3-D Printing – That's the Ticket!

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What is 3D Printing?

3D Printing is a type of additive manufacturing that creates objects by printing them out layer over layer (Source 1). There are a range of materials that can be used to create objects, but the most common ones are plastic-based. These materials that the printer *extrudes* (prints) to create models are called *filaments*. Different filaments are used to create final models of different colors, strengths, and levels of flexibility.

Source 1

What Can You Use 3D Printing For?

3D printing is being used in a variety of fields such as the food, toy, manufacturing, housing, and medical industries. Perhaps its most interesting and appealing characteristic as a method of production is that you can 3D print ***any***thing for any ***specific*** purpose. Let the enormity of that sink in… If you need spare parts for a machine that was discontinued, you can print them yourself. If you would like to create a unique one-of-a-kind architectural design for a prospective client, you can go ahead and create it with the right printer. Medical researchers have even printed organs and small body parts out of cells (Source 1)!

Source 2

Source 3

Source 4

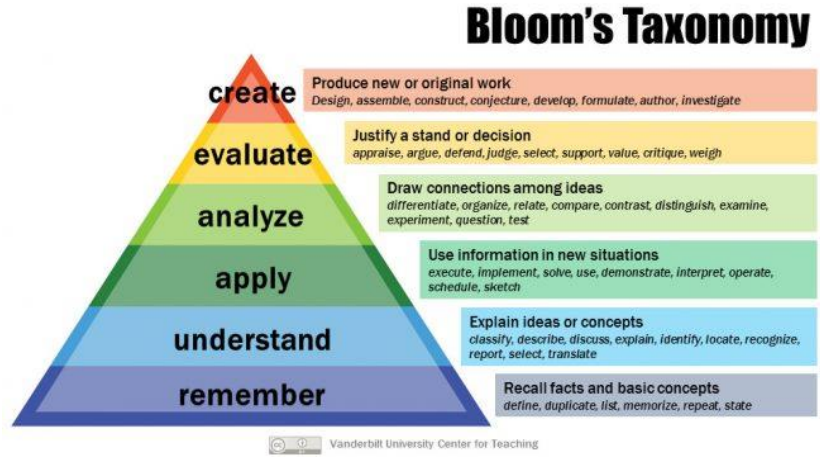
Source 5

The Design Process

1. The 3D printing process begins with having an idea! It could be the solution to a problem, or it could come from a stroke of artistic or technological inspiration!
2. The next step is to create the virtual design of that idea. A printer can only print an existing virtual model, so designing it is crucial in having your idea come to life.
3. Once the virtual design is complete, it must be run through your printer's software to ensure the printer can read it correctly and create it.
4. Your printer reads your final file and creates your product!

Why Should I Use 3D Printing in my Classroom?

As teachers, we know that children do not truly learn if we only ask them to recall facts and reproduce them. We need to hold students to a higher standard by developing their problem-solving abilities and tapping into their innate creativity.



Source 6

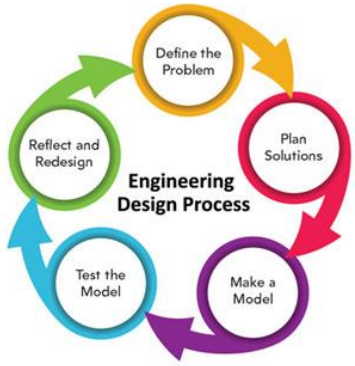
The benefit of integrating the design and creation process that accompanies a 3D printer into your classroom is that it allows students the opportunity to synthesize different pieces of knowledge and apply what has been taught to them to designing their own creations! Using a 3D printer represents a remarkable opportunity to turn students from technological consumers into technological producers! Furthermore, if this technology's use continues to grow, you will be gifting them a skill that they will be able to take with them into a variety of possible future careers.

Common Core Standards

MAFS.7.NS.1.1a	Describe situations in which opposite quantities combine to make 0.
MAFS.7.G.1.1	Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
MAFS.7.G.1.3	Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.
MAFS.7.G.2.4	Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.
MAFS.7.G.2.6	Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

S.T.E.A.M. Integration

Another benefit of integrating a 3D printer's use into your existing lesson plans and study units is that it automatically turns them into S.T.E.A.M. lessons / units. The design process that accompanies 3D printing is a perfect example of the engineering process.



