IT in Education Subject-related Series:

Using 3D-Printing Technology and e-Learning Tools to Enhance Learning, Teaching and Assessment of Science (S1-3) Curriculum

Session 2

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Objectives

Session 2

Using 3D-Printing technology for conducting scientific investigation

- Review the designing work of 3D devices for scientific investigation (common errors in CAD modelling and guidelines for successful 3D printing will be reviewed)
- Distribution of 3D printed devices and carry out the 2 investigations in group basis
- Reporting the results of investigations with e-learning tools
- Sharing of common 3D printing resources and discussions on implementation issues

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Part 1 : Review on designing work of 3D printed devices

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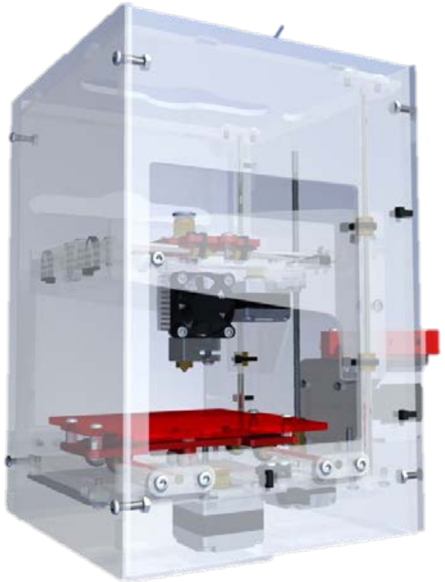

Session 2

CMA Secondary School, Technology Subject Panel

CHEUNG, Man Yuen / Mrmcuman@gmail.com

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Part 1 : Review on designing work of 3D printed devices

1

Object Pla

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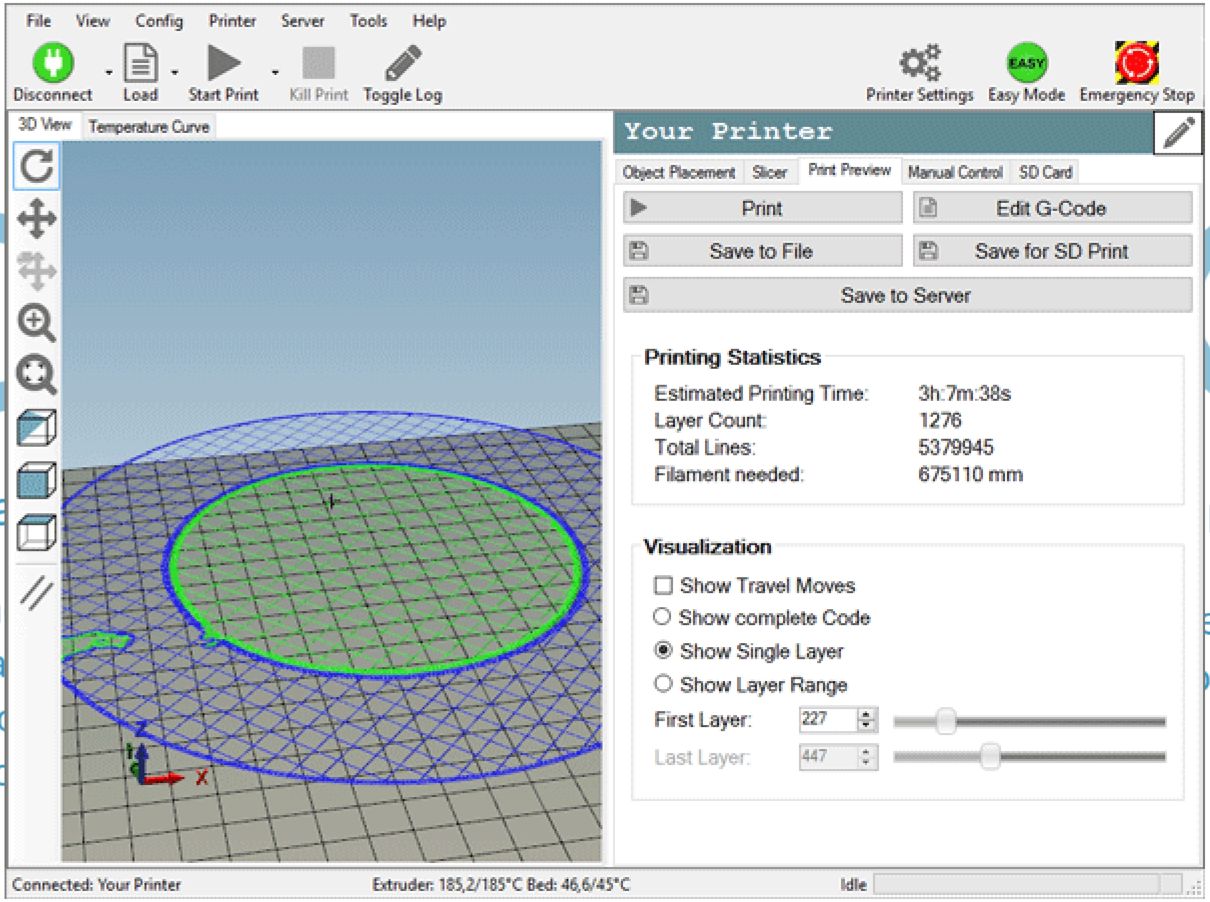

3

review

esult completely, in
r layer for layer.

