MATERIAL VARIETY

Module VI: Lesson Plan

MODULE GOALS

This module will familiarize students with the different types of materials that con be used in additive manufacturing. A variety of special filaments will help to demonstrate how even desktop 3-D printers can make parts with different properties.

Having familiarized themselves with 3-D printing processes over the last five modules, this module encourages students to move beyond conventional processes and materials, and experiment.

ESSENTIAL QUESTIONS

- What is the difference between traditional **ABS** and **PLA** filament types?
- What other, less traditional, materials are available for 3-D printing, both with the tools at hand in the student's place of learning, and in general?
- What is multi-material printing?
- When and why does a particular material address specific creative problems better than others?

MEANING AND ACQUISITION

- Students will understand the difference between **filament**, **liquid resin**, and **powder** materials for use in additive manufacturing.
- Students will learn about the unique opportunities allowed by different filaments for material extrusion.
- Students will gain knowledge regarding what printing parameters may impact their ability to extrude printed material.
- Students will think critically about how the choice of materials is itself a potentially meaningful, impactful, and ethically weighty artistic choice.
- Students will understand that 3-D printing, like any creative practice, is not a strictly prescriptive process, and invites material experimentation and exploration.

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FORMATIVE ASSESSMENT STANDARDS

- Students demonstrate willingness to experiment and develop skills in new art-making technologies and materials **(Cr2.1.5a)**.
- Students know and use fundamental vocabulary relevant to understand the different materials used in an additive manufacturing environment **(Cr3.1.1a)**.
- Students actively engage with different materials and assess their potential use in a creative fashion **(Cr.1.1.Ia).**
- Students are able to discuss and explain the differences between materials to their peers and help facilitate peer-to-peer learning **(CrI.1.11)**.

SUMMATIVE ASSESSMENT STANDARDS

- Student work demonstrates reflectivity on how artists and designers use different processes and materials to produce their pieces **(Re7.1.3a)**.
- Student work demonstrates an understanding of the synthesis between creative and analytical principles and techniques of the visual arts, and technical concepts from the sciences, such as those present in discussions about materials **(Cr2.3.IIa)**.
- Student work demonstrates the exploration of new art-making technologies and materials, and the different uses associated with these **(Cr2.1.4a)**.

MATERIALS

- Multiple different filament material types.
- 3-D printer (with multi-material extrusion for full material exploration).
- Example objects printed using different materials.

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KEY TERMS

- **ABS plastic** - A common plastic used in a great deal of manufacturing, including Lego bricks, electronics, and car bumpers. ABS has a higher printing temperature than PLA, which can cause warping with smaller details. ABS is more flexible and less brittle than PLA, making it more popular for manufacturing non-disposable objects. ABS is short for "Acrylonitrile Butadiene Styrene."
- **Filament** - A thin, thread-like piece of material. Plastic filament is used in most common 3-D printers, which use an FDM ("Fused Deposition Modeling") method. The filament is extruded through a heated printer head which gradually builds up layers from a base.
- **Liquid** - Some FDM printing doesn't use a molten filament, but rather extrudes a thick liquid, such as soft clay, concrete, or molten chocolate, which then dries and is solidified.
- **PLA plastic** - A biodegradable (when disposed of properly) plastic derived from renewable sources such as corn starch or sugarcane. One of the most popular "bioplastics," it is often used in disposable cups and medical implants. PLA has a lower melting temperature than ABS, making it easier to print with, and less likely to warp, allowing for finer detail. PLA is short for "Polylactic Acid."
- **Powder** - SLS printing ("selective laser sintering") use a high-powered laser to fuse small particles of plastic powder, layer by layer, as the powder is added to a tank. The un-fused powder supports the printed forms, meaning powder-based printing doesn't require support structures like FDM or SLA printing. SLS is the most common form of additive manufacturing in industrial applications, as the resulting objects are almost as strong as traditionally-manufactured parts.
- **Resin** - Resin is the printing material used for stereolithography ("SLA"), one of the oldest forms of 3-D printing. In stereolithography, a computer-controlled laser is fired into a tank of liquid resin chemically treated to harden into plastic when hit by light. Like FDM printing, the model is slowly built up, layer by layer. SLA prints are typically sturdier than FDM prints, as the resin has been chemically bonded, rather than applied in layers.

