2 Keeping preterm babies safe

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Teacher sheet

Problem-based learning resources

The **Royal Academy of Engineering** is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

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Project brief and variations

The safest place to be born is in a well-equipped and well-staffed hospital. If anything goes wrong or the baby comes early staff and equipment are present to help. However, this is not always possible and babies can be born early and in distress for a number of reasons: war zones, disaster aftermaths or even a simple accident. This project looks at an incubator which can be rapidly deployed to these situations and ensure the baby gets suitable care and protection for as long as is required to get them to safety.

Maintenance, Installation and Repair (MIR) candidates will develop a simple alarm system to indicate any problems with the incubator (e.g. battery failure, falling temperature) or the baby (e.g. rising temperature, lack of movement). They will show how the sensors and control system work together to ensure both incubator integrity and functioning is stable and that the baby will be kept safe by the equipment. They will look at how this can be done onsite and remotely and suggest preemptive maintenance strategies to ensure 24/7 functioning of the incubator.

Manufacturing, Processing and Control (MPC) candidates will design and test the ‘shell’ of the incubator that will hold the baby safely. The material used must be light, strong, transparent and easy to manufacture and clean. They will identify and test suitable materials and assess how easy they would be formed into the required shape during manufacturing and repair in the event of damage. The likely failure rates and a selection of suitable replacement parts, with a maintenance strategy that can be implemented by non-skilled workers, will be described in a clear plan.

Design and Development (D&D) candidates will specify the size, shape and weight of the incubator based on needs of intended users (baby and medical staff). They will identify the key factors needing monitoring to ensure baby health and produce at least two possible designs: a simpler, cheaper version suitable for most preterm babies and a more complex device for very high-risk or small babies with multiple needs.

The projects are organised around a version of the engineering design process as shown in **Figure 1**. The CODIFY and PRESENT components are focused on clients 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 can 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

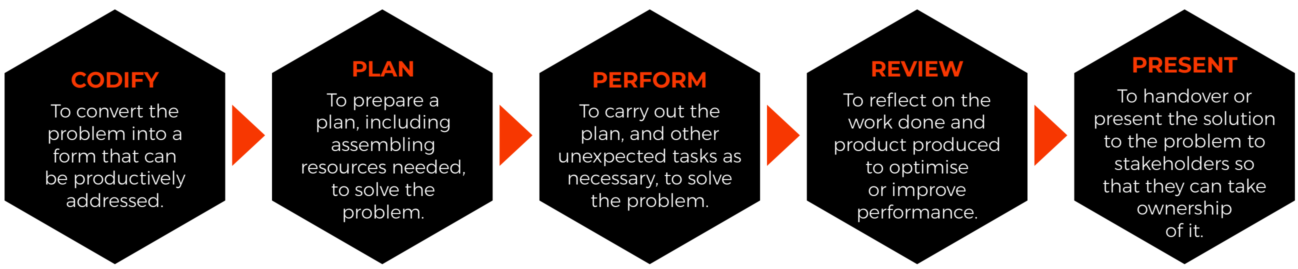

Figure 1: The Engineering Design Process

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.

The following extra details are supplied for the MPC pathway in the Keeping preterm babies safe project:

- **Teaching sequence:** advice on lesson management including suggestions for formal outputs that can evidence student achievement.
- **Resources:** materials to support particular tasks.

Project deployment

The full project is a time-consuming endeavour (roughly 30 hours of teaching time). This provides significant learning benefits, particularly in terms of student self-management, by giving time for greater exploration and optimisation. However, this is not always possible. Two options are possible to solve this problem:

1. Provide some of the material needed for the project directly to students, e.g. giving them a pre-built plan rather than asking them to develop their own, supplying experimental data to analyse rather than asking students to plan and carry out an investigation to generate their own. This allows the teacher to explore particular aspects of a project or try out interesting approaches without committing to the whole project.
2. Opting for a slightly modified project with a smaller scope. Again, these will not allow the full skill development of the whole project but can focus on particular aspects of the process where students need extra support. Examples are given in **Table 1** below.