18 Common 3D Printing Problems: **Overview**

If you don't know the name of your problem you can zap through all problems by clicking on the images.

1. Warping
2. Elephant Foot
3. More First Layer Problems
4. Layer Misalignment
5. Missing Layers
6. Cracks In Tall Objects
7. Pillowing
8. Stringing
9. Under-Extrusion
10. Over-Extrusion
11. Shifting Layers
12. Blocked Bowden Nozzle
13. Snapped Filament
14. Stripped Filament
15. Broken Infill
16. Ghosting of the Internal Structure
17. Gaps Between Infill and Outer Wall
18. Non-Manifold edges

Reference:
https://all3dp.com/common-3d-printing-problems-3d-printer-troubleshooting-guide/

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Types of 3D printers

- Broadly speaking, there are <u>four</u> categories of additive manufacturing:
  - Fused deposition modeling (FDM) 熔融沉積成型
  - Selective Laser Sintering (SLS) 選擇性雷射燒結
  - Stereolithography (SLA) 立體光固化成型法
  - Digital Light Processing (DLP) 數位光處理

Types of 3D printers

- Fused deposition modeling (FDM)
  - FDM is an affordable 3D printing process compared to other 3D printing technologies.
  - FDM is at the very entry of the market as it mainly used by individuals.
  - This process works by material being melted and extruded through a nozzle (or hotend) to 3D print a cross section of an object each layer at a time.
  - The print bed lowers for each new layer and this process repeats until the object is completed.
  - Layer thickness determines the quality of the 3D print.
  - Some FDM 3D printers have two or more print heads to print in multiple colours and use support for overhanging areas of a complex 3D print.

Reference: https://www.youtube.com/watch?v=WHO6G67GJbM

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Types of 3D printers

- Selective Laser Sintering (SLS)
  - SLS makes a 3D printed object from powder (metal and gypsum 石膏 are common materials) by applying binding agents or heat to fuse the powder's particles together.
  - A laser is used to fuse one layer of powdered material at a time.
  - The first layer is fused to a platform, and then another thin layer of powder is added above the first, and so on as the model is built up.
  - The powder acts as a supporting medium for the print, so that very complex and delicate prints can be created.
  - The fine powder can be hard to deal with, though, and the printers tend to be expensive.

Reference: https://www.youtube.com/watch?v=wD9-QEo-qDk

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Types of 3D printers

- Stereolithography (SLA)
  - The process of printing involves a uniquely designed 3D printing machine called a stereolithograph apparatus (SLA), which converts liquid plastic into solid 3D objects.
  - The process of printing includes several steps:
    - Creating 3D models in computer-aided design (CAD) program
    - Generating Standard Tessellation Language (STL) file that contains information for each layer. There could be up to layers per each millimeter.
    - SLA machine exposes the liquid plastic (resin) and laser starts to form the layer of the item.
    - After plastic (resin) hardens a platform of the printer drops down in the tank a fraction of a millimeter and laser forms the next layer until printing is completed.
    - Once all layers are printed the object needs to be rinsed with a solvent
    - Placing the model in an ultraviolet oven to finish processing

Reference: https://www.youtube.com/watch?v=yYGycgnYlBM

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Types of 3D printers

- Digital Light Processing (DLP)
  - The DLP technology was created in 1987 by Larry Hornbeck of Texas Instruments.
  - Very similar to SLA.
  - Instead of using a UV laser (by SLA) to cure (or solidify) the photopolymer resin, a safelight (light bulb)/ a consumer projector is used.
  - With the object being either pulled out of the resin (bottom up), or down into the tank (top down), the next layer being cured at the top.

Reference: https://www.youtube.com/watch?v=2T_2-_xvKHA

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A quick summary of common 3D printing technologies

Technology	Additive Manufacturing Process	Advantages	Disadvantages	Plastic based material	Metal	Resin	Multicolour
Fused Deposition Modelling (FDM)	Material Extrusion	- Strong parts - Easy to print yourself	- Poorer surface finish and slower - Requires support structures	Yes	No	No	Two-colour
Selective Laser Sintering (SLS)	Powder Bed Fusion	- No support required - High heat - Chemical resistant - High speed	- Precision limited to powder particle size - Rough surface finish	Yes	Yes	No	No
Stereolithography (SLA)	Photopoly- merisation	- Complex geometries - Detailed parts - Smooth Finish	- Post-finishing required - Requires support structures	No	No	Yes	No
Digital Light Processing (DLP)	Photopoly- merisation	- Concurrent production - Complex shapes and sizes - High precision	- Thickness limitation - Limited range of materials	No	No	Yes	No

Reference: https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/

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Main steps of 3D printing

- **Step 1 - Prepare 3D file for printing:** This 3D file can be created using CAD software, with a 3D scanner or simply downloaded from an online marketplace.

