Royal Academy of Engineering

Sheffield Hallam University | Sheffield Institute of Education

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Electric vehicles: charging onwards?

Teacher sheet

Problem-based learning resources

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Project brief and variations

Students will act as consulting engineers to explore the issues involved in designing, installing and maintaining a charging station for electric vehicles (EV). The activities will include practical, investigative work in the workshop or lab, group work (e.g. team planning meetings) and a series of individual paper-and-pencil exercises (e.g. writing reports, mathematical exercises).

Maintenance, Installation and Repair (MIR) candidates will review the conditions typical of a busy EV charging facility and identify possible points of failure to develop a pre-emptive maintenance strategy and a set of procedures for rapid diagnosis and treatment of faults. They will suggest a stock of spare parts to be stored onsite and practise simple replacement techniques. They will look at sensors to monitor throughput of EV to indicate times of maximum activity and potentially support an increase in the size of the facility.

Manufacturing, Processing and Control (MPC) candidates will draw up designs for a charging point for an EV station that will have a range of connectors for different EV types and be easy to disassemble for service and repair. They should suggest suitable materials for the charging station based on their properties and indicate forming and manufacturing strategies to produce these devices as quickly and cost-effectively as possible.

Design and Development (D&D) candidates will plan a layout for an EV-charging facility matching the connectors and supply systems with expected customers while providing the maximum number of charging bays within the space provided. Investigative work will look at the effects of flow of charge along a conductor to clarify any safety issues (e.g. overheating) and derive suitable formulae to calculate power delivery through a variety of possible circuits. The characteristics of different circuit layouts will be explored and an optimum design created and tested in a small model.

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 provided for 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.

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 support sheets for particular topics or techniques can be made available during 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.

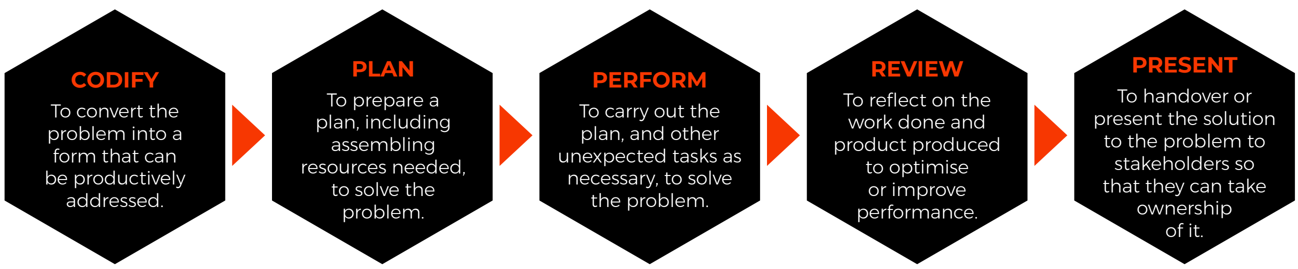

Figure 1: The Engineering Design Process

- **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 are also supplied for the MIR pathway in the Electric vehicles: charging on? 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 EV deployment across the UK.
- Conduct research as required to develop their existing engineering knowledge and understanding (e.g. flow of electric charge, prioritising work schedules, diagnostic tests) in order to support sophisticated engineering problem-solving decisions (often containing compromises between different priorities).
- Develop a maintenance strategy which will ensure maximum system up-time and performance through identifying most likely

Table 1: Project deployment

Activity	Phases targeted	Brief description of the activity	Time / hrs
Choosing an EV	**CODIFY**	The introduction of EVs will produce significant social and environmental changes. Ask students to explore these issues and create a prediction for what an all-EV society will look like. What will happen to oil companies, car mechanics, road networks and journey times? Encourage students to think more widely than simple technological changes but insist that they justify their predictions by reference to technological developments that are likely in the next ten years.	6
	PLAN	Batteries are a key component of EVs. Ask students to explore the behaviour of batteries as they charge-discharge. How does the time taken to charge relate to current supplied? How does the output vary over time? Does temperature have an effect on battery performance? Ask students to develop an inquiry strategy to explore some of the issues they identify as key to EV batteries in daily use.	4
	PERFORM	Ask students to carry out some of the inquiries formulated in the planning activity above and use their work as an assessment of workshop and laboratory skills.	4
	REVIEW	EVs are an expensive purchase but are supposedly cheaper to run than internal combustion vehicles. Ask students to review the financial implications for a variety of people (e.g. a young professional worker, a pensioner, someone living in a remote location). Identify the key issues to be considered and suggest the best compromise of cost/specification for an EV for each client.	3

points of failure and mechanisms (skills, equipment and components) to ensure this.

