Unit 3: Product Design and Manufacture in Engineering

Delivery guidance

The aim of this unit is to provide learners with opportunities to explore engineering product design and manufacturing processes, and complete activities that consider function, sustainability, materials, form and other factors.

Approaching the unit

This mandatory unit (for all sizes other than the Certificate) is intended to give learners the knowledge and skills that they will need to meet design challenges and produce effective engineering solutions to solve problems.

There is opportunity within the delivery of this unit for a range of design activities to be carried out, along with hands-on practical investigations of existing engineering products.

Delivery of this unit is likely to use a range of different methods, including tutor presentations, individual and group work along with paired investigations. The focus should be on equipping learners with the skills they need to be able to develop their design concepts coherently using an iterative approach and to be able to validate their own designs.

This unit, like the other mandatory units, could be delivered in a specialist context such as aeronautical, manufacturing or electrical and electronic engineering. For example, a centre wanting to deliver the mandatory units in an electrical/electronic context could explore a range of basic electrical products such as an iron or a food blender to explore the design and manufacturing processes applied; however, care must be taken to ensure learners are well prepared for the task based Pearson Set Assignment.

Learners will develop the skills needed to identify and respond to design triggers so that they can develop their own product design specifications and subsequently their own developed design solutions. They should be equipped with the skills needed to address a range of challenges including those related to sustainability issues or modern manufacturing techniques. They should be able to draw on their wider experience of engineering from other units and the wider engineering world to present coherent design solutions.

You can involve local employers in the delivery of this unit if there are opportunities to do so.

Delivering the learning aims

Learning aim A

Learning aim A provides the foundation for the unit, introducing learners to possible reasons for developing a product, and then the related theory to consider the suitability of a range of manufacturing processes.

First, introduce learners to the range of design triggers and challenges that are often the starting point of the design process. This could be addressed by considering an engineering product and discussing with learners the possible reasons that led to its development. Use a product that learners are familiar with, such as a smartphone, or something less familiar, such as product

manufactured by a local engineering organisation. This analysis should provoke discussion that you can then build upon by encouraging learners to carry out their own independent study into other design triggers.

Then, carry this forward by discussing how design triggers often lead onto a design challenge. Again, the same products could be considered with learners investigating the trends that have led to a particular design challenge being placed on a product. Consider more holistic challenges, such as those associated with the integration of different power sources into vehicles that could also have sustainability issues and reflect on energy recovery features. Learners analyze this issue using a range of statistical methods to document and justify the range of consumer, governmental and manufacturing issues associated with the environment and sustainability issues.

Continue to investigate the factors that give opportunities or place limitations on the design and development of engineered products. For example, the taxation issues facing consumers and issues faced by manufacturers with the integration of different power sources for vehicles. Try to use a whole-class discussion and move this topic forward from a group discussion to paired research tasks to investigate the starting points in greater depth.

Having considered a range of factors that will need to be taken into account while designing a product, you will then need to help learners to gain the skills that they will need to be able to develop a product design specification (PDS) from a given design brief. You should make sure that learners have an understanding of how to interpret product requirements in order to produce a product design specification. This can be achieved by giving learners a range of case studies that feature a client brief from which they can then develop a PDS.

Give learners a research task so that they gain an understanding of the commercial protection of designs. This could then be complemented by further paired or group activities where learners investigate the regulatory constraints associated with given engineering products and scenarios.

Finally, introduce learners to the various analysis skills which they will need to employ when producing their own designs, and how engineering goals can be affected by factors relating to the potential market, the performance requirements of the product and the likely manufacturing methods that would be used to produce a solution.

Learning aim B

The delivery of learning aim B is likely to be approached more holistically, using a range of design challenges to build on the skills which learners will need to possess in order to present their design proposals for the Pearson Set Assignment. Approach the topic by refreshing the required presentation skills which learners will be expected to employ, for example, 2D and 3D sketching, rendering, use of technical drawings, etc. These skills could then be employed by tasking learners with a number of design challenges for which they will need to develop a range of initial ideas. These challenges could be linked to work with an industry partner who may give learners suitable contexts to address.