- **Step 2 - Printing:** First, choose the material achieves the specific properties required for your object. The variety of materials includes plastics, ceramics, resins, metals, sand, textiles, biomaterials, glass, food and even lunar dust.

- **Step 3 - Finishing:** This step requires specific skills and materials. When the object is first printed, often it cannot be directly used or delivered until it has been sanded, lacquered or painted to complete it as intended.

Reference: https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/

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Part 2 : Scientific Investigations

Stages of scientific investigation

Setting a question

Proposing a hypothesis

Designing a fair test

Carrying out the experiment

Taking measurement / recording data

Analyzing results

Drawing conclusion

Presenting the findings

Planning

Doing

Reporting

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2 Examples of scientific investigation

Topic 1:

Turbine design
&
Hydroelectricity

Topic 2:

Water Tap design
&
conservation of water

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Scientific investigation 1:

Turbine design
&
Hydroelectricity

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Investigations on the energy-generating efficiency of a turbine:

Investigation	Independent Variable	Dependent Variable
1	Number of paddles	Average voltage generated
2	Size of paddle	Average voltage generated

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Scientific investigation 2:

Water saving faucet

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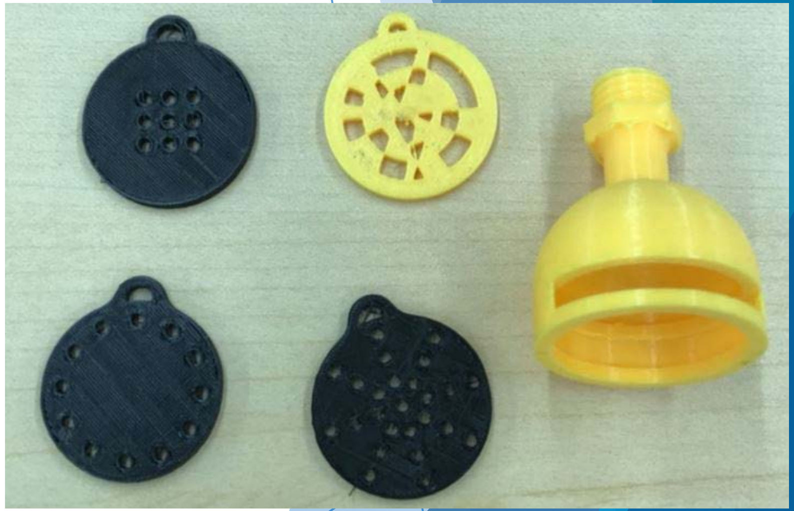
Investigations on the effect of design of filters on the performance of a water-saving faucet:

Investigation	Independent Variable	Dependent Variable
1	Design of filter	Water flow
2	Design of filter	Water pressure



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Arrangement for Investigations

- 4 in a group, each group gets
  - 1 set of bottle & basin
  - 1 set of data logger, hair dryer & clamp

- Each of you will be given 1 set of 3D-printed devices which include:
  - 2 pieces of turbine and a motor
  - 5 pieces of nozzle filter and 1 nozzle mount

- Carry out the investigations using the materials provided
- You have 20 minutes for each investigation

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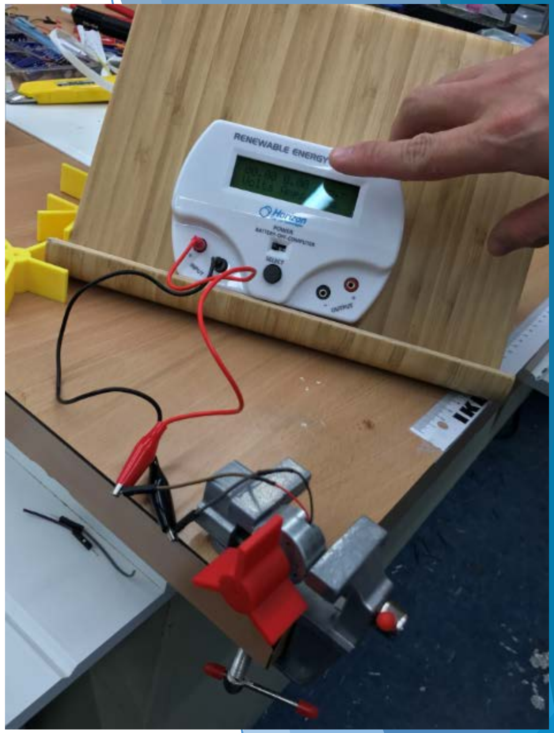
Investigation 1: Design of Turbine

- Connect the **generator**, **data-logger** and **tablet**
  - Beware of the **com port** assignment of the data logger when it is connected to the tablet.
  - Beware of the **polarity of connection** as the rotation of generator is arbitrary, the colour code on the generator is meaningless.
- Hold the hair dryer steadily with **constant angle and distance** to the turbine
  - To avoid the release of bad smell, use **COLD wind** to blow the turbine.