- Work effectively in teams to 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 sophistication as they move from the left-hand column across to the right-hand side. 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.

Maintenance, Installation and Repair

Maintenance, Installation and Repair (MIR) candidates will review the conditions typical of a busy EV charging facility and identify possible points of failure to develop a pre-emptive maintenance strategy and a set of procedures for rapid diagnosis and treatment of faults. They will

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.

suggest a stock of spare parts to be stored onsite and practise simple replacement techniques. They will also look at sensors to monitor throughput of current and vehicles to indicate times of maximum activity and potentially provide evidence to support an increase in the size of the facility (**Table 3)**.

Teaching sequence

CODIFY (4 hrs)

Exemplar tasks

- Students consider the key parameters for the charging station, e.g. throughput of vehicles, peak times, current record of downtime, likely growth over next decade, to formalise the problem.
- Students identify likely points of failure drawing on realtime data from existing stations and theoretical considerations based on rate of use, resilience of components etc.
- Students explore the existing provision of EV charging stations in their local area in terms of charge points, connectors available, likely throughput (customers and power) and identify any deficiencies or limiting factors to more widespread use of EVs.

Teaching strategies

The move to EV is accelerating and current fuel price rises for internal combustion engine (ICE) vehicles will probably increase the rate of change. However, EVs do take longer to refuel than ICE vehicles and the charging networks, in 2022, are still patchy which can contribute to 'range anxiety' amongst EV drivers. Introduce the project to the students asking them to prepare a quick summary of the positive and negative features of EVs for a variety of users (e.g. themselves, people who mainly travel short distances around town, sales representatives or similar commercial car users who do 20,000+ miles a year etc). This type of activity might be best conducted in small groups and the output could be a poster or display of some sort.

The review above will almost certainly identify initial cost and EV charging station availability as two of the more significant negatives. Discuss with students how engineers can address these two issues to make EVs more attractive. The cost issue will improve slightly with increased production numbers (economies of scale) and potential new, more powerful, technologies (e.g. graphene batteries) but changes will be relatively small and long term. Charging station provision could be changed relatively quickly.

When students are familiar with the context ask them to consider what engineers might do in a similar situation. Encourage them to think about possibilities, what might happen, as opposed to simply describing what they can see in the contextual material. Use this opportunity to draw out students' interests and encourage creativity. Typical examples of work that they might consider doing include:

- How can EV charging stations be maintained so that they are always working and delivering a good service? Who has to service these stations and what equipment and supplies two they need?
- EV charging stations are exposed to the elements – especially in wet and windy North Wales! What materials and technologies can stand up to this exposure 24 hours a day 365 days of the year and still function efficiently? And how easy are the charging stations to open up for servicing?
- We know what petrol stations look like – vehicles drive in, stay 2 minutes and drive out agaion. EV charging stations have a minimum of 20 minutes charging – how will this affect the design of the charging stations? What is the best layout to get in the maximum number of cars and the most efficient distribution of power?

Ask students to map the distribution of EV charging stations in the local area, assess how well it meets current needs (e.g. how likely are drivers to find an open space when they arrive?) and predicted future needs. They should also consider the best site for new EV charging stations related to their audit of current provision, likely increase in EV numbers and local knowledge.

Output and evidence

The output from this stage should be a clear statement of the problem to solve in engineering terms and an outline plan showing possible options for progress. This could be evidenced by:

- An overview showing the key problems faced by motorists using EV and how failures or problems with charging stations can exacerbate these. The proposal should also suggest how maintenance and repair can solve many of these problems and suggest an outline strategy to deliver a suitable maintenance capacity. This will need to be suitable for a non-specialist audience and should include at least one illustration, one mathematical diagram or chart with no more than 500 words of text.
- A technical annexe showing the data that has informed the strategy, its source and a measure of its reliability. It should be appropriate for a technical audience and include all calculations used and full background justification for the proposal components.

