LESSON PLAN

SUMMARY

Date	Aug 14, 2024
Subjects	STEAM · Design & Technology · Fashion, Materials & Textile Design
Years	Year 7 · Year 8 · Year 9
Main Topic	3D Printed Textile with Flexible Filaments using the infill Method
Key Concepts	flexible filament fundamentals, infill methods for textile creation, print settings impact, TinkerCAD design, slicing software, experiment documentation, analysis, presentation, application ideation
Time Duration	180 – 200 minutes

MATERIALS NEEDED

- [ ] 3D Printer
- [ ] Flexible Filaments
- [ ] Scissors
- [ ] Swatch Book
- [ ] Duct Tape
- [ ] TinkerCAD
- [ ] Slicer (PrusaSlicer, Cura ...)
- [ ] Canva

LEARNING OBJECTIVES

1. Design, print, and analyze 3D printed textile swatches using flexible filament and the infills method.

2. Explore how various print settings affect the quality and properties of the printed fabric.

3. Document findings to gain a deeper understanding of 3D printed textile creation process.

ASSESSMENT

Students will create a comprehensive swatchbook containing at least five 3D printed textile samples, each utilizing different print settings. For each swatch, they will provide a detailed analysis explaining how specific settings (such as temperature, speed, retraction, infill type, etc.) affected the final product's quality, flexibility, and texture. The students will be evaluated based on the following criteria:

- [ ] Variety of samples (demonstrating experimentation with different settings)
- [ ] Accuracy and detail of documentation
- [ ] Depth of analysis and understanding of the relationship between print settings and textile properties
- [ ] Creativity in exploring potential applications for the created textiles
- [ ] Completion of assignments in the worksheet including reflection

LESSON OUTLINE

DURATION	ACTIVITY	SUMMARY
15–20 minutes	Opening	Introduction to 3D printed textiles through demonstrations and discussion about the potential impact of this new technology.
50–55 minutes	Introduction of a new topic or continuation of a previous lesson	Introduction to infill methods for 3D printed textiles, TinkerCAD, and to a slicing software. Explanation of the key print settings.
50–55 minutes	Guided practice	Safe 3D printer operation training. Design of the first textile swatch in TinkerCAD and djustment of print settings in slicing software. Observation of the printing process, and brainstorming modifications for future projects.
50–55 minutes	Independent practice	Documentation of swatches and printing processes. Experimentation with various print settings to create at least five different textile swatches.
10–15 minutes	Closing	Share best and worst swatches with a partner. Discuss the impact of different settings and potential real-world applications.

OPENING

1. Begin by showing examples of flexible, fabric-like 3D printed textiles to capture students' interest.
2. Ask students: "How do you think we can make fabric using a 3D printer?" Encourage creative responses and discussion.
3. Pass around a simple 3D printed textile swatch, allowing students to touch and examine it closely.
4. Explain that today, they will become textile innovators by creating their own 3D printed fabric swatches.
5. Briefly discuss the potential impact of 3D printed textiles on fashion, industry, and everyday life to contextualize the lesson.

MAIN TOPIC

1. Explain the infills method for creating 3D printed textiles, using visual aids to illustrate the concept.
2. Introduce TinkerCAD and demonstrate how to design a simple textile swatch:
   - Show how to create a basic shape
   - Explain the importance of size and thickness in relation to printing time and flexibility
3. Introduce slicing software and demonstrate how to prepare the design for printing:
   - Explain the purpose of slicing software in the 3D printing process
   - Show how to import the TinkerCAD design into the slicer
   - Demonstrate how to add patterns or textures to the swatch design
   - Point out key areas of the interface for adjusting print settings
4. Discuss the key print settings that affect textile quality, explaining each in detail:
   - Temperature (bed and nozzle): How it affects adhesion and filament flow
   - Print speed: Its impact on print quality and flexibility
   - Retraction settings: How they prevent stringing and affect print cleanliness
   - Travel speed: Its role in print time and quality
   - Flow rate: How it affects the amount of material extruded and print density
   - Infill types and density: Their impact on flexibility, strength, and texture
   - Swatch thickness: How it influences overall flexibility and drape
5. Address the common misconception that “3D printed objects are always rigid and inflexible“ by explaining how flexible filaments and specific print settings can create pliable structures.

