nameplate Instructions**

- Projector
- Student Chromebooks
- Student notebooks
- Student writing and drawing instruments (pens, pencils, etc.)
- Handout: *Design Brief*
- Handout: *Tinkercad Nameplate Instructions*

Setup

- Provide Students with the handouts, and key Tinkercad vocabulary, terms and tools.
- Be prepared to demonstrate the relevant Tinkercad tools and commands prior to beginning on the project. Peruse the project details provided in the *Tinkercad Nameplate Instructions* handout to properly demonstrate the project specifics during the lesson.
- Prepared Slide Presentation.

Vocabulary List

- Design Brief

- Design Concepts
- Concept Drawing
- Workplane
- Height/Length/Width
- Anchor Point
- Align and Group Tools

Sentence Stem

1. Using the concepts from the _____, I designed a nameplate using the ideas I drew out in my _____.

   Answers: 1) Design Brief, 2) Concept Drawing

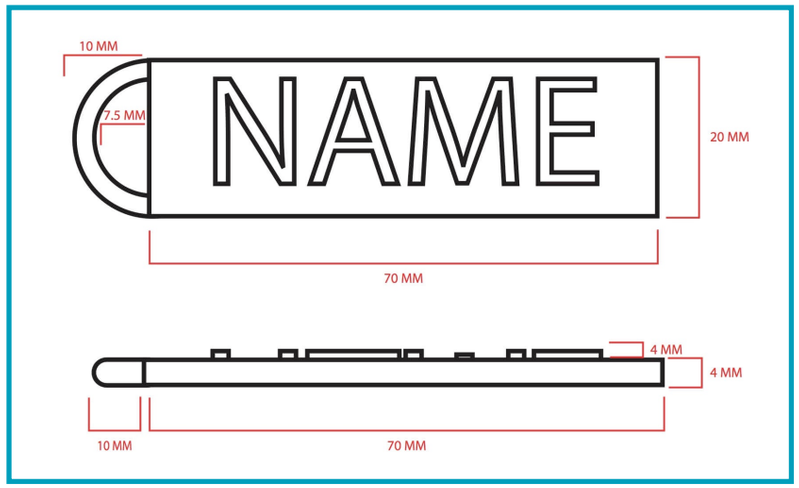
Attention Getter: (5 minutes)

Materials

- Teacher computer
- Slides 1-7
- Projector

Background Concepts:

What is a Concept Drawing?



Sample Nameplate concept drawing. Refer to slide 7 for details.

- Student writing materials

Process

1. State: "Today we are going to create our own custom designed nameplate in Tinkercad. Before we start, we need to plan out our designs using **Concept Drawings** and a **Design Brief**."
2. Go through a brief explanation of concept drawings and their function to students.
3. Work through slides 1-7.
4. Demonstrate to students by creating a concept drawing sketch for a Tinkercad nameplate on the board as shown in slide 7.

Activity 1: (20 minutes)

Materials

Handout: **Design Brief**

- Teacher Computer
- Slides 8-12
- Student writing materials
- Handout: *Design Brief*

Handout: **Tinkercad Nameplate Instructions**

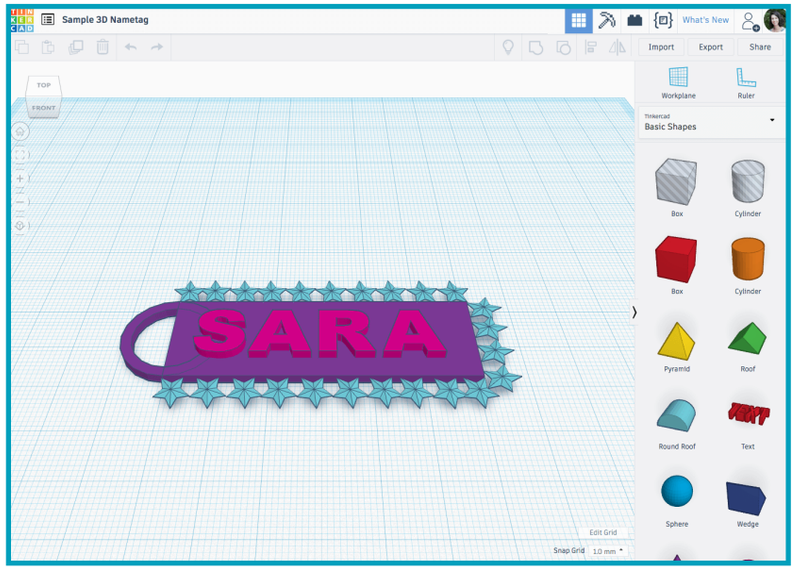
Process:

1. State: "Before we can create a design, we need to learn about the design process."
2. Work through slides 8-12, working through the design process with students. Work through the Nameplate project requirements with students (as referenced in slide 12).
3. Work with students through the *Design Brief* handout. Check for student understanding of the design process.

