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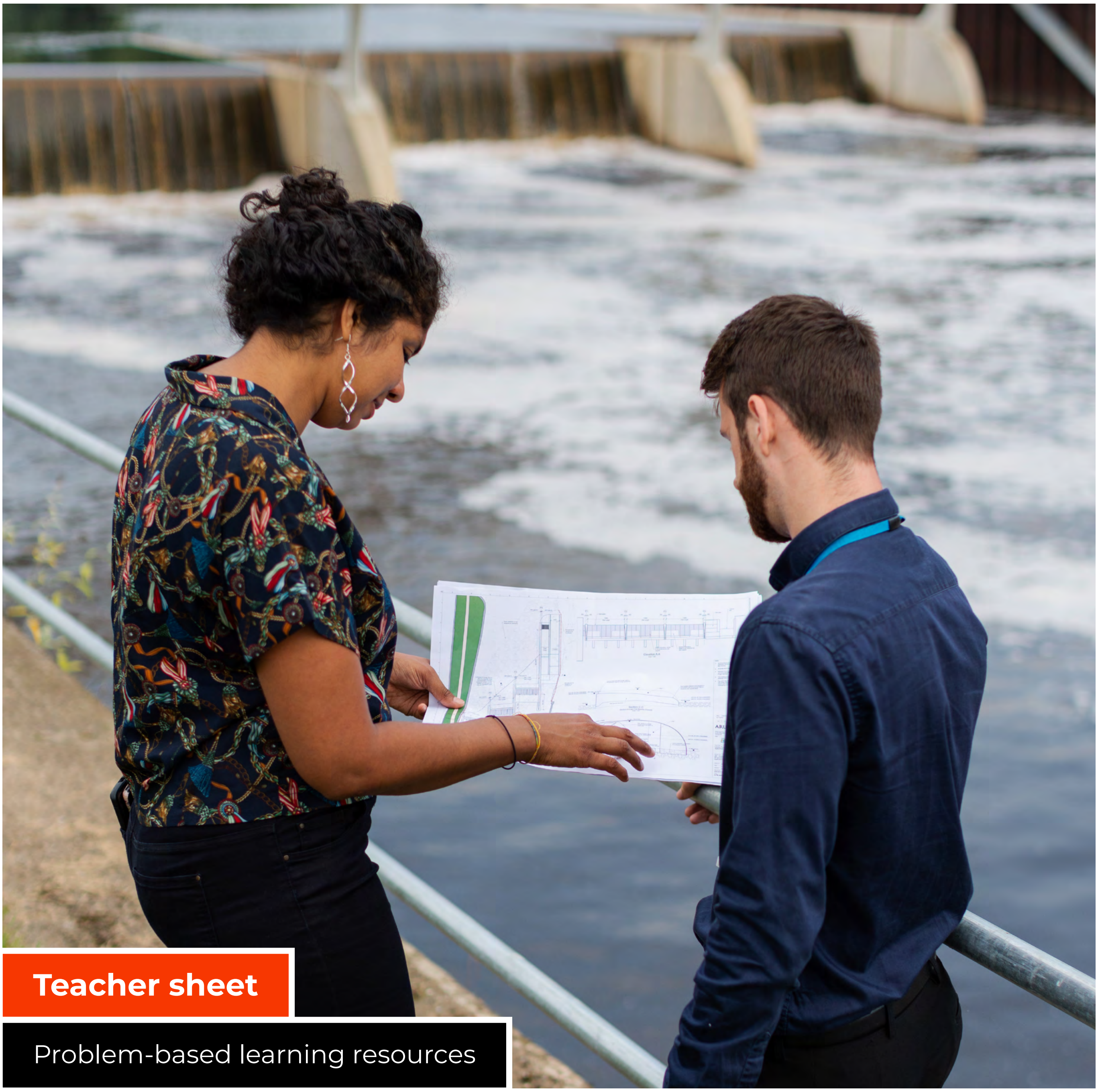
5 Engineering opportunities



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Teacher sheet

Problem-based learning resources

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Project brief and variations

This project emphasises the creativity and teamwork underlying all successful engineering projects. Through a series of activities students are introduced to a range of creativity techniques and team working skills and are given an opportunity to work through an engineering design cycle concerning a project they identify in their own area.