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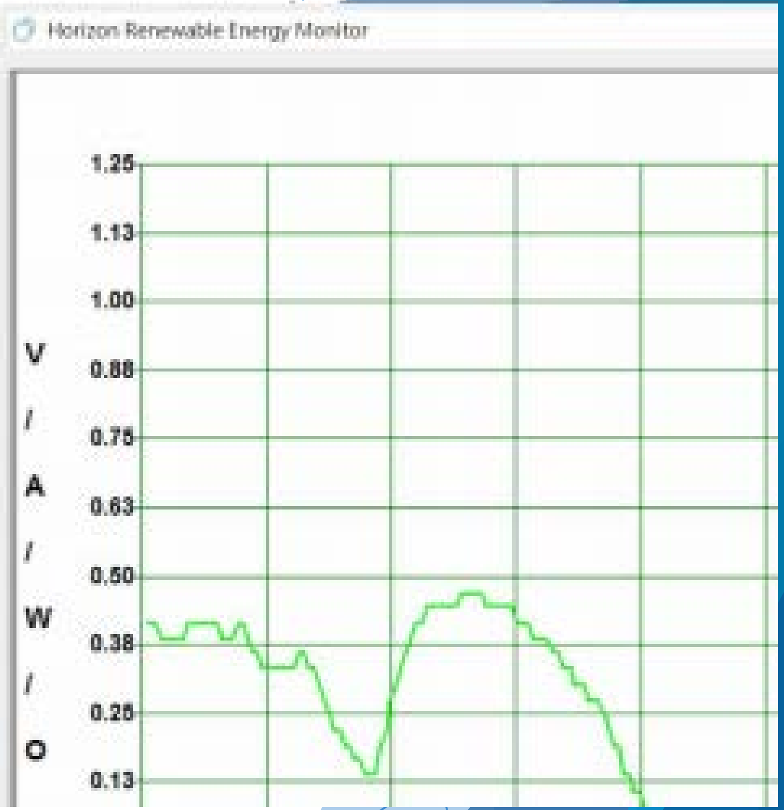
Investigation 1: Design of Turbine

- Adjust the **scale of y-axis** of the voltage-time graph by pressing the **+ / - button**

- Capture the voltage-time graph by pressing the **screen capture button**

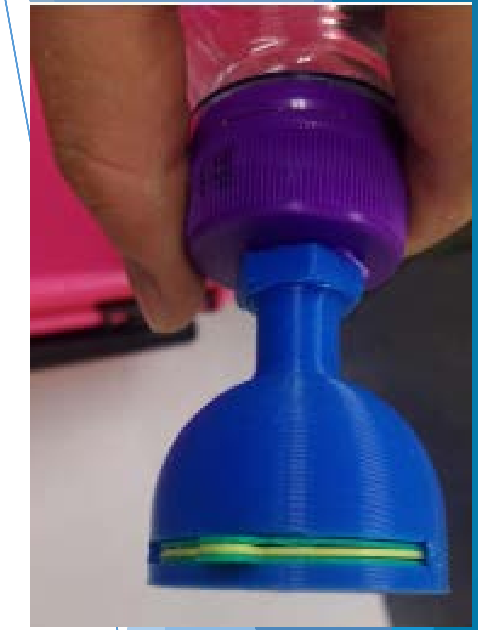
- The screen captured will be saved under the **folder horizon** under the ‘My document’ folder

- **Rename** your set of captured screens before changing the turbine for another measurement



Investigation 2: Water saving faucet

- Insert a combination of **3 filters** (ring or patterned plate) into the nozzle mount to make a faucet
- Fill up the water bottle by inserting the whole water bottle into the basin of water
- Erect and raise the water bottle to let the water level drop to your desired level
- **Measure the time taken** for the water to flow out of the bottle
    - You may video-record the whole process for more accurate measurement of time taken, if preferred
- Refill the water bottle and let water flow out from the faucet onto your hand to feel the water pressure



