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Oxford Cambridge and RSA

GCSE (9–1)

Delivery Guide

DESIGN AND TECHNOLOGY

J310
For first teaching in 2017

Topic Area 7: Manufacturing processes and techniques – Timbers

Version 1

www.ocr.org.uk/gcsedesignandtechnology

Contents

TOPIC AREA 7: MANUFACTURING PROCESSES AND TECHNIQUES – TIMBERS

Introduction

GCSE (9-1)

DESIGN AND TECHNOLOGY

A guide to approaching the teaching of the content related to Topic Area 7: Manufacturing processes and techniques – Timbers.

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- **Content:** A clear outline of the content covered by the delivery guide;
- **Thinking Conceptually:** Expert guidance on the key concepts involved, common difficulties learners may have, approaches to teaching that can help learners understand these concepts and how this topic links conceptually to other areas of the subject;
- **Thinking Contextually:** A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk

Link to qualification:

http://www.ocr.org.uk/qualifications/gcse-design-and-technology-j310-from-2017/

Sub Topic 1: Making iterative models

Exam content

7.1 How can materials and processes be used to make iterative models?

a. The processes and techniques used to produce early models and/or toiles to support iterative designing.

NEA content

a. Be able to use specialist techniques and processes to shape, fabricate, construct and assemble at least one high quality prototype, including techniques such as wastage, addition, deforming and reforming, as appropriate to the materials and/or system components being used.

b. Be able to use specialist tools and equipment, appropriate to the materials or system components used (including hand tools, machinery, digital design and manufacture), to create models and prototypes.

c. Be able to use appropriate and accurate marking out methods including: measuring and use of reference points, lines and surfaces; use templates, jigs and/or patterns where appropriate; work within tolerances; understand efficient cutting and how to minimise waste.

Thinking conceptually

General approaches:

The process of making models should be a highly fluid stage in the design process, and an area in which learners can demonstrate a creative approach to problem solving. In order to achieve this, learners will need to fully establish what problems and issues their design ideas will be solving. Having explored some potential ideas through a sketching, sketch-modelling and/or possible CAD approach, they will now be focusing on the physical reality of potential design solutions and the issues they present. The subsequent process of solving these issues through iteration in model form will be key to the learners' success in their NEA, and give them a clear understanding of the purpose of iterative modelling ready for the exam.

Prior to commencing any modelling process, learners will have already been exposed to the broad range of modelling materials and their associated processes for cutting and wasting them, adding to and subtracting from them and, wherever possible, they will be in a position to creatively use their properties and characteristics in clever ways. An example would be in the combining of materials into composites for a model that can provide some form of function thanks to multiple materials used together. For example, a polypropylene live hinge tapped to a denser blue modelling foam material to create a moving part in a design.

Once learners have a full understanding of the range of materials, how to process them, and an understanding of how to be safe and achieve a good quality finish with them, they will want to begin to use them to create physical and, wherever possible, functional models of their sketches. Learners will want to pay attention to the stock forms of materials, and consider these accordingly in their modelling, avoiding waste or excessive use of materials for a short-term model.

Where learners are aiming to achieve a quality outcome, they will be actively working with a range of measuring and marking out tools, and should as appropriate be encouraged to develop jigs to aid repetition, templates which support the evidence for iteration, and all the while be considering where they might need to employ CAD/CAM later to create multi-part patterns or where tolerance by hand will be challenging. An appropriate use of CAD/CAM can be identified in the modelling stage if learners consider where high tolerance and specific functions will be best served by controlled equipment over manual techniques.

During the iteration process, learners will need to evidence the changes, and if possible, all of them to track the iterations being made as they work towards the final solution.

In order to facilitate regular and quick iteration in a model, learners will need access to a range of processes suited to their modelling material, such as appropriate joining techniques and hand tools. These will need to be delivered to consider the health and safety implications as well as the appropriate general use in a workshop environment.

Common misconceptions or difficulties learners may have:

The iteration process in model-making is a step up from the common approach in previous specifications, given that the process should be fully active, on-going, and will award credit to learners who act with purpose each time, and evidence their approach. The "next step" process of development will require learners to make comprehensive and progressive developments with intention, with the outcome looking to reach some technical goal in a functional prototype. Learners will also be credited with being critical thinkers during this process; therefore, learners will be required to be consistently critical about their solution(s) until it meets an objective set of demands. Superficial or subjective approaches to iteration, leading to a solution-based on little technical evidence of change will struggle to achieve highly in the NEA.

Because of this, learners must be able to reflect critically on all matters in their design approach, and will need to maintain a critical approach throughout a potentially lengthy process. Many learners may feel able to design the "perfect" solution during their sketching and ideation stage, but this should be discouraged to allow the learner to become the reflective designer they need to be to demonstrate iteration.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

The act of working with materials using appropriate processes will link well with the making of the final prototype, and the processes and materials the learner chooses to work with. A focus on quality and health and safety will support learners during the final prototype make.