In designing their 3D prints, students have to plan, model, evaluate, reflect upon, and redesign their products constantly before printing!

Source 7

Furthermore, given the fact that students are engaged in using technology to create their designs on a virtual modelling software and sharing it with one another during the design process, lessons / units automatically gain the technology component of a S.T.E.A.M. lesson / unit as well! To see which Computer Science standards this modelling and printing process satisfies at your grade level, please visit CPALMS.

Source 8

Adaptability

I would like to stress the adaptability of this project to any grade level. The mathematics, computer science, and visual arts standards that follow are 7th grade and Middle School specific. However, the principles of creative design tied to preparing a model for production are relatable to multiple math standards across grade levels and feasible for varied ages ranging from Elementary to High School.

Goals & Objectives

The goal of this mini-unit is to foster students' problem-solving abilities and encourage their creativity by giving them relative freedom to complete the following summative task: create the virtual design of a house for later 3D printing that incorporates specific objectives.

Academic Core Objectives

- Incorporate 2D figures that result from slicing 3D figures. (MAFS.G.1.3)
- Incorporate circles whose area and circumference is to be calculated. (MAFS.G.2.4)
- Incorporate various student-constructed 3D shapes whose volume and surface area is to be calculated (MAFS.G.2.6)
- Reproduce the entirety of the model to a different scale (MAFS.G.1.1)
- Describe a situation where group members have leveled an uneven surface using opposite quantities combining to make 0. (MAFS.NS.1.1)

Academic S.T.E.A.M. Objectives

The mini-unit also becomes a 4.0 S.T.E.A.M. unit by adhering to the following standards:

Science	No Science standards chosen for this unit.
Technology	**SC.68.CS-CC.1.3**: Students will design and develop a collaborative digital product using a variety of digital tools and media-rich resources that demonstrate and communicate concepts to inform and entertain.
Engineering	Students will define their problem (creating a house), plan their solutions, make their model, evaluate / test their model, reflect upon their model, and then redesign it as often as necessary.
Arts	**VA.68.S.1.1**: Students will manipulate content, media, techniques, and processes to achieve communication with artistic intent through the creative design process
Mathematics	Students will incorporate the aforementioned requirements from the Academic Core Objectives section, displaying mastery of 5 different 7th grade math standards.

Course Outline & Overview

Lesson 1

- Students will be introduced to the free online modelling software they will use to design their creations: Tinkercad.
- Students will be walked through creating their student accounts.
- Students will be given 20 minutes to explore the Tinkercad website, take tutorials, and learn how to create different objects.
- Students will be informed of what their summative task is that they must work on, their completion date, and the requirements for said summative task.
- Students will be divided into groups.
- Students will be given time in class to work on their projects.
- Students will be allowed to work on their projects for homework.

Lesson 2

- Students will be separated into groups and left to work together on their housing projects.
- Instructor will walk among students to ensure they stay on task, answer questions students might have about their requirements, and offer words of advice and encouragement to help and motivate students.
- Students will be allowed to work on their projects for homework.

Lesson 3

- Students will be given the first half of the class to put the finishing touches on their projects.
- Student groups will then come up to present their housing projects to the class.

Grading Rubric

Component	Excellent	Satisfactory	Unsatisfactory
MAFS.G.1.3	Student project used 2D shapes resulting from slicing 3D figures. Students identified which 3D figure would produce the corresponding 2D shapes in their designs when sliced.	Student project used 2D shapes which they identified as resulting from slicing 3D figures.	Student project did not use 2D shapes resulting from slicing 3D figures.
MAFS.G.2.4	Student project included circles whose area and circumference were correctly calculated.	Student project included a single circle whose area and circumference were correctly calculated.	Student project either did not include a circle or included a circle whose area and/or circumference were incorrectly calculated.
MAFS.G.2.6	Student project included a rectangular prism, a triangular prism, and a pyramid. The surface area and volume of each was correctly calculated.	Student project included a rectangular prism, a triangular prism, and a pyramid. The surface area and volume of at least two of these objects was correctly calculated.	Student project did not include all of the following: a rectangular prism, a triangular prism, and a pyramid. **AND / OR** The surface area and volume of whatever shapes were included was incorrectly calculated.
MAFS.G.1.1	Student project was reproduced correctly to a different scale. Students could successfully explain and detail the reproduction process.	Student project was reproduced to a different scale correctly, but the students could not successfully explain how they did so.	Student project was not reproduced to a different scale or was reproduced to a different scale incorrectly.
MAFS.NS.1.1	Student project incorporated an instance where an uneven surface within the model was leveled using opposite quantities to make 0. Group members could successfully explain how they did so.	Student project incorporated an instance where an uneven surface within the model was leveled using opposite quantities to make 0. Group members could not successfully explain how they did this, though.	Student project did not incorporate an instance where an uneven surface within the model was leveled using opposite quantities to make 0.

