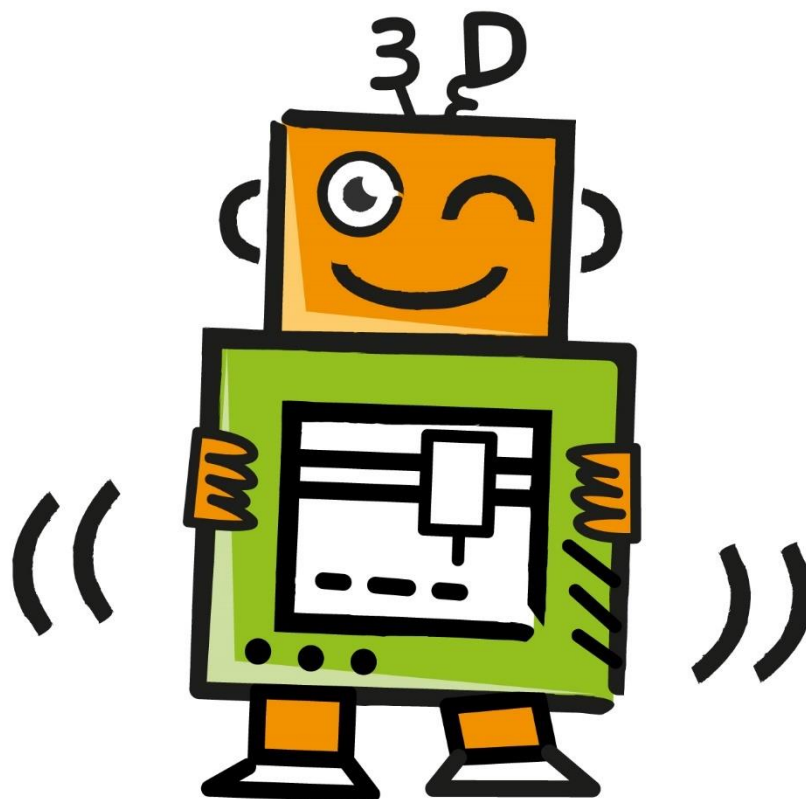




EMPOWER3D

TEACHER TRAINING MANUAL

 Recommended for online delivery  Recommended for in-person delivery

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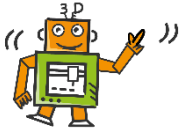
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1 – An Introduction to 3D Printing

Slide 3

1.0 Introductions

Intro from partners

What is your interest / experience in 3D printing?

What do you hope to get out of the training programme?

Programme overview: Hands-on experiential learning about 3D printing and design from a manufacturing perspective.

Slide 4

1.1 What is 3D printing - Brief Introduction

What is 3D printing

3D printing is the construction of a 3-dimensional object from a digital model. Also known as additive manufacturing, it involves laying down successive layers of material until the object is completed. Each layer is a thin slice (a cross-section) of the object.

One of the main benefits of 3D printing is that it gives the ability to produce complex 3D objects that might be impossible to make by hand in one piece.

3D printing allows for the prototyping and testing of designs in a relatively short timeframe - also known as rapid prototyping. This has had a huge impact on product development in almost every industry.

The vast majority of 3D printers are FDM printers. Fused Deposition Modelling (FDM) involves extruding thermoplastics through a heated nozzle and applying the melted plastic layer by layer onto a build platform.

Slide 5

Working with X, Y, Z axis

A 3D printer's lateral (side to side) movement is assigned to X and Y coordinates. The Z coordinates correspond to vertical movement. So

each layer is deposited according to the X and Y axis, and each layer height is determined by the Z axis (which is set in the slicer software settings).

Slide 6

Difference between additive and subtractive manufacturing

3D printing, or additive manufacturing is the opposite of subtractive manufacturing, which involves creating objects by removing materials using cutting, boring, grinding and drilling techniques. Historically, manufacturing has been focused on subtractive processes.