Derived from:

- FormLabs. (n.d). 3-D printing technology comparison: FDM vs. SLA vs. SLS. https://formlabs.com/blog/fdm-vs-sla-vs-sls-how-to-choose-the-right-3d-printing-technology/
- Giang, K. (n.d.). PLA vs. ABS: What's the difference? https://www.3dhubs.com/knowledge-base/pla-vs-abs-whats-difference/#what-are-abs-and-pla

MATERIAL VARIETY

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PROPOSED ACTIVITY

1. Students will learn about the different materials used in additive manufacturing:
   - Explore the handout and see the provided information.
   - Check the spools holding diverse materials to see the differences between them.
2. Students will learn about the multiple uses of different materials:
   - Use the handout to review the examples.
   - Explore the example printed objects to see how different materials have been used to create multiple objects.
3. Students will understand what multi-material 3-D printing is:
   - Observe and reflect on how the multi-material printing process works, and when should it be used for a particular design.

MATERIAL VARIETY
Module VI: Case Study

ALEX LE ROUX

Using the technique of material extrusion as the base for his invention, and considering the potential of this technique to work with a wide array of different materials, engineer Alex Le Roux designed and built a 3-D printer capable of printing a small house out of concrete ("Baylor engineering grad builds America's first 3D-printed tiny house", 2016, para. 1).

Utilizing a second iteration of his 3-D concrete printer known as the Vesta, Le Roux successfully printed what is believed to be America's first livable 3-D-printed shelter (Scott, 2016, para. 1).

Adapted from open-source RepRap designs, the 3-D concrete printer measures eight feet cubed and was able to print an 8 x 5 x 7 foot structure in just 24 hours (2016, para. 3). After completing the tiny house structure, Le Roux began working on a third iteration of the concrete printer in on effort to continue evolving the potential of additive manufacturing in architecture and construction ("Baylor engineering grad builds America's first 3D-printed tiny house", 2016, para. 3).

Figure 1. The tiny house during the printing process.

Figure 2. Le Roux with the printed tiny house.

MATERIAL VARIETY

Module VI: Case Study

PROJECT DESCRIPTION

The intersection between design and additive manufacturing is a growing field that's being explored and expanded more and more every day, thanks in part to accessible technology and open-source content. The use of 3-D printing technology in architecture and construction was once inconceivable, and now there ore companies and individuals across the globe who ore successfully implementing entire homes via additive manufacturing (Scott, 2016, para. 5).

Alex Le Roux, an engineer located in the United States, is an example of the innovative potential to be realized in the expanding field of 3-D printing. Using the possibilities given by the extrusion process and its flexibility to function with different materials, Le Roux built his 3-D concrete printer, adapted entirely from open source RepRap printer technology. With it, he has printed the first livable 3-D printed house in the United States.

The structure, located in Houston, Texas, was funded portly by Le Roux as part of a senior project at Baylor University, and portly by a Michigan-based architectural firm that favors environmentally friendly methods of construction (Alec, 2016, para. 3). Le Roux's printer, called the Vesta, involves limited labor and only requires one person to operate the computer and another to feed the concrete to the printer (Scott, 2016, para. 4). While able to print at a speed of .3 feet per second, Le Roux is hoping to create a third iteration of the printer which will be even more streamlined and will experiment with more environmentally friendly cements ("Baylor engineering grad builds America's first 3D-printed tiny house", 2016, para. 3). In doing so, Le Roux will continue to pursue the potentials of 3-D printed architecture, including increased customization, reduced construction waste, reduced manual labor needs, and faster build times (Scott, 2016, para. 3).

MATERIAL VARIETY

Module VI: Case Study

REFLECTION QUESTIONS

1. Even though the construction and manufacturing industries are dominated by corporations with extensive budgets, many small startups and individuals have been responsible for some of the most inventive 3-D printing innovations. What communities and resources foster these smaller-scale, non-corporate projects? How might accessible 3-D printing technology change the landscape of architectural and construction initiatives?
2. What do you think are some of the limitations of using concrete as a material for 3-D printing? What kinds of shapes could not be achieved through printing with this type of material? What kind of housing could not be made?
3. Additive manufacturing technologies allow for the use of different materials. Le Roux adapted an existing open-source printer to extrude concrete. What other materials do you imagine could be used for 3-D printing? What could be gained from using them?