The project can be deployed in 2 forms:

- a shorter (8-10 hours) sequence focusing on practising skills
- a longer (approx 30 hours) project that uses those skills to create a new product

Both options adopt a common sequence, the engineering design sequence, as shown below in **Figure 1**. The CODIFY and PRESENT components are focused on clients (in this case the students themselves) and their circumstances while the PLAN, PERFORM and REVIEW processes tend to be internal to the engineering team. This process is often shown as a cycle (the output from one cycle providing an input to stimulate another) and, while the project resources are based around a global arc from CODIFY to PRESENT, teaching and learning will inevitably involve some smaller repeated cycles, or cycles with some components omitted for convenience, throughout the 30 hour project.

Exemplar tasks are mentioned to support students who might be finding it difficult to formulate a way forward but these are only examples of what might be possible rather than mandatory requirements. Students should be encouraged to develop their own work plans, within the limits imposed by the relevant specifications and college timetables, to prepare them better for the world of work.

Project resources

Student resources

The Students booklet gives details of the proposed context and a series of forms to fill in during the project work. This will help to form a record of their progress.

Individual sheets offering support with particular topics or techniques are also available and can be made available at appropriate points in the project.

Teacher resources

The Teacher resources are provided in a single file and describe the teaching approach used to drive the project. Each context an be interpreted to support particular T-level qualifications (Design and Development (D+D), Maintenance, Installation and Repair (MIR) and Manufacturing, Process and Control (MPC). They equally work well with other technical qualifications. The following parts of the project are common to all three pathways and derive from the context:

- **Project overview:** a simple overview of the content in terms of the relevant core skills from the T-level engineering specifications with a suggested schedule.
- **Learning focus:** the purpose and emphasis of the project in general terms.
- **Success criteria:** illustrative success criteria at three levels for students.
- **Exemplar tasks:** examples of the kinds of tasks suitable to deliver and demonstrate learning linked to the T-Level Core Skills.
- **Teaching sequence:** advice on lesson management including suggestions for formal outputs that can evidence student achievement.
- **Resources:** materials to support particular tasks.

Learning focus

This project will focus on students' abilities to:

- Recognise problem or opportunity that is amenable to an engineering solution.
- Identify the features of a proposed solution, expressed in terms of benefits to potential users.
- Formulate a plan to deliver a solution that reflects the resources (materials, equipment),

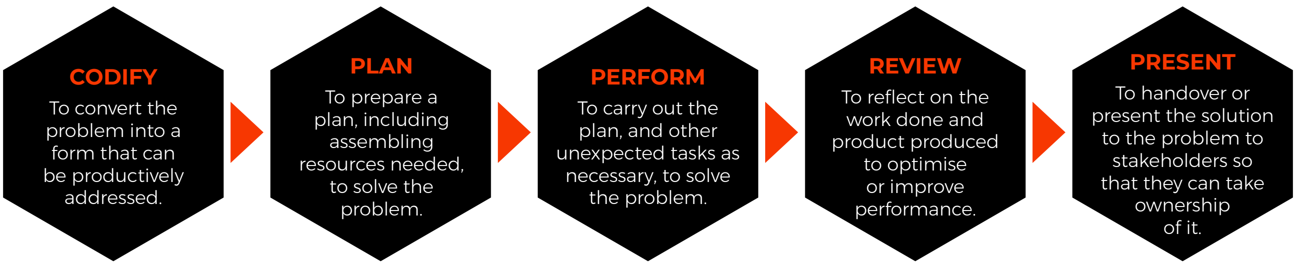

Figure 1: The Engineering Design Process

people (knowledge and skills) and time available to deliver it.

- Review their proposed plan for compliance with Health and Safety requirements and any relevant, explicit ethical considerations.
- Reflect on their experiences identifying key learning and suggesting ways yo develop their knowledge and skills further.
- Report to others (e.g. supervisors, clients) appropriately and within the agreed timeframe.

If the project is run over 30 hours a PERFORM focus is also available:

- Implement their plan responding as required to unexpected problems or changes in circumstances to ensure a satisfactory outcome (even if different from the original plan).

Success criteria

Assessment opportunities across the project will allow all candidates to practise key skills and gather evidence of success in the general competencies and their increasing background knowledge.

The statements in **Table 1** below are examples of the typical achievements at three levels of achievement. They can be edited and added to during the process and not all students will be expected to hit all outcomes – they should not be seen as a simple checklist to tick.