Useful resources

3: Environmental assessments. Considering the environmental impacts of a project (e.g. building a

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 (eg requirements, resources, precedents, technical issues, costs, health and safety, regulations, possibilities).	Students consider the key parameters for the charging station, e.g. throughput of vehicles, peak times, current record of downtime, likely growth over next decade etc. to formalise the problem. Students explore the existing provision of EV charging stations in their local area in terms of charge points, connectors available, likely throughput (customers and power) and identify any deficiencies or limiting factors to more widespread use of EVs.	4
PLAN	**Core skill B: Planning and preparation** - Propose and plan key activities, stages, methods, processes, techniques, documentation, resources (inc. types of tools and equipment) and risk assessments.	Students identify likely points of failure drawing on realtime data from existing stations and theoretical considerations based on rate of use, resilience of components etc. Students draw up a strategy to deliver an appropriate level of maintenance to provide a specified up-time for the system while recognising cost implications and waste production of this approach. Students plan how the relevant staff, equipment and replacement components will be delivered to the EV charging station. They estimate how often the station will need to be checked and suggest suitable indicators, with associated sensors, of imminent failure at the station.	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 carry out exemplar repair/replacement activities(including situations which require some disassembly of mechanisms) related to EV charging stations 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 develop and respond to simulations of a 24 hour period managing the EV charging station portfolio in their area showing how they would tackle faults and routine maintenance tasks. 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, any diagnostic tests and direct observation to 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 (eg diagrams; physical and digital records, presentations).	Students present their MIR strategy with accompanying data, calculations and risk analysis to the client (e.g. an EV charging station start-up looking to contract a suitable maintenance partner for their portfolio of new charging stations) and respond to questions posed by the client.	2

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 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. 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 skills to sharpen your creativity.

PLAN (10 hrs)

Exemplar tasks

- Students identify likely points of failure drawing on realtime data from existing stations and theoretical considerations based on rate of use, resilience of components etc.
- Students draw up a strategy to deliver an appropriate level of maintenance to provide a specified up-time for the system while recognising cost implications and waste production of this approach.
- Students plan how the relevant staff, equipment and replacement components will be delivered to the EV charging station. They estimate how often the station will need to be checked and suggest suitable indicators, with associated sensors, of imminent failure at the station.

Teaching strategies

A key aspect of the project involves developing a repair and maintenance strategy that pre-empts system failure and responds as rapidly as possible to any faults that do occur. Encourage students to explore how they could monitor performance at the station, what factors might indicate impending failure and how this data would be collected (e.g. appropriate sensors, sampling frequency, possible visits or reporting by users).

The students will already have data and insights from the previous activity. They will need to use these to develop a flexible and responsive plan for maintenance that meets the needs of the EV-using public but addresses some potential points of conflict and compromise. Should faults be dealt with on a strictly 'first come first served' basis or should a basic service be available across all sites before dealing with any extra demands? Should the stations in most use be given priority? Should components be replaced and discarded prior to failure on a routine maintenance program (reduced chance of failure, greater waste produced) or left until they fail and only then replaced (increased chance of failure, less waste produced)?

Ask students to draw up a maintenance strategy that resolves these issues. This will inevitably involve making decisions about whose interests are prioritised and students should justify their decisions in the light of the impact on the different stakeholders. This provides a good point to raise issues of sustainability and considering future generations as being stakeholders (even if not yet born!) in engineering decisions. Stress to students that their engineering knowledge will help them when tackling this task and that they should mention it explicitly when justifying decisions. This may involve them carrying out research to gather more understanding or you may choose to provide extra content at various points to supplement their existing understanding.

The next section of the project involves engaging in repair and replacement workshop activities typical of the MIR workplace. The exact tasks will vary according to local circumstances but students will need to plan their work in terms of skills and parts needed, time required and quality assurance issues. Ask students to predict the most likely faults in an EV charging station based on their current understanding and any research that they have done. A technical specification of an EV charging station would be a useful resource for them to explore at this point. What do they think is likely to fail and what skills, tools and parts do they need to remedy these faults? How will they ensure that the part is functioning appropriately after they have completed the repair?