The marking criteria is complementary to the area of CAD/CAM where learners will be able to make use of detailed and quality models to support CAD modelling. If CAD/CAM isn't appropriate for the making of the final prototype(s), the skills can still be credited through earlier modelling.

Learners will be able to use a broad range of skills from the mathematical element of the specification, from taking measurement of parts to calculating volumes and surface area. Forces will be able to be tested, but need to take account of the limitations of the modelling materials used in the model.

Working with materials taster

In this activity, learners use a range of materials to model ideas quickly. Each material is used in isolation to the other, to make a single material model that can be developed using iteration. During this activity learners will record through sketches or photographs the iterations taking place and the justified reasons for each. To commence the process, the learner will need to be provided with a technical drawing of the part or product to be made and will need a demonstration of how to make it accurately.

Materials the learners may choose to work with (with suggested models to make) include but are not limited to:

- blue foam modelling - a hand-held tool such as a toothbrush
- corrugated card - a storage device
- acetate - a storage folder
- aluminium bar - a tablet stand
- clay or dough - a computer mouse
- foam board - an architectural model
- carton board - a mechanical grabber
- dowel/balsa wood - a bridge structure.

With each of these materials, the learner will need a set of appropriate tools, equipment and processes with which to shape and form them, and suitable adhesives to join them.

Once initial models have been made, learners will be tasked with developing, through iteration, their models. For example, the toothbrush model could be changed and developed due to its purposefully uncomfortable shape in the learner's hand.

Multi-material model-making task

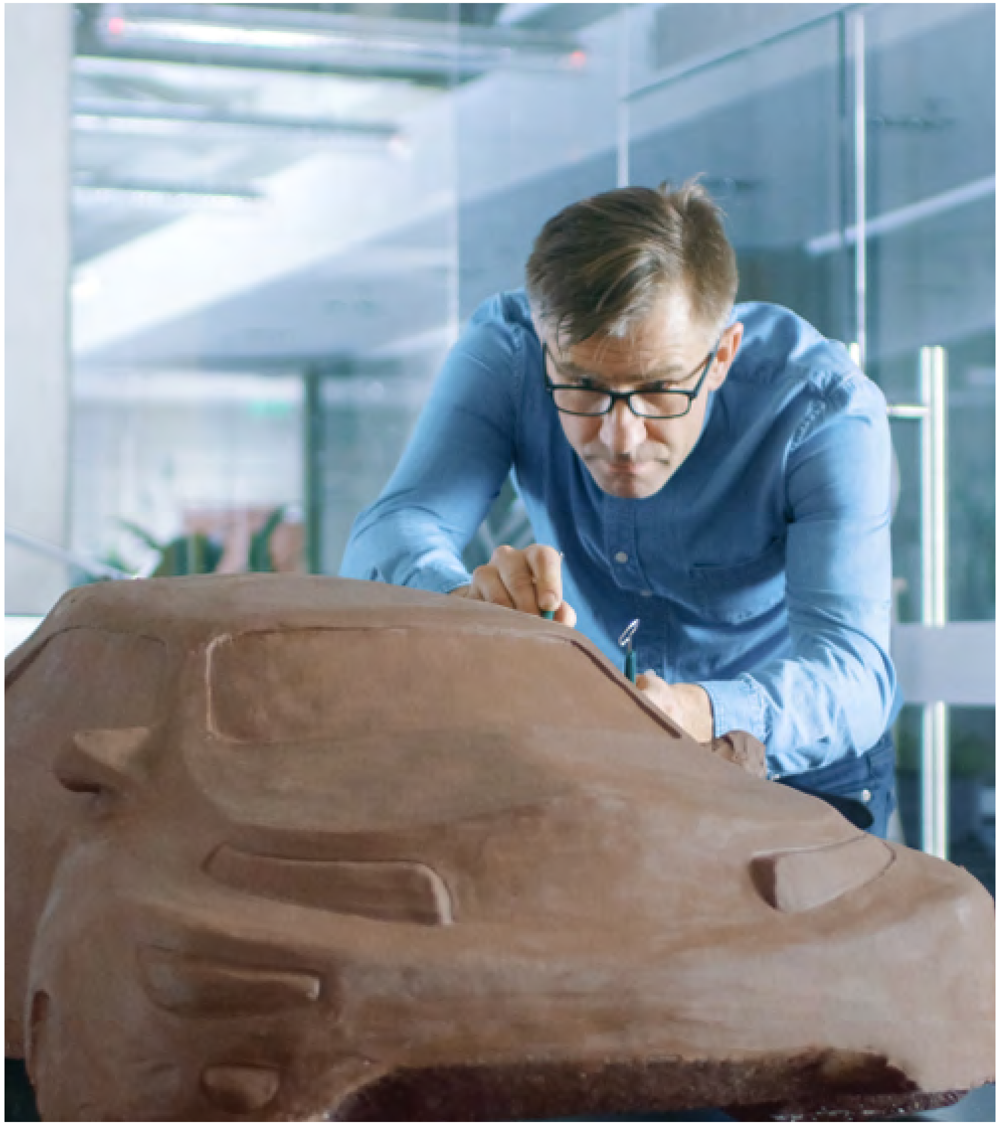
In this activity, the learners are given freedom to use any materials to create a more complex outcome. For example, the modelling of a hand-held electrical device, in which different materials will be needed to create explicitly different shaped parts in the design. A wide range of joining techniques will also be needed to assemble each part into a full final model. The learners will need some specific guidance on what to model and make initially, either through exemplar work or a possible video/photographed example. The learners will again develop and iterate, based on their own ideas. Alternatively, a specification for what the solution needs to achieve could give learners the experience of working towards technical outcomes. Wherever learners are trying to achieve a physical outcome, such as a direction light in a lamp, they should be encouraged to use actual electrical components or off the shelf finished sets of equipment that can allow them to test and critique their models as they progress.