Activity 2: Create a Nameplate in Tinkercad (20 minutes)

Materials:

- Teacher Computer
- Projector
- Slide 13
- Student Chromebooks
- Tinkercad
- Handout: *Tinkercad Nameplate Instructions*



Sample Tinkercad nameplate project

Attention Getter:

1. State: "Now it's time to create your design in Tinkercad."
2. Show students the sample nameplate from slide 13.
3. Ask students to consider what elements they would incorporate to create their own nameplate.

Process

1. State: "Once you have incorporated the required design elements you can choose to add other design considerations and details."
2. Work through with students to create the name tag base, using the handout. Check for understanding: ensure students can successfully create the base and hole piece according to the design brief specifics.
3. Walk around the room to check for understanding.
4. Instruct students to customize their designs after they complete step 2.

Recap and Wrap Up: (5 minutes)

Materials

- Student notebooks
- Writing instruments (pens, pencils etc)

Process:

1. Instruct students to reflect on their designs and what aspects or details they might improve upon.
2. Instruct students to work through the Sentence Stem written on the board and write their answers in their notebooks.

Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

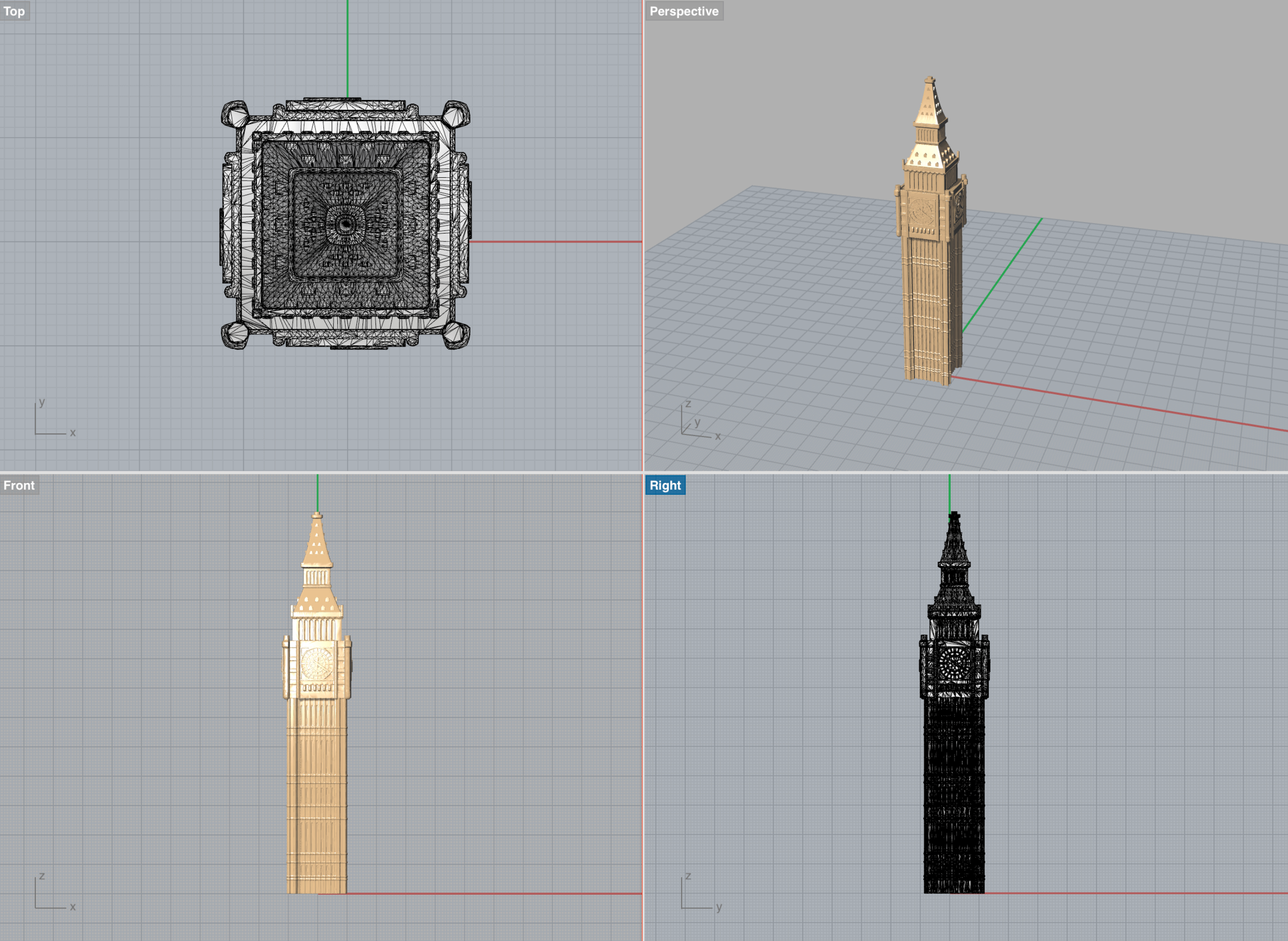
1. A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

2. Presentation Slides. In PDF format. **Available here:**

3. Handout: **Design Brief**

4

Handout: **Tinkercad Nameplate Instructions**


Top
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Perspective
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Right
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CHAPTER 8

Lesson 6: Design Concepts and Troubleshooting

Lesson Highlights

1. Students will learn about **Good** versus **Bad Design** concepts.
2. Students will receive the first iteration of their 3D printed nameplate created in the previous lesson.
3. Students will reflect on their nameplate designs using the concepts of **'Good'** and **'Bad Design'** learned in this lesson, and modify their designs.
4. Students will use peer feedback to modify their nameplate designs.