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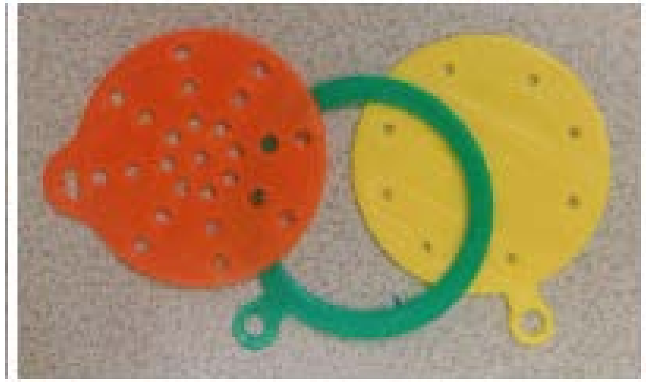
Investigation 2: Water saving faucet

- Repeat the steps with another combination of **3 filters** (ring or patterned plate) and measure the time taken for the same amount of water to flow out of the water bottle



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Investigation Report

- Purpose
- Experimental set-up
- Variable Table
- Materials & Apparatus
- Procedure
- $\boxed{\text{Results}}$
- Conclusion
- $\boxed{\text{Discussion}}$

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Results & Discussion for Investigation 1

- Go to https://goformative.com/join
- Enter the Quick Code: XXVC997
- Click the purple box "Continue without logging in"
- Enter **your FULL name** (so that we can count your assignment submission)
- Click "Begin"
- Answers the two questions
- Click "Submit"

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Results & Discussion for Investigation 2

- Go to https://goformative.com/join
- Enter the Quick Code: WUPH649
- Click the purple box "Continue without logging in"
- Enter **your FULL name** (so that we can count your assignment submission)
- Click "Begin"
- Answers the two questions
- Click "Submit"

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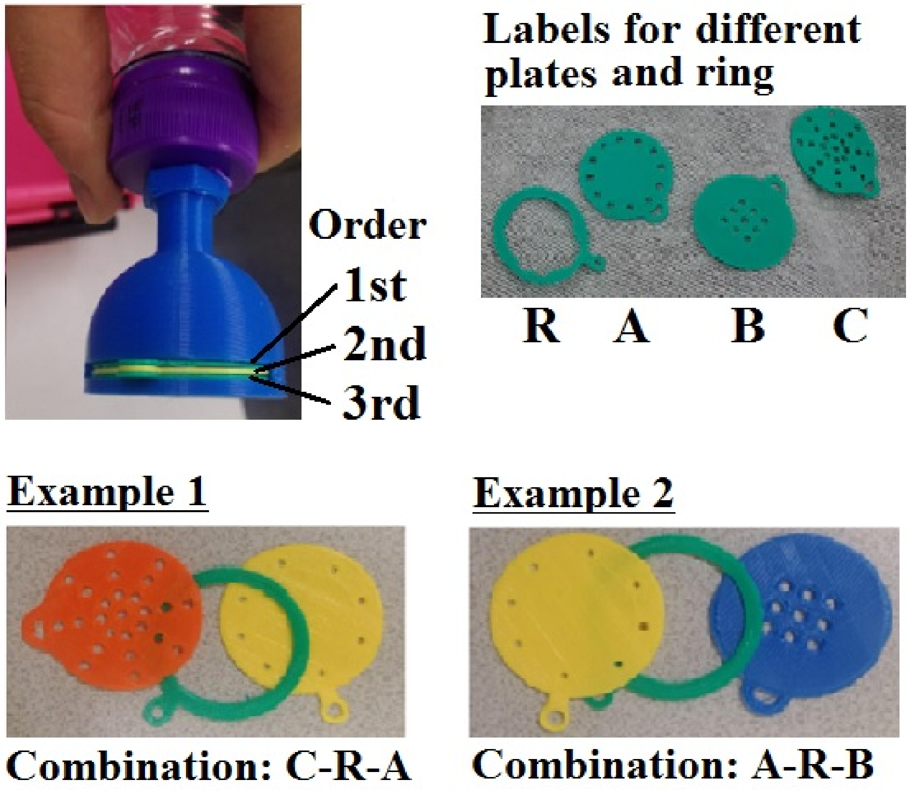
Question 1: (Results)

State your group's results.

- E.g. (for Investigation 1)
  Large / 5 paddles: ????V
  Large / 7 paddles: ????V

- E.g. (for Investigation 2)
  Combination A-R-B: ?? s
  Combination A-R-C: ?? s



Question 2: (Discussion)

(i) **What is the major difficulty / problem your group faced when taking measurement?**

(ii) **Suggest how the experimental set-up / the 3D-printed object can be modified to solve the problem.**

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Part 3 : 3D Printing Resources and Implementation Issues

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Part 3：3D Printing Resources and Implementation Issues

Getting Started Guides

[Make: Ultimate Guide to 3D Printing]

