3D Printing
In the Primary Curriculum
www.createeducation.com
3D printing technology is now being used widely throughout a range of industries including engineering, medicine, product design and the arts. Until recently 3D printers were large industrial machines costing tens of thousands and totally out of reach of educational institutions. Recent developments in the technology now means that high quality, professional grade desktop 3D printers such as the Ultimaker range are now available at a price that allows schools to invest in the technology.

With the expansion of the applications of 3D printing technology throughout industry, it is important that students start to develop the design and technical skills required to harness this technology. This will provide a future workforce with the skills required to meet the demands of this expanding industry.

Developing these skills can begin in the Primary school, although the cost of a 3D printer still represents a significant investment for Primary Schools. Schools can maximise on their investment by embedding 3D printing across the school at all levels and in multiple subject areas, using it as a tool to increase pupil engagement and attainment.

This guide has been developed by The Create Education Project to provide Primary Schools with an overview of how 3D printing can be utilised within a Primary school setting across all ages, levels and curriculum areas.
Getting started with any new technology can be an absolute minefield – or dare we say it a total nightmare! 3D printing is no different, if you are new to the technology there may feel like a lot to learn and get your head around before you feel confident introducing it to the students.

With this in mind we have put together a separate getting started guide for schools, which you can download at: http://www.createeducation.com/resource/getting-started-guide/

The guide includes:

- Let’s get started
- All about CURA
- Setting up your Ultimaker and your very first print
- Understanding the 3D printing process and introducing 3D printing to your students
- Moving on – developing your first project
- Which 3D CAD software?
- Integrating 3D printing in the curriculum
- Further support and professional development
- Sharing and showcasing your work with the Create Education community

This professional development resource allows you to learn some of the basics before introducing 3D printing in the classroom and give you some ideas once you are up and running for developing projects and maximising the opportunities for 3D printing in school.
3D printing can be accessed by all pupils from Reception up to Yr6 and beyond. However the scope of projects and activities need planning to allow pupils to develop their skills and progress from simple 2D to full 3D modelling. The following outline provides a structured skills progression with some example projects and activities for all ages and skills levels.

**Progression from 2D drawings to 3D prints**

Initially and especially with younger children, producing a 3D model can be challenging, even with the simplest 3D modelling software. However the software “Cura” that prepares files for 3D printing contains a very simple tool that extrudes a 3D model from a 2D image. Utilising this tool allows even very young children to produce 3D models from their own designs.

You can learn how this feature works in Cura with this tutorial created by our ambassador Steve Cox.

www.createeducation.com/resource/2d-to-3d
Step 1: Create a 3D model from a 2D solid shape picture (suitable for Reception and upwards)

In this activity pupils create a black and white picture, using a variety of 2D shapes in different sizes pre-prepared from black paper or card. Pupils create their picture by selecting, arranging and gluing a variety of shapes onto some white background paper.

The picture can then be photographed and imported into Cura the image can be resized and the file can be saved for printing.

Note: for the 3D shape to print correctly, all of the shapes that make up the picture must touch each other or overlap so that a single solid black shape is produced. If a small white circle (eg the holes from a hole puncher) was positioned and glued onto the black shape somewhere near the edge, it would produce a hole to allow the printed item to be made into a keyring.

Curriculum Links: This activity links well with work that pupils may be doing with 2D shapes as it allows them to name and describe the shapes they have used. It can also link with one of their curriculum topics for example pupils can make pictures of dinosaurs, animals, transport vehicles, space rockets etc. Pupils can talk about their picture and their finished item, displaying their knowledge of the topic.

For older pupils this same technique could be used however pupils could fold and cut paper snowflakes, photograph and print them to produce christmas tree decorations.
Step 2: Create a 3D object from a 2D hand drawing (suitable for Year 1 and upwards)

This activity allows pupils to draw their own simplified design for printing by drawing in a single colour (black marker pen works best) onto a white background. This technique allows pupils to hand draw quite complex shapes and patterns which would be more difficult to produce in 3D modelling software.

The picture can then be photographed and imported into Cura the image can be resized and the file can be saved for printing.