Encourage learners to take an iterative approach to their design work, refining and improving their ideas until they have a solution that best fulfils the needs of the design. Emphasise to learners the level of detail that they will need to include in their developed design solution.

Learners should reflect upon the materials which they select for design proposals and developments. Learners need to be familiar with a wide range of material types and their associated properties and uses. Assessors could provide case studies of different engineered products highlighting materials used, properties, behaviours and modes of failure. Alternatively, learners could work in pairs or small groups to research a range of material types which they then present and share their findings to the collective whole. This would be an appropriate

activity to commence a sequence of lessons with at the beginning of this learning aim, alongside the sketching and rendering exercises.

Together with work completed and presented to learners about material properties it would be prudent to provide opportunities to develop their understanding of a range of different manufacturing processes and scales of manufacture. Introduce the characteristics and effects of manufacturing that impacts on the selection of engineering materials and components when design an engineering product. Learners should annotate design proposals, highlighting manufacturing methods and scales of manufacture as well as the provision of justifications behind their reasons for the selection of these processes. In order to be successful engineers, learners need to have a deep level of knowledge and understanding of materials, their properties and how forming processes are used to realize engineered products.

Give learners the opportunity to investigate design documentation that accompanies existing engineering products. This will give them an insight into the level of detail and range of documentation that they should include in their work. Remember to develop learners' ability to use concise and appropriate annotation to accompany design ideas, and discuss the importance of recording and justifying changes they make to their concepts. It would be appropriate to introduce mechanical power transmission after this (topic A5). Learners could research a range of tutor lead topics in order for learners to be able to understand the characteristics of different types of engineering systems. The group could be broken up into several sections or teams to investigate electrical, mechanical, thermal and chemical power transmission processes. Moving forward from this research a brief could be presented to learners whereby they use some of these transmission processes to solve an engineering problem. For example, experiments to demonstrate the mechanical motion of vehicles.

Learning aim C

Finally, for learning aim C you could use a range of existing engineering products that learners can investigate to justify the design solution. In pairs learners could discuss and develop a product design specification for a given product, also this would act as a useful recap and revision tool for content learnt in learning aim A. This could then be presented to the collective whole for discussion. This feedback from this activity could be then taken away and referenced using objective referencing against these initial proposed criteria which learners have produced. It is important that learners understand how solutions to engineering problems can present indirect benefits and opportunities. You could highlight this by preparing your own case study in order to present these issues to the group. From this investigation into a range of different engineered products learners could move forward by proposing improved features to the analysed products. Work completed would also need to be reflective upon the opportunities for product constraints and limitations. To develop this work further tutor input regarding engineering design for manufacture and opportunities for modifications though technology would be appropriate. How can learners improve their design proposals by manufacture or technology-led adaptions?

You could work in partnership with a local engineering organisation to give learners the opportunity to validate designs, based on products which the organization manufactures using their PDS or a weighted matrix. You should allow learners the opportunity to consider the manufacturing of the product and how advances in technology may lead to design improvements.

Assessment model

Learning aim	Key content areas	Recommended assessment approach
A Explore design triggers, challenges, constraints, opportunities and operational requirements	**A1** Design triggers **A2** Design challenges **A3** Equipment level and system level constraints and opportunities **A4** Design for a customer **A5** Regulatory constraints and opportunities **A6** Market analysis **A7** Performance analysis **A8** Manufacturing analysis **A9** Statistical methods	This unit will be assessed through a Pearson Set Assignment. Learners will be required to use design processes to develop a product proposal. Learners' work will be submitted in the form of a completed assignment, which will be assessed by centre staff using the assessment criteria in this unit.
B Use an iterative process to develop ideas and a modified product design	**B1** Design proposals **B2** Communicating designs **B3** Iterative development process **B4** Material properties **B5** Mechanical power transmission **B6** Manufacturing processes	
C Generate technical justifications and validations for the design solution	**C1** Technical justifications and validating designs	