GUIDED PRACTICE

1. Set clear expectations for safe and responsible use of 3D printers, emphasizing proper handling of equipment and materials.
2. Guide students step-by-step through the process of designing a simple 5cm x 5cm textile swatch in TinkerCAD:
   - Creating the base shape
   - Ensuring appropriate thickness for flexibility
3. Demonstrate how to export the design from TinkerCAD and open it in the slicing software.
4. Show students how to adjust various print settings in the slicer, explaining potential effects of each change:
   - Adjust temperature settings and explain how they might affect the print
   - Modify print speed and discuss its impact on quality and print time
   - Change infill patterns and density, relating these to flexibility and strength
5. Print a sample swatch as a class, encouraging students to observe and discuss what they see during the printing process.
6. While the swatch is printing, have students brainstorm in small groups how they might modify settings to achieve different results (e.g., more flexibility, interesting textures).
7. Once the print is complete, examine it as a class, discussing its properties and how they relate to the chosen settings.

INDEPENDENT PRACTICE

1. Provide students with a template for their swatchbook documentation, explaining how to record settings, observations, and analyses.
2. Instruct students to design and print at least five different textile swatches (in groups or individually), each with unique print settings:
   - Encourage experimentation with different infill types, densities, and other settings
   - Suggest trying extreme settings (within safe limits) to see dramatic differences
3. Remind students to document their settings and observations for each swatch:
   - Record all print settings used
   - Note observations about the printing process
   - Analyze the final swatch's properties (flexibility, texture, strength, etc.)
   - Hypothesize about potential applications for each swatch
4. Circulate the room to provide assistance, ensure safe printer operation, and ask probing questions to deepen student understanding.
5. Encourage students to compare their results with classmates and discuss differences and similarities.

CLOSING

1. Have students pair up and share their most successful and least successful swatches, explaining why they consider them as such.
2. Facilitate a class discussion on the following questions:
   - What settings seemed to have the biggest impact on textile quality?
   - Were there any unexpected results from your experiments?
   - How might these 3D printed textiles be used in real-world applications?
3. Ask students to reflect on the potential of 3D printed textiles in fashion, industry, or other fields, encouraging creative thinking.

EXTENSION ACTIVITY

For students who finish early or want an additional challenge, have them design a clothing that incorporates their best 3D printed textile swatch. This activity allows students to apply their newly gained knowledge to a practical design problem.

HOMEWORK

Assign students to research one real-world application of 3D printed textiles in fashion or industry. Have them write a short paragraph (150-200 words) explaining:

- How the technology is currently being used in their chosen example
- How it might be improved based on what they learned in class

- A new potential application they can imagine for 3D printed textiles

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Makeful Tip

Remember to check your 3D Printers and prepare your TinkerCAD class room before the lesson. Store all of the flexible filaments in sealed bag with silica gel to avaid humidity absorption.

MAKEFUL

GLOSSARY

Word	Definition
Bias (on Textile)	**Definition**: The bias of a fabric refers to the diagonal direction of the weave, which is at a 45-degree angle to the lengthwise (warp) and crosswise (weft) threads. **Explanation**: When fabric is cut on the bias, it has more stretch and drape, making it ideal for creating garments that fit closely to the body, such as dresses or fitted tops.
Bed	**Definition**: The bed is the flat surface on which a 3D print is built. **Explanation**: It can be heated to help with adhesion of the first layer and prevent warping during the printing process.
FDM	**Definition**: FDM is a 3D printing technology that creates objects by melting thermoplastic filament and depositing it layer by layer. **Explanation**: This is one of the most common and accessible methods of 3D printing, used in both hobbyist and industrial applications
Fiber (Textile)	**Definition**: Fiber refers to the basic structural unit of textiles, which can be natural (like cotton or wool) or synthetic (like polyester or nylon). **Explanation**: Fibers are spun together to create yarns, which are then woven or knitted to produce fabric.
Hot end	**Definition**: The hot end is the component of a 3D printer where the filament is melted before being extruded through the nozzle. **Explanation**: It consists of a heating element and a temperature sensor, ensuring that the filament reaches the appropriate temperature for smooth extrusion.

