Royal Academy of Engineering

Sheffield Hallam University | Sheffield Institute of Education

THIS IS ENGINEERING

2

Developing your own engineering solutions projects

Support material

Problem-based learning resources

Introduction

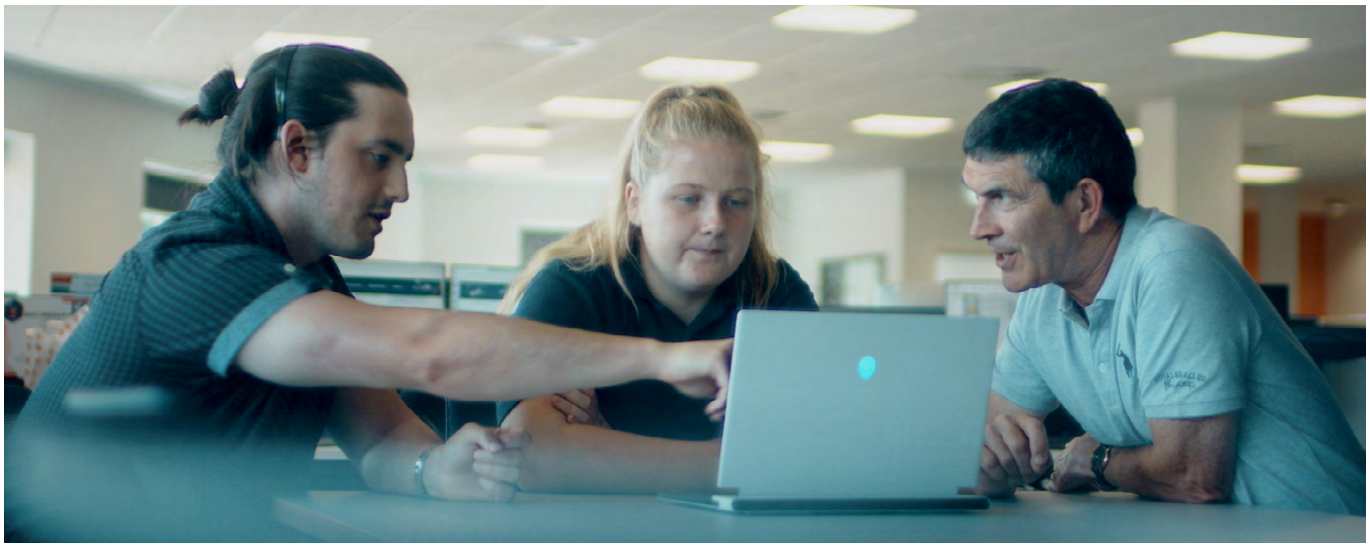
Engineering Solutions provides a range of pre-built projects, but you may want to develop your own to match your particular needs. This document identifies a number of the issues to consider when developing your own. It is presented as advice to use, if appropriate, rather than a model which must be followed so ensure that what you produce matches your needs rather than reproducing the exact form of existing projects.

1. Choosing the context

Research show that placing material, particularly new or demanding ideas and skills, in a context that is accessible to learners significantly improves motivation. When choosing a context for your work consider the following:

- **Is the context local?** Generally, local contexts are better than exotic ones because learners spend less time mastering the details of the context and get into the significant conceptual material more quickly. So, if looking at transport systems pick one local to your area. If a local manufacturer is a major producer of a particular product (e.g. electric vehicles) or service (e.g. maintenance of computer systems) a context involving these will be more obviously relevant to learners. However, some contexts can be motivating because they are not local or immediately familiar. A context involving the choice of materials used to build a spaceship for the trip to Mars or the engineering of the Great Wall of China can be interesting specifically because it is novel and outside students' prior experiences.
- **Is the context topical?** Another approach is to pick issues which are currently in the news. These contexts can have an immediately obvious connect to engineering (e.g. building a new road or development of AI systems). Other news stories can provide a useful hook (e.g. the Women Football World Cup could be used to look at building stadia or the best materials for making footballs) but it may be necessary to plot a path for students to recognise the engineering opportunities available to explore.
- **Is the context interesting?** This is difficult. What may be interesting to you as the lecturer could be boring or irrelevant to your learners. Strive to make contexts interesting but accept that sometimes your enthusiasms are not shared!
- **Does the context allow multiple ways forward?** A good context, perhaps better called a scenario, allows for students to locate a number of issues to address. Research shows that offering choices, of problems to address or ways to address them, is very motivating. This is better than engineering a context so tightly that the only possible problem or development is immediately apparent. Try to avoid these as they are often perceived as window dressing before students start on the real work.
- **Are people front and centre in the context?** Engineering techniques or highly sophisticated kit can be motivating but research shows that convincing contexts are best developed in terms of the human impact. A few quotes from people having to deal with the implications of the problem tend to be more motivating than impersonal descriptions of a problem. Ensure that people (give them names, include photographs if possible) are visible in your context materials. Note that these people can be fictitious provided that they are believable.