This technique can be used for a number of different 3D printing projects, for example pupils could design and make drinks coasters, biscuit cutters or personalised keyrings. Designs could be constrained to specific dimensions or outline shapes by providing a template outline that pupils draw their designs inside.

Curriculum Links: This makes a lovely art project as it allows pupils to explore shape and pattern to produce designs that are realised in a different material. Designs could be linked to other subject topics eg plants or seasonal changes in science - for example in groups of 4 pupils produce designs to depict each season to make a set of 4 drinks coasters. In design and technology pupils could design and make customised biscuits, first by designing and printing biscuit cutters, then using them to make biscuits.
Step 3: Create a 3D object from a 2D CAD drawing (suitable for Year 2 and upwards)

In this activity pupils progress from hand drawing to using a computer drawing program to create a design in 3 colours.

Pupils use a paint/drawing program to design a simplified 2D image using 3 colours (black, white and grey). Black will be the thickest part of 3D shape, grey will be the thinnest part of the 3D shape and white will be the areas not printed eg holes in the design. Any paint/drawing program that pupils have access to can be used for this activity, files can be saved as a .jpeg and imported directly into Cura where the image can be resized and the file can be saved for printing.

This activity lends itself nicely to personalised projects such as bookmarks or door name plates as it allows text to be added to the design easily. Designs could be constrained to specific dimensions or outline shapes by providing a template outline file that pupils open in the specified software then draw their designs inside.

Curriculum Links: This makes a good computing project as it allows pupils to utilise a computer drawing program using tools such as lines, brushes, text, shapes and fill. Designs could be linked to topic work eg a Braille topic in history could link to designing a Braille name pendant or in Science pupils could design a minibeast bookmark.
Creating a 3D model using Purple Mash

Many primary schools in the UK have subscriptions to the online Purple Mash suit of tools by 2Simple. Due to this, it is worth highlighting how the 2Design & Make Tool in Purple Mash can be used to allow even very young students to create their own 3D model. It serves as a nice introductory activity for pupils prior to getting started with 3D modelling software.

You can download a step-by-step guide to using 2Design & Make and how to 3D print your model here: www.createeducation.com/resource/2design-make
**3D CAD Skills Progression**

**3D Modelling Software**

Once pupils have experienced 3D printing from a 2D image, they are ready to progress to 3D modelling using 3D CAD programs. There are a number of different 3D CAD programs available, however many of these are professional tools with interfaces that are very complex and difficult for Primary students to find their way round. There are however some very good CAD programs with simpler interfaces that are more suitable for Primary pupils to develop 3D CAD skills.

This guide focuses on using TinkerCAD to demonstrate how pupils can progress. This particular 3D CAD tool has been selected to be featured in this guide for a number of reasons:

1. It is FREE to use for all schools.
2. It is a powerful 3D design program that has a simple interface suitable for younger pupils and beginners.
3. It is browser based so students can access it anywhere, it doesn’t need installing on the school network and it provides free cloud storage of your designs.
4. You can set up a main teacher account and invite students to join, student accounts will then be linked to your account.
5. There are lots of free step-by-step tutorials and projects available through TinkerCAD and Project Ignite that pupils can work through to develop their CAD skills and produce their own 3D designs.
   [https://www.tinkercad.com/learn/](https://www.tinkercad.com/learn/)
   [https://projectignite.autodesk.com/classrooms/](https://projectignite.autodesk.com/classrooms/)
6. As Pupils progress through to secondary school they can easily progress to more Powerful 3D CAD programs in the Autodesk suite that are commonly used in Secondary schools - 123Design and 3D Fusion as the interfaces have common elements.

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**Please note:** There are other 3D modelling programs and apps available which are free to use and suitable for younger pupils and/or beginners and new ones are being developed all the time. You may wish to explore or trial different software with students before choosing which one to adopt in your school. Visit the 3D CAD software pages at CREATE Education to find out more about these and more software options and access help and tutorials.