Table 1: Success criteria

INCREASING SOPHISTICATION →		
All students will:	**Most students will also:**	**A few pupils will also:**
Recognise a clearly-defined problem.	*Draw out the key issues in a scenario to codify a problem to be solved.*	Consider competing interests in formulating a problem so that multiple strategies to solve it can be suggested.
Use 'common sense' insights to solve a problem.	*Consciously and explicitly use their existing engineering knowledge and skills to solve a problem.*	Recognise relevant gaps in their existing engineering knowledge and skills and explicitly seek to fill these in order to help with producing a valid solution to a problem.
Collect useful data and modify this raw data as appropriate (e.g. calculating averages, graphing) prior to communicating the data in a report.	*Design a valid experimental procedure to generate valid, reliable and useful data.*	Modify their experimental procedures to solve problems as they emerge during the activity explaining why their new approaches will produce more useful, valid data.
Justify their strategy decisions by reference to collected data and the original project brief.	*Justify their strategy decisions by reference to their existing engineering knowledge and skills, collected data and the original project brief.*	Recognise that the first solution to a problem may not be the best and seek to optimise and finesse their initial ideas and products to improve performance. Make decisions between competing priorities (e.g. cost and performance, ease of replacement of components and waste production).
Contribute to a shared report taking personal responsibility for an indentifiable component (e.g. digitising calculations with a spreadsheet, producing graphics or specific items of text).	*Present a report that is constructed to reflect the needs of the audience.*	Manage the delivery of the report answering questions and taking suggestions for future developments as appropriate.
Provide and receive respectful, honest and helpful feedback within their teams.	*Modify their behaviour / approach in the light of respectful, honest and helpful feedback.*	Support other team members as they seek to modify their behaviour or approaches.

Teaching sequence

CODIFY (2 hours)

Exemplar tasks

- Students conduct a review of their local environment looking for opportunities to use their engineering skills to improve it (e.g. improving power supplies in workshop, installing a network of wifi repeaters, designing, building and installing installing secure storage facilities)
- Students conduct a survey amongst their peers to identify issues or problems with the provision of facilities in their workshop/department/college.
- Students liaise with other departments (e.g. art, health and social care) to look for tasks where engineering knowledge and skills could be used to make things better (e.g. creating a public artwork, upgrading the alarm system for a care home).

Teaching strategies

This project emphasises the processes of engineering so students can use any technology or materials they want to realise their plans. This opens can be demanding so start the project off by encouraging them to think about what they might do, as engineers, in their workspace or classroom. Emphasise the need to think as 'engineers' rather than just agreeing to a quick paint job! The kinds of opportunities an engineer might see around them:

- How can my workplace be made more stimulating or comfortable to work in? Can I upgrade the power supplies? Or improve the seating? Or add a drinks machine?
- Everyone tells us to recycle our rubbish – but no-one makes it easy! How can I develop a system to collect and sort school, college or workplace rubbish to prepare it for efficient recycling?
- We have a great lecture theatre with a large stage. It would work really well as a theatre for concerts and plays … but the lighting is poor. How could we design and build a suitable lighting and stage rig so that the theatre can be used for other purposes?

The opportunities above, and problems they embody, are typical of real world, 'messy' situations with a range of complexities. These require organising and understanding before any significant planning can occur and so differ from standard problems often presented in training contexts. Codifying involves identifying key factors, including the range of potential stakeholders, in a complex situation to allow engineers to prioritise work in a given situation. Codifying a situation involves three stages:

- recognising a problem or opportunity – where are we starting from?
- identifying success – where do we want to end up?
- selecting a strategy – how can we get there?

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Recognising a problem or opportunity

This is understanding where we are starting from. Ask students to review their local environment and identify problems to solve or opportunities to improve things. It depends on divergent thinking.

A whole class brainstorm is one way to do this – manage the brainstorm carefully and ask students to write down their ideas in advance for two or three minutes before the brainstorm itself. This helps to prevent the loudest and most confident students from dominating the activity.

Alternatively students could work in smaller groups to generate a range of options. These can then be shared with the whole class.

Spending time in the problem context (e.g. visiting the site, taking photographs and speaking to stakeholders) is a useful pre-activity. The photographs can be used to construct a display of the problem space to stimulate thinking back in the workshop.

Identifying success

This involves describing where we want to end up. For example, if the issue raised is that the workshop has poor power supplies or inadequate lighting success would be defined in terms of the optimal number of power sockets (taking cost of installation into account) or where lighting systems need to be installed (e.g. in areas that involves working with very small components). At this stage the mechanics of how to get to the desired situation is not important – that will be explored in the next stage.