Lesson 1

Unit Standards	Objectives
MAFS.G.1.3	Students will create & identify 2D figures that result from slicing 3D shapes.
MAFS.G.2.4	Students will create various circles with different radii and diameters. Students will then calculate the area and circumference of those circles.
MAFS.G.2.6	Students will construct a variety of 3D shapes including rectangular prisms, triangular prisms, and pyramids. Students will then calculate their surface area and volume.
MAFS.G.1.1	Students will take their model and reproduce it to a different scale using a set scale factor.
MAFS.NS.1.1	Students will have to use opposing quantities to make 0 in the context of their modelling activities.
SC.68.CS-CC.1.3	Students will design and develop a collaborative digital product using various digital tools and media-rich resources that demonstrate and communicate concepts both to inform and entertain.
VA.68.S.1.1	Students will manipulate content, media, techniques, and processes to achieve communication with artistic intent through the creative design process.
Vocabulary	
Two-dimensional, three-dimensional, rectangular prism, triangular prism, pyramid, square, circle, radius, diameter, circumference, area, rectangle, triangle, scale drawing, & scale factor.	
Materials	
Every student should have a laptop for best results; however, students will be in groups, so if laptops are insufficient in number and must be shared, students will still be able to complete their modelling task.	
Bell Ringer	
Students will be introduced to the free online modelling software they will use to design their creations: Tinkercad.	
Students will be walked through creating their student accounts.	
Students will be given 20 minutes to explore the website, take tutorials, and learn how to create different objects. Students will be encouraged to talk among each other and discuss their learning.	
Lesson & Classwork	
Students will be informed of their summative task, their completion date, and the requirements for their summative task. Students will also be given access to the rubric which will be used to grade them.	
Students will be divided into different groups and given the remainder of class to work on their projects.	

Reflection
Students and instructor will engage in a class discussion about how their summative task is going and their thoughts on what should be completed next.
Home Learning
Students will be encouraged to work toward completing their projects at home.
Accommodations
SPED & ELL: Some students will receive personal assistance – teacher, aide, peer, volunteer, or interpreter.
SPED: Some students may receive additional time to complete the assignment.
SPED & ELL: Some students may receive guides or prompts for specified tasks.
Differentiated Instruction
As students complete their bell ringers / classwork, they will be encouraged to assist one another as they are solving their problems and to get up and help one another when possible. This will be peer-to-peer DI.
As students complete their bell ringers / classwork, the instructor will walk among them pulling small groups up to the board or helping individual students with individual questions and concepts based on who is struggling with different skills or tasks.

Lesson 2

Unit Standards	Objectives
MAFS.G.1.3	Students will create & identify 2D figures that result from slicing 3D shapes.
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Bell Ringer
Not Applicable
Lesson & Classwork
Students will be separated into groups and left to work together on their housing projects.
Instructor will walk among students to ensure they stay on task, answer questions students might have about their requirements, and offer words of advice and encouragement to help and motivate students.
Reflection
Students and instructor will engage in a class discussion about how their summative task is going and their thoughts on what should be completed next.
Home Learning
Students will be encouraged to work towards completing their projects at home.
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Materials	
Every student should have a laptop for best results; however, students will be in groups, so if laptops are insufficient in number and must be shared, they will still be able to complete their modelling task.	
Bell Ringer	
Not Applicable	
Lesson & Classwork	
Students will be given the first half of class to put their finishing touches on their projects.	
Student groups will then come up to present their housing projects to the class and instructor, one by one.	
Students will be informed that if they are disrespectful or inattentive when another group is presenting, it may result in points being taken from their final score.	
Reflection	
Students will discuss with their instructor what they think they have learned from, what they liked, and what they did not like about this project.	
Home Learning	
Students will be given frontloading assignments for the next topic they will study – Statistics & Probability.	
Accommodations	
SPED & ELL: Some students will receive personal assistance – teacher, aide, peer, volunteer, or interpreter.	
SPED: Some students may receive additional time to complete the assignment.	
SPED & ELL: Some students may receive guides or prompts for specified tasks.	