Assessment guidance

Due to the nature of this unit, with the extended Pearson Set Assignment relating to a pre-release case study, it is important that learners are fully prepared with the skills they need to be able to interpret a design brief into a set of requirements, opportunities, constraints, health and safety factors and sustainability considerations and to then apply an iterative approach to the development of a solution. This is most likely to be achieved with a range of practical design tasks where learners could address aspects of the content prior to carrying out a practice task, possibly based on the sample assessment materials or past Pearson Set Assignments.

It is important that learners have a good understanding of the materials and processes involved with the manufacture of engineering products. You should ensure that they also are proficient in presenting design ideas and have the skills to be able to analyse both products made by others and those designed by themselves.

Getting started

This provides you with a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 3: Product Design and Manufacture in Engineering

Introduction

In the delivery of this unit, there is the opportunity for you to develop links with local engineering organisations that may be able to give learners suitable design challenges or scenarios to develop their design skills. You could approach this unit in a number of ways; however, it is likely that once the underpinning knowledge and understanding which is covered in learning aim A has been addressed, a more holistic approach encompassing learning aims B and C could be employed which would give learners a similar experience to that which they will encounter in their Pearson Set Assignment.

Learning aim A: Explore design triggers, challenges, constraints, opportunities and operational requirements

- Introduce learning aim A with a discussion on possible design triggers that can lead to the development of both new and improved engineering products or services (e.g. using an existing common product, such as a smartphone or a tablet computer). As a group, discuss the possible triggers leading to the development of the product, whether technological or consumer led. In pairs, ask learners to research a range of design triggers that are considered by engineering designers when developing products. Extend the investigation by considering the design challenges that engineering designers face when developing products. This again could be approached through a paired investigation that would allow learners to develop their interpersonal skills.
- Ask learners to work collaboratively in groups to consider the constraints and opportunities that exist at either an equipment or system level concerning the design and development of engineering products. They can then present their findings to the wider group developing the transferable skills they may need in future employment.
- Once learners have an understanding of design triggers and challenges, you should now provide learners with the knowledge and understanding for them to be able to develop a product design specification (PDS). This should address the requirements of the design brief, which you provide, whilst also taking into consideration external factors such as regulatory requirements or intellectual property rights. This topic offers you the opportunity to develop links with an industry partner who could provide design briefs that your learners will need to interpret in order to develop a product design specification (PDS) that addresses the client needs (both internal and external). There is scope for collaborative working between learners in the first instance, so they can develop their skills in working independently prior to beginning their Pearson Set Assignment.
- Introduce the activity by giving learners a relatively simple design brief. They could then work through this, in either groups or pairs, to come up with specific criteria needed for the PDS. Following on from this, learners should consider the regulatory opportunities and constraints that relate to a design brief. Discuss as a group, and then allow learners to work in pairs to investigate the relevant legislation, codes of practices and other regulatory factors that relate to a given design brief. Learners could then modify their own PDS in light of the regulatory constraints that they have identified.

- Learners then look at a further range of external factors which, although not regulatory, can have an impact on the design of an engineering product. Look at engineering products that are considered to have a marketing advantage over competitors' products. This will allow learners to consider the unique selling point of a product, or the benefits of the design for the potential consumer. For consumer electronic products, there could also be some consideration of obsolescence as a method to stimulate the market. Finally, learners could again work collaboratively to consider a number of products that they can analyse with respect to their performance requirements and possible manufacturing considerations. This should include an analysis of both the processes used during manufacturing and the need to consider how a product would be manufactured or assembled whilst being designed. When producing this performance and manufacturing analysis it would be appropriate for learners to use statistical methods in order to present their findings on a range of performance requirements of the product and the range of manufacturing processes needed to ensure a high-quality product is produced.
- In summary, offer learners the opportunity to complete a number of revision activities where they can develop a product design specification which considers the customer and external influences, and allows designs to be produced that would fulfil the requirements of the design brief.