Learning focus

This project will focus on students' abilities to:

- Audit and use their existing engineering knowledge and understanding to produce a viable solution to problems, identified by the students, concerning preterm baby care across the UK and, potentially, in poorer countries or disaster areas.
- Conduct research as required to develop their existing engineering knowledge and understanding (e.g. key health indicators, sensor devices, prioritising work schedules, diagnostic tests) in order to support sophisticated

Table 1: Project deployment

Activity	Phases targeted	Brief description of the activity	Time / hrs
Exploring an existing maintenance schedule	**CODIFY** **REVIEW**	Ask students to consider the maintenance plans for a variety of devices and systems. How often do they need to be serviced? How is the service history tracked and what systems are in place to prevent failure of the maintenance schedule. Ask students to conduct a risk assessment and suggest possible improvements to make the systems more resilient.	4
Testing materials for desirable properties	**PLAN** **PERFORM**	Ask students to test a selection of materials for a specified selection of properties relevant to their use in portable incubators. The time required for this task can be reduced by providing more support in terms of selection of materials and testing procedures.	8
Identifying key safety parameters for preterm babies	**CODIFY**	Ask students to research the key parameters to be monitored in an incubator. They should relate the needs of the newborn to the environment the incubator can provide and produce a list of parameters with their safe limits.	4
Reviewing available incubator solutions	**REVIEW**	Ask students to review the range of incubators currently available on the market. They should explore the typical use cases and identify the preferred systems and models for each. Ask them to identify scenarios where currently-available models are less adequate and suggest how a new incubator could be designed to overcome these limitations.	4

engineering problem-solving decisions (often containing compromises between different priorities).

- Develop a maintenance strategy which will ensure maximum resilience and performance for the incubator (electronic systems and mechanical components) through identifying most likely points of failure and mechanisms (skills, equipment and components) to ensure this.
- Work effectively in teams to a identify and analyse a problem, create a plan of work to solve the problem and organise the delivery of this with others in a collaborative manner.

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 2** below are examples of the typical achievements at three levels of performance. 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 2: 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 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.
Produce a rudimentary plan with a clear sequence of tasks	*Show tasks, resources and people needed to deliver work with key dates specified.*	Agree the plan with relevant parties in consultation and have potential back-up strategies available.
Collect data in an inquiry 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 of components, ease of replacement of components and waste production).
Contribute to a shared report taking personal responsibility for an identifiable 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.

Maintenance, Installation and Repair

Maintenance, Installation and Repair (MIR) candidates will develop (design, build and test) a simple alarm system to indicate any problems with the incubator (e.g. battery failure, falling temperature) or the baby (e.g. rising temperature, lack of movement). They will show how the sensors and control system work together to ensure both incubator integrity and functioning is stable and that the baby will be kept safe by the equipment (**Table 3**). They will look at how this can be done onsite and remotely and suggest preemptive

Table 3: Maintenance, Installation and Repair

Phase	MIR core skills from City and Guilds T-level specification (8712)	Exemplar tasks	Time / hrs
CODIFY	**Core Skill A: Analysing and interpreting** ▪ Evaluate and confirm the brief with reference to context, objectives and constraints (e.g. requirements, resources, precedents, technical issues, costs, health and safety, regulations, possibilities).	Students consider the key parameters for monitoring baby health and the environmental conditions (e.g. incubator temperature, humidity) needed to keep baby safe. Students prioritise the parameters to measure and controller very early, early and low birth weight babies born at full term.	4
PLAN	**Core skill B: Planning and preparation** ▪ Propose and plan key activities, stages, methods, processes, techniques, documentation, resources (including types of tools and equipment) and risk assessments.	Students review the components needed to construct a monitoring and control system for an incubator and identify those that match criteria they have designed to produce a resilient incubator. Students estimate the cost of the various components and use these to generate a rough project cost for a one-off prototype and manufacturing 1000 incubators.	10
PERFORM	**Core skill C: Implementing plan** ▪ Propose maintenance, installation and repair processes for achieving specific objectives and quality outcomes, using relevant techniques, and technology, within limits of own authority.	Students construct a simple system using the components they have selected and test it. Students carry out exemplar repair/replacement activities(including situations which require some disassembly of mechanisms) related to incubator monitoring and control systems in the workshop noting the skills they develop (including any formal accreditation), the equipment and parts used, the time taken and the waste generated. Students collect data on time to complete repair/ replacement, ease of task and likely cost in terms of parts, labour and disruption to normal service.	10
REVIEW	**Core Skill D: Evaluating and QA** ▪ Investigate components and systems, to gather and evaluate relevant evidence and data, and to confirm the suitability of processes, actions and outcomes (including quality control and quality assurance activities).	Students review their activity and comment on it showing how they used their engineering knowledge and direct observation to test their suggested system showing how the data generated could be used to maintain the incubator. Students perform the repair and replacement task and consider the resilience of their expected maintenance schedule 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.	4
PRESENT	**Core Skill E: Communication and presentation** ▪ Record, report, communicate and present plans, proposals, processes, issues, risks and outcomes to both technical and non-technical audiences, across a range of suitable formats and media (e.g. diagrams; physical and digital records, presentations).	Students present their MIR strategy with accompanying data, calculations and risk analysis to the client (e.g. a medical supply company opting to develop a new low-cost incubator for use in sub-optimal conditions like a war or disaster zone) and respond to questions posed by the client.	2