Developing a solution for batch production

In this activity, learners can work from an existing model or product, and are challenged with developing appropriate supporting jigs, templates and systems to make multiple copies of the original prototype. This can be with a team dynamic to the activity, but will involve learners looking to make accurate outcomes, achieve a level of quality in functional aspects and reduce or minimise wasting of materials. Simple models, such as a replica Vernier Caliper tool made from rigid card, will challenge learners to maximise stock forms of material, create production lines in teams, and help engage learners with the tools associated with quality checking.

Title	Web link	Summary description
Professional model-making classes	http://www.judepullen.com/designmodelling/	Using this website as a base, learners can access videos, lists of suggested tools and equipment, and learn how to model to a professional level by following an expert model-maker. Example projects are provided which may also support the teacher in developing longer learning experiences.
Bluefoam modelling strategies	https://davidneat.wordpress.com/styrofoam/	This resource provides learners with 'how to' approaches to achieving certain aesthetic outcomes in bluefoam for model-making. They include guidance on tools and approaches, with detailed photographs to follow.
Prototyping and model-making - Learners of product design episode 5	https://www.youtube.com/watch?v=gWk6br5Ngkc	This video resource looks at prototypes and model-making. One of the reasons industrial design projects are not successful is because the designer didn't make enough prototypes to test ideas, prove concepts and highlight problems.

What is the purpose of model making and iteration?



Introduction

Watch the video (https://www.youtube.com/watch?v=gWk6br5Ngkc) about prototyping and model making. During the video, make rough notes on how to answer the questions in your hand out. Use shorthand and sketches as well as written words to record your thoughts and the things you learn.

The activity

Answer the following question in short hand first during the video, then write a more detailed response as a paragraph that answers "Why do we make models and prototypes?"

1. Why can design projects not be successful?
2. What is a good prototype?
3. What will move a prototype forward?
4. What is a model?
5. What is a prototype?
6. What are the limitations of sketching alone?
7. What can we learn from testing prototypes?
8. What is the risk of not making prototypes?
9. What are the benefits and restrictions for rapid prototyping?
10. Why is it important to work to scale?
11. What is the benefit of taking products apart?

Now with your responses, respond to the main question of "Why do we make models and prototypes?"

Extension activities/questions:

Explore case studies of successful modelling (Dyson) and prototyping that could support your argument for the process in design.

Specification content (Sub Topic 2)

Sub Topic 2: Making final prototypes in a workshop

Exam content

7.2 How can materials be manipulated and joined in different ways in a workshop environment when making final prototypes?

a. The use of specialist techniques, hand tools and equipment used to shape, fabricate, construct and assemble high quality prototypes, with exemplification of the following processes:

- **i.** wastage, such as:
  - timber, e.g. sawing, drilling and turning
- **ii.** addition, such as:
  - timber, e.g. adhesion, joining and laminating
- **iii.** Deforming and reforming, such as:
  - timber, e.g. steaming and pressing

7.3 How do designers and manufacturers ensure accuracy when making prototypes and products?

a. The use of appropriate and accurate marking out methods, including:

- **i.** measuring and use of reference points, lines and surfaces
- **ii.** templates, jigs and/or patterns
- **iii.** working within tolerances
- **iv.** understanding efficient cutting and how to minimise waste.

NEA CONTENT

a. Be able to use specialist techniques and processes to shape, fabricate, construct and assemble at least one high quality prototype, including techniques such as wastage, addition, deforming and reforming, as appropriate to the materials and/or system components being used.

b. Be able to use specialist tools and equipment, appropriate to the materials or system components used (including hand tools, machinery, digital design and manufacture), to create models and prototypes.

c. Be able to use appropriate and accurate marking out methods including: measuring and use of reference points, lines and surfaces; use templates, jigs and/or patterns where appropriate; work within tolerances; understand efficient cutting and how to minimise waste.

Thinking conceptually

General approaches:

The manufacture of a prototype is arguably the most engaging element of the course, and as such, should be highly rewarding if learners are able to work with quality materials, a broad offer of processes and finishing techniques, and the opportunity to use these with freedom and without barrier. The topic will likely be an area of learning already familiar with most learners who have opted for the GCSE course, especially if they are following a rich and challenging lower school experience. If this is the case, learners will want to revisit topics only as a reminder, before developing a much deeper understanding of the potential for different materials and processes. For timbers, this topic can be exceptionally rewarding where a deep appreciation of the material itself is afforded.