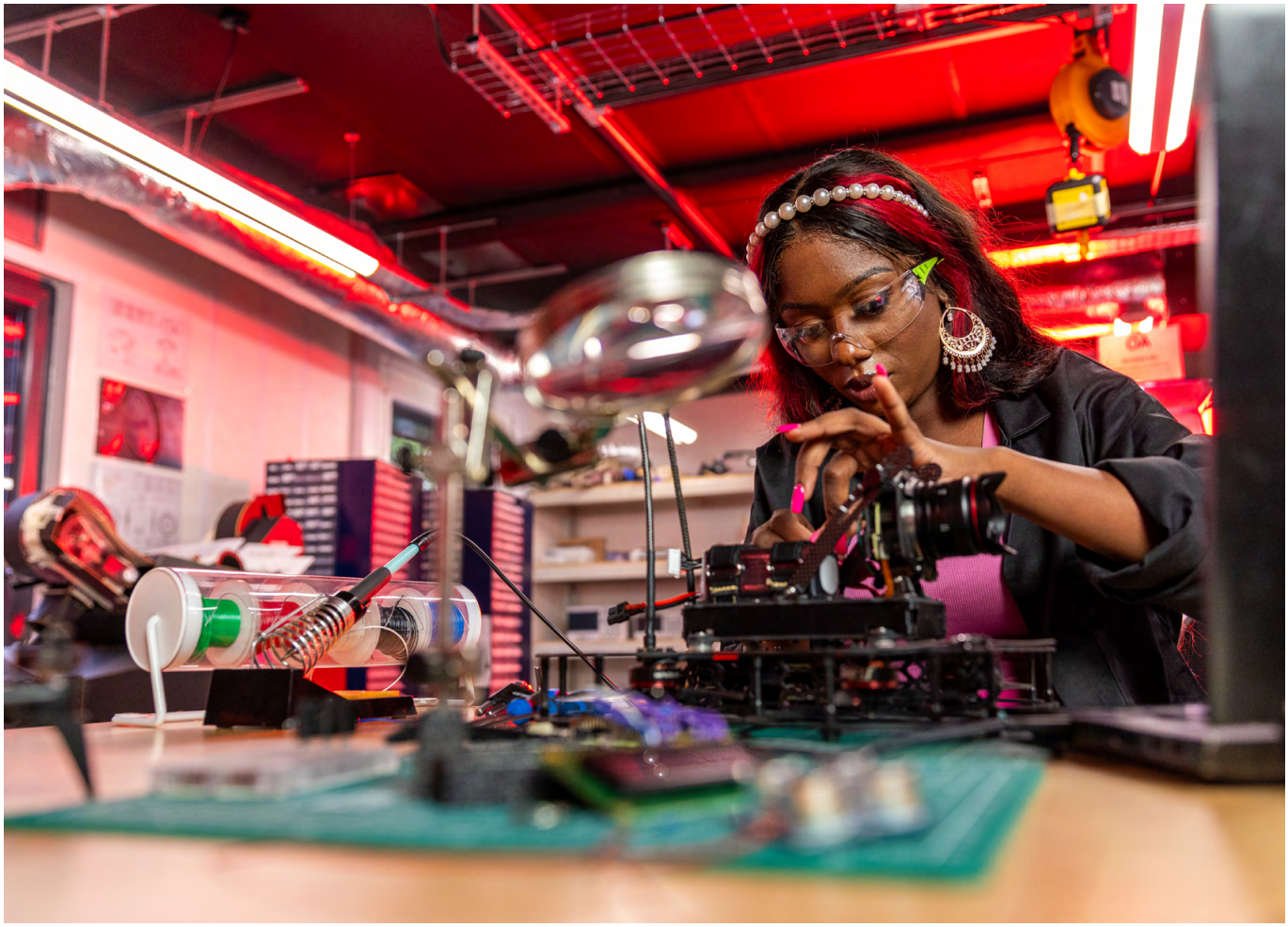
Note that the points above are general and can be interpreted in a number of ways to generate a convincing and motivating context. A good way to test your initial ideas is to ask students before you devote a lot of time to researching and developing a context.