Word	Definition
Infill	**Definition:** Infill refers to the internal structure of a 3D printed object, which fills the space between the outer walls. **Explanation:** The infill pattern and density can be adjusted in the slicing software, affecting the strength, weight, and material usage of the final print. Common patterns include grid, honeycomb, and triangles.
Perimeters/Walls	**Definition**: Perimeters, or walls, are the outer layers of a 3D printed object that define its shape and provide structural integrity. **Explanation**: The number of perimeters can be adjusted in the slicing software to increase strength and improve surface finish.
Shore hardness	**Definition**: Shore hardness is a measure of the hardness of a material, specifically flexible materials like elastomers and rubbers. **Explanation**: It is measured on a scale (Shore A or Shore D), with lower numbers indicating softer materials and higher numbers indicating harder materials. This measurement helps designers choose the right material for their specific application in fashion.
SLA	**Definition**: SLA is a 3D printing technology that uses a laser to cure liquid resin into solid objects layer by layer. **Explanation**: This method is known for its high precision and ability to create intricate details, making it popular for prototypes and jewelry design, but it typically requires post-processing to remove excess resin.
Retraction	**Definition**: Retraction is the process of pulling the filament back into the nozzle during non-printing movements to prevent oozing. **Explanation**: This helps maintain clean prints by reducing stringing and blobbing, ensuring that the filament only flows when it is supposed to be extruded.
Travel	**Definition**: Travel refers to the movement of the print head (or nozzle) when it is not extruding filament. **Explanation**: During travel moves, the printer moves the nozzle from one point to another without depositing material. Optimizing travel paths can help reduce printing time and improve print quality by minimizing the distance traveled.

COVERED AREAS

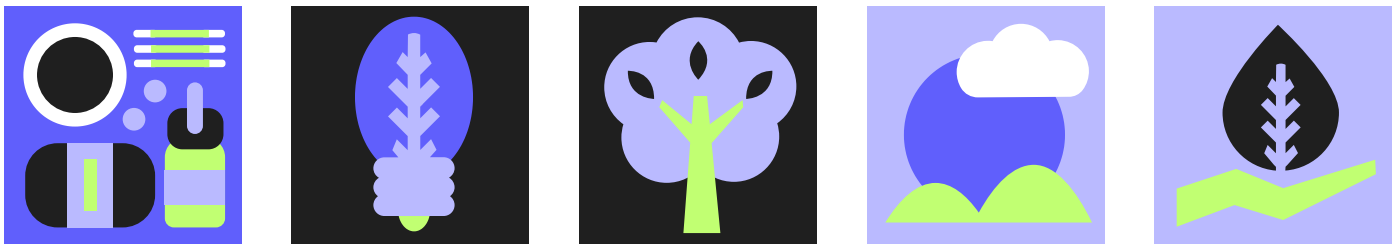
Intro to 3D Printed Fashion

History & Important Milestones

Key Influencial Persons

3D Printed Fashion Techniques

Commonly Used Flexible Filaments



INTRODUCTION TO 3D PRINTED FASHION

3D printing has revolutionized the fashion industry, allowing designers to create innovative, customized, and sustainable garments and accessories. This technology has opened up new possibilities for design, production, and personalization, transforming the way we think about fashion. From haute couture to ready-to-wear, 3D printed fashion has made its mark on the industry, showcasing the potential of additive manufacturing to push the boundaries of creativity and innovation.

The Evolution of 3D Printing in Fashion

Initially, 3D printing was predominantly associated with art pieces and high-end couture, where designers could experiment with intricate, complex designs that were often limited to the catwalk or art exhibitions. However, as the technology has evolved, its applications have expanded significantly. Designers are now leveraging 3D printing not just for artistic expression but also for practical, everyday fashion items. This shift is largely due to

advancements in printing technologies, materials, and the decreasing costs associated with 3D printing, making it more accessible for designers at all levels.