[http://www.createeducation.com/professional-development/3d-software](http://www.createeducation.com/professional-development/3d-software)
Step 1: Creating a 3D model from a template of parts
(suitable for Year 3 & upwards)

One way to get pupils started using TinkerCAD is to run a project that allows them to design their own unique item using a template of pre-drawn parts. This introduces them to the TinkerCAD software and allows them to develop skills in dragging and dropping shapes and then connecting them together to create a single model for printing.

To run this project, you need to start with a template file which contains all the unique pre-drawn parts for the project. Depending on the project you can create your own template file and draw the parts you need or use of the curriculum specific resources available on the Create Education website. Pupils open up the template file and save a unique copy in their name, then they can drag and drop the pre-drawn parts to build their design.

Curriculum Links: Two example curriculum projects that utilise a TinkerCAD template of parts are available on the Create Education website are detailed below. However there are many other creative projects that could be developed that use a template of parts these could link to design and technology and other curriculum topics for example personalised items using templates containing letters, design a dinosaur, space rocket etc.

Design and make a “Print-sect”. This activity links well to a mini-beasts topic in Science or for older students Print-sect designs could be used for a practical insect classification activity: www.createeducation.com/resource/print-sect

Design and make an “Egyptian Cartouche”. This activity links well to the Ancient Egypt topic in History. www.createeducation.com/resource/cartouche
Step 2: Create a 3D model from a tutorial (suitable for Year 3 & upwards)

One of the best ways for pupils to develop their TinkerCAD design skills is to follow a step-by-step tutorial to create their own model. The tutorials allow them to familiarise themselves with the TinkerCAD interface, build models from a series of shapes, connect shapes and add holes.

**Build a boat tutorial** - this is a great introductory tutorial covering all the key elements of the TinkerCAD software in nice easy to follow steps.

[http://www.3dvinci.net/PDFs/GettingStartedInTinkercad.pdf](http://www.3dvinci.net/PDFs/GettingStartedInTinkercad.pdf)

Tutorials on TinkerCAD: [https://www.tinkercad.com/learn/](https://www.tinkercad.com/learn/)

Tutorials on Project Ignite: [https://goo.gl/QSz4eP](https://goo.gl/QSz4eP)

[https://projectignite.autodesk.com/app/browse/?tags=3d%20design](https://projectignite.autodesk.com/app/browse/?tags=3d%20design)

**Curriculum Links:** As TinkerCAD primarily uses 3D shapes as building blocks and the interface allows students to view the shapes from different angles and manipulate them, these tutorials allow students to develop their understanding of the properties of 3D shapes in a visual and practical way. It also develops skills in design, shape and form linking well with the art and design technology curriculum. Many of the project tutorials on TinkerCAD and Project Ignite also link well to other curriculum topics, this is dependent upon which tutorials the students follow.
Step 3: Design your own 3D model (suitable for Year 4 & upwards)

Once pupils have experience in using the TinkerCAD interface and mastered the basic skills in using TinkerCAD they will be ready to consolidate and further develop their 3D CAD skills in this software by undertaking a project that allows them to design their own 3D model.

Curriculum Links: This opens up a plethora of project opportunities for design technology and across the curriculum. The curriculum subject ideas section of this guide provides some starting points for developing your own 3D printing projects to support and enhance different subject areas. A nice initial design technology project would be the “Design a Space Rocket Project” shared on Create Education by Marius Bridge Primary School. Once pupils have designed their rocket, they can use TinkerCAD to create 3D models of their designs and then print them. [www.createeducation.com/resource/marus-bridge](http://www.createeducation.com/resource/marus-bridge)
There are many opportunities for embedding 3D printing across the curriculum to enhance delivery of different subjects and engage pupils in different ways.

All the resources and blog posts on the CREATE Education website have been tagged to the appropriate subject areas. You can filter the resources and posts by subject to find ideas for how you can use it in different subject areas. Remember to revisit the website regularly as new resources, ideas and inspiration are being added all the time.

Cross-curricular

Many of the 3D printing project ideas in this guide are by their very nature cross-curricular projects, covering elements of the National Curriculum POS in multiple subject areas.

In addition to these project ideas “Object of the Week” is a fully resourced open-ended cross-curricular classroom resource developed by the Create Education Project to provide regular opportunities throughout the year for students to explore the world of 3D printing.