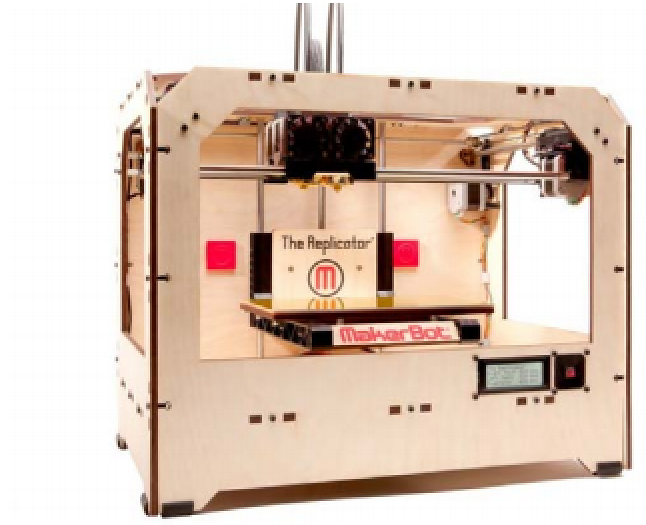
3D Projects

- Thingsiverse
  Make, share, and discover over 100,000 3D models at Thingsiverse. This is the world's largest 3D printing community and a place where you can find designs, talk about creations, and remix 3D things, no matter their technical expertise or previous experience.
- Makerspace Sample Projects
  The Makerspace directory has put together this list of articles that are all project ideas and detailed, step-by-step instructions for making 3D things such as a Soda Bottle Rocket, Bird Feeder, Amazing Rubber Band Cars, and more.

Reference: http://oedb.org/ilibrarian/the-maker-culture-in-libraries-and-education/

3D Printing

Create complex 3D shapes from plastic or other materials. Extrusion-based 3D printers build objects by squeezing out thin layers of plastic, one on top of the other. Many different kinds and colors of plastics can be used, including ABS (the same plastic used by LEGO) and PLA (a biodegradable plastic). There is even glow-in-the-dark material! Add other items such as windup motors to create motion or other interesting capabilities.



Safety

3D printers are generally very safe. The print extruder does heat to several hundred degrees and should not be touched. There will be a slight "hot plastic" smell when printing with ABS plastic. It's non-toxic but can be an irritant and the printer should be placed in an open area or near ventilation.

Software

There are a large number of applications that can create 3D models for printing. Popular free offerings include Google Sketchup, Blender, Wings 3D, tinkerCAD, and Autodesk 123D. Commercial packages include Rhino, Autodesk Inventor, and Solidworks. The price varies from several hundred to thousands of dollars, though many software publishers offer educational discounts.

Considerations

- You need a minimum 24" x 24" of dedicated table or desk space.
- If buying a kit, you'll need 12-16 hours and skills in assembly and soldering.
- Certain models may require a computer to operate the printer.
- A 3D printer requires a grounded outlet.
- 3D printing is not a particularly fast process. Speed almost entirely depends on the volume of plastic needed for the project. For example, a small whistle is mostly hollow and will print in around 5 minutes, while larger pieces can easily take hours.
- The output of extrusion printers often requires a bit of cleanup by hand after printing.
- While a computer is not required to print, makers will need access to one to create or download the files for printing.
- Advanced printers can have more than one print head (extruder) that can print in multiple plastics at the same time. This allows printing in multiple colors or printing with more than one material in an object. When one material is water-soluble much more complex shapes can be printed. One example would be printing a wheel on an axle with water-soluble material separating them. When the material is dissolved the wheel can spin freely on the axle.
- In lieu of a full 3D printer setup, consider sending your students' work to service bureaus like Shapeways and Ponoko. They can print with more detail and in other materials such as metal, ceramics, and in full color. Price depends on material and the volume of the object.
- It takes 1 to 3 hours to learn to use and maintain 3D printer. Initial setup and calibration takes several hours.
- In addition to creating original 3D models, designs can also be freely downloaded from sites like Thingiverse.com.