Video: Danit Peleg – Future of Fashion

Customization and Personalization

One of the most significant advantages of 3D printing in fashion is the ability to customize and personalize garments. Each piece can be tailored to fit an individual's unique measurements, ensuring a perfect fit that traditional manufacturing methods cannot easily achieve. This capability aligns with the growing consumer demand for personalized products, allowing brands to offer bespoke clothing that caters to specific preferences and body types. As a result, 3D printing facilitates a more inclusive approach to fashion, accommodating diverse body shapes and sizes.

Sustainability in Fashion

The fashion industry is notorious for its environmental impact, characterized by wasteful production practices and fast fashion trends. 3D printing presents a more sustainable alternative by significantly reducing material waste. Traditional garment manufacturing often involves cutting patterns from large fabric rolls, resulting in excess material that is discarded. In contrast, 3D printing uses only the necessary amount of material, minimizing waste and allowing for the production of items on-demand. This not only conserves resources but also reduces the carbon footprint associated with overproduction and unsold inventory. Moreover, many designers are exploring biodegradable and recyclable materials for 3D printing, further

enhancing the sustainability of this technology. For instance, innovative materials derived from recycled plastics or organic substances are being developed, allowing for the creation of eco-friendly fashion items that do not compromise on style or functionality.

HISTORY & IMPORTANT MILESTONES

The history of 3D printed fashion can be traced back to the late 1990s, when the first 3D printed dress was created by Jiri Evenhuis and Janne Kyttanen for Freedom of Creation in 1999. This groundbreaking piece showcased the potential of additive manufacturing in fashion, paving the way for future innovations. The dress, which featured a delicate, intricate design, demonstrated that 3D printing could be used to create fashion items that were not possible with traditional manufacturing methods.

Photo by Janne Kyttanen & Jiri Evenhuis

Photo by Vogue – Iris Van Herpen Crystalization Collection

In 2010, Dutch fashion designer Iris van Herpen presented her “Crystallization“ collection at Amsterdam Fashion Week, featuring the first 3D printed couture pieces to be displayed on a runway. Van Herpen’s designs, such as the “Crystallization“ top, have since become synonymous with the intersection of technology and haute couture, pushing the boundaries of what is possible in fashion. The “Crystallization“ top, inspired by the intricate structures of shells, combined organic forms with high-tech fashion, showcasing the potential of 3D printing in creating visually unique garments.

The year 2013 marked a significant milestone in the world of 3D printed fashion when Danit Peleg, an Israeli designer, created the first fully 3D printed fashion collection. This achievement demonstrated the potential for at-home 3D printing in fashion, making the technology more accessible to designers and consumers alike. Peleg's collection, which took over 2,000 hours to print using a home 3D printer, featured geometric cutouts in bold colors, showcasing the versatility of 3D printing in creating wearable fashion items.

Photo by Danit Peleg

Photo by Haute Living – ThreeASFOUR Harmonograph

In 2016, the design collective ThreeASFOUR showcased their "Harmonograph" dress at New York Fashion Week, exploring how biological forms and natural morphologies can be replicated using 3D printing. This collection, part of their "Biomimicry" series, highlighted the potential for 3D printing to create intricate and organic designs that would be challenging or impossible to produce using traditional manufacturing methods. The "Harmonograph" dress, inspired by natural harmonic vibrations, showcased the delicate balance between nature's randomness and precision that can be achieved through 3D printing

More recently, in 2018, Julia Daviy, a Russian-American designer, presented her 3D printed skirts, proving that high-tech and high-fashion can coexist in a sustainable way. Daviy's designs showcase the potential for 3D printing to create unique and environmentally friendly fashion pieces, aligning with the growing demand for sustainable fashion solutions. By using biodegradable materials and minimizing waste, Daviy's work demonstrates the positive environmental impact that 3D printing can have on the fashion industr

Photo by Julia Daviy

3D Printed Fashion in numbers

1999

First 3D Printed Fashion Garment

Pioneers Janne Kyttanen and Jiri Evenhuis

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Waste Reduction

Traditional garment manufacturing can result in up to **15% to 20% waste** of materials due to cutting patterns and excess fabric. In contrast, 3D printing can reduce material waste to as low as 5% by using only the necessary amount of material for production through additive manufacturing techniques.