A series of stand-alone classroom activities have been developed to support the project. The activities allow students to:

- use their imagination
- develop speaking and listening skills
- develop descriptive and creative writing skills
- be creative
- develop research, evaluation and presentation skills
- explore future careers
- learn how real life problems are solved
- develop their own solutions

Visit the “Object of the Week” section of the CREATE website for more information, to download the teaching resources and to access a new feature object each week.

http://www.createeducation.com/object-of-the-week/
Design Technology

3D printing technology lends itself most naturally to Design Technology and utilising a 3D printer can significantly enhance pupils experiences in this subject, it allows pupils to design and make a range of products and realise their ideas. 3D printing projects can cater for all elements of the design process and allow for rapid prototyping and testing of ideas, so that pupils can experiment and improve their designs.

Any of the ideas suggested in the skills progression section would make good design technology projects for example keyrings, drinks coasters, bookmarks, biscuit cutters, door name plates, christmas tree decorations etc.

The 3D printer could be also be used to make custom parts or kits for structures, vehicles or moving toys projects, take a look at the following examples to see how:

www.createeducation.com/resource/rocket-car

www.createeducation.com/resource/anfield-truss
3D Printing across the curriculum

Other project ideas include:

- Jewellery - bracelets, pendants, charms or brooches/badges
- Gadgets to solve design problems - containers, stationary/pencil pots, stands (eg for a mobile phone), hooks and kitchen gadgets
- Customised objects - cases, stands, photo frames

You can also print resources and manipulatives to use as teaching and learning aids to help pupils understand mechanical concepts such as cams, gear systems, pulley systems, levers and linkages.

Mathematics

There are many opportunities throughout the Primary mathematics curriculum to embed 3D printing and the very process of pupils developing 3D models allows for the practical application and development of many mathematical skills. It also allows pupils to connect and engage with the mathematical concepts in a meaningful way.

In geometry, how better can pupils learn about 2D and 3D shapes than constructing their own polygons in a 3D CAD program and printing them. The printed 3D shapes and polygons also serve as physical classroom resources to use with pupils.

In using 3D CAD and slicing software to draw and manipulate models, pupils also get the opportunity to utilise and develop their knowledge of axis (x, y and z), distance and measurements, angles, trigonometry, scale, transformations, proportion and symmetry.

The 3D printer can also be utilised to print very low cost mathematical manipulatives. Class sets of these resources can be printed over time to allow greater access to the manipulatives for all pupils. Pupils can engage and interact with these physical resources to help develop their understanding of mathematical concepts.

You can read more about the benefits of manipulatives in this article from the NRICH project https://nrich.maths.org/10461

Visit our classroom prints page to access some example mathematical manipulatives 3D print files https://www.createeducation.com/resource/classroom-prints/
3D Printing in the Primary Curriculum

English

3D printing captures pupils’ imaginations and can provide many opportunities for pupils to develop oral and written communication skills by embedding literacy activities into 3D printing projects. Activities ideas include:

- Explaining the 3D printing process.
- Writing instructions to guide users through the 3D printing process.
- Developing advertising literature to accompany products pupils have designed.
- Designing product packaging.

The “Object of the Week” resources have specific literacy activities including:

- Describe It
- Describe and Draw It
- Imagine It
- Explain It
- Present It
- Advertise It

Further information and resources can be accessed here:
http://www.createeducation.com/object-of-the-week/

Students can also use the technology to design and print models to inspire creative writing including character and setting development. Watch out for our fully resourced Shape Heroes Creative Writing project available to download in Spring 2017.
Science

There are many opportunities to embed 3D printing within the Science curriculum. In particular the technology provides real world context for pupils in the properties and uses of everyday materials. Pupils can study the changing states of plastic materials that occur in the 3D printing process, observing how changes occur to the plastic materials - starting as a solid reel of filament, being melted by the heated nozzle to a liquid state allowing for extrusion into a new shape and solidifying into the new shape as it cools again.

Students could also develop practical investigations using 3D printed items for example:

Test the properties of different filament materials and conduct experiments to see which material is the strongest (eg comparing PLA with ABS) or testing/describing the effects of different forces on the printed samples.