Selecting a strategy

The strategy is the initial 'big picture' plan that identifies the initial direction rather than the detailed steps. Encourage students to think at this level first. They should select the project they most want to pursue (the brainstorm should have generated many candidates) and suggest approaches that they think will be most productive. This focussing down from the wide range of possibilities to one or two choices is an example of convergent thinking and is complementary to divergent thinking.

The chosen options may deal with the most important problem, or be the option that utilises existing strengths or shows the greatest chance of successful completion. There is no single correct answer but make sure that any chosen option can be justified by reference to explicit criteria.

Output and evidence

The output from this stage should be a list of possible projects ranked by some explicit criteria to generate one or two candidates for future development. The final outcome of the project should be described in detail in terms of benefits to identified users (e.g. this will improve the networking for the laptops and make it easier for students to access technical documents online when working in the workshop) rather than features (this will increase the number of wifi repeaters by 50% on current levels). This could be evidenced by:

- A written description or presentation of the issue to be tackled, justification and proposed benefit to identified users.
- An documentary account (text, images, audio and video) of evidence gathered with notes showing the significant insights generated.

Useful resources

3: Environmental assessments. Considering the environmental impacts of a project (e.g. building a new gigafactory to make batteries) or change (e.g. a switch to EV cars) in the immediate and medium-term and for the local area and more widely.

10: Knowledge inventory. Identifying the knowledge base appropriate to a project and the likely future needs.

19: Conducting site surveys. Conducting a site survey for a construction project (e.g. cliff railway, EV charging station, temporary building) or installation (e.g. installing a computer server , refrigeration unit) taking measurements of key features to produce a detailed map with significant measures clearly marked.

25: Engineering design cycle. Using the engineering design cycle to stimulate creative solutions to problems.

28: Creative thinking. Using divergent and convergent thinking approaches to become more creative.

PLAN (2 hours)

Exemplar tasks

- Students identify the detailed steps in a plan to solve a specified problem or develop a novel product to an agreed specification.
- Students show how the relevant staff, equipment and materials will be involved in the project.
- Students describe how any Health and Safety issues will be addressed providing details of any Personal Protective Equipment or safety procedures required.

Teaching strategies

By the time the planning stage begins students should have a clear view of the issue they are going to address and what they want to achieve. Planning how to achieve this involves three stages:

- reviewing the resources (people and equipment) available to develop the project
- generating a sequence of tasks and a schedule for completion
- Health and Safety, ethical and sustainability issues

Reviewing the resources

Problems or opportunities imply making changes and these changes can be demanding. Ask students to review the knowledge and skills they currently have that are relevant to the planned activity, identify any deficiencies and suggest ways to deal with these deficiencies (e.g. consulting an expert or an instruction manual). Simple, familiar projects might just involve a list of components (e.g. 20 power sockets, 10m of electrical cable etc.) and a degree of knowledge and skills (e.g. workers qualified to work with electric power supplies). More complex projects in unfamiliar contexts will probably involve listing skills or knowledge that they do not currently have and this can make ordering kit difficult. The worksheet **27: Planning projects** can help to identify these requirements.