To begin with, learners will need to understand the nature of working with timber, through the areas of wastage, addition, and both deforming and reforming. Wherever possible, learners should do this in the context of a practical environment, with materials and processes available to explore, experiment and with which to make mistakes and learn from. For example, learning the process of drilling with different drill bits and analysing the physical performance of each tool as it drills different materials, as well as the resulting holes they create. Learners might make notes on the difficulty relating to different densities, or the tearing of a surface where the wrong approach has been taken.

In a workshop environment, where a safe and broad set of tools and equipment are available, learners should be able to use samples to experiment and test using or following some form of modelling; this could be by a teacher or through video. Where this activity can lead to a physical outcome, like a simple product, there will be an additional motivation to the learner.

Learners will want to establish approaches that result in a high quality outcome(s). Following testing and experimenting, it will be important for learners to have time to either identify their mistakes or to see but ideally experience the correct approach for an ideal outcome. For example, learners could experience sawing with different saw types, but have a demonstration of the right technique using the right saw by a teacher, and then be allowed to conduct this to cement learning of this skill.

Where specific outcomes are desired, like the correct choice of adhesive or the correct lamination process, learners will need both the information and a demonstration to embed this learning. The teacher should deliver this with examples of outcomes supporting the desired approach.

In a workshop environment, learners will need to have access to the learning and tools required to achieve a high level of outcome. For example, a set square for marking onto a timber length for cutting or using the right settings and auto-focus function for laser cutting sheet board. In order to engage learners with terms like tolerance or waste minimisation, the learner will need to see and feel different 'good' and 'bad' examples. This could be achieved through the activity, or in the materials used to support the demonstration and modelling.

The desired level of ability and learning expected in this topic is that learners will be able to take an independent approach to selecting the right materials, processes and techniques for a given design solution, and through their application of these produce an outcome that considers:

- quality - through tolerance and surface finish
- the Environment - through waste minimisation and joining techniques
- safe approaches - through understanding process limitations
- scales of production - through the use of jigs, templates, and repeatable processes
- challenge - through combining different materials, processes and techniques
- innovation - through challenging all of the above.

Where learners are making their final prototype(s), they should aim, wherever possible, to use appropriate and comparable materials, processes and techniques to achieve either the aesthetic or functional outcome desired as intended by their design solution. Where this is not possible consideration of a material or process that best replicates the intentions of the design solution will need to be planned. This is important as it will form part of the reflection and iterative process and the learner needs to engage with their prototyping to deliver the highest possible same level of rigour and challenge to present it well any third party.

Common misconceptions or difficulties learners may have:

Learners are often limited in this topic by considering materials to only be workable with a specific set of processes and techniques. While in some areas of the specification this may be true, learners should have the opportunity to safely challenge these. For example, while laser cutting will not be suitable for thick oak, engraving is feasible, while a thin veneer applied to another material will cut well and give a similar aesthetic.

For learners to work with accuracy, an ability to work within or towards a given tolerance. While an industrial manufacturer would expect a tolerance of 1% in many instances, an appropriate target for learners can be anywhere between 1-5% depending on the application. Learners should work with a tolerance in mind, in order to achieve a quality outcome that can be critiqued against this target during evaluation in the NEA.

While it is not a prerequisite for learners to constantly work towards a larger scale of production, it will be beneficial to their learning that they can consider and make attempts to batch produce their design solutions. This may include making three matching parts, but only requiring two for the final outcome. In this way, learners can, as many professions do, give themselves opportunities to practise and improve their approach.

Learners will struggle to identify where multiple processes can support one another to manufacture a specific or unique part. This means being able to use one process to create an outcome that is then used in the next process. Examples include lamination of materials before turning on a wood lathe, or laser cutting sheet materials before layering up with adhesion to create a unique form to name just two. Learners will need support from the teacher to be able to experiment and make contextual links between different processes.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

The broad area of study that the manufacturer of models and working prototypes offers means that this topic will have considerable overlap with other areas of study. For example, learners will want to fully engage with the application of CAD/CAM so that they can apply this learning to the area of CNC and timber processing using available machines in the department.

The manufacturing of prototypes will likely overlap and support areas of study including the design thinking section of the specification, where designing and manufacturing will support one another, designing for a material or process, and manufacturing according to a design sketch or CAD.

The working properties of materials will be put into application in this part of the course, and learners will not only be able to see first-hand the different properties in action, but also be able to identify limitations to these properties, such as how tough is a material to a point or how far beyond a yield point will a material not revert back to its original state.

Learners will be able to put into action the full spectrum of mathematical calculations associated with manufacturing, from measuring using simple tools and calculating area and volume, to developing a better understanding of percentages and ratios in instances such as shrinkage or deflection.