Lesson 6: Design Concepts and Troubleshooting

Students will engage in a series of activities during this lesson to evoke and internalize concepts of '**Good'** and **'Bad Design'** principles. Students will be exposed to examples of well and badly designed objects, building and art as they work through the lesson.

In the second portion of the lesson, students will receive the first iteration of their 3D printed nameplate from Lesson 5. Students will incorporate the principles of '**Good'** and **'Bad Design'** learned in the beginning of the lesson in order to reflect on their design and improve their projects for the next print.

Students will further make use of peer feedback in order to modify and improve their nameplate designs. Students will seek critique from their peers to further refine their projects for a successful outcome.

Lesson Objectives (Students will learn…)

1. Design principles.
2. Concepts of **'Good'** and **'Bad Design'**.
3. How to conduct proper peer feedback for design projects.

Lesson Outcomes (Students will be able to…)

1. Identify and label examples of '**Good'** and **'Bad Design'**.
2. Identify examples of '**Good'** and **'Bad Design'** in fellow students' 3D printed nameplate projects.
3. Improve their own nameplate projects using design principles and peer feedback.

Materials

- Computer
- Projector
- Chart Paper
- Student Chromebooks

- Student Notebooks
- Student writing and drawing instruments (pens, pencils, etc.)

Setup

- Bring in students' 3D printed nameplates from Lesson 5 for critique and design tweaking
- Source examples of '**Good'** and **'Bad Design'** as described further in this lesson. These examples may come from everyday objects or from internet resources that can be compiled prior to the lesson. See link in the sidebar for further inspiration.

Navigate to **The Uncomfortable** -a series of deliberately inconvenient everyday objects designed by Katerina Kamprani for inspiration on **"Bad Design"** concepts

Vocabulary List

- 'Good Design'
- 'Bad Design'

Sentence Stems

With these Sentence Stems, students may draw out the first portion of the answer, followed by a label of the object and an explanation of the type of design.

1. An example of **'Good Design'** is: _____ , because: _____.

   Answer Examples: 1) A fork. 2) It has sharp points to grab food.

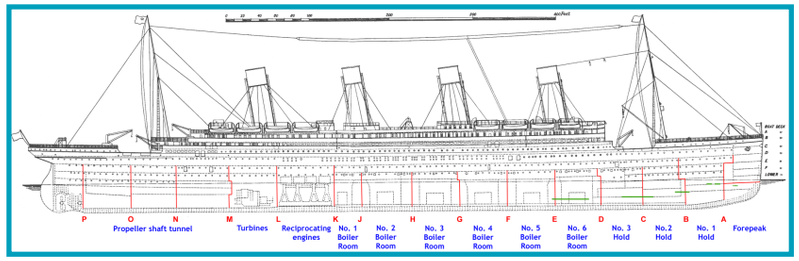
2. An example of **'Bad Design'** is: _____ , because: _____.

   Answer Examples: 1) A rain boot with holes. 2) The holes would let in water and feet would get wet.

Attention Getter: (5 minutes)

Materials

- Teacher Computer
- Prepared examples of 'Good' and 'Bad' design objects



Engineering Journal: 'The White Star liner Titanic', vol.91. Public Domain Licensed.

- Projector

Process

1. Project the image of the Titanic from the side bar.
2. "Think about one of the most famous examples of **'Bad Design'**, or a design flaw in the RMS Titanic. The bulkheads in the lower portion of the ship were not sealed at the top, and after the ship hit an iceberg, water was able to flood all the compartments and sink the Titanic. Let's view some examples in everyday objects and architecture, and see if why can find similar flaws."

Activity 1: 'Good' vs 'Bad Design' and Principles of Design (15 minutes)

Process:

1. Work through examples of 'Good' and 'Bad' design that you have sourced, projected onto the screen.
2. Discuss with students the elements that make each example either 'Good' or 'Bad' design.

3. Instruct students to think about the image examples of **'Bad Design'**? What makes them likely to break easily or not work as they should?

Activity 1: The Principles of Design (15 minutes)

Materials:

- Chart Paper
- Writing and Drawing materials (pencils, pencil crayons, crayons, markers etc.)

Attention Getter:

1. State: "Now it is time for you to try out your own 'Good' and 'Bad' Designs!"

Process

1. Draw **Chart 6.1** on the board
2. Break students into small groups of 4-5

3. Instruct Students to use their chart paper to draw **Chart 6.1** and sketch examples of **'Good Design'** and **'Bad Design'** of the following objects: a teapot, car, house, shoes, bicycle and object of their choice in their group.
4. Tape up finished charts for students to do a gallery walk to see the different variations each group produced.