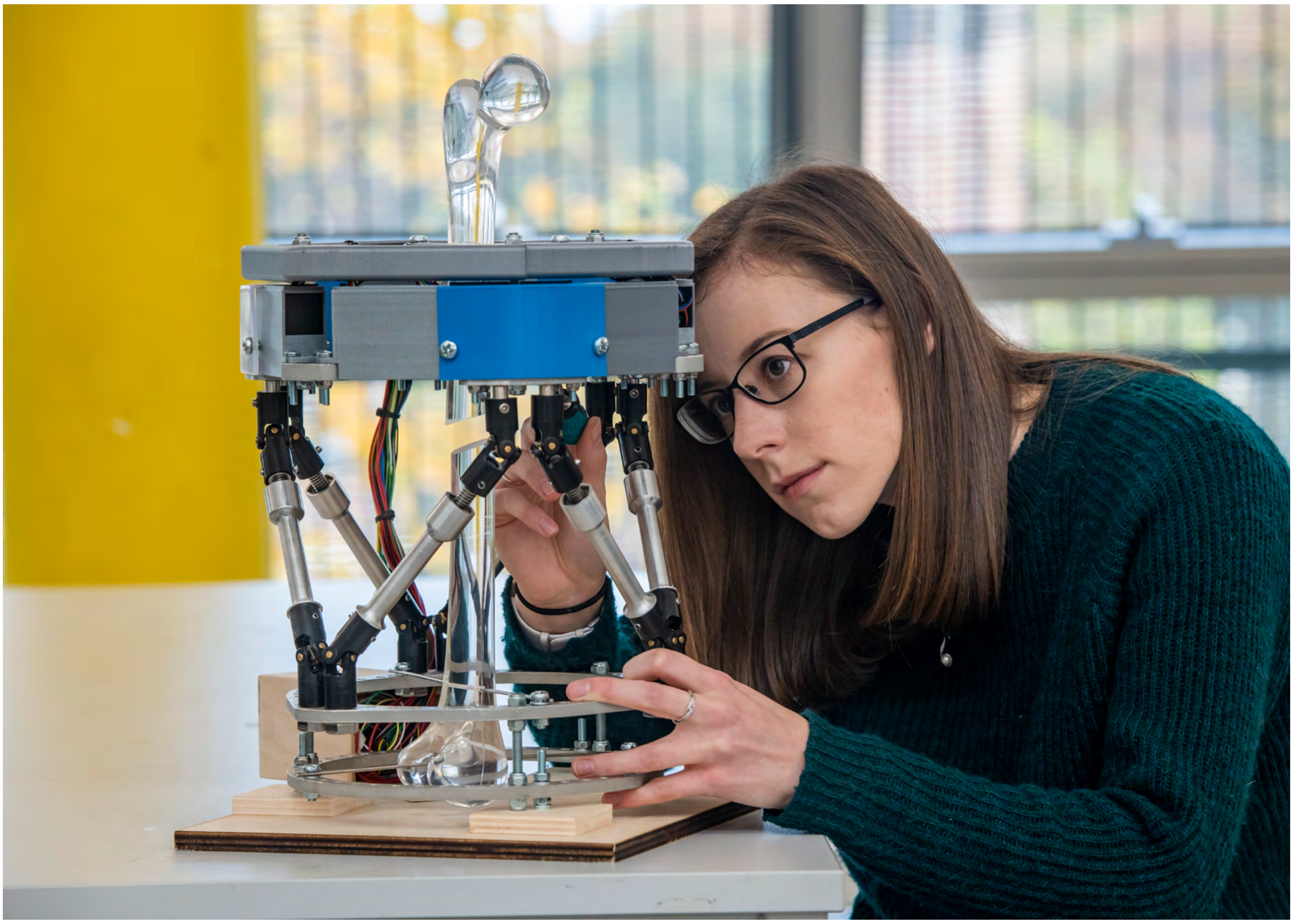
At the end of this stage students should have a clear view of what resources (material, equipment, people and skills) they need to complete the project.

Generating a work sequence

Once students know what they need, they can start to organise the tasks that make up the project into a sequence including indications of time required for each task. When working in teams, these tasks might be shared out within the team to maximise efficiency and some tasks may require more than one person working on it while others are simpler and need only a single person.

As part of the planning process, students should identify and agree roles within the team. Take this opportunity to stress the fact that most engineers work in teams and depend on others making their contributions to complete their own work. Ask students to consider how workplaces can be organised to reinforce this team spirit – this provides a useful opportunity to discuss rights and responsibilities in the workplace – everything from punctuality to pay! It would also be a useful time to remind students that they depend on a larger team than the colleagues who work alongside them. Other people in the company might be managing orders, arranging deliveries and liaising with the client company to facilitate access etc.

At the end of this stage, students should have a clear plan of the task sequence, who will be responsible for each task and when they need to complete their work.



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Health and safety, ethical and sustainability issues

Health and Safety (H+S) is a key consideration for all engineering projects and should be addressed at the planning stage. Unsafe practices are both illegal and immoral and students should not plan to do anything which puts themselves or their colleagues at significant risk. However, encourage them to see H+S as a positive exercise allowing them to identify any potential risks and choosing safety equipment or appropriate procedures to minimise these risks. This may involve their work being approved by a supervisor before the work begins.

It is also useful to conduct a risk assessment to explore what might go wrong, ways to make this less likely or less damaging and, if possible, think about possible alternative ways forward if the problem does occur.

Engineering projects have a social and ethical dimension and students should be encouraged to consider these during planning. Some projects may appear innocuous while others may raise very significant ethical or sustainability issues. As with H+S, encourage students to see these not as negative issues but as chances to modify their plans to become more ethical (e.g. in sourcing of materials, ways of working with others) or sustainable (e.g. reducing waste production).

At the end of this stage, students should be confident that their prosed work programme follows all relevant ethical and sustainable policies and is safe to complete (this may involve access to suitable safety equipment).