Differentiated Instruction
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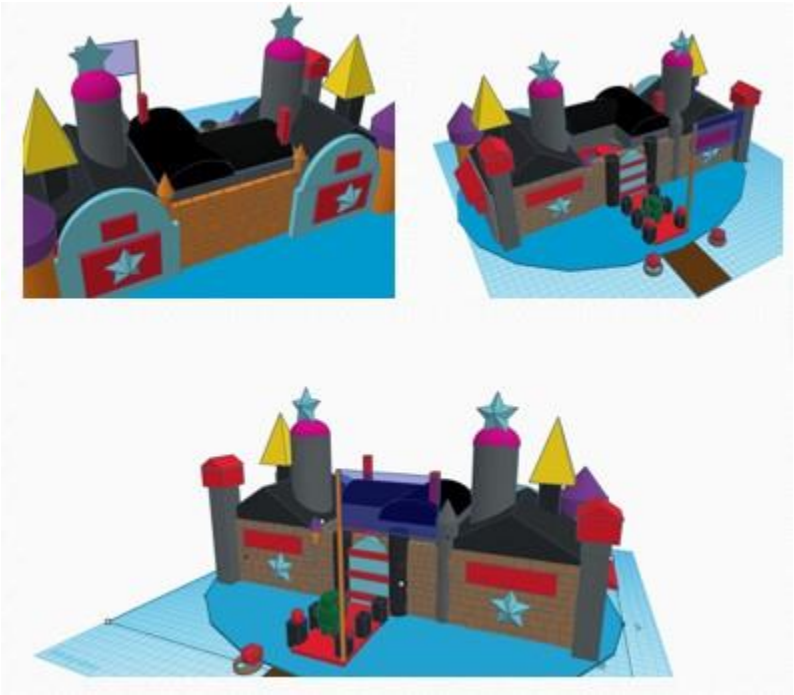
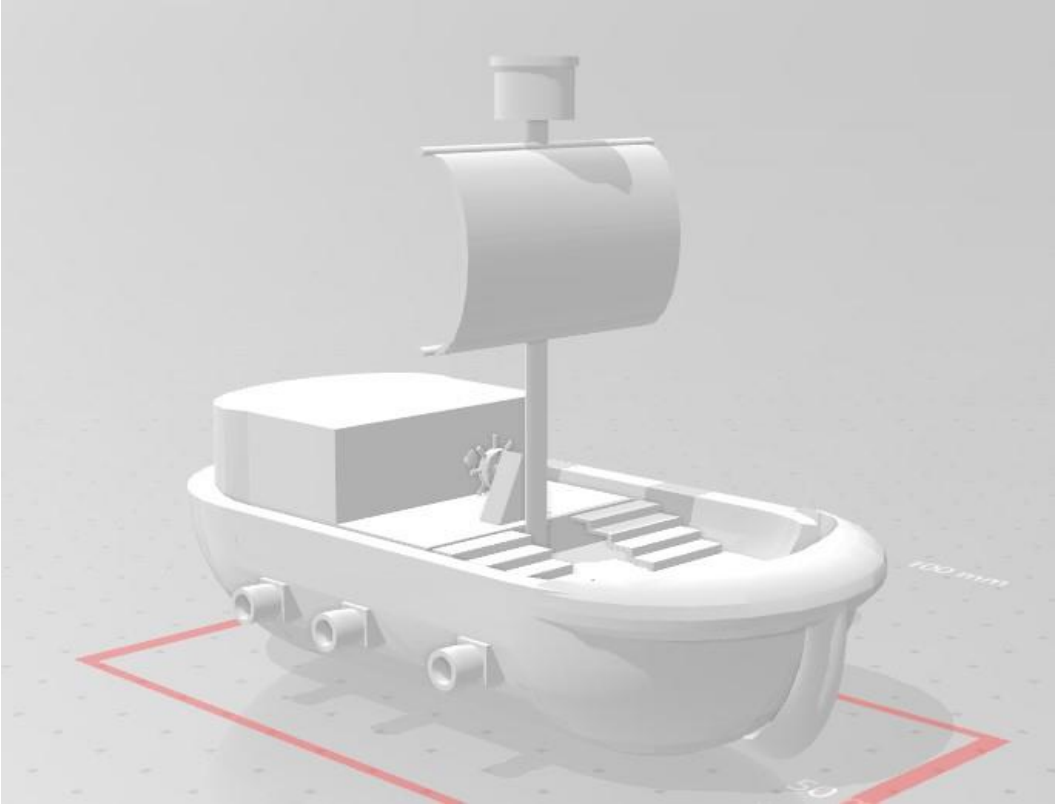
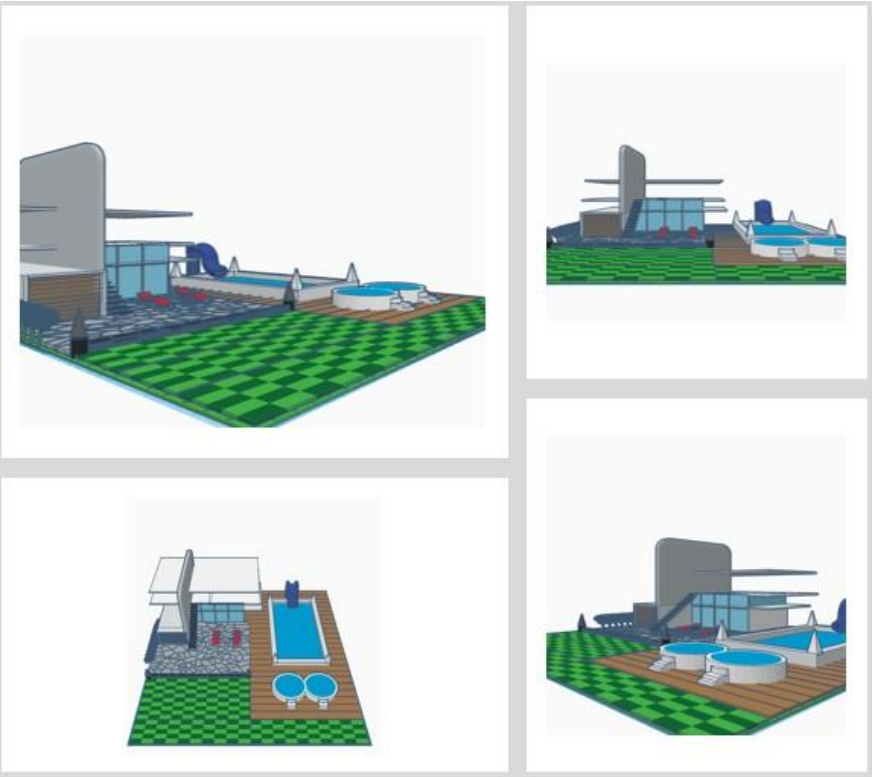
As students complete their bell ringers / classwork, the instructor will walk among them pulling small groups up to the board or helping individual students with individual questions and concepts based on who is struggling with different skills or tasks.