Learning aim B: Use an iterative process to develop ideas and a modified product design

- The focus of learning aim B is for learners to use an iterative process in order to develop a range of ideas which will lead to a modified engineered product.
- As with learning aim A, there is the opportunity to take advantage of industry links in order to deliver learning aim B. To address this learning aim, begin by introducing a range of presentation techniques that learners will potentially need to employ when presenting their design proposals. Address this by initially presenting the techniques to learners, with the use of practical exercises by learners to refine their skills. This could then be followed by a review of graphical presentation techniques used when presenting design propositions to potential clients.
- Once you have covered the presentation skills required of learners, you could then introduce a simple design challenge. This could be in the form of a product design specification that learners can use to produce a range of initial design proposals. These could then be refined with respect to the criteria. You should emphasise the importance of creativity in learners' design work, and that any designs that are produced should be in the correct context.
- Give learners suitable design opportunities that will require them to refine and develop their concepts generally, with the need to carry out further secondary research. The use of an iterative approach to design should be encouraged.
- A number of similar design tasks could be used to develop the design skills of learners prior to them producing a developed design idea. You could prepare learners for the production of a developed design by considering each of the criteria that could be included in the design, explaining to learners that much of this information can be shared using detailed and concise annotation. Review the level of understanding of material properties and manufacturing processes that learners may have developed through their studies in other units. Expand upon this knowledge with reference to the need to select materials and manufacturing processes for engineering applications that have the properties required to fulfill the design requirements. You could set either individual

research activities or group tasks where research skills could be developed. Existing products could be used to consider the materials used, and therefore the properties of these materials, with surface treatments and finishes and how the product will be form also considered.

- Look at the linkages that are used within engineering systems along with the potential sources that could be used to power these systems, and the related control systems used to manage power transmission. Try to set up a visit to an organisation where power transmission systems are manufactured, or use video resources to demonstrate to learners how mechanical power is transmitted.
- As a final preparation for their Pearson Set Assignment, you could give learners a further design brief which they will interpret into a set of requirements, opportunities, constraints, health and safety factors and sustainability considerations; they can then subsequently produce ideas, and develop a design proposal that will be presented using a range of appropriate design documentation. The product to be designed need not be complex, but it must offer learners the opportunity to be able to refine an idea prior to presenting it as a design solution.
- Learners will also need an understanding of the manufacturing processes that are used for a range of materials. If possible, arrange for learners to visit an industrial partner where manufacturing processes are carried out, as learners will observe first-hand how products are manufactured. Similarly, there is scope for the use of video resources to illustrate to learners a range of manufacturing processes.

Learning aim C: Generate technical justifications and validations for the design solution

- Learning aim C draws together the design process with developed designs and solutions being justified and validated against a set of criteria. Approach this unit by giving learners examples of products along with their related product design specification. They can then analyse the products with respect to the PDS to validate the success of the design and the clarity of the specification. As previously, this can be done in partnership with an industry partner who could give learners examples of products and related documents. You could use the same products to consider the validation of the designs with respect to a weighted matrix, comparing the results to determine if there are any differences. Moving forward on this topic ensure that learners investigate the indirect benefits and opportunities that the products which they investigate have when in use. This could be demonstrated by yourself with the provision of an investigated product which has indirect benefits to internal or external users. For example, vehicles with low carbon emissions have reduced taxes for consumers and reduced tariffs for manufacturers.
- Task learners to consider the wider implications of product use when generating technical justifications and validations for products. Ensure that they investigate the products in enough depth to justify how improved features should be balanced with possible constraints and limitations, particularly when reflecting upon the aspects which cannot be re-designed. Discuss with learners the concept that improving a product for one reason will often have other benefits, and the overall benefit of redesigning or developing a new product should be considered with respect to the costs. This could be considered by learners using case studies, for example, hybrid or electrical technologies used in vehicles could be considered with the principle goal being the environmental benefits caused by a reduction in emissions. Learners then consider the costs of developing these technologies and any indirect benefits that have been achieved as a result. Learners also reflect on the constraints and limitations which may be presented as the product is manufactured and