2. Setting the problem

At the heart of all *Engineering Solutions* projects is a problem or selection of problems. Ideally these will be identified and explored by students rather than being presented as a clear problem to solve which has an obvious solution. When developing a possible problem for your work consider the following:

- **Is the problem real?** Wales losing to England in the Rugby World Cup is a major problem to proud Welsh men and women but leaves others untouched! Similarly, some engineering problems do not have sufficient emotional impact for most people to drive engagement. If students respond with 'who cares?' to your chosen problem – think again! Problems which tend to work have an emotional impact, involve issues that address a large number of people (e.g. climate change, the cost of energy or food) or affect a smaller number of people very seriously (e.g. availability of cheap and effective preterm baby incubators).
- **Does the problem have multiple solutions?** Again, related to the idea of avoiding over-prescriptive contexts, a problem which has been engineered to permit only one possible solution is perceived as bogus and reduces students' creativity. The sense that they are being maneuvered into a particular path is very demotivating. Ensure that any problems at the heart of your projects could have multiple viable solutions. This also requires students to consider the optimal solution to a problem – a key engineering skill.
- **Does the problem require engineering knowledge and skills?** The problems in *Engineering Solutions* are designed to *require* engineering knowledge and skills to solve them. The whole point of the problem is to drive students' acquisition of key knowledge and skills. A common sense approach is often useful but it is not sufficient to drive knowledge acquisition. A way to lead students towards engineering knowledge and skills is to specify in your problem that it must use a particular idea or set of resources to solve it.
- **Can students formulate their own problems?** *Engineering Solutions* refers to this process as 'codifying a problem'. It is an essential part of the learning and requires students to explore all aspects of the context and related problems to focus on the key issue to be addressed. Allowing students space to do this is very motivating as they begin to 'own' the problem they have identified.



3. Identifying success

The projects in *Engineering Solutions* are designed to support student learning and have clear success criteria – if the student has not learnt anything the project is a waste of time! Since the best contexts, and the problems they generate, are open-ended this can be difficult to quantify. *Engineering Solutions* solves this by offering clear criteria that are based around skills rather than knowledge. If students have shown these skills, which often require deployment of sophisticated engineering knowledge, then they can be deemed to have succeeded.

The generic success criteria in the published projects offer a way to quantify this success. You may want to modify these to emphasise particular skills or add your own criteria that are knowledge focussed. The particular qualification your students are studying for may also have specific targets. For example, if a key output required by the qualification is the ability to select and carry out tests of various physical properties for a specified range of materials you may want to add this to the success criteria.

Generally, success is not a simple 'yes/no' decision so consider a range of criteria from basic compliance to more sophisticated skills. These are organised at three levels in the published *Engineering Solutions* projects. In some instances, you might choose two levels of performance but a single 'Yes/No' criteria is rarely helpful as they often need to be elaborated by a range of qualifiers (e.g. 'students can perform X *with* or *without* help', 'in *familiar* or *novel* contexts', 'when *told* to do it or left to *choose* to do it').

So, basic success may be demonstrated by using an ammeter with skill while the more sophisticated level might involve choosing when you use the ammeter and to what purpose. Ensure the purpose referred to here, involves using the data or understanding generated data is used in pursuit of a solution to the specified problem rather than simply to 'get better at using an ammeter'.

© Facebook

4. Creating a support strategy

A common misconception about Problem-Based Learning is that students are left on their own and discover what they need to know along the way. While there are times when you might want to leave students to puzzle things out for themselves this does not mean that the teacher role is reduced to watching! You might still need to offer motivational support ('Come on, you can do this!'), time keeping ('You really need to have chosen, and ordered, the materials you need for this project by the end of this week'), content support (e.g. 'Gather round while I explain how to work out the correlation coefficient for this dataset' or 'I want to talk to you about the nature of risk assessments') or even pastoral support 'Are you alright? You seem a bit distracted today?').