Slide 7

3D printing used in industry

3D printing is a versatile technology used across various industries:

1. **Aerospace:** 3D printing is used to produce lightweight and complex parts for aircraft and satellites, resulting in improved fuel efficiency and reduced manufacturing costs.
2. **Automotive:** The technology enables rapid prototyping, design optimisation, and production of customised parts, streamlining the manufacturing process and promoting innovation in vehicle design.
3. **Healthcare:** 3D printing revolutionises the medical field by creating patient-specific prosthetics, orthotics, and implants. It also enables the production of anatomical models for surgical planning and medical training.
4. **Construction:** In the construction industry, 3D printing is used to fabricate customised building components, enabling faster construction and reducing material waste. It also has the potential to create affordable housing solutions.
5. **Consumer goods:** 3D printing allows the creation of bespoke products such as jewellery, clothing, accessories, and homeware items, catering to individual preferences and needs.
6. **Education:** The technology is employed in schools and universities to enhance learning experiences by creating tangible models and prototypes, encouraging creativity and problem-solving skills.
7. **Art and design:** 3D printing opens new doors for artists and designers, enabling them to produce intricate and innovative sculptures, installations, and other creative works.

8. Food industry: 3D food printers can create unique and intricate culinary creations, offering personalised nutrition and innovative dining experiences.
9. Manufacturing: The technology is widely used for rapid prototyping, allowing companies to speed up product development and reduce time-to-market.
10. Research: 3D printing aids researchers in creating complex structures and devices for scientific investigation, enabling new discoveries and innovations.

3D printing is transforming industries by offering cost-effective, customisable, and efficient manufacturing solutions, driving innovation, and reshaping traditional production processes.

Slides 8-12



Physical: Samples of a selection from above list



Video: How 3D Printing is Changing the world*

https://www.youtube.com/watch?v=GV8zPtqOyqg&list=LL&index=5&ab_channel=VICENews

*Play up to 2.01 and any additional relevant parts

Slide 13

Women in STEM in the EU

- Represent 33% of STEM graduates
- Represent 41% scientists and engineers
- 12% engineering, 21% ICT specialists, majority life and social sciences
- Represent 26% in leadership roles in STEM, earn 81% of male counterparts
- Minority women represent 10% of STEM workforce

Slide 14

Benefits of 3D printing in the primary curriculum

3D printing aligns with the primary school curriculum by fostering creativity, innovation, and problem-solving skills in students.

It supports various subject areas such as Science, Technology, Engineering, Arts, and Mathematics (STEAM), integrating seamlessly with the curriculum's learning objectives.

In Science, 3D printing helps students understand concepts like materials, structures, and forces by bringing them to life with tangible models.

In Mathematics, it aids in teaching geometry, shapes, and spatial reasoning through the creation of 3D objects.

Technology and Engineering subjects benefit from the hands-on experience of designing, building, and testing prototypes.

The Arts curriculum is enhanced by encouraging students to create unique and imaginative designs, promoting creativity and self-expression.

By incorporating 3D printing in the primary school curriculum, schools prepare students for the future by developing their digital literacy, design thinking, and collaborative skills, all crucial for success in an increasingly technology-driven world.

Slide 15-16

1.2 3D printing during a global pandemic

- Charlotte valve adapted from Decathlon snorkelling mask
- Ergonomically fitted face-masks
- Nasopharyngeal swabs with complex tip structures
- Training aids using anatomically correct complex models
- Temporary emergency dwellings for healthcare workers requiring isolation

[Fatau Juka Dabor](#) set up Gambia's first 3D printing company ([Make 3D Company Ltd](#)) and is the only female led STEM company in Gambia with a focus on medical and educational devices

Slide 18

1.3 Main components of a 3D printer

Brief introduction

3D printers have their own vocabulary for their components and functions. It is important to know these words when carrying out maintenance and troubleshooting using online websites and forums so that issues can be accurately described.



Demo: Walkthrough on printer

Bed, motors, extruder, filament

Printer bed: The surface of a 3D printer where the material is placed in layers to form a printed object.

Motors: The parts that allow the print head to move along the X Y and Z axis

Extruder: The part of the print head that ejects the semi liquid filament through a nozzle onto each print layer

Filament: A continuous plastic thread which comes in a spool. It is fed into the extruder where it is melted before being ejected through the nozzle. There are many different types of filament, each with their own properties.