maintenance strategies to ensure 24/7 functioning of the incubator.

Teaching sequence

CODIFY (4 hrs)

Exemplar tasks

- Students consider the key parameters for monitoring baby health and the environmental conditions (e.g. incubator temperature, humidity) needed to keep baby safe.
- Students prioritise the parameters to measure and controller very early, early and low birth weight babies born at full term.

Teaching strategies

There are about 60,000 babies born in the UK before 37 weeks of pregnancy (about 8% of all births). These babies are referred to as preterm or premature. Of these 60,000, 5% were extremely preterm (before 28 weeks), 11% were very preterm (between 28 and 32 weeks) and 85% were moderately preterm (between 32 and 37 weeks). Survival rates for babies born at 22% is only 10% but rises rapidly so that by 27 weeks the rate is roughly 89%.

Incubators are devices that improve the survival chances of preterm babies by closely monitoring their physical health (e.g. body temperature, blood oxygen saturation), generating alarms if these stray outside acceptable values and modifying environmental conditions (e.g. temperature, humidity) inside the incubator to maintain baby comfort.

Ask students to identify the key parameters to measure and control to ensure baby health. This will involve research into medical or nursing topics rather than simple engineering and provides a good opportunity to stress to students that understanding the needs of the end user of a piece of equipment is more important than mastering the technology. Detailed knowledge of medical physiology is not required but key parameters should be identified and their safe normal ranges.

Then ask them to consider how engineers might use this combination of medical and engineering knowledge and skills to develop systems to keep preterm babies safe. This project really could be a matter of life or death! The kinds of issues engineers might be called on to address if manufacturing incubators on a large scale might include

- How can the design of a device affect its manufacturing? Will a simpler device do the job just as well and will it be cheaper and easier to produce?
- Can the electronics needed for a smart device like an incubator or Apple Watch be shrunk from multiple separate components into a simpler system on a chip?
- Can the design and manufacture of a device make it easier to service and repair?

Output and evidence

The output from this stage should be a clear statement of the problem to solve in engineering terms and an outline of the key parameters to be monitored. This could be evidenced by:

- An overview showing the key parameters that medics use to monitor baby health with suggestions as to which are the key values and which are useful to have for more significantly needy infants. The document should also indicate the range of safe values associated with each parameter and indicate the precision and accuracy needed in potential sensors.

Useful resources

3: Environmental assessments. Considering the environmental impacts of a project (e.g. the use of plastic in the incubator construction) in the immediate and medium-term and for the local area and more widely.

10: Knowledge audit. 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. a construction facility for incubators) or installation 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 skills to sharpen your creativity.

PLAN (10 hrs)

Exemplar tasks

- Students review the components needed to construct a monitoring and control system for an incubator and identify those that match criteria they have designed to produce a resilient incubator.
- Students estimate the cost of the various components and use these to generate a rough project cost for a one-off prototype and manufacturing 1000 incubators.

Teaching strategies

Ask students to gather costs for their chosen components from online or other sources.

This will involve some exploration and in many cases only an estimate will be possible but it provides an opportunity to consider the complexity of costing a project. While collecting prices students should also explore modifying their designs to reduce costs – provided the final product remains within their agreed performance specification.