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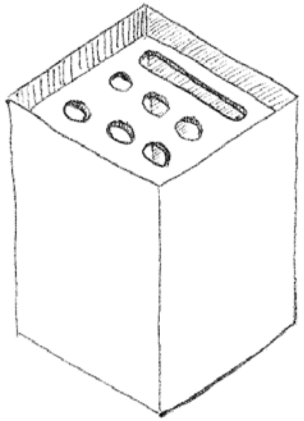
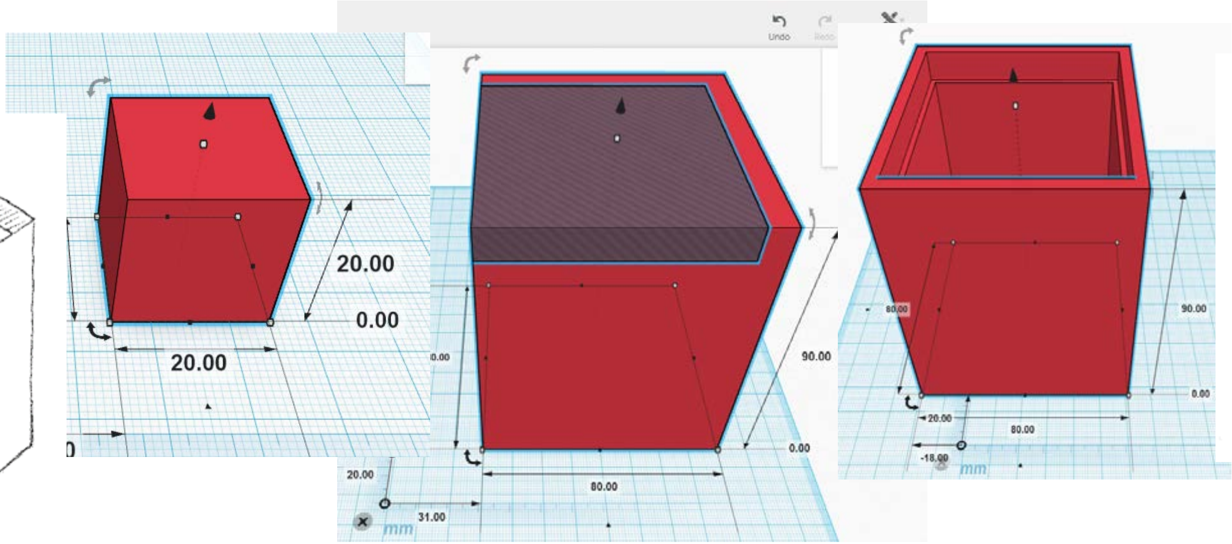
3D Printing: Tools & Equipment

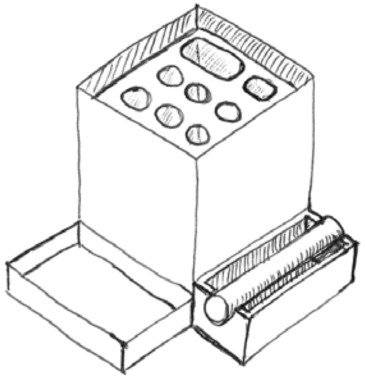
Tool	Description	Example*	Quantity	$ Each	$ Total
Extrusion-based 3D Printer		Example	1	$2000	$2000
Accessories					
SD Card	1GB or larger SD card for transferring student models to the printer		25	$2	$50
Consumables					
Plastic filament	1kg ABS 1.75mm. Any color.	Example	1	$50	$50
Plastic filament	(Additional roll/color)	Example	1	$50	$50
PVA (water soluble) filament	1kg PVA 1.75mm	Example	1	$90	$90
			Intermediate Total:		**$2240**

Sample STEM Lesson: **Pen Stand**

Science	Estimate **centre of gravity**, and **moment** by considering the height/ mass (i.e. weight) of the stationeries (e.g. pens/ pencils).
Technology	Decide and apply **3D model software application** by creating primitive shapes, followed by adding and subtracting with other primitive shapes for a finalised pen stand.
Engineering	Create a **solid** pen stand by considering **the minimum wall thickness** based on the **layer resolution** (e.g. 0.05mm) of a particular 3D printer.
Mathematics	Understand **three dimensional Cartesian coordinate system** for the creation of 3D models; Consider the **maximum print bed dimensions** before creating a 3D model.







What can be “3D-printed” with STEM/ STEAM education?

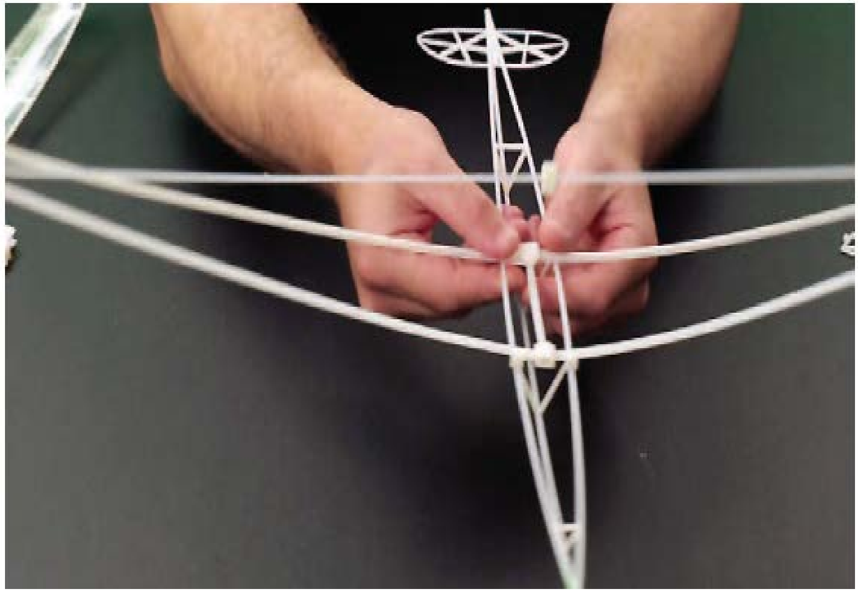
- Learning kits (calculation/ spelling)
- Drawer set (for stationery)
- Calendar (re-usable)
- Gifts for special seasons:
  - lights for Christmas tree (use transparent filaments)
  - gearbox for toy car
  - remote control car case and parts