Slide 19

Health & safety

Heat, electricity, motors, emissions



Demo: Walkthrough on printer

Nozzle is heated to over 200 degrees Celsius. Keep away from skin and clothing when in operation.

Printer is connected to mains electricity supply. Do not carry out maintenance while printer is plugged in.

Motors move while printer is in use. Keep body and clothing away from motors when in operation.

Some plastic filaments release ultrafine particles when heated and may require air filtration. It's generally advisable to ensure ventilation while printer is in operation. Polylactic Acid (PLA) is the standard filament used in education and home settings and is considered safe to use without air filtration.

It's important that schools include 3D printer and associated activities along with other school equipment and activities on their insurance policy.

Electricity usage

An average consumer 3D printer uses approximately 80 watts of power per hour of continuous use. For context, a laptop uses c. 60 watts, a fridge uses c. 180 watts.

Slide 20



Handout: Printed diagram of a 3D printer



Activity: Using the given diagram - please label the parts that you have learned about so far (this can be updated later)

Slide 21

1.4 3D Printer filament



Physical: Samples of filaments

3D printing filament is the thermoplastic used by FDM (fused deposition modelling) printers. There are many types available - each having their own properties and temperature requirements in order to produce successful prints.

There are many suppliers of filament, each with varying range of price and quality. It is recommended that as a beginner, only brands recommended by your 3D printer manufacturer are used. Even small differences in filament properties can have a real effect on prints.

Buying the best filament for your printer will save time, stress, and money in the long run. As you become more experienced with 3D printing additional filament can be explored.

Filament types and applications

Printer filament comes in a long thread of plastic on a spool (like a very large spool of thread!)

Slides 22-24

Filament types & description

PLA - consumer products, biodegradable

ABS - functional mechanically stressed parts, toxic fumes

PETG - used a lot in food industry, less rigid than PLA or ABS

Flexible - Elastic parts, wearables, can be difficult to print

Additional details on the properties, as well as pros and cons of each filament, can be found on the Prusa website.

https://help.prusa3d.com/en/category/material-guide_220

Slide 25

1.5 Popular 3D printing types

Fused Deposition Modelling (FDM) - plastic filament is extruded layer by layer onto a build platform

Stereolithography (SLA) - UV light is applied which hardens liquid resin layer by layer

Selective Laser Sintering (SLS) - melts powders (nylon or a polyamide) into solid plastic (and other materials like metals)



2 – 3D Printing and Sustainability

Slide 27

2.1 3D Printing and Sustainability

Additive vs Subtractive manufacturing

The carbon footprint of additive manufacturing (AM) compared to conventional manufacturing methods can vary depending on the specific processes, materials, and applications involved. In some cases, additive manufacturing can have a higher carbon footprint per kilo due to factors such as energy-intensive processes, material waste, or post-processing requirements. However, additive manufacturing also has the potential to reduce the overall carbon footprint in certain situations, offering benefits such as:

1. **Material efficiency:** AM processes often use only the material needed to create the object, minimising waste and reducing the amount of raw material required. In contrast, conventional manufacturing methods like milling or cutting can produce significant material waste.
2. **Lightweight designs:** Additive manufacturing enables the creation of complex, lightweight structures that can reduce material usage and improve energy efficiency, particularly in industries such as aerospace and automotive.
3. **Reduced transportation emissions:** AM allows for localised production, reducing the need to transport goods over long distances, which can contribute to a lower carbon footprint.
4. **Lower production energy consumption:** For some applications, especially low-volume production and prototyping, AM may use less energy than traditional manufacturing methods, such as injection moulding or casting.
5. **Use of sustainable materials:** Some additive manufacturing processes can utilise eco-friendly materials, such as biodegradable plastics or recycled materials, potentially reducing the environmental impact.