15%

Waste Material Reduction

36%

Prefer customized producst

Prefence of customized products

According to a report by Deloitte, 36% of consumers expressed interest in purchasing customized products. This growing demand for customization highlights the importance of 3D printing technology in enabling designers to create tailored fashion pieces that meet individual consumer preferences.

Photo: 3D Printed Trouser by Brigitte Kock using Balena's sustianable filament

KEY PERSONS OF INFLUENCE

These key events and pioneering designers have played a significant role in shaping the history of 3D printed fashion, showcasing the technology's potential to revolutionize the industry and push the boundaries of creativity and sustainability.

Iris van Herpen

A Dutch fashion designer known for her avant-garde designs and pioneering use of 3D printing in haute couture. Her collections often feature intricate, sculptural pieces that challenge the traditional boundaries of fashion.

Julia Daviy

A Russian-American designer who has embraced 3D printing as a sustainable and innovative manufacturing method for her fashion collections. Her designs focus on creating biodegradable fashion and minimizing textile waste.

Danit Peleg

An Israeli designer who created the first fully 3D printed fashion collection, demonstrating the potential for at-home 3D printing in fashion. Her work has inspired many to explore the possibilities of 3D printing in fashion design.

3D PRINTED FASHION TECHNIQUES

The techniques used in 3D printed fashion have evolved significantly, allowing for greater creativity and functionality. Here are some of the most prominent techniques used in the industry:

Direct-to-Textile Printing

This innovative technique, exemplified by Stratasys' 3DFashion technology, enables designers to print directly onto fabric. This method allows for full-color designs and intricate patterns, creating stunning visual effects and textures on garments and accessories. The technology optimizes the absorption rate mechanism, allowing for perfect adhesion on a variety of fabric types, which enhances the overall aesthetic and functionality of the garments.

Video: Ganit Goldstein & Stratys Direct-To-Textile 3D Printing

Multi-Material Printing

This technique allows for the combination of different materials in a single print, enabling the creation of garments with varying textures and properties. This is particularly useful for creating pieces that require flexibility and durability, such as footwear and activewear. Multi-material printing can also facilitate the integration of functional elements, such as sensors or lighting, into the garment design.

Parametric Design

This approach involves using algorithms to create designs that can be easily modified and customized. Designers can create unique, personalized garments that fit individual body shapes and preferences, enhancing the customization aspect of 3D printed fashion. Parametric design allows for the exploration of complex geometries and patterns that would be difficult to achieve with traditional methods.

Commonly Used Flexible Filaments

The choice of flexible filament is crucial in 3D printed fashion, as it affects the final product's appearance, durability, and comfort. These flexible filaments allow designers to create innovative, customized, and sustainable garments and accessories that challenge the traditional norms of the fashion industry. By exploring the possibilities of these materials, fashion designers can push the boundaries of what is possible with 3D printed fashion.

Photo by Balena, Biodegradable Flexible Filament

TPU (Thermoplastic Polyurethane)

A flexible and elastic material that is ideal for creating wearable fashion items. TPU is known for its high resistance to abrasion, wear, and tear, as well as its excellent impact resistance and elongation at break. It is a popular choice for accessories and garments that require stretch and comfort.

TPE (Thermoplastic Elastomer)

Also known as thermoplastic rubber, TPE is a highly elastic material that can be extended up to 4.5 times its original size before breaking. It offers a wide spectrum of hardness and flexibility, ranging from Shore 98A to Shore 60A, making it adaptable to various fashion applications.

TPU (Thermoplastic Polyurethane) and TPE (Thermoplastic Elastomer) are both flexible materials used in 3D printing, but they differ in their composition, with TPU being a specific type of TPE characterized by its polyurethane structure. TPE is generally softer and more flexible than TPU, with a wider range of hardness, while TPU is more rigid and durable, making it suitable for applications requiring abrasion resistance and tensile strength.

Nylon

While typically known for its strength and durability, certain formulations of nylon can also exhibit flexibility. This makes it suitable for creating intricate designs and durable garments that require some degree of stretch, making it a favorite among fashion designers.