During this sourcing process it will become apparent that some components are unavailable or prohibitively expensive (or complex and difficult to use) so the plans for the final system will almost certainly need to change. Use this opportunity to help students to refine their design.

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.

Students will need to use a variety of mathematical techniques to calculate key values and these calculations should demonstrate the feasibility of their suggestions.

Output and evidence

The output from this stage should be a clear plan that identifies key problems, strategies to solve them and roles and responsibilities of all in the team. This could be evidenced by:

- A strategy document (>800 words) outlining the policy on pre-emptive maintenance, the rules about responding to newly-reported faults and justifications for these decisions in terms of engineering best practice and the interests of identified stakeholders. This strategy should address issues like staffing, key skills for engineers involved in the maintenance, any equipment and components issues and include suggestions for how to solve these issues. All decisions should be justified by reference to existing engineering knowledge and skills, the particular needs of the context and the characteristics of the proposed solution.
- 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.

22: Responding to a brief. Developing a strategy to deliver on a brief or win a tender.

PERFORM (10 hrs)

Exemplar tasks

- Students construct a simple system using the components they have selected and test it.
- Students carry out exemplar repair/replacement activities (including situations which require some disassembly of mechanisms) related to incubator monitoring and control systems in the workshop noting the skills they develop (including any formal accreditation), the equipment and parts used, the time taken and the waste generated.
- Students collect data on time to complete repair/replacement, ease of task and likely cost in terms of parts, labour and disruption to normal service.

Teaching strategies

Ask the students to assemble and test their monitoring and control system. 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 an account of their work building and testing the monitoring and control system. It should include a clear description of any proposed solutions to any problems that surfaced as they transformed their initial designs int a finished product. Any decisions should be justified in terms of engineering knowledge and skills and any supporting data from the practical work. This could be evidenced by:

- A poster showing the completed monitoring and control system, schematics of the original design and annotations to show where the final product was modified in the light of the manufacturing process.
- A logbook with an account of a particular repair and replacement practical task 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, storage containers) based on measured or published data.

6: Using mathematical formulae. Calculating safe working parameters for structural components (e.g. incubator case or trolley for transporting it) 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 (4 hrs)

Exemplar tasks

- Students review their activity and comment on it showing how they used their engineering knowledge and direct observation to test their suggested system showing how the data generated could be used to maintain the incubator.
- Students perform the repair and replacement task and consider the resilience of their expected maintenance schedule 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 mechanisms resilient?') 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 in the context of developing a control strategy for an incubator. 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 repair and replacement 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 done some work 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, if that has not been possible, clarified. 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 areas for development. This could be evidenced by:

- An statement agreed within the team, and potentially by an external adjudicator, and 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, 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 (2 hrs)

Exemplar tasks

- Students present their MIR strategy with accompanying data, calculations and risk analysis to the client (e.g. a medical supply company opting to develop a new low-cost incubator for use in sub-optimal conditions like a war or disaster zone) and respond to questions posed by the client.

Teaching strategies

If the previous Review section was inward-looking for the team and individual this Presentation 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 incubator) 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. medical staff, parents, 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. an incubator, a production facility).

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

Manufacturing, Process and Control

Manufacturing, Processing and Control (MPC) candidates will design and test the 'shell' of the incubator that will hold the baby safely. The material used must be light, strong, transparent and easy to manufacture and clean. They will identify and test suitable materials and assess how easy they would be formed into the required shape during manufacturing and repair in the event of damage. The likely failure rates and a selection of suitable replacement parts, with a maintenance strategy that can be implemented by non-skilled workers, will be described in a clear plan (**Table 4**).