Slide 28

The Circular Economy

The circular economy is a sustainable model that minimises waste, reduces resource consumption, and maximises product value throughout their life cycles. It contrasts the traditional linear "take-make-waste" economy. The circular economy focuses on three principles:

1. Designing out waste and pollution
2. Keeping products and materials in use through durability, repair, and reuse
3. Regenerating natural systems using renewable resources and regenerative practices.

This model promotes a more sustainable and efficient economic system, benefiting both the environment and society by reducing our dependence on finite resources and minimising negative impacts of waste and pollution.

There are many industries benefiting from 3D printing technology, but let's look at one industry that most people will have familiarity with: the construction industry.

Slide 29

Home Building

3D printing offers several advantages in the field of home building, revolutionising traditional building methods and presenting innovative solutions for housing challenges.

https://www.youtube.com/watch?v=XHSYEH133HA&list=LL&index=4&t=212s&ab_channel=TheB1M

Play up to 2.13 and any additional relevant parts

Some key benefits of 3D printing in home building include:

1. **Speed and Efficiency:** 3D printing technology enables rapid construction of homes, as large-scale printers can build walls and structural elements layer by layer in a fraction of the time compared to conventional methods. This results in reduced construction time and labour costs.

2. Customisation: 3D printing allows for greater design flexibility and customisation, as homes can be easily tailored to meet individual preferences, site-specific requirements, or local architectural styles. Complex designs and shapes can be achieved that would otherwise be difficult or expensive to construct using traditional methods.
3. Material Optimisation: 3D printing uses additive manufacturing, which means material is only deposited where needed, leading to less waste and more efficient use of resources. This contributes to a more sustainable construction process and reduces the overall cost of building materials.
4. Affordable Housing Solutions: As 3D printing can significantly reduce construction time, labour, and material costs, it offers the potential to provide affordable housing solutions for low-income communities and areas with housing shortages.
5. Disaster Relief and Remote Locations: 3D printing can be used to quickly construct temporary or permanent homes in disaster-stricken areas or remote locations where conventional building methods may not be feasible or cost-effective.
6. Eco-friendly Materials: Some 3D printing technologies allow for the use of environmentally friendly materials, such as recycled plastics or locally sourced natural materials like clay, reducing the environmental impact of construction.
7. Energy Efficiency: 3D printed homes can be designed with improved insulation and optimized passive solar design, reducing energy consumption and promoting energy efficiency.
8. Integration of Services: 3D printing technology has the potential to integrate services like plumbing, electrical wiring, and heating systems directly into the walls, floors, and ceilings, streamlining the construction process and reducing the need for additional labour.

While 3D printing is still an emerging technology in the construction industry, it holds great promise for transforming the industry by offering innovative solutions, cost savings, and sustainable practices, ultimately making housing more accessible and affordable for people worldwide.

Slide 30

Furniture

- Printing furniture on demand reducing inventory, space and waste
- Printing close to customer cuts down on transportation, uses source materials closer to the site, eliminating supply chain and logistical issues and delays, localising manufacturing

While 3D printing offers several benefits that can support the circular economy, it is important to consider the entire life cycle of a product, including the energy and materials used during production, transportation, and end-of-life disposal or recycling, to fully understand and optimize its environmental impact.

Slide 31

Product Life Cycle

The life cycle of a product consists of several stages, each with its own environmental and social impacts. The main points involved in a product's life cycle include:

1. **Raw material extraction:** The process of obtaining raw materials from natural resources, such as mining metals, drilling for oil, or harvesting timber.
2. **Material processing:** Transforming raw materials into usable forms, such as refining metals, processing petrochemicals, or pulping wood.
3. **Manufacturing and production:** Combining processed materials to create the final product, involving assembly, fabrication, and other manufacturing processes.
4. **Packaging and distribution:** Preparing the product for transportation and sale, including packaging materials, transportation logistics, and warehousing.
5. **Retail and consumption:** Selling the product to the end consumer, which involves marketing, retail operations, and the actual use of the product by the consumer.
6. **Maintenance and repair:** Activities aimed at extending the product's lifespan, such as providing spare parts, repair services, or maintenance support.
7. **End-of-life management:** The disposal or recycling of the product once it has reached the end of its useful life, including waste collection, sorting, recycling, and landfilling or incineration.
8. **Product recycling and reuse:** Repurposing or recycling the materials or components of the product to create new products, reducing waste and conserving resources.