Activity 2: Applying Design Principles in Tinkercad

(35 minutes)

Materials

- Student 3D Printed Nameplates
- Student Chromebooks

Process:

1. Hand out the 3D printed nameplates students completed in the previous lesson.
2. Instruct students to refer to their groups from the previous lesson, and apply the principles of '**Good'** and **'Bad Design'** learned in the

current lesson to give constructive feedback on the 3D printed nameplates.

3. Instruct students to use the critiques from their peers to improve their projects for a reprint the following week.

Recap and Wrap Up: (5 minutes)

Materials

- Student notebooks
- Writing instruments (pens, pencils etc)

Process:

1. Instruct students to work through the Sentence Stems written on the board and write their answers in their notebooks.

Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

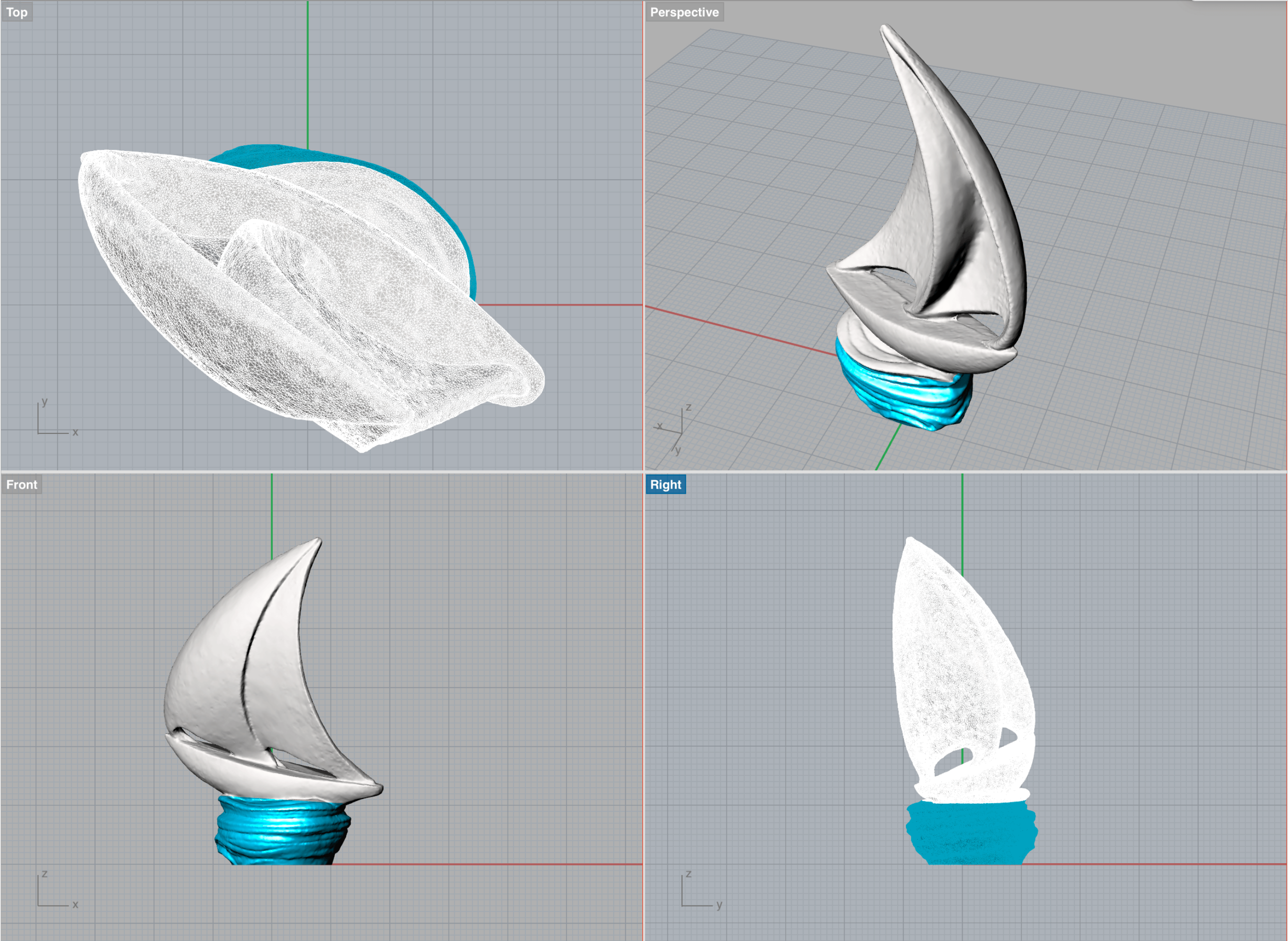
1 A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

2 Examples of **'Bad Design'** in **The Uncomfortable** by Katerina Kamprani.

3

Chart 6.1

Object	‘Good Design’ Version	‘Bad Design’ Version


Top
Perspective
Front
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CHAPTER 9

The Anatomy of a 3D Printer and Technical Communication Concepts

Lesson Highlights

1. Students will get hands-on tactile exploration with 3D printed 'mishaps.'
2. Students will learn in depth how 3D printers work and perform.
3. Bring in a 3D printer for student interaction, to connect lesson concepts.