A preterm baby being cared for in an incubator

Table 4: Manufacturing, Process and Control

Phase	MPC core skills from City and Guilds T-level specification (8713)	Possible tasks	Time / hrs
CODIFY	**Core Skill A: Analysing and interpreting** ■ Evaluate and confirm the brief with reference to context, objectives and constraints (eg requirements, resources, precedents, technical issues, costs, health and safety, regulations, possibilities)	Students identify the key functional requirements of a baby incubator with particular emphasis on the shell (e.g. need for medics to access the baby, systems to allow monitoring leads to be inserted, sufficient volume for baby and equipment). Students suggest the properties of materials that could form the incubator shell and justify their choices. They clarify their understanding of properties of materials as required.	4
PLAN	**Core Skill B: Planning and preparation** ■ Propose and plan key activities, stages, methods, processes, techniques, documentation, resources (including types of tools and equipment) and risk assessments.	Students suggest suitable materials and construction mechanisms (e.g. forming, assembling) to produce the incubator shell based on established properties and technologies. Students plan suitable tests and procedures to check the suitability of their chosen materials and components.	10
PERFORM	**Core Skill C: Developing responses** ■ Apply engineering and manufacturing processes to achieve specific objectives and to produce quality outcomes, using relevant techniques and technology, within limits of own authority.	Students carry out experimental inquiries into the properties of selected materials to identify those that might be most suitable for manufacturing the incubator shell. Students explore ways of joining/connecting their individual parts to make a functioning component – both as a prototype and during manufacture. Students identify and describe the key steps in a manufacturing process and consider kit and materials needed to perform this. Students predict likely component failures based on their explorations of the materials/ forming technologies and suggest a range of spare parts to be included with the incubator package.	10
REVIEW	**Core Skill D: Evaluating and quality assuring** ■ Carry out investigations, generate proposals and options, identify standard components and systems at relevant stages to gather and evaluate relevant evidence and data, and to confirm the suitability of plans, processes, actions and outcomes (including quality control and quality assurance activities)	Students review their proposed solution and comment on their work and performance individually and as a team. Students prepare their work output for presentation to client.	4
PRESENT	**Core Skill E: Communication** ■ Interpreting, using and producing engineering representations and drawings following graphical language and industry conventions. ■ Interpreting and using technical information and media. ■ Communicating with technical and non-technical audiences using technology.	Students present their plans, data, calculations and risk analysis to the client (e.g. a medical supply company opting to develop a new low-cost incubator for use in sub-optimal conditions like a war or disaster zone).	2

Design and Development

Design and Development (D&D) candidates will specify the size, shape and weight of the incubator based on needs of intended users (baby and medical staff). They will identify the key factors needing monitoring to ensure baby health and produce at least two possible designs: a simpler, cheaper version suitable for most preterm babies and a more complex device for very high-risk or small babies with multiple needs. The incubator should also support baby health by creating suitable environmental conditions (e.g. temperature or humidity) and students should explain how these conditions can be maintained (e.g. heaters, heat lamps). Students will build and test a simple monitoring system using at least two proves, a control unit, an output display and a system to change one environmental parameter (e.g. temperature, light levels) (**Table 5**).

Table 5: Design and Development

Phase	D+D core skills from City and Guilds T-level specification (8714)	Exemplar tasks	Time / hrs
CODIFY	**Core Skill A: Planning and preparation** ■ Interpreting and confirming project requirements. ■ Planning and scoping project parameters (e.g. timescales, resources, costs). ■ Developing project plans.	Students explore the needs of preterm and low birth weight babies identifying factors that need constant monitoring (e.g. body temperature, blood oxygen saturation). Students select the issues (monitoring and treatment) that are most critical for two categories of preterm or low birth weight babies justifying their choices.	4
PLAN		Students select suitable components/ technologies to develop their control system. Students draw up initial plans for the system using these components/ technologies and identify success criteria for the final product.	10
PERFORM	**Core Skill C: Developing proposals and concepts** ■ Designing proposals to meet set requirements. ■ Developing, modelling and revising concepts.	Students design, build and test their baby monitoring system using a model incubator our similar device to mimic typical hospital use cases. Students use their experimental data to refine their initial plans if required and formalise their designs for the two classes of incubator.	10
REVIEW	**Core Skill D: Evaluation** ■ Carrying out tests, evaluation and analysis. ■ Evaluating how well project requirements have been met.	Students review their proposed solution and comment on their work and performance individually and as a team. Students prepare their work output for presentation to client.	4
PRESENT	**Core Skill B: Communication** ■ Interpreting, using and producing engineering representations and drawings following graphical language and industry conventions. ■ Interpreting and using technical information and media. ■ Communicating with technical and non-technical audiences using technology.	Students present their plans, data, calculations and design to the client (e.g. a company seeking to develop a new incubator).	2