Ask students to prepare a 'kit bag' of tools (simple hand tools like screwdrivers with the correct head, torque wrench), diagnostic devices (e.g. meters, computer-based test systems) and replacement parts (relays, switches, connectors) that would allow them to repair a malfunctioning EV charging station. This activity inevitably involves much guesswork but encourage students to make informed guesses based in their engineering knowledge rather than simply listing everything! The quality of this kit bag will be reviewed after students have engaged in the practical workshop activities.

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 (e.g. deriving and extrapolating from percentage failure rates, probability of finding an EV charging station open/functional) 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 – 1,000 words) outlining the policy on preemptive 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 carry out exemplar repair/replacement activities(including situations which require some disassembly of mechanisms) related to EV charging stations 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 develop and respond to simulations of a 24 hour period managing the EV charging station portfolio in their area showing how they would tackle faults and routine maintenance tasks.
- 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 carry out exemplar repair and replacement activities that reflect local circumstances. These activities should also include experience of suitable diagnostic equipment and systems. 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 documentary complete record of activities showing how they fitted into the overall MIR strategy. 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 or similar chart showing the steps in the diagnostic routine used to locate the problem in a system and suggest possible repair or replacement strategies. The chart should be illustrated with photographs or real data to show safe and functional conditions.
- 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. temporary building, storage containers) based on measured or published data.

6: Using mathematical formulae. Calculating safe working parameters for structural components (e.g. 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 (4 hrs)

Exemplar tasks

- Students review their activity and comment on it showing how they used their engineering knowledge, any diagnostic tests and direct observation to 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 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 in the context of developing a MIR strategy for an EV charging station. 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 focusing 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 (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 (2 hrs)

Exemplar tasks

- Students present their MIR strategy with accompanying data, calculations and risk analysis to the client (e.g. an EV charging station start-up looking to contract a suitable maintenance partner for their portfolio of new charging stations) 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 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. an EV charging station, a production facility).

21: Delivering a presentation. Present a pitch (e.g. an EV charging station, 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 draw up designs for a charging point for an EV station that will have a range of connectors for different EV types and be easy to disassemble for safe service and repair. They should suggest suitable materials for the charging station based on their properties and indicate forming and manufacturing strategies to produce these devices as quickly and cost-effectively as possible (**Table 4**).

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 charging station for EV and suggest key features that would deliver these. They identify issues concerned with the development and manufacture of these charging stations to ensure lowest possible cost of manufacture and ease of maintenance.	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 identify particular components of the charging station (e.g. connectors and cables, information screens, protection against the elements) and their desired properties. Students suggest suitable materials and construction mechanisms (e.g. forming, assembling) to produce the charging station based on established properties and technologies.	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 design and carry out experimental inquiries into the properties of selected materials to identify those that might be most suitable for manufacturing components of the EV charging station. 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.	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 (an EV charging startup company).	2

Design and Development

Design and Development (D&D) candidates will plan a layout for an EV-charging facility matching the connectors and supply systems with expected customers while providing the maximum number of charging bays within the space provided. Investigative work will look at the effects of flow of charge along a conductor to clarify any safety issues (e.g. overheating) and derive suitable formulae to calculate power delivery through a variety of possible circuits. The characteristics of different circuit layouts will be explored and an optimum design created and tested in a small model (**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 an EV charging station in their local area in terms of numbers and types of EVs likely to visit in a given time. Students select a site for an EV charging station and justify their decision based on how well local conditions match their identified needs.	4
PLAN		Students draw up a detailed specification with relevant measurements to show how the EV station would be laid out with indication of proposed power supply systems.	10
PERFORM	**Core Skill C: Developing proposals and concepts** ▪ Designing proposals to meet set requirements. ▪ Developing, modelling and revising concepts.	Students carry out an inquiry into the effect of electrical flow (a.c. and d.c.) along different circuit types (e.g. parallel, series) to identify most appropriate system for EV charging station. Students use their experimental data to refine their initial plans if required and calculate power supply values for their proposed EV throughput.	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 (an EV charging startup company).	2