Lesson 7: The Anatomy of a 3D Printer and Technical Communication Concepts

This lesson is essential to teach students how 3D printers work and perform. Students will learn about the anatomy and interior workings of a 3D Printer. By bringing in a printer for students to view and interact with as a print is conducted, students will bridge the core technical concepts learned during this lesson with the concrete example of viewing a live printer in action. Students will also engage in activities reflecting the importance of technical communication. Students will learn the necessity of communicating their ideas clearly and succinctly in order to convey information accurately, as well as working on their English Language skills.

This lesson is sectioned at the end of this series. However, the lesson can fit in anywhere in the course, after the first lesson. The concepts learned in this lesson can be applied to many different areas of this course on 3D printing, and can thus be left to teacher discretion as to timing.

Lesson Objectives (Students will learn...)

1. The core functions and components of a 3D printer.
2. About common 3D printing mishaps and how to troubleshoot common problems.
3. The essentials of technical communication.

Lesson Outcomes (Students will be able to...)

1. Identify and locate the core components of 3D printers.
2. Identify and communicate the core functions of a 3D printer.
3. Communicate basic commands and details in a technical, accurate manner.

Materials

- Teacher Computer
- Student Chromebooks
- Chart Paper
- Student Notebooks

- Student Chromebooks
- Writing and Drawing Instruments (Pens, Pencils etc.)
- 3D Printer
- 3D printer filament
- 3D Printed Mishaps. See **Chapter 2: Readings and Resources > Section 5: Recommended Course Materials > Page 25**

Setup

- Prepared slide presentation.
- Review information on the different types of 3D printers, as well Fused Deposition Modeling (FDM) -type 3D printer components to prepare for the discussion in *Activity 1*
- Source and bring in a number of 3D printed 'mishaps' as described in the *Materials* section for this lesson.
- Be prepared to create a small object in Tinkercad for printing, such as a simple nameplate.
- Bring in and set-up a 3D printer, have it ready to print during the lesson.

For information on the different types of 3D printers, see the article on ***Types of 3D Printers*** by 3D Printing from Scratch.

For in-depth information on 3D printer specifics, see ***The Anatomy of a 3D Printer*** article by Matterhackers.

Vocabulary List

- 3D Printer
- Filament Feeder
- Extruder
- Hot End
- Build Plate
- Print Axes

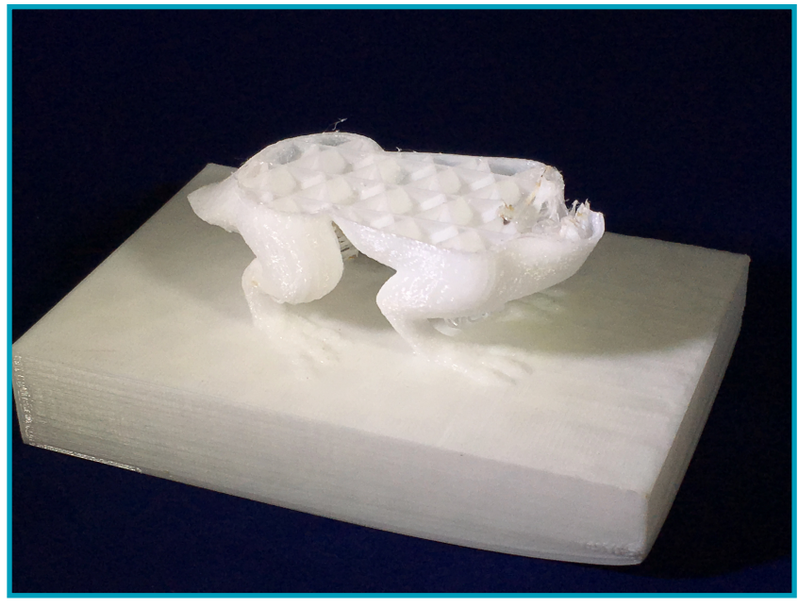
Sentence Stems

1. The _____ feeds the filament through to the _____.

   Answers: 1) Filament Feeder 2) Extruder

2. The filament is then heated up by the _____, and the print is output on the _____.

   Answers: 1) Heat Sink 2) Build Plate



Example of a 3D print of a frog that halted halfway through. Note the interior structure of the print. By showing these mishaps to students, they can get a tactile example of how a Fused Deposition Modeling (FDM) -type 3D printer lays down filament to build a solid object.