Each stage of a product's life cycle has its own environmental, social, and economic impacts, which need to be considered when assessing the overall sustainability of a product. Life cycle assessment (LCA) is a

methodology used to evaluate these impacts and identify opportunities for improvement throughout the product's life cycle.

Slide 32

Recycling 3D printer filament

Plastic packaging waste for use as raw materials for 3D printing is becoming more available. Waste products like water bottles and food containers can be used to make filament as well as other finished products.

https://www.youtube.com/watch?v=76AFNIxYjUE&t=133s&ab_channel=OneArmy

PLA is made from renewable sources such as corn-starch and sugarcane and although it's biodegradable, it requires specific conditions which are not really viable for consumers. Community organisations like Precious Plastics offer options on recycling. Other 3D printer materials (ABS, resins, metal powders, etc.) are harder to recycle, with some requiring special disposal methods. Research centres like I-Form are investigating how to recycle metal powders, for example, and ensure it returns consistent and high-quality results.

Recycled filament is becoming more available and offers an increasingly wider variety of colours. This gives users an opportunity to lower their environmental impact while conserving resources and fostering a circular economy within the 3D printing industry.

Slide 33

Summary - How 3D printing supports a more sustainable world

1. Design More Efficiently

Redesign your prototype to make it more efficient and use less material. Less waste by customising products for the customer. Products once requiring multiple parts can now be printed in one, reducing material, time, cost, and labour.

2. Use Less Raw Material & More sustainable material

AM rather than SM uses less material. Allows for less waste, lighter products, using less fuel (Elimination of drilling, cutting, milling), with less carbon emissions.

Many 3D printers are able to use other materials e.g. metal, ceramic, wood dust, and corn-based biodegradable plastic (PLA) which is commonly used for consumer 3D printers

3. Repair & Remanufacture

3D printers can quickly and cheaply make replacements parts for equipment, allowing older vehicles / equipment to remain functional that may otherwise be obsolete. (EU Right to Repair movement).

Remanufacturing is an industrial process by which a previously sold, worn, or non-functional product can be rebuilt and recovered. Through the disassembly, cleaning, repair and replacement of worn out and obsolete components, the piece can be returned to a 'like-new' or 'better-than-new' condition and will be just as reliable as the original product.

4. Localise Making

Opportunity for consumers to prototype rapidly. Reducing transportation and supply chain logistics and storage costs

5. Eliminate Inventory

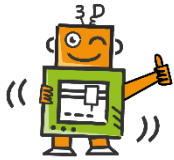
Print on demand, small batches

6. Streamline Manufacturing

Ideation to production is generally much faster. No tooling or moulds necessary, eliminating a lot of labour, equipment and energy costs.

7. Smaller factories

A 3D printer can replace several pieces of manufacturing equipment. Less equipment means smaller space and less carbon emissions. Improvement of filtration process to eliminate toxic fumes. Smaller factories can be closer to town centres.



3 – An Introduction to 3D Design Software

Slide 35

3.1 What is 3D design software

3D design software, also known as computer-aided design (CAD) software, is a type of digital tool used to create, modify, analyse, and visualise three-dimensional objects and structures.

3D design software enables users to create and manipulate virtual models in a 3D space, defining the object's geometry, materials, textures, and colours. Users can easily modify and refine their designs by changing dimensions, adding or removing elements, and altering shapes. Once the design is complete, it can be exported in various file formats for 3D printing.



Visual: Examples of digital CAD designs



Physical: Samples of real-world prints

An introduction to TinkerCad



TinkerCad 1: Basics, Sizing, Rotating

<https://youtu.be/MWxzJ3FzyS8>



TinkerCad 2: Group, Align, Mirror, Rule

<https://youtu.be/uz4MKCLJXBo>

Slide 36

3.2 First 3D printed design



Activity: Design & Print a Basic Shape

Working in pairs, design a simple child's toy which teaches an understanding of basic shapes

Design parameters:

100mm x 100mm x 100mm max

Must be printed under 120 mins



Demo: Design export & print walkthrough

Activity reflection & feedback

Slide 37

Workflow from ideation, to design to print

Recap on design & print process

Slide 38

3.3 A closer look at 3D design

What are supports and why are they needed

As each layer is printed it needs to be supported by the layer underneath. If a design incorporates an overhang or bridge a support may need to be printed so that the print object remains intact.