Thinking contextually

The best method for delivering this topic is with a practical activity which enables learners to:

- measure and calculate
- make choices and experiment with options
- work with freedom but under guidance
- combine materials, processes and techniques in new ways
- work with a reference to desired outcomes or tolerance
- make decisions about approach that affect quality and wastage
- make a finished outcome that can be critiqued.

In many instances, learners can work with a range of timber materials to cut, shape and form these into parts of a larger product or system. Similarly, they can work with a range of the same materials in sample form to apply and test different joining methods and finishing techniques. An example would be where learners are given technical drawings (with tolerances and measurements) of parts for a simple timber product like a tablet/phone stand, and given a range of materials with which to work. Parts made could be initially modelled in a modelling material such as blue foam or card, before using this learning to make final parts in the timber available to the group.

Once parts have been made, learners can join and finish these with again some form of choice, such as a wax or varnish, using PVA glue or mitre glue, etc.

In order to broaden, differentiate or complement learning, tools such as custom jigs, templates, group work opportunities and measuring equipment will all provide the learner with opportunities during the manufacture. For example, a custom jig for sanding circles on a disk sander, paper templates to follow using a hand saw, grouping parts to be cut on a laser cutter, and providing micrometers or calipers to check at measurements through certain stages of making a prototype(s).

Where learners do not have access to a workshop environment, materials with which to practise or a prior experience of using a manufacturing process, it will be important for the teacher to recreate these experiences in another way. The teacher could video a manufacturing process, or the entire 'make' of a product and play it to learners for them to analyse and discuss. Alternatively, videos online of manufacturing techniques can be used in a similar way.

Title	Web link	Summary description	Additional description detail
Pinterest: Toy technical drawings	https://uk.pinterest.com/pin/497295983833987659/	For this activity, the learner selects (or is provided) a technical drawing of a timber toy from Pinterest, and challenged to make it using materials and processes in the workshop. The learner will need to select and use these with skill and accuracy, and work from a technical drawing.	
Plan Toys reverse engineering	http://plantoys.com/product-category/new-products/	Using a purchased plan toy as a starting point, the learners are challenged with manufacturing a replica using materials and processes and techniques available in their workshop. The teacher will need to select appropriate products for this task to succeed.	
Conor Coghlan	https://www.youtube.com/playlist?list=PLBdtGoD6S4F9s-40OHWm2JEScSFcgUD2X	In this series of videos, learners can observe and learn about the process of manufacturing a prototype chair in timber, conducted by a freelance designer maker.	(N.B please consider parental guidance with these videos given the very rare poor language heard in one video only.) Video 12:17 seconds in.

Replica manufacturer of technically drawing toy

Introduction

In this activity, you are tasked with manufacturing a timber-based toy product using a range of materials, processes and techniques. You will need to choose between different materials, the processes used to shape them and techniques to create the right finish.

The activity

Click on the link below to see Craftsmanspace's Funny airplane kids' toy plan.

http://www.craftsmanspace.com/free-projects/funny-airplane-kids-toy-plan.html

Extension activities/questions:

Learners can propose alternative processes, where off the shelf parts could be employed or design jigs and templates for manufacturing specific parts for batch production.

Sub Topic 3: Using digital tools to support design development and manufacture

Exam content

7.2 How do industry professionals use digital design tools when exploring and developing design ideas?

a. The use of 2D and 3D digital technology and tools are used to present, model, design and manufacture solutions, such as:

- rapid prototyping
- image creation and manipulation software
- digital manufacture
- interpretation of plans, elevations of 3D models
- CAD, CAM, CAE.

NEA CONTENT

b. Be able to use specialist tools and equipment, appropriate to the materials or system components used (including hand tools, machinery, digital design and manufacture), to create models and prototypes.

General approaches:

For the topic of digital design tools, it is important for centres to provide a software platform that is trusted and of industry standard, where the teacher can support learners in developing a free-flowing ability to use the software as a tool for designing and subsequent manufacture. The use of software to develop both 2D and 3D design work, ranging from technical drawings for third party manufacturers through to stereolithography (STL) files for 3D printing technology applications, will empower learners to develop ideas iteratively and produce outcomes that are of a high standard.

In the area of timbers, learners will need to learn about the use of digital tools to create technical drawings which can be interpreted for subsequent part manufacture, product assembly, or to communicate sectional views and projections to provide information to other technical individuals. A learner can work in 2D forms, and translate these into 3D forms, or vice versa, work in a 3D software package and output 2D forms. Neither method provides an advantage over the other, but it will be important for learners to experience the entire process of CAD, through to CAM and CAE.

Using an appropriate software package, learners will want to develop an iterative approach, able to document modelling in the virtual environment, and changing design features as an improving design strategy. Learners may wish to screenshot this evidence or save versions of files to demonstrate the change over time.

Learners will be able to output rendered images of virtual models in generic colours or in the material finishes being considered. These images can be post-processed using desktop software to cut out and superimpose them onto images in context. This is a useful form of development where users or customers can comment on the images as part of a critique of progress.