Attention Getter: (10 minutes)

Materials:

- 3D Printed Mishap Objects for student exploration

Process

1. State: "Sometimes when we output a 3D print, even though all design elements work, the print may still mess up due to a number of factors. This is incredibly common, but the good news is, unless something is seriously wrong with the printer, the answer is usually an easy fix, by tweaking printer or program settings.
2. Discuss the objects from 3D Printing gone wrong, and lead a short discussion with the class on how 3D print failures are common, and why they occur.
3. Emphasize to students the importance of failure, and of learning from your mistakes, and how these concepts apply to 3D Printing and for student success.
4. Play the 'Broken 3D Object Guessing Game' -have students guess what the object was intended to be.
5. After talking, pass around broken 3D Prints for student tactile exploration.

Activity 1: In Depth with 3D Printers (20 minutes)

Materials:

- Teacher Computer
- Projector
- Slides 1-8
- 3D Printer

Process:

1. State: "Let's get into the essential elements of how the 3D printer works we use in class works, and how all its components function. Before we do that, we need to learn about the *different* types of 3D printers."
2. Work through slides 1-6. Discuss with students the different types of 3D printers.
3. Work through slides 6-8 and discuss with the class how FDM 3D printers work more in depth.
4. State: "Now it is time for you to see a 3D printer in action!"
5. Open Tinkercad or a 3D modeling program of your choice. Create a simple nameplate and adding some text. Show the object in each

viewport to show students how 3D space works. The object should be fairly small so it will print quickly.

6. Export the name tag and import the STL into Cura. Send the object to print.
7. Break students into small groups and allow them to observe and investigate the 3D printing progress.

Activity 2: Technical Communications Concepts

(25 minutes)

Materials:

- Teacher Computer
- Projector
- Slide 9
- Writing Instruments (Pens, Pencils etc)
- Chart Paper

Attention Getter:

1. State: “Now it is your turn to be the teacher!”

Read through the article ***How to Make a Peanut Butter and Jelly Sandwich*** from Beyond the Chalkboard for further information on this concept.

2. Instruct students that they will learn how to teach you how to create a simple object in Tinkercad.
3. Show the video from Slide 9 on how to write instructions for a peanut butter and jelly sandwhich.

Process

1. State: "When designing 3D objects for CAD, we need to learn to be especially precise, otherwise the object may not print, or look the way we want it to. It is essential to learn how to harness this precision to create successful objects when you design."
2. Discuss with the class strategies for creating precise and technical instructions, such as the need for clear language, non-ambiguous language etc. See the link at the side-bar for further information.
3. Split students into groups of 4-5. Give each group a simple shape transformation in Tinkercad. For example: create a flat disc from a cylinder (by reducing the height), or resize a rectangle in every dimension.
4. Instruct students to work in their groups to write instructions for their shape transformation assignment on chart paper.
5. Give students approximately 5 minutes to complete the instructions.

Take student instructions as literally as possible. For example, students will most likely forget a step, or not be explicit enough. For example, if students do not explicitly tell you to 'open the computer' for example, will you be able to complete their exercise?

6. Have students present their instructions to you and the class, as they 'teach the teacher.'
7. After each group has presented their instructions, and most likely failed at their task, allow them to try once more on providing the correct instructions for the teacher in this exercise.
8. Discuss with students why it is so difficult to provide clear instructions to those with no knowledge of a particular subject. Ask students to reflect on why technical, precise language is essential for teaching and learning.

Recap and Wrap Up: (5 minutes)

Materials

- Student notebooks
- Writing instruments (pens, pencils etc)

Process:

1. Instruct students to work through the Sentence Stems written on the board and write their answers in their notebooks.

Supplementary Materials

Links to all presentation slides and handouts used in the lesson as well as relevant internet resources.