Output and evidence

The output from this stage should be a clear plan that identifies key problems, contains a sequence of tasks with an expected schedule for completion to deliver the proposed solution and roles and responsibilities of all in the team. This could be evidenced by:

- A safety document showing the key risks and how these can be minimised by the use of Personal Protective Equipment and suitable safe procedures. A selection of relevant rules to observe when carrying out a task can show students' understanding.
- A plan for a typical job showing the knowledge and skills involved, the tools, any replacement parts, any access issues and a full breakdown of safety issues with a risk analysis.

Useful resources

2: Risk analysis. Conducting a risk analysis for a process or project and identify key safety practices and equipment that would be necessary (legally) and advisable (good practice).

13: Setting SMART objectives. Reviewing the characteristics and use of objectives to drive development.

14: Avoiding crises. Identifying priorities and strategies for work .

15: Rights and responsibilities. Identifying key rights and responsibilities in the workplace and how they affect working life.

16: Managing meetings. Facilitating a meeting to explore possible solutions to a problem, generate a decision and a report with clear recommendations and their justification.

17: Working in teams. Developing strategies for successful team working – and suggesting behaviours which can undermine teamwork.

PERFORM (2 hours or 15 hours)

Exemplar tasks

- Carry out a specific task (e.g. wiring a single power supply socket in situ, constructing a simple prototype to test one part of the device) related to the plan maintaining a reflective attitude at all times to note problems, progress and learning.
- Create a new prototype product or system to solve the identified problem.

Teaching strategies

If this project is skills-focussed and working to a tighter timescale (8-10 hours) students should review their plans, pick one task and perform it.

It is possible to complete this project within 30 hours and students should complete all their proposed tasks to produce a viable product. It is also possible to use this project as a skill-development exercise and take a shorter timescale. In this case, ask students to conduct one or two exemplar activities that will allow them to test their plan and respond to any unexpected problems.

Students should be managing their own activities as much as possible during this task so the role of the teacher is as a facilitator supplying expert knowledge and skills (e.g. demonstrating specific items of equipment, explaining the results of a diagnostic test) when required and general encouragement. Encourage the students to take responsibility for both the task completion and team cohesion so watch out for one or two members taking over and doing everything while the others are excluded – or complained about!

Inevitably engineering projects throw up problems and difficulties as they progress so encourage students to constantly review their methods to ensure success. At the same time, if a good approach does not work the first time because of unforeseen circumstances (e.g. staff or team absence) or bad luck (e.g. a piece of equipment is faulty) they should repeat the work rather than give up and try something else. In all cases, students should be able to justify their decisions about changes to their plan when challenged.

Students may need help to reflect informally and continuously on their practical work as opposed to simply waiting for formal assessments or appraisals. Ongoing, continuous reflection is known to maximise learning from a task. Help them to do this by asking them to keep a logbook to document their progress (e.g. through simple photos with their phones) and make reference to this document regularly. All their work will still have to be checked to make sure it has been completed to the required standard (compliance with specification and safety) but encourage a parallel, and continuous, reflection on their performance.

Output and evidence

The output from this stage should be a record of their activities showing how they fitted into the overall plan. A clear description of any proposed solutions to the identified problem should be provided with any decisions justified in terms of engineering knowledge and skills and any supporting data from the practical work. This could be evidenced by:

- A flow chart showing the tasks completed and how they relate to the proposed product. The chart should be illustrated with photographs or real data to show safe and functional conditions.
- A logbook with an account of the project with notes that show the student has reflected on the process, picked up any potential problems and organised themselves effectively to complete the task to the required standard and within the specified timescale.