Prepare your support strategy when planning the project – do not expect to work it out on the spot! A support strategy includes two aspects: what you will *do* and any *resources* you will supply to support your teaching and learning plan. Looking first at what you will *do*, consider the following:

- **Which material is new?** Much of the material you need to cover will be new to students. Indeed, acquisition of this new material may define the teaching and learning purpose of the task. Note that this is where you will need to focus your support. However, some material which students *should* have mastered may need you to intervene as their skills are not as developed as the task demands. This is often true of mathematical skills where students may be able to complete a calculation when instructed to but have limited understanding of the purpose of the procedure or the use of the results. If you find answers with large numbers of trailing numbers after the decimal point this is often a clue that students are not as proficient as their previous assessments might suggest!
- **Which ideas or skills have caused problems for students in the past?** You know your students and you have probably taught much of the course material before. You will know which parts are particularly difficult or are critical to ensure progress. Concentrate on these when preparing your support strategy.
- **What content required by the specification needs particular emphasis?** Every course makes specific demands, and these may need emphasis. Ensure your support strategy is ready to reinforce this as you work through the material. You may also need to gently steer students towards particular knowledge or skills to fulfil the course requirements.
- **How are *my* students progressing *now* with *this particular* problem?** Plans are great – until they meet reality! You will already have ideas about the parts of the course that will cause problems, but you will notice individual students or groups needing extra support at times. Having a good comprehensive support strategy can create space for you to handle these unexpected or very specific needs.
- **Do I need to be present and available for this support activity?** Some support is only possible when a lecturer is present. That critical conversation about a project development or a check on student learning will need you to be present and available. Do not attempt to automate this – it rarely works. However, simple content can often be covered with an information sheet or may already exist online which can save you time to spend on the aspects of support that need your direct involvement.

5. Creating support resources

You will almost certainly have a range of support resources already available either from previous courses, bought in specifically for the course from a commercial provider, shared college resources and others. However, you may well need to modify these resources and will probably need to create some of your own for your own students. Resources in this context include any object which can help learning and will include worksheets (printed and online), audio and video clips and online communities or software simulations. When planning your support strategy, you will need to manage the deployment of these resources.

- **Do existing resources cover this topic well?** There is no point in rewriting an existing textbook or reproducing materials that are available online. Before you start to develop a support resource ensure that it is unavailable elsewhere – save your time if it is!
- **How does copyright affect what I produce?** Not everything on the internet is free to access or copy. Some useful resources may be hidden behind a paywall and you, as a lecturer, might have access which your students do not. Check that anything you wish to access is available. Copying material and making it available in public forum can be fraught so check you are not infringing copyright. However, most resource owners are comfortable with 'non-commercial use' and this usually includes educational use. Always credit owners when you copy something (a simple weblink is usually sufficient), and check before using.
- **Is the resource format suitable for my intended use?** Video clips and animations are often attractive but can obscure meaning in special effects and over-enthusiastic presenters. Sometimes a few words are worth a thousand moving images. If you do use a video clip try to link it to a specific task. So, watching something about the building of the Millennium Dome or deployment of EV charging stations can be interesting but if you want students to extract a particular understanding from it provide a task that encourages them to focus on that insight in particular (e.g. why was the Dome built with fabric rather than a rigid canopy?). If the video is long (and editing it is not always possible for online videos) provide a timecode for the portion you particularly want to use (e.g. watch the clip from 2:30 mins to 6:56 mins).
- **What makes a learning resource more accessible?** Research shows that after about 20 minutes working in an online learning environment the engagement and learning degrades rapidly. Similarly, very long documents can be a temptation to skim and miss important points. Always aim for shorter documents and check that the focus of a resource is clear – think in terms of presentations, three key points per slide is the maximum that works. A sentence giving the purpose of a document is also useful (e.g. this resource will explore the issues around carbon costs in biofuel production).
- **Do I need to change my writing style?** The answer is probably no, write in ways that you are comfortable with but remember your readers may not share your enthusiasms for detail or reading stamina. Useful rules include:
  - *Shorter sentences with active verbs and limited nominalisation* are better (e.g. 'use an ammeter to measure current flow' is better than 'the use of ammeters for current measurement is recommended')