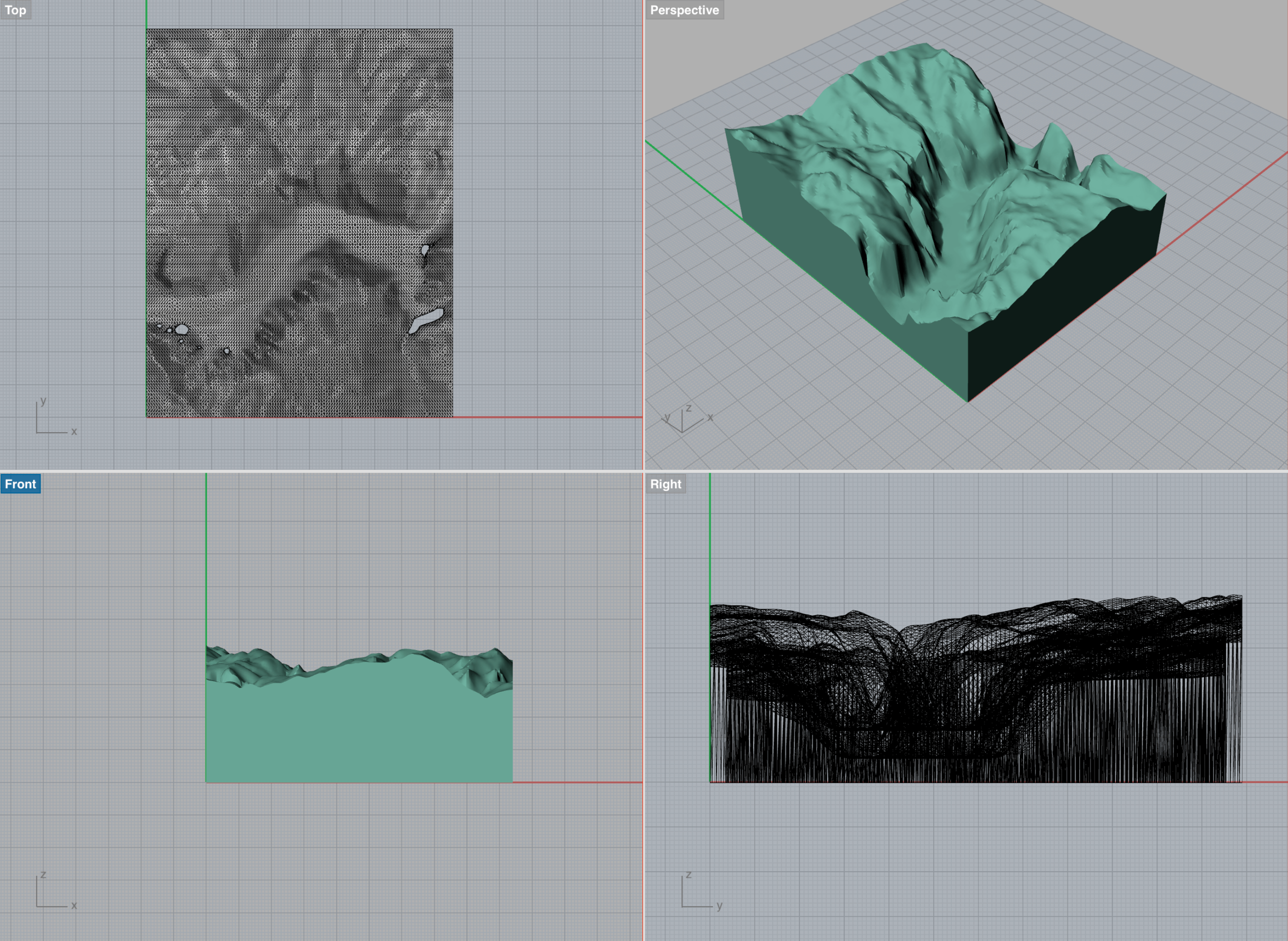
1. A printable version of this lesson plan. Formatted for 2D printers and ease of readability and use. **Available here:**

2. Presentation Slides. In PDF format. **Available here:**

3. For information on the different types of 3D printers, see the article on ***Types of 3D Printers*** by 3D Printing from Scratch.

4

For in-depth information on 3D printer specifics, see ***The Anatomy of a 3D Printer*** article by Matterhackers.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CHAPTER 10

Where to go from here...

Future Project Ideas

1. Create a Mars habitat to practice the vertical move tool in Tinkercad. **See here** for details on the actual NASA project.
2. Use group work to have students create a full-scale Mars or space colony.
3. Create a rubber-band car.
4. Design a 3D printed bridge. How much weight can it hold until collapse?

Continuing Lessons in 3D Printing

This manual has laid out a number of one-hour long lessons detailing concepts of 3D printing and design. These lessons have been designed to teach students about the internal workings of 3D printers, how to troubleshoot common design issues and how to utilize proper, technical communication.

These lessons will give students a foundation in Tinkercad that will serve as the basis for further study in 3D modeling and design, as well as imparting fundamental concepts of working with CAD programs should they choose to continue their studies further.

Other projects can be incorporated into this course, utilizing the lesson structure outlined in this manual. For example, students might build a sample Mars habitat, reflecting the current contest NASA is running to create large, 3D printed, livable habitats for future Mars colonists. Or students might collaborate to build a scale model Mars or space colony.

Browse websites such as Thingiverse or MyMinifactory, to get inspiration for future projects and lesson ideas for students. Both sites have sections detailing projects and 3D builds for educational considerations.

As students take on and create further projects, gaining greater proficiency with CAD and 3D space, they will be able to design and create ever more complex and well-functioning objects. 3D printing and design encourage STEAM learning in students, as well as opening up possibilities for new educational avenues in the classroom. Students will be inspired as they rapid-prototype their designs in real-time, with a template for engineering design and manufacturing right in the classroom.

Project Resources

1. Many of the websites noted throughout this manual, such as MyMinifactory, Thingiverse and Tinkercad also have sections dedicated to educational considerations. Use these resources for inspiration and further project planning.
2. As students advance further in their studies on 3D Printing, Design and CAD, they can attempt more complex projects, such as those found in the 3D Instructables Lessons series. Students can combine other elements into their projects, such as simple circuits.

Further Lesson Resources

Below are a number of resources that can be utilized for further lesson ideas and inspiration in a longer, or higher-level course on 3D printing and design.