Understanding angles, overhang, etc., how to avoid supports

The 45-degree rule: If the overhang tilts at an angle of 45 degrees or less you may not need support. Your printer will determine exactly what angle range will work best.

3D Printing Tips

https://www.youtube.com/watch?v=QdvSzXByi_g&list=LL&index=2&ab_channel=TeachingTech

Play from

3.02 - TIP #1: Design parts with a flat base

4.48 - TIP #2: Avoid steep overhangs

Slide 39

3.4 Further Work with TinkerCad



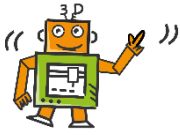
TinkerCad 3: Cruise, Snap Grid, Patterns, Lock

<https://youtu.be/NctGSWVNDHc>



TinkerCad 4: Snap Parameters, Shape Generator

https://youtu.be/gNW12j_KCX0



4 – Design Thinking

Slide 41

4.1 An introduction to Design Thinking

Contrary to the name, design thinking is not just used by designers. It is a process used by many innovators in many fields, including art, music, science, engineering, software development, education, manufacturing and retail.

Design thinking is a human-centred technique used to solve problems using an iterative process. At the heart of design thinking is the importance of understanding of the user - the person you are designing for. Developing empathy by asking questions, challenging assumptions, and testing designs with the user in order to measure success are all key elements in the design thinking process.

Slide 42

The standard design thinking cycle format has been adapted to a primary school aged children; Think, Draw, Build, Test.

Slide 43

Description of each stage of the design thinking cycle

[Reference this standard format when explaining concept to the group]

1. Empathise: Understanding the user, the person you are designing for. Gathering information, interviewing the user group, understanding the problems they face
2. Define: Take everything you have learned in step one and concluding the user's problem that you want to solve

3. Ideate: Take everything you have learned in step 1 and 2 and come up with ideas about to solve the problem highlighted in step 2
4. Prototype: Quickly making a version of the solution to the defined problem that can be tested with users
5. Test: Taking the prototype and testing it with real people, the user group that you are designing for. You will get feedback from the user and feed this back into the design cycle process until your prototype is more refined.

Slide 44

4.2 Classroom tool mini-challenge



Activity

Using the design thinking process, design a tool that solves a problem that a teacher has in the classroom

Send file to print

Activity reflection & feedback



5 – A Further Look at 3D Design Software

Slide 46

5.1 A closer look at slicer software



Prusa Slicer 1: Download and Install

<https://youtu.be/q4oBUiuPwtk>



Demo: Walkthrough Prusa Slicer set-up with group

The slicer software acts as the middleman between the 3D design software and the 3D printer. Everything about your print will be decided in the slicer; print size, filament, wall thickness, layer height, infill, supports, etc. Prusa Slicer is one of the most popular free slicer software options available today.

When installing your slicer software make sure to choose the correct printer model you are working with - the in-built profile settings for each printer are usually very accurate and produce good results, often with little need for tweaking.



Prusa Slicer 2: General Overview

https://youtu.be/GU4_SLnnTMM



Visual / Physical: Examples of different layer height / infill settings / etc.



Activity: Explore different printer profiles

Slide 47

5.2 Tips for successful 3D designing and printing

https://www.youtube.com/watch?v=QdvSzXByi_g&list=LL&index=2&ab_channel=TeachingTech

6.54 - TIP #3: Layer line direction dictates strength

7.55 - TIP #4: Pay close attention to size

8.51 - TIP #5: Be patient and iterate

Slide 48

5.3 Review TinkerCad Resources



Activity

Projects

<https://www.tinkercad.com/projects>

Lesson plans

<https://www.tinkercad.com/lessonplans>

Review TinkerCad resources and practice your skills!