- *Look for lists disguised as paragraphs.* If you are using words like 'firstly, secondly…' or 'and' appears often think about converting the text to a list. Use bulleted lists when the order of items is unimportant (e.g. 'the main types of insulation appropriate for outside walls') and numbered lists for instructions (e.g. '1: Check meter is appropriate for the expected range of measurements. 2: Locate any probes required. 3 …').
- *Keep to recommended word counts* – particularly if the document is to be used online. Every click or scroll can lead to confusion and loss of the readers' place.
- *Use images carefully to promote document accessibility* – but avoid photographs as decorations. If a photograph is included ask what its purpose is. Can you link it to a task to ensure students extract the important information from it (e.g. 'identify 5 possible hazards in this photograph of a metal fabrication workshop.').
- *Emphasise tasks rather than information* – ensure that the documents or resources you create have an activity that requires students to do something with it rather than simply reading. This does not have to be practical work. Suitable tasks might include:
  - Identifying the 3 key points.
  - Reducing word count by 50%.
  - Converting text-based instructions into images/audio or video clip.
  - Answering a series of comprehension questions – but be aware creating these questions is a non-trivial task.
- *Use appendices* – sometimes essential detail or specifications can disrupt the flow of the narrative. Don't let your readers drown in detail when you want to emphasise a specific key issue. Appendices referenced in the main text can be a useful store of this extra detail.
- *Avoid footnotes and 'drive-by clarifications'* – if a word needs an explanation in brackets explain it fully the first time and consider a glossary of the key terms. Use bold for key terms and, if online, a live link to the glossary text can be helpful and easily ignored by students who do not need them.

6. Packaging and sharing the project

Developing a context, identifying possible problems, formulating success criteria and constructing support strategies (and resources) is not easy! You will have devoted considerable time to this so it is wise to ensure that the delivery is as easy as possible for students and that other lecturers can share your work (and you their's!).

Colleges will have their own systems for managing resources but when developing your delivery strategy consider the following:

- **Does the project have a clear title which indicates what it covers?** Clever titles can be fun but labelling your project 'A good scrap!' or 'Something from nothing' may not lead colleagues to realise it is a brilliant resource for looking specifically at using offcuts from the workshop in a new project!
- **Are the intended users clear?** If the project tackles a particular set of objectives (e.g. T-level Engineering: Maintenance, Installation and Repair Core Skill A) or is suitable for a particular type of student (e.g. someone who needs extra support with the mathematical demands or someone who has shown considerable skills in self-management and is near the end of their course) make sure that this is covered in the description.
- **Is it appropriate for particular parts of the year?** A project which involves considerable work outdoors may be better in the late spring or summer rather than the coldest parts of the winter.
- **Does the project need specific, and limited, resources?** Some projects require only basic kit or readily available materials. Others may need a particular press, a machine that needs to be booked in advance or a visit to an engineering company. Make sure that this is clear in your description of project demands.
- **Is the link to the qualification requirements clear?** Qualifications, and the assessment systems that drive them, often have very specific rubrics about what must be covered and how the coverage must be recorded. Ensure that your project plan identifies any of these requirements and describes them in the language, or with the coding, used by the qualification specification. This is a very boring job, but your colleagues will thank you for it!
- **How can you support colleagues – or access support from them?** Producing learning resources is not an easy task. It takes time! Agree with colleagues which resources you will produce and which ones they may be able to take responsibility for creating (or modifying). Most teachers and lecturers find it difficult to use resources produced by others, but it is worth spending some time agreeing the materials to be produced, shared style guides (number of headings, font use) and specifications (e.g. 'every document must have a clear learning objective' or 'every resource must include 3 activities at differing levels of demand').

7. Developing the project

Some people get it right first time – most of us don't! Be prepared to revise your project in the light of experience. Your students can offer advice with this. Indicators that a resource include:

- **Is the success rate too high?** Counterintuitively, every student getting every task 100% correct this is not a strength as it might indicate that the demand is too low, or the material covered is trivial.
- **Is the success rate too low?** This is a more obvious problem and could indicate that essential pre-knowledge is missing, the tasks are too demanding for your students, or the task instructions are not clear enough.
- **Resources are abandoned or require too much input from you to make them work.** Learning resources should create time for you to deal with issues that need you in person (e.g. running discussion groups). If you are needed to support their use, consider ways of re-writing the tasks or developing other resources to support them. Aim to make your resources self-standing – this will also make them more useful for your colleagues and encourage them to make the ones they produce more useful for you!

Dr. Gareth Price
Sheffield Institute of Education