For friction investigations simple ramps and mats with different surface textures can be designed and printed to roll toy cars on, the cars themselves could also be designed and printed to investigate the effects of different vehicle sizes and weights.

To investigate air resistance, after studying how sycamore seeds fall through the air, pupils could design and print model “helicopters” with different blade designs, lengths and angles then predict and test how each design affects the time it takes to fall to the ground.

Another main benefit of 3D printing for science is to print scientific models to use as classroom resources. This is a very low cost way of resourcing for science allowing multiple copies of models to be produced over time so that pupils have more access to the models. The designs of scientific models can be downloaded free of charge from many of the online 3D file repositories.

Visit our classroom prints page to access some example science resource 3D print files [https://www.createeducation.com/resource/classroom-prints/](https://www.createeducation.com/resource/classroom-prints/)

Examples of useful models that could be printed include:

- Teeth models of humans and other animals to allow students to study and compare them.
- Bones and internal body parts to enable pupils to learn about the parts of the body.
- Planets and the solar system.
- Different levers, gears and pulley systems to investigate forces and how mechanisms allow a smaller force to have a greater effect.
Computing

3D printing offers a multitude of opportunities for enhancing the Primary Computing Curriculum. In particular it addresses the following aims of the Primary computing curriculum by enabling pupils to develop 3D CAD and knowledge and practical experience of the 3D printing process:

**To ensure that all pupils:**
can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems
are responsible, competent, confident and creative users of information and communication technology.

In addition to developing 3D CAD skills, 3D printing in itself can be used to cover elements of the computing curriculum such as algorithms. Pupils can document the 3D printing process as an algorithm either as a list of step by step instructions or a flowchart. Older pupils can draw simple 3D shapes, export them as .stl files and open them in Notepad to examine the .stl code, what are the common features of the code and what is the difference between the code for different shapes.

An “Algorithm Art” project enables pupils to 3D print the output of their coding. Using Logo or Scratch and the pen feature, pupils can draw images, use a screen capture tool to save the images, then 3D print them using the 2D to 3D print process. Printed designs make good coasters or smaller prints of the designs can be used to make keyrings. This is a great project for implementing sequence, repetition and functions in Logo or custom blocks in Scratch.

3D printing can also be used a tool to enable physical computing. It allows pupils to design and print physical parts to accompany programmable devices for example designing ramps and maze parts for spherio’s or designing casings and robotic/mechanical parts for use with Codebugs or Arduinos. Take a look at this idea from one of our Create Hub Leaders Rob Jones:
One interesting project that combines technology is this way is a 3D printed rain gauge, which is connected to the computer with a Makey Makey and programmed in scratch: https://www.youmagine.com/designs/3dkanjers-rain-gauge-regenmeter

You can get more ideas from our Create Ambassador Carl Simmons, who kindly shared his 3D printing in Computing workshop from the regional CAS Manchester conference: www.createeducation.com/resource/computing-workshop

Look out for our “Guide to 3D printing in the Computing Curriculum” to be published in Spring 2017 for more project details and resource links to these and other computing projects: https://www.createeducation.com/resource/computing-guide/

**Art & Design**

There are many opportunities to embed 3D printing into Art and Design projects to produce three dimensional pieces of art, fashion accessories or artistic items for the home.

3D printing can be used along with appropriate software for pupils to design and make their own sculptures. Gravity Sketch is a great app for Year 2 and upwards, for older pupils (Year 5 and upwards) you may want to try out Sculptris. Gravity Sketch and Sculptris are both free to download and you can find out more and download them here:

Sculptris: http://pixologic.com/sculptris/
Gravity Sketch: https://www.gravitysketch.com/

Pupils can also design three dimensional images using the 2D to 3D process either from pencil drawings or in a 2D drawing program incorporating different percentages of grayscale.
History

3D printing can be used as a medium to bring history to life for pupils. Students can design and make their own historical objects related to the topic they are studying for example stone age huts, viking shields or egyptian cartouches.