Discuss possible challenges around introducing 3D printing activities to your classroom

Slide 49

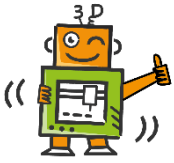
5.4 TinkerCad in the Classroom

TinkerCad 6: Classrooms

<https://youtu.be/KtJ5Was7cGA>



Activity: Time to practice using TinkerCad classroom activities



6 – 3D Printer Maintenance

Slide 51

6.1 3D printer maintenance

Carrying out regular maintenance is essential in keeping your machine reliable, working well as well as reducing time spent on troubleshooting. It is especially required from a health and safety perspective.

Always check the maintenance guide for your particular printer brand for details on maintenance.

https://www.youtube.com/watch?v=4kJThmWDcCo&ab_channel=MatterHackers



Demo: On the physical printer

General cleaning

Wipe down each part of the printer with a microfibre cloth to clean dust and print debris from each component. Use compressed air for hard-to-reach components.

Cleaning bed & nozzle

A clean bed helps with print adhesion. Wipe down your printer bed using the recommended cleaning product for your bed.

Lubrication

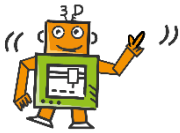
Check your axis rods, if dry, apply a small amount of grease.

Diagnostics, calibration, etc.



Demo: Walk through calibration process

For [more details](#) on 3D printer parts and maintenance



7 – Conclusion

Slide 53

7.1 Industry Talk

A representative from the host organisation (EIT-M Partner), or a relevant industry partner, will deliver a presentation to the teachers.

The presenter can tailor the presentation according to their experience and the work of their organisation, but should cover one or more of the following areas:

- An overview of the manufacturing industry
- The future of the manufacturing industry
- Career opportunities in the manufacturing industry
- Their career path as a STEM professional

Slide 54

7.2 Classroom challenge

Host organisation (EIT-M Partner) to introduce details about the challenge competition including photo examples of previous participants



Activity: Brainstorm ideas around the challenge



Activity: Working in pairs, design a solution to the specific challenge

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7.3 Next Steps

Course reflection + feedback

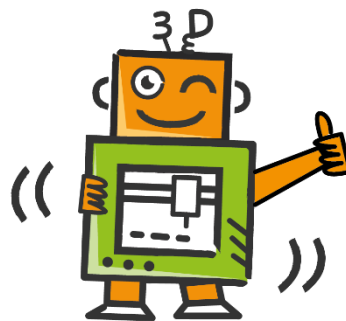
Reminder to please complete the surveys!

Content, additional skills/support needed, etc

Dates for challenge competition

Online 'refresher' training – optional

END OF COURSE



Additional Resources

Autodesk TinkerCad

TinkerCad [Essentials](#)

Additional TinkerCad resources
<https://www.tinkercad.com/teach>

TinkerCad [Keyboard Shortcuts](#)

3D Printing

Prusa Slicer [Essentials](#)

Video of 3D printing [workflow](#)

[Thomas Sanladerer](#) on YouTube - lots of helpful videos especially his series of 10 videos called 3D Printing Basics

[Maker's Muse](#) on YouTube - lots of helpful videos on 3D printing

[Teaching Tech](#) on YouTube - lots of helpful videos on 3D printing

[Prusa](#) on YouTube - lots of helpful videos about Prusa printers

[Printer maintenance](#)

[Types of 3D printing](#)

[3D printing materials](#)

Progressing to Fusion 360

[Desktop Makes](#) has a great free course for beginners

Downloads

[Prusa Slicer](#)

[Autodesk Fusion 360](#)

Printing via Wi-Fi & Raspberry Pi

Octopi is the software used on the Raspberry Pi. Set-up guide [here](#)

[Raspberry Pi kit](#)

[Power supply](#)

(you will also need a webcam)

Inspiration

Ted Talk: [How 3D printing is enabling the 4th industrial revolution](#)

Sustainable 3D Printing - [Forust: Building a greener future through 3D printed wood](#)

[3D printed homes](#)