FlexPHA

A flexible filament made from polyhydroxyalkanoates (PHA), a biodegradable material produced by bacteria. FlexPHA combines flexibility with sustainability, making it an attractive option for designers focused on eco-friendly fashion.

FlexPLA

A flexible variant of polylactic acid (PLA), FlexPLA offers the ease of printing associated with PLA while providing the added benefit of flexibility. This filament is ideal for creating soft, wearable designs that require a comfortable fit.

WORKSHEET

Fill in the Blank

Complete each sentence by filling in the blank with the correct word or phrase from the word bank.

Sentence	Your Answers
3D printing allows designers to create __ and __ garments and accessories that fit perfectly.	
One major advantage of 3D printing in fashion is the ability to __ garments to fit an individual's exact measurements.	
3D printing is more __ than traditional manufacturing because it reduces material waste and allows for on-demand production.	
Fashion designers are exploring __ and __ materials for 3D printing to make eco-friendly fashion items that are better for the environment.	
The integration of __ intelligence in the future is expected to enhance the design and production processes in 3D printed fashion, making it even more efficient and customizable.	
3D printing in fashion facilitates a more __ approach by accommodating diverse body shapes and sizes.	

Word bank: sustainable, artificial, customize, innovative, biodegradable, recyclable, personalized, inclusive

Multiple Choice Questions

Select the best answer for each question from the options provided.

1. What is one of the main advantages of 3D printing in fashion?

- [ ] a) It's more expensive than traditional methods
- [ ] b) It allows for easy customization and personalization
- [ ] c) It uses more materials in the production process
- [ ] d) It takes longer to produce each item

2. How does 3D printing help make fashion more sustainable?

- [ ] a) By using more energy in the production process
- [ ] b) By creating more waste materials
- [ ] c) By reducing material waste and allowing for on-demand production
- [ ] d) By increasing transportation costs for finished products

3. What type of fashion was 3D printing initially associated with?

- [ ] a) Everyday casual wear
- [ ] b) Sports and athletic clothing
- [ ] c) High-end couture and artistic pieces
- [ ] d) Children's clothing and accessories

4. How is 3D printing making fashion more inclusive?

- [ ] a) By making all clothes the same standard size
- [ ] b) By easily accommodating diverse body shapes and sizes
- [ ] c) By only creating expensive, high-end clothing
- [ ] d) By limiting design options to simple styles

5. How might 3D printing affect the fashion industry's environmental impact?

- [ ] a) It will likely increase the industry's carbon footprint
- [ ] b) It won't have any significant effect on sustainability
- [ ] c) It could reduce overproduction and material waste
- [ ] d) It will require more water usage in the production process

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Open Ended Questions

Answer the following questions in complete sentences. Use examples or details from what you've learned about 3D printing in fashion to support your answers.

1. Can you think of an item of clothing or an accessory that could be improved by using 3D printing? Explain your answer and describe how 3D printing might enhance this item.
2. How might 3D printing in fashion help the environment? Give at least two examples of how this technology could make the fashion industry more sustainable.
3. What challenges do you think the fashion industry might face in adopting 3D printing technology more widely? How might these challenges be overcome?

Answer Key

Fill in the Blank

1. innovative, personalized
2. customize
3. sustainable
4. biodegradable, recyclable
5. artificial
6. inclusive

Multiple Choice Questions

1.b, 2.c, 3c, 4.b, 5.c,

Open Ended Questions (Example responses)

1. Shoes could be greatly improved by 3D printing. They could be made to fit each person's feet exactly, taking into account individual arch height, foot width, and any specific comfort needs. This could make shoes more comfortable, supportive, and potentially reduce foot-related health issues caused by ill-fitting footwear.
2. 3D printing in fashion can help the environment in several ways. Firstly, it can reduce waste by only using the exact amount of material needed, unlike traditional methods that often create excess waste when cutting fabric. Secondly, it allows for on-demand production, which could reduce overproduction of clothing that often ends up unsold and in landfills.
3. Some challenges the fashion industry might face in adopting 3D printing include high initial costs for equipment, the need for specialized training, and ensuring the durability and quality of 3D printed items matches traditional methods. These challenges could be overcome through investment in research and development, partnerships with tech companies, and gradual integration of the technology alongside traditional methods.