1 **The Makerbot Educational Guide.** Sign up to receive free lesson plans and resources from Makerbot, a popular manufacturer of FDM-type 3D Printers.

2 **Tinkercad Learn.** Tinkercad provides a number of guided tutorials and lessons designed to get students started with manipulating the program.

3 **Instructables Lessons** on 3D Printing. These lessons are designed for grades six through eight, and lay out a number of fairly detailed, involved projects for students with a familiarity in Tinkercad design processes.

4 The Fab Foundation's **Lesson Galleries** provides a number of lesson and project ideas for possible implementation in more advanced coursework.

5 **Thingiverse Education**: Lays out a number of projects by grade level, designed for students from kindergarten through college level in a number of subject areas. This section is a great source of inspiration for further projects.

6 **MyMinifactory Education**: Like Thingiverse, MyMinifactory also has a number of projects and files for download with a variety of subject matter.

Final Supplementary Materials

Links to the course post-assessment and certificate of completion.

1 Course Post-Assessment. **Available here:** Assess student knowledge and experience gained in the course.

2 Certificate of completion. **Available here:** Students can take home a custom-designed certificate noting their participation in the course.

GLOSSARY

Relevant Terminology and Definitions

3D Views

In 3D space, when using a CAD program, the user can also manipulate their **Point of View** in 3D space. These views can be from Perspective (world), Top, Front and Right (side) view, most commonly. Each view allows the user a number of options and precision when creating 3D objects.

Related Glossary Terms

CAD Drafting, CAD Modeling/Sculpting, Computer Aided Design (CAD), Workplane

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Index Find Term

Anchor Point

A point on an object on the workplane, usually found on edges or vertices. Users can control anchor points in order to change the dimensions of an object, such as height or width.

Related Glossary Terms

Computer Aided Design (CAD), Fused Deposition Modeling (FDM)

Index Find Term

CAD Drafting

These programs are rooting in 2D drafting concepts. They are mainly used to create functional, measurable 3D objects. Often in these programs, 2D drawings are translated digitally to 3D representations of objects. These representations may take the form of surface shells, or as mathematically solid materials. [1]

These programs are best suited to designs that need precision and function mechanically, such as objects with interlocking and moving parts.

Software programs such as Tinkercad, Fusion 360 and Rhino 3D are examples of drafting-based CAD programs.

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[1] Simon Thomas, Andrew. "CAD vs Modeling: Which 3D Software to Choose?" October 22, 2016. Accessed December 1, 2017. https://www.shapeways.com/blog/archives/27653-cad-vs-modeling-which-3d-software-to-choose.html

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Related Glossary Terms

3D Views, CAD Modeling/Sculpting, Computer Aided Design (CAD)

Index Find Term

CAD Modeling/Sculpting

For design considerations that involve freeform, artistic work and flowing curves, CAD Modeling/Sculpting programs may be a better fit. These programs are based on surfaces that are created from 3D geometry.[1]

When models are composed of organic forms and shapes, CAD Modeling/Sculpting programs are the best fit.

Software programs such as Z-Brush, Blender, Sculptris and Maya are examples of Modeling/Sculpting based CAD.

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[1] Simon Thomas, Andrew. "CAD vs Modeling: Which 3D Software to Choose?" October 22, 2016. Accessed December 1, 2017. https://www.shapeways.com/blog/archives/27653-cad-vs-modeling-which-3d-software-to-choose.html

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Related Glossary Terms

3D Views, CAD Drafting

Index Find Term

Computer Aided Design (CAD)

Computer-aided design (CAD) is the use of computers to aid in the creation, modification, analysis or optimization of a design. CAD software increases the productivity and often the technical specifications of a designer's products.[1] In the context of this course, CAD refers to a program allowing the user to create 3-dimensional representations of objects, that can be output and printed on a 3D printer.

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[1] Lalit Narayan et al. "Fundamentals of Design, Computers and Controllers." *Computer Aided Design and Manufacturing.* Prentice Hall of India, 2008. pp 1-4.

Related Glossary Terms

3D Views, Anchor Point, CAD Drafting, Fused Deposition Modeling (FDM), Workplane

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Index Find Term

Fused Deposition Modeling (FDM)

A common type of 3D printer is the Fused Deposition Modeling type. This is a type of additive manufacturing in which the 3D printer lays down material layer by layer to create a solid object. The filament will most often take the form of a spool or coil that is fed into the printer, most likely some sort of thermoplastic, that is heated up and extruded.[1]

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[1] "FDM Technology. 3D print durable parts with real thermoplastic" Stratasys. Accessed December 13, 2017.http://www.stratasys.com/3d-printers/technologies/fdm-technology

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Related Glossary Terms

Anchor Point, Computer Aided Design (CAD)

Index Find Term

Workplane

The space of the CAD interface program where designs are created and modified. The workplane is usually a grid, that can also be manipulated and transformed according to user specifications. Users can view the workplane from several different points of 3D View (Perspective/World, Top, Front, Side etc).

Related Glossary Terms

3D Views, Computer Aided Design (CAD)

Index Find Term