Useful resources

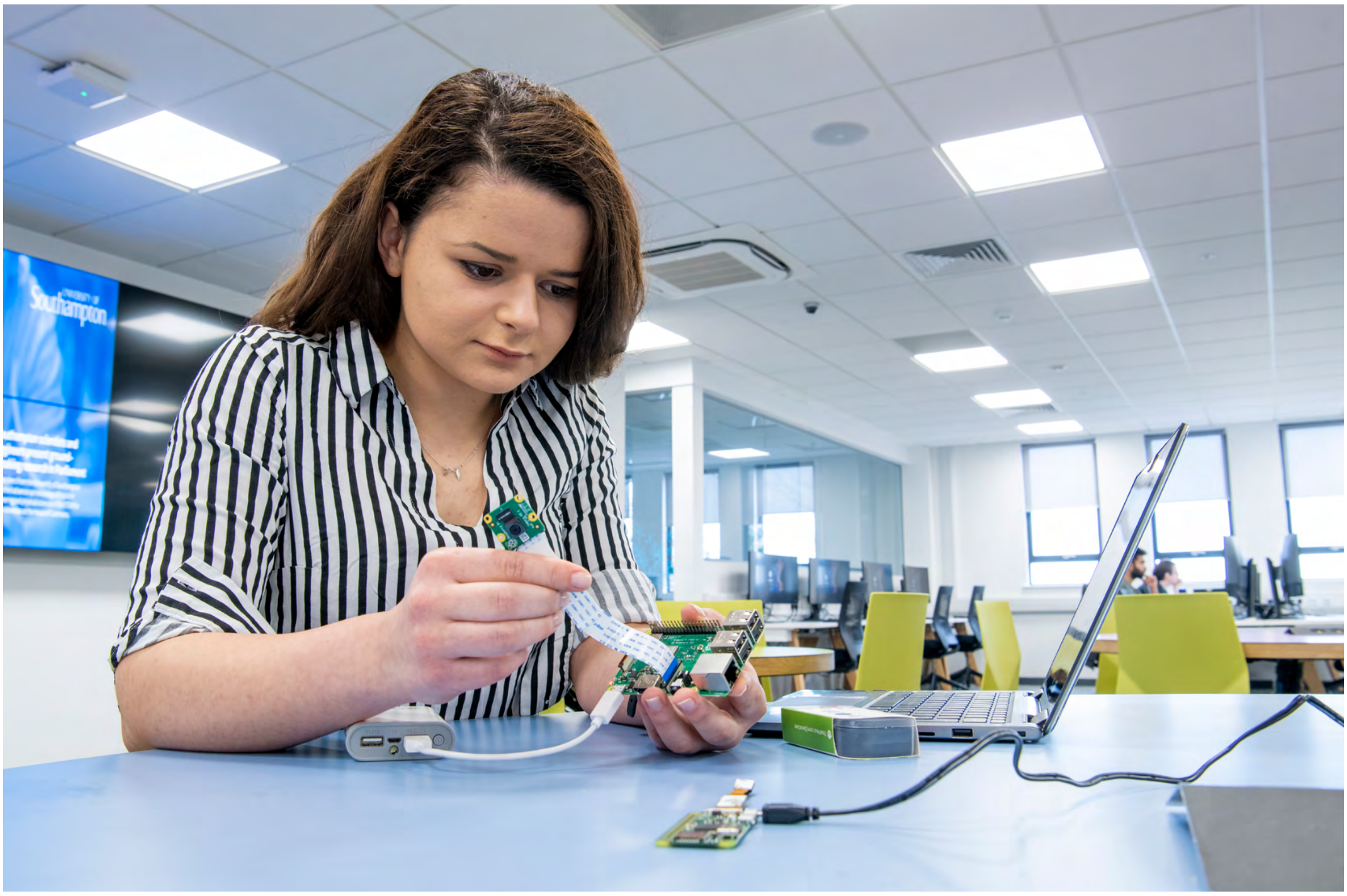
5: Working with shape and space. Calculating volume, height, angles of corners, articulations of a 3D shape (e.g. an incubator, temporary building, storage containers) based on measured or published data.

6: Using mathematical formulae. Calculating safe working parameters for structural components (e.g. incubator trolley, temporary building roof or struts) based on measurements of properties of materials and published data.

7: Converting between units. Converting between different measuring units as appropriate (e.g. Celsius to Fahrenheit or Kelvin, meters to inches, metres to millimetres or kilometres) .

17: Working in teams. Developing strategies for successful team working – and suggesting behaviours which can undermine teamwork.

18: Prioritising projects. Deciding which parts of a project or work package should be done first.



REVIEW (1 hr or 4 hrs)

Exemplar tasks

- Students review their activity and comment on it showing how they used their engineering knowledge to perform any tasks considering the resilience of their plans and any potential crises in the light of their experiences.
- Students reflect on their team's and their personal performance and consider options for improvement in the future.

Teaching strategies

Remind students that there are two aspects to any review of work completed: a check that the task output is up to specification (e.g. 'is the circuit functional?', 'is the motor fitted securely?') and a reflection on the performance of the individuals and team (e.g. 'did everyone know what they were supposed to do?', 'did the team work well together?'). This 'task' and 'team' perspective is important and, while the judgements must be clear and supported by evidence, the emphasis should be on development and strategies for improvement rather than simply aiming for a 'met/not met' judgement about preset success criteria or a notional mark out of ten.