Sample Student Work

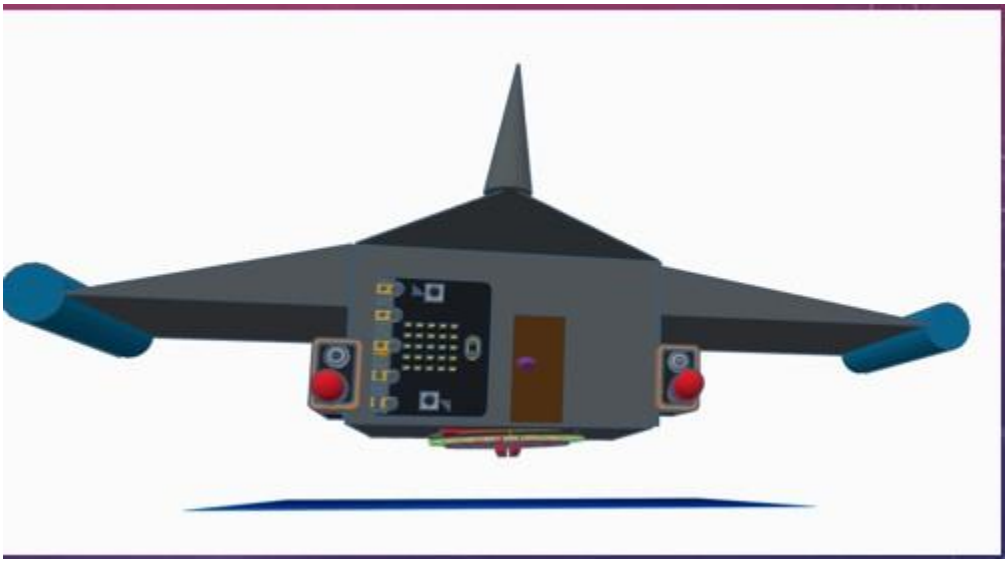




This design's creators successfully argued that, since you could live on a boat, it qualified as a house. - 1



This design's creators were adamant that their home include chicken legs… - 2



Taking inspiration from the previous boat / house, this team pointed out that people could live on spaceships too. - 3

Selecting a Printer Model

The printer which I use in my classroom is a Flashforge Creator Pro. However, you may find that you would like to use a different model for your classroom. There are a variety of different characteristics to consider when choosing a 3D printer, including:

- Its bed size
- Whether it must remain tethered to a computer
- If it has an active user community for support
- Its reviews
- Its price
- If it comes with software included
- The type of filaments it can print out

To help you make the right choice, I recommend doing some comparative shopping and determining which model is right for you. There is a 3D Printer Comparison Chart included below in the Resources List for your convenience.

Selecting a Design Software

There are a variety of different design software that you or your students can use to create 3D models for printing. They include:

- Sketchup
- Autodesk Inventor
- Solidworks
- Blender
- Catia
- 3ds Max
- AutoCAD
- Rhino3D
- 123D Catch
- Tinkercad
- Onshape

Do not despair over the sheer volume of options, you only need one software to use in class! In my classroom, my students and I use Tinkercad to create our designs. I have little experience with the other types of software, but I plan to continue exploring!

Acknowledgements

I would be remiss if I did not give a huge thank you to and acknowledge Dr. Suzanne Banas, a science teacher at South Miami Community Middle School. She was a disseminator at the 2018-2019 Idea Expo and her presentation / packet, *Engineering with 3-D Printing*, was the inspiration for my own use of my 3D printer in my classroom.

Resources List

1. How to Get Started in 3D Printing – Popular Mechanics
2. The Ultimate Beginners Guide to 3D Printing
3. 3D Printer Comparison Chart
4. Dr. Banas' *Engineering with 3-D Printing* – Ideas with Impact 2017 – 2018 Publication

References

Source	Citation
Source 1	[Mashable]. (2019, August 4). W*hat Is 3D Printing and How Does It Work? | Mashable Explains?* [Video File]. Retrieved from https://www.youtube.com/watch?v=Vx0Z6LplaMU
Source 2	Flowalistik. (2017, January 27). Low-Poly Toys @ Pinshape. Retrieved from https://pinshape.com/items/29974-3d-printed-low-poly-toys
Source 3	Moon, M. (2019, July 19). A San Francisco startup 3D printed a whole house in 24 hours. Retrieved from https://www.engadget.com/2017/03/07/apis-cor-3d-printed-house/?guccounter=1
Source 4	XyzThreeDee. (2017, December 22). Ava's Gear Toy 2 @ Pinshape. Retrieved from https://pinshape.com/items/20629-3d-printed-avas-gear-toy-2
Source 5	Wake Forest Researchers Successfully Implant Living, Functional 3D Printed Human Tissue Into Animals. (2016, December 15). Retrieved from https://3dprint.com/119885/wake-forest-3d-printed-tissue/
Source 6	Mcdaniel, R. (2018, August 13). Bloom's Taxonomy. Retrieved from https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/
Source 7	Steam & Engineering Design Process - Lessons - Tes Teach. (n.d.). Retrieved from https://www.tes.com/lessons/HBWAsazW5LbErg/steam-engineering-design-process
Source 8	Soomro, S. (2009, October 01). Engineering the Computer Science and IT. Retrieved from https://www.intechopen.com/books/engineering-the-computer-science-and-it