REFERENCES

Alec (2016). Alex Le Roux 3-D prints livable concrete structure 'Tiny House' in just 24 hours. http://www.3ders.org/articles/20160620-alex-le-roux-3d-prints-livable-concrete-structure-tiny-house-in-just-24-hours.html

Baylor Proud. (2016). Baylor engineering grad builds America's first 3D-printed tiny house. https://www2.baylor.edu/baylorproud/2016/07/baylor-engineering-grad-builds-americas-first-3d-printed-tiny-house/

Scott, C. (2016). 3-D printed, livable tiny house built in only 24 hours by the Vesta V2 concrete printer. https://3dprint.com/139022/vesta-3d-printed-tiny-house/

IMAGE ATTRIBUTIONS

Figure 1. Retrieved from https://www.3printr.com/concrete-3d-printer-creates-livable-tiny-house-3340343/

Figure 2. Retrieved from https://www.3printr.com/concrete-3d-printer-creates-livable-tiny-house-3340343/

MATERIAL VARIETY

Module VI: Handout

PRINTING MATERIALS

Different types of materials can be used in additive manufacturing. The unique properties of these materials create different opportunities based on their capabilities, which are affected by printing parameters.

Two of the most common printing filaments ore Acrylonitrile Butadiene Styrene (ABS) plastic and Polylactic Acid (PLA) plastic. While they look similar; each has its own pros and cons:

POLYLACTIC ACID (PLA)		ACRYLONITRILE BUTADIENE STYRENE (ABS)	
PROS	CONS	PROS	CONS
• Can be printed on a cold surface • More environmentally friendly (biodegradable, made from plant-based sources) • Shinier and smoother appearance • Potential for finer detail • No harmful fumes during printing • Higher print speed	• Can easily deform due to heat • Less sturdy than ABS 	• Sturdier and less brittle than PLA • Suitable for machine or car parts • Higher melting point • Longer lifespan 	• Oil-based. Not biodegradable, and made from non-renewable sources • Deforms if not printed on heated surface • Toxic plastic fumes when printing (requires ventilation) • Slower, more difficult to print • Resulting objects cannot be used with food

MATERIAL VARIETY

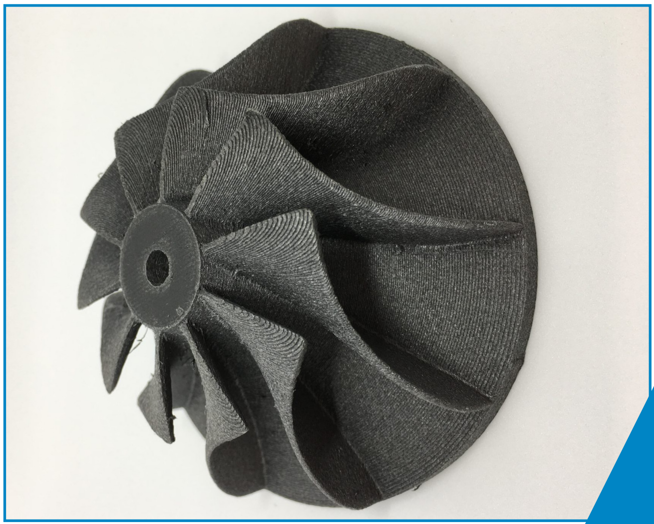
Module VI: Handout

Material extrusion isn't just limited to ABS or PLA. There ore a variety of other material types available for printing that con give objects unique properties or characteristics.

Flexible Filament: Used to create flexible hinges or stretchable objects. Can eliminate the need to design assemblies with moveable joints.

Wood Polymer Filament: A PLA filament infused with wood particles. Used to create decorative objects where the appearance and feel of wood has sensory importance.

Metal-Loaded Filament: Used to give objects slight metallic properties. Allows parts to be polished and gives them more weight than traditional plastics.



Carbon Fiber Filament: Used to increase the strength of printed parts without additional weight. Makes ports more rigid, but can wear down a print nozzle.