While timber is restricted only to wood fibre filament in 3D print technology, digital manufacture will create broad opportunities for timber to be used in processes such as laser cutting, CNC lathe and milling operations, CNC routing, or through the application of processes which can be applied to timbers, such as dye sublimation of 2D graphics to the surface.

It will be important for manufacture that learners can not only create, but also read and interpret technical drawings of plans, elevations and exploded views to name a few. This will support the NEA in which technical drawings will form part of the evidence for creating a technical specification.

Learners will want to learn about CAD, CAM and CAE in the context of timbers by seeing examples of the technology in application, including examples such as Ikea furniture manufacture or similar automated production.

Where learners have the opportunity to explore materials for fabrication and iterative modelling, they will need to engage with a wide range of progressively more complex tools, from simple hand tools like saws and files, through to machines such as pillar drills and bobbin sanders, software to aid to development of designs, and finally the setup and operation of CAM tools such as a laser cutter. A thorough understanding of the tools and equipment will help learners to become independent, but also better designers by considering the outcomes, limitations and potential to innovate using each manufacturing process.

Common misconceptions or difficulties learners may have:

In this section, it is not essential that all equipment is accessible to the learners, and learners will not be restricted because they do not have access to equipment such as CNC lathes or laser cutters. Learners who have learnt how each works and their potential and their limitations, will be able to design for these in their NEA, where a free and open design process without limitations will be important.

The importance of being able to generate and use technical drawings cannot be understated here, as this will be a vital learning aim for all learners, and support learning for both the NEA and the examination.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

This topic will support learners in a broad number of areas across the specification. It will allow learners to develop a better awareness of industrial practice and the modern manufacturing approaches in use today and into the future.

It will be important for learners who are aiming to create a true technical specification, to have a full and clear grasp of a software package to support this digital approach, as this will be a key area of application in the NEA, and in the area of design thinking and design communication in the marking criteria.

The understanding of CAD systems will help learners engage with the topic of electronics and systems where technical drawings will communicate circuit design and layout, while learners might find opportunities to apply their learning in this topic to the exploration of levers and motion, where they might create technical drawings to show mechanical systems in use.

Reverse Engineering

In this approach, learners are provided with a technically challenging and appropriate product or system for which they will be measure and create virtual parts using a CAD software package. Depending on ability, time limitations and the choice of product by the teacher, learners can be provided with an object from which they can disassemble, take measurements and create replica versions in their software package. A simple object such as a timber-based toy will provide surprising challenge due to the nature of learners working from a finished product where measurements are not likely to be easy to identify whole numbers. Likewise, where the selected item is complex, perhaps in the alignment of parts or in the assembly, the learners will need to be able to analyse and document in note form the product provided, consider the parts needing to be modelled, and then subsequently model these into virtual replicas.

Reverse Engineer and Improve

Where available, learners can improve an existing product, by first reverse engineering the parts in a software package, before selecting items to improve, then manufacturing these using an appropriate manufacturing process. For example, learners may reverse engineer a simple timber-based toy, remove an element such as a puzzle, and laser cut a replacement item that presents more challenge. In this instance, it will be important for the teacher to provide suitable items which have opportunity for available CAM processes to be used to make parts.

Manufacture/Assembly using Technical Drawings

Based on prepared technical drawings handed to the learners, there is the opportunity for them to interpret the information provided in plan, side and cross-sectional views, before they select from a range of provided materials or parts, and manufacture or assemble the finished item. The use of the technical drawings will help learners recognise the important information that will be needed for their NEA. Likewise, well-designed technical drawings will provide opportunities for learners to spot mistakes, or ask for missing information.

CAD/CAM challenge

Using 2D design software, or appropriate 3D design software, learners are challenged with first modelling in card or paper an idea for a slot together item, such as a chair, and then using the CAD software to model these parts accurately. They will then be able to fabricate these using a laser cutter, or print these 2D images out and layer up onto a sheet of material for cutting by hand. Either approach is applicable with different learning associated with each. Learners will need to build and present their design ideas as part of a critique of outcomes in which the whole group can review and feedback to their peers about the design outcomes.

Virtual presentation

For this activity, learners will design and 'make' a timber-based design solution, and use digital tools as the manufacturing process. This simply means that learners will not make the outcome but use digital tools to create the impression of a finished product in use. The outcome here will be a superimposed digital image of the design in use and context. Learners will need to be provided a design brief to a context, develop sketches of ideas, before committing to a digital design, rendering in the software, and using output images to cut out, edit and superimpose the design into the design context, for example a timber seating solution superimposed onto a playground space. Learners will then have to present the design idea(s) as a finished solution, and use their images to engage discussion and request critique from their peers.