Many museums from around the world are now scanning their collections of artifacts and making the 3D files available to download. In addition to this many historical models and buildings are also available from 3D file repositories to download and print. This allows you to 3D print small scale models of real artifacts to bring history into the classroom. The British Museum and other cultural organisations have published 3D models which are available to download on Sketchfab, you can access the British Museum collection here:

https://sketchfab.com/britishmuseum

Take a look at this example lesson activity using the 3D model of an Egyptian Ushabti from The National Museum in Cardiff www.createeducation.com/resource/ushabti
Geography

3D printing can be utilised to enhance subject resources in Geography. Miniature models can be made of geographical features, landforms and even built up areas. This will allow pupils to visualise these features and enhance their understanding of the subject.

You can export any area directly from Google Earth into an .stl file using Terrain2STL, a simple, free online tool [http://jthatch.com/Terrain2STL/](http://jthatch.com/Terrain2STL/)

Pupils could also design and print their own weather station apparatus...for example: weather vanes, wind turbines and rainwater collectors.

Business Enterprise

3D printing lends itself perfectly to running enterprise projects. Students can work in teams with different management roles to develop ideas and designs for objects to print and sell to the school community.

Ideas for low cost, quick-to-print items include: keyrings, bookmarks, trolley tokens and christmas tree decorations. However, by giving students a brief that includes maximum size or cost constraints, students will come up unique ideas of their own.

As Cura gives you an indication of how much filament is required for each print, students can calculate the cost to produce each print and determine selling price and calculate their profit at the end of each project.

Students can develop advertising campaigns and work in competition with each other to make the most profit.

Read about how Kennoway Primary School ran an enterprise activity using their Ultimaker on our blog. [www.createeducation.com/blog/kennoway-primary-school](http://www.createeducation.com/blog/kennoway-primary-school)
We hope that in producing this guide, it will provide you with a wealth of ideas of how to embed 3D printing across the Primary curriculum. Some of the ideas in this guide have complementary resources available to download now - free of charge - from the Create Education Project website. Many of the other ideas in this guide (and more) will be developed into fully resourced projects in the coming year, so don’t forget to keep visiting the website to keep up to date with project developments and new resources.

www.createeducation.com/resources

Introducing any new technology is always a challenge, but the CREATE Education project is here to support you in every step of your journey. Our website provides information and links to access technical support and further professional development.

Technical Support:
http://www.createeducation.com/help-support/technical-support/

Documentation:
http://www.createeducation.com/help-support/documentation/

Training Workshops:
http://www.createeducation.com/professional-development/face-to-face/

Online Professional Development Resources:
http://www.createeducation.com/professional-development/online/

Community Access:
http://www.createeducation.com/professional-development/community-access/
Share and showcase your work with the CREATE Education Community

The CREATE Education Project is an open-source project dedicated to helping and supporting educators and schools in their 3D printing journey. This is only made possible with the continued support of our 3D printing community. Once you have got started we would love for you to share what you are doing with the CREATE Education Project. We can showcase your school and share your resources so that others can benefit. This also helps to promote your school to the community. There are many ways in which you can do this:

1. Write a blog post about your experiences or a post to share ideas and inspiration.

2. Help us to produce a case study of your work, outlining what you are doing with your Ultimaker and how your students and school community are benefiting.

3. Share your classroom resources - these can be schemes of work, lesson plans, presentations, student worksheets, project booklets etc. Don’t worry if your resources are incomplete or are not professionally presented. We have experts in-house that with your ideas and guidance can refine them and turn them into a professional publishable resource in which your school will be credited.

4. Share examples of your student projects so that others can be inspired by their creativity and technical prowess.

If you have any ideas, stories or resources to share please contact:

Sonya Horton
s.horton@ultimaker.com

And finally
Enjoy your experience with 3D printing and never forget the CREATE Education Project and the Ultimaker technical support team are always available to support you.

Keep in touch and up to date with our latest news, stories and resources through our website and social media channels:

Website: createducation.com
Linked In: linkedin.com/in/create-education-645814114
Twitter: @UltimakerCREATE
Facebook: facebook.com/createducationproject
Instagram: @createducation

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Linked In: linkedin.com/in/create-education-645814114
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