The review should compare the whole project against the original problem codified by the students. To what extent have they met their original objectives and what compromises have they had to make? Have they now changed their understanding of the original problem even if they have not been able to produce a definitive solution? This is best done as a small group activity focussing on the impersonal aspects of the task rather than the performance of individual team members. This 'task' review will also provide material that can be fed into the presentation that forms the final part of the project.

Each student should also be asked to reflect on their personal performance and identify successes, surprises and scope for change. The particular tasks in the workshop can provide a useful focus for this activity. It can be quite intimidating for students with low self-esteem or confidence issues and, equally, can encourage the over-confident to bluster and assume that they are doing very well! More formal self-reflection structures and support systems at the start of the course can help to get students used to this type of activity and identify those that may need more support. Eventually all students should be able to reflect on their personal performance, give and receive respectful, helpful feedback and identify ways in which they can improve. Peer review activities are useful but should not be used until you know the class well – probably after they have also completed some structured activities on giving and receiving feedback.

Output and evidence

The output from this stage should be an assessment of the extent to which the identified problem has been solved, or clarified, or the proposed product has been developed. The assessment should take into account the needs of the various stakeholders in the original context and identify any compromises or negative impacts that will occur if the proposed solution is implemented. As part of the process students should also engage in self-reflection, supported by peer and teacher comments as appropriate, to identify possible ares for development. This could be evidenced by:

- An statement agreed within the team, and potentially by an external adjudicator, related to the original context, the problem identified and any other relevant parameters (e.g. schedule, budget) about the degree of success of the project. The statement should be backed up by objective evidence.
- A personal statement, possibly in a log book, of the lessons learned during the project including technical material (e.g. knowledge of electric motors, power calculation skills), team aspects (e.g. working with others, managing conflicts) and personal insights (e.g. 'I work better in the morning', 'I tend to put off work until the last minute and then panic'). This account should include a suggestion of a way to develop an aspect of their work in the coming project.
- A laboratory or workshop logbook can provide a useful record of work done and support conversations about performance between teacher and students.

Useful resources

11: Providing and receiving feedback. Providing respectful, honest and helpful service to a colleague, subordinate on a product or service.

12: Reflecting on your performance. Reflecting on performance – how self-reflection can help development.

13: Setting SMART objectives. Reviewing the characteristics and use of objectives to drive development.

PRESENT (1 hour or 3 hours)

Exemplar tasks

Students present a review of their project with any accompanying data, calculations and risk analysis and respond to questions posed by their teacher or work colleagues client.

Teaching strategies

If the previous Review section was inward-looking for the team and individual this PRESENT section is outward-looking and involves presenting the work to others. The work is best done in teams but all members of the team should have a clear role and present an aspect of the project by themselves.

Presentations are typically digital and students often waste more time on transitions, colour choices and digital tricks than the important content of the document. Encourage them to review the original scenario and problem and explain that the presentation must show how this problem has been solved and provide full justification for any decisions made – especially if they are surprising and forced on the work by new data (e.g. power consumption by an electric motor) or changes in circumstances (e.g. a rise in expected traffic or a change in budget).

Presentations should have a time limit which must be enforced – a one-minute warning can be helpful but stick to the time agreed. It is also helpful for students to offer a slide count limit as well – one slide per minute is reasonable, three slides per minute is impossible. The surest way to fail with a presentation is to have too many slides to fit into the time slot allocated and start rushing – inevitably, important information is left out!

The presentations can be to the remainder of the class, a senior member of staff, college visitors invited specifically for the task or a combination of all three. Experience of presenting to local employers is particularly valuable – but maybe towards the end of the course when students have had chance to hone their skills.

Output and evidence

The output from this stage should include a presentation and technical document created for a specific audience.

This could be evidenced by:

- A team-based presentation of the strategy, the considerations that helped form the strategy and its likely impact on a variety of stakeholders (e.g. motorists, EV station operators, maintenance engineers) and a statement on the environmental costs and sustainability of the proposed strategy.
- An illustrated 'walk through' of a particular repair or replacement task to showcase an individual candidate's individual skills. This document should also provide any diagnostic data that would stimulate the repair and explain the implications of not carrying out timely maintenance.

Useful resources

20: Making a pitch. Preparing a pitch or proposal for a piece of engineering work (e.g. a cliff railway, production facility).

21: Delivering a presentation. Present a pitch (e.g. a cliff railway, production facility) to a body that will make the decision on basis of needs, costs, suitability, sustainability.