Title	Web link	Summary description	Additional description detail
Autodesk Fusion 360 Product Design course	https://www.udemy.com/product-design-fusion-360/learn/v4/overview	In this course, a learner will get started with product design in Autodesk Fusion 360. During the course they will learn how to sculpt their idea, then move to parts and assembly modelling, and, as a final step, create drawings, renderings and prepare for manufacturing on CNC machine or 3D printer.	Fusion 360 is a cloud-based CAD/CAM tool for collaborative product development. Fusion 360 enables exploration and iteration on product ideas and collaboration within distributed product development team. Most importantly, Autodesk Fusion 360 combines organic shapes modelling, mechanical design and manufacturing in one comprehensive package. Learn more about Autodesk Fusion 360 at the official website as well as download the product. Learners, educators, enthusiasts and start-ups (no commercial product available yet) are entitled for a free licence. After completion of the course, you will be able to design your own product from idea to prototype. The course contains 4 hours of video lessons, written step-by-step instructions and datasets. On average, a learner needs around 16–24 hours to complete the course.
NX8 Router demonstration	https://www.youtube.com/watch?v=WceR92i7Q9Y	In this video, learners can be talked through the use of CAD/CAM to create the complex form of a vehicle using a CNC router to machine into MDF layers materials.	
Innovation - Learners of Product Design	https://www.youtube.com/watch?v=Oee8VfjR1CE	These videos are a series on the design process. This particular link to video 6 has a focus on prototyping and outlines hand timber prototyping approaches.	

Sub Topic 4: Making products to different scales of production

Exam content

7.5 How do processes vary when manufacturing products to different scales of production?

a. The methods used for manufacturing at different scales of production, including:

i. one-off, bespoke production

ii. batch production

iii. mass production

iv. lean manufacturing and just-in-time (JIT) methods.

b. Awareness of manufacturing processes used for larger scales of production, such as:

- timber, e.g. CNC routers, sawing and steam bending machines and lathes

7.6 How do new and emerging technologies have an impact on production techniques and systems?

a. Critical evaluation of the benefits and implications of incorporating new and emerging technologies into production processes, such as:

- consideration of economies of scale
- how disruptive technologies such as 3D printing and robotics are changing manufacturing.

General approaches:

Scales of production is a topic that will provide learners with an opportunity to place in context a wide range of material, process and technique knowledge either developed before the GCSE course or during. The topic will enable learners to study example products and systems as a series of case studies, and using a range of approaches the teacher will be able to provide memorable experiences relating to their specific area of study.

For timbers, learners are going to need to be able to identify the features of each progressively larger scale, so that they can distinguish between what one-off and mass might look like in industry. These features will link to many areas of the specification, from material selection to manufacturing processes, provide opportunity to include learning about digital technology, data, technology and energy, and will likely be influenced by broader areas of study, such as design influences, the environment, flowcharts and CAD/CAM to name just a few. During this learning, there are opportunities to match workshop practice to scales of production, such as the learner's own GCSE approach being comparable to one-off. Where workshop practice cannot mimic larger scales, supporting materials such as videos as part of a case study, or a site visit would benefit learners. The ability for learners to identify, through different scenarios, which scale of production is appropriate, and the likely production methods and techniques, would be an ideal outcome from this topic.

As learners' progress through each increasing scale, they will need to understand how production has evolved, including lean and just-in-time methods. When learners are ready to, the introduction of disruptive technologies such as 3D printing would provide both an extension and a challenge to previously held views on production scales. Learners will need to understand how modern manufacturing might look in the present or near future thanks to these disruptive methods, and again case studies from up to date sources such as crowd funding platforms or industrial design blogs will help teachers provide memorable examples.

By the end of this topic, learners will want to be in a position to critically evaluate case studies of scales of production, before evaluating their own approach in the NEA, whereby they can convey as supporting evidence of knowledge, information about different scales of production and how they affect the design process they are completing.

Common misconceptions or difficulties learners may have:

Scales of production should not be tackled as a standalone topic of study, but should be integrated into the day-to-day learning about design and technology. Though the course on offer might be delivered with a narrow range of materials in consideration, it might be important that multiple material case studies are used to deliver the learning in a rich way to the learners.

The topic can also overlap into much of the course specification due to it being a part of all design to make activities, and as such could be a topic that is not addressed alone but part of the learning of all topics. However, learners must at some point establish clear definitions and be able to identify the advantages and disadvantages of each.

The nature of disruptive technology and how new and revolutionary it has been in the lifetime of our learners, means that this area of the topic will evolve as technology evolves. The notion of disruptive technology is not a static area of study, and as new technology in areas of robotics and 3D printing develop, the planned learning will too need to update. While every effort can be made to maintain up-to-date information of these emerging and cutting edge areas of our manufacturing society, it should be noted that what is not achievable in one year of teaching might not be the case the following year.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

The topic of scales of production will have large overlap in the areas of CAD/CAM, including forming the justification and basis for company investment. The human factor, including society and ethics will also be a linked topic to this one.

The circular economy, being an area of new study for learners, will likely follow this topic or can be taught alongside this as a method of critiquing the modern way of things.

All production processes and material areas will be taught with an additional reference to scales of production, with learners in the workshop learning the practical skills to produce one-off and batch produced design solutions, all the while considering the larger scales for the mass market.

Disruptive technology, modern manufacturing approaches regarding energy, material sourcing and lifecycles of products and systems will all have a required acknowledgement to this topic.