sold. Example questions could be: what is the life cycle of the lithium batteries required to power these vehicles? What are the environmental implications of the mining required to gain access to these resources require to manufacture the power source?

- Finally, give learners a final design challenge that could be based around the sample assessment materials or a past Pearson Set Assignment. They should follow the design process through from the beginning by interpreting a given brief. An iterative approach should then be taken to produce a developed design proposal that is finally validated with regards to the brief. You can also give learners the opportunity to suggest further refinements to their solution, which could be based on modern materials, or other technology-led developments, along with a consideration of how the product would be manufactured.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This mandatory unit links to most other units in the suite of qualifications, including:

- Unit 1: Mechanical Principles
- Unit 2: Delivery of Engineering Processes Safely as a Team
- Unit 4: Applied Commercial and Quality Principles in Engineering
- Unit 5: A Specialist Engineering Project
- Unit 6: Microcontroller Systems
- Unit 7: Calculus to Solve Engineering Problems
- Unit 32: Computer System Principles and Practice
- Unit 39: Modern Manufacturing Systems
- Unit 48: Aircraft Flight Principles and Practice
- Unit 57: Electrical and Electronic Principles

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International in Engineering. Check the Pearson website (http://qualifications.pearson.com/endorsed-resources) for more information as titles achieve endorsement.

Textbooks

- Baskinger, M and Bardell, W, *Drawing Ideas*, Watson-Guptill, 2013, ISBN: 9780385344623.
  This focuses on design and communication methods and techniques.
- Childs, P.R.N., *Mechanical Design Engineering Handbook* (2nd edition), Butterworth-Heinemann, 2018, ISBN: 978-0081023679.
  Reference materials on design, specification selection and a wide range of engineering processes.
- Gibson I, Rosen D and Stucker B, *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing* (2nd edition), Springer, 2014, ISBN: 9781493921126.
  This resource covers a wide range of additive manufacturing methods in detail.
- Johnson, A and Gibson, A, *Sustainability in Engineering Design*, Academic Press, 2014, ISBN: 9780080993690.
  Features a range of techniques to use in engineering design, including an iterative approach.
- Jones, D.R.H. and Ashby, M.F., *Engineering Materials 1: An Introduction to Properties, Applications and Design* (4th edition), Butterworth-Heinemann, 2011, ISBN:

9780080966656.
Key information on materials science and engineering.

- Mitchell, B, *An Introduction to Materials Engineering and Science for Chemical and Materials Engineers*, Wiley-Blackwell, 2005,
  ISBN: 9780471742098.
  A comprehensive range of engineering materials are covered, along with an iterative design approach.
- Robertson, M, *Sustainability Principles and Practice* (2nd edition), Routledge, 2017,
  ISBN: 9781138650244.
  A comprehensive overview of the interdisciplinary field of sustainability.

Videos

For a useful range of video resources, visit video sharing websites and search for the following:

- 'Additive manufacturing BMW'
- 'The power of 3D additive printing' - General Electric
- 'Sustainability in Engineering'
- 'Materials Engineering'
- 'Koenigsegg channel' - A range of videos on modern design and manufacture

Websites

- Visit gov.uk Intellectual property office for official guidance on copyright, designs, trademarks and patents.
- The James Dyson Foundation contains many resources that relate to an iterative approach to design.

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling students to access them through the school/college intranet.