SEVEN 3D PRINTING STEM PROJECTS TO DO WITH YOUR CLASS

IDEA #1. DESIGN A NEW GAME CONTROLLER

Lake Zurich high school students designed game controller shown here in CAD rendering.

IDEA #2. STUDY THE SCIENCEOF AERODYNAMICS



Students can build this glider through an online tutorial from Stratasys.

Reference: White Paper - Seven 3D Printing Stem Projects to do with your class

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IDEA #3. MAKE MANIPULATIVES FOR MATH AND SCIENCE

IDEA #3. MAKE MANIPULATIVES FOR MATH AND SCIENCE

Students at the STARBASE non-profit design and test their own rockets using 3D printers.

IDEA #4. ENGINEER WITH A PURPOSE

A Chico High School student reverse engineers small engine parts and printed physical models on the school's 3D printer.

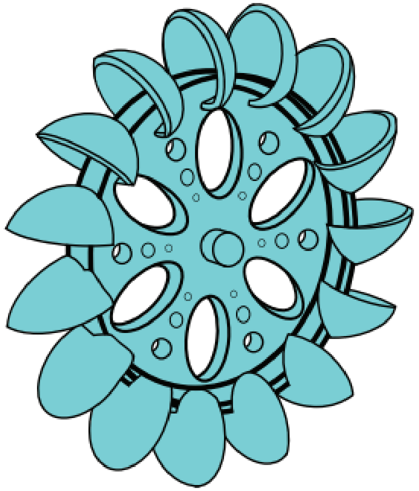
IDEA #5. TAKE FLIGHT WITH A NASA PROJECT

Cypress Woods High School students test their remotely operated vehicle in a weightless environment.

IDEA #6. CREATE A SOURCE OF HYDRO POWER

IDEA #6. CREATE A SOURCE OF HYDRO POWER

The Pelton wheel was an ingenious marvel of the 19th century that's still in use today. Although waterwheels existed aplenty before Lester Pelton came up with his unique design, none was more efficient than his off-center, curved-bucket approach, which allowed for the flow or jet of water to turn kinetic energy into rotational energy.



A Pelton wheel

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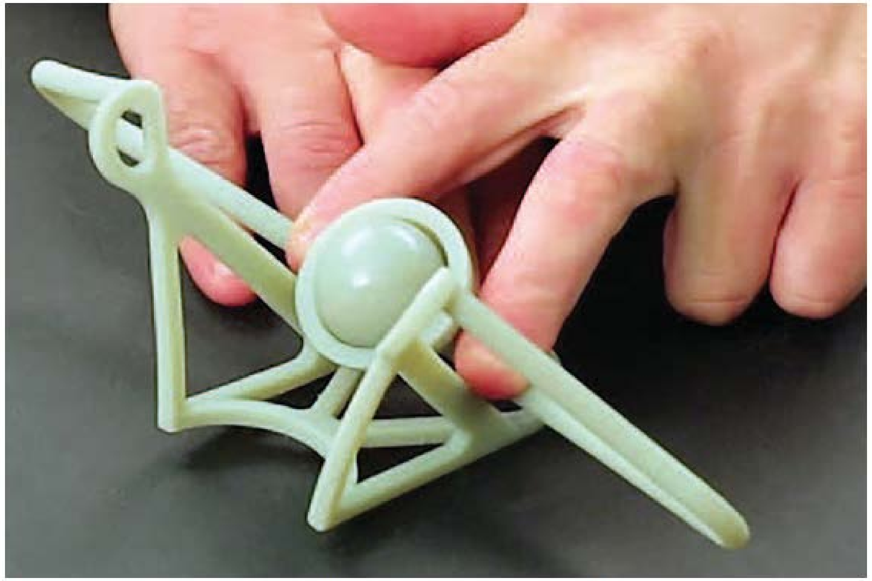
IDEA #7. STUDY HISTORIC TECHNOLOGY



Students can build this catapult through an online tutorial from Stratasys.

PUT YOUR PRINTER ON DISPLAY

- There are few things more enticing to people than watching the amazing process of a design being turned into a physical object.
- “Students are fascinated by the printer. I could sell popcorn and soda and make a fortune … ”