What are the aesthetic features of different products from different production scales?

For this activity, learners will need to be provided with carefully selected products or systems, which feature materials and their associated production methods that relate commonly to a scale of production. A typical example might be a hand carved oak sign for a house front, an oak CNC routed version, and an injection moulded sign with fake grain surface finish. Each of these items will have a connection in that they are used for the sample purpose, and all relate to the same material area of timber. For this activity, learners will need to be provided sufficient information about each product, for example:

- retail cost
- materials used
- processes used
- retailer description, etc.

The learner's task will be to identify which scale of production has been used for each, and identify the advantages and disadvantages each offers to:

- the customer
- the manufacturer.

Learners may then be able to provide a design brief and specification to support the design of these outcomes. Learners can go on to compare and contrast each product against the other from a personal perspective, deciding what value each offers to themselves, or conduct the process by formulating a survey and conducting it with another peer or someone away from the classroom environment.

Extension activities will offer learners considerable scope to overlap into the other areas of the curriculum. For example:

- learners are tasked with proposing a new enterprise, and will need to create a short pitch for funding to launch a 3D printed version of the product/system being analysed. Learners will need to justify the production scale, the use of the disruptive technology, and identify their perceived issues and solutions to the new business.

Why would they buy that?

In this activity, learners are given different persona or characters, each supported by a profile. This stakeholder is the considered as the buyer for a number of different products, with a range of prices, scales of production and features. The learners are tasked with identifying the motivations of stakeholders in purchasing certain products over others, and how scales of production influence this. For example, the learner is given a large range of garden furniture items, to consider, ranging in materials, design, features, production methods and scales of production. The learner is then given three different personas, and has to identify which product each should purchase based on what they know about the character.

As an extension to this activity, learners can propose methods by which the products might be advertised, writing product descriptions for retail sites or catalogues, and look at ways in which they can market the products depending on the quality and outcome of each.

Finally, learners might be able to redesign outcomes to improve them for their target market. This might include changing the material, the process, or the scale of production, but will help learners to appreciate the design decisions being made and worked around by modern designers and manufacturers.

Design for growing demand

In this activity, the teacher provides the learners with a series of project outcomes, perhaps products made by a previous cohort of learners or photographs of previous GCSE work, and their task is to:

- identify the materials used
- identify the processes used
- identify the techniques used
- identify all of the stock forms and off the shelf components
- estimate the cost of the finished solution.

With all of this information, they are tasked with proposing changes to all of the above to improve its current scale of production (which will likely be one-off or batch), to improve quality or reduce unit cost, and/or develop the outcome for larger scale mass production. Learners may be skilled enough that they can subsequently sketch changes, cost the new developed outcome, or create a written proposal with justification for the changes proposed.

Title	Web link	Summary description	Additional description detail
Case Study: Ikea	http://www.ikea.com/gb/en/this-is-ikea/about-the-ikea-group/	In this case study, learners can read the information page about Ikea and identify by way or research or the supporting videos what scales of production Ikea employ and how they benefit from these.	Learners will need access to this area of the website about innovations in Ikea to support their case study for an evolving business. http://ikea.today/category/innovations/
Large scale manufacturers turning waste into material	http://www.core77.com/posts/45630/How-Large-Scale-Producers-Turn-Sawdust-Into-Something-Useful	In this activity, learners can read the case study and watch the supporting videos, showing how a manufacturer on a large scale for timber, turns waste into new retail worthy material.	
BBC bitesize revision and assessment online	http://www.bbc.co.uk/schools/gcsebitesize/design/resistantmaterials/processindpracrev1.shtml	Learners can complete a series of short learning activities relating to industrial practices before completing an online test about the information covered. Learners are provided with examples for scale of manufacture, with linked learning to CAD/CAM and industrial practice included.	

Learner Activity

Critical analysis of 3D printing technology

Introduction

In this task, you are going to learn how to critically analyse the strengths and weaknesses of a production process. By doing this, you will be able to identify appropriate materials and production methods for future products you design.

The activity

Learners are provided with an input on the process of 3D printing. This can be teacher led, with a hand out, or using a video which provides sufficient information about the process. An example is here: https://www.youtube.com/watch?v=Vx0Z6LplaMU

Following this input, the learners are provided with information about the design and production of a product to be made by this process, using the timber filament (https://www.youtube.com/watch?v=CvWU5bVh9Ig)

Task:

What are the opportunities for producing a wooden looking statue in 3D printing wooden filament over the use of a traditional timber like oak?

List all of the pros to the 3D print process, and all of the cons. Consider the user and the manufacturer.

List all of the pros and cons for the traditional process of carving by hand.

Which approach is best for manufacturing a number of products for growing demand?

Justify your answer with reference to your pros and cons.

For the following topics, consider how you might change your response:

- the environment
- capital setup cost
- skills required of the maker
- quality
- sustainability and environmental factors.

Extension activities/questions:

Consider for the product you are critiquing, whether an alternative material, process or scale of production would be better suited to different users or customers. Identify why this might be the case.

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