The Royal Institution
Science Lives Here
Masterclass network

Engineering Masterclass Development

Overall structure of the session

You could consider one big project for your Masterclass or a selection of smaller activities that fit one theme. It could take the shape of a design/make/test style of project, an engineering challenge for them to complete, a workshop based around a particular process that incorporates specific engineering principles or techniques, or something else entirely!

As you develop your session, think about a narrative that will run through everything, linking each activity together and providing a thread that the students follow from start to conclusion.

Main activity

- What project/activity you will give them to do?
- Will they work in teams or individually?
- If they are creating something, how they will go about it and test the designs? What materials will they need?
- If they are completing a challenge, think about the background information they will need. Will they need to create and test things, or do research? How will they do this?
- Ensure there is enough for every single student to do throughout the whole session. We don't want any 'back-seaters' so create some additional activities or worksheets just in case (and keep groups small so that no group members become disengaged). These can also be used as an extension exercise in case any groups get through the activity very quickly.
- You could introduce an element of competition (student groups respond really well to this).
- Will part of the project time be given to design improvement and retesting? You may not have enough time for this if it is a complex build, but bear it in mind – they often learn a lot from making initial mistakes and then having the time to go back and correct those. If you cannot factor this into the class, make-sure a round-up at the end where you look at the work produced with the whole group includes a 'what went well, even better if' section.
- Kit is very important to think about. Most engineering sessions use kit of some type or another, and you will need enough to provide kit packs for each student group (see below for more details). You need to consider cost, transport, consumables, and scaleability.
    - If you have a piece of complex kit that you want to demonstrate to students then think about how this effects the session. We would discourage this if the students are waiting for a long time to have a go at something that has limited access. They will get bored and play up unless they have something to be getting on with. Either keep them busy doing the main challenge or give them a worksheet to complete. Bear in mind that during the period that you are demonstrating the equipment, you are not free to support the groups, so think about whether the demo equipment is actually providing a significantly useful addition to the session before you commit to adding it in.

The addition of STEM theory

- What maths and science lies behind your topic and how will you present it so they will grasp it quickly? Use clear, colourful diagrams in a presentation when introducing new aspects of science. Can you introduce audience participation (ask them questions or get them to complete worksheets with a few calculations, draw a graph, make a quick measurement, etc)?
- Look for ideas on the internet for how to present the theory of your topic to school students. There are lots of good ideas out there.

- You could choose to focus on an engineering principle instead such as cost analysis, building strength and construction techniques, need for precision, process engineering, etc. All those elements that make people 'think like engineers'. If you can, include aspects of this in whatever you do – and get them thinking about areas such as societal and environmental impacts.

Your introduction

- This is often detail of your line of work, hopefully challenging their notion of engineering. Inspire by showing cutting-edge technology, and use colourful images, videos, or props, etc.

Other good elements to introduce

- Environmental issues. What are the environmental, ethical or societal issues that are faced in your line of work, or in the activity you are presenting to them
- Realism. How will you introduce engineering realism to the project? (See activity examples below)
- End the class with a bang, not a whimper. Do a brief but impactful closing talk, announce the results of the competition, show a 'wow factor' video, etc.

Materials

Many engineering projects require a considerable amount of materials. Plan this well in advance, as you are developing the project.

- What will need to be bought in? Think about the preparation needed – especially for consumables. Will this take a lot of time or effort? Can you do this for every Masterclass? Think about portability – can you transport it to Masterclasses easily?
- Are there any materials that the organiser can provide? Contact them well in advance to arrange this.
- How much of the materials do you need? This depends on whether the students are working in teams or individually. Make sure you have more than enough. Also consider scalability, especially if you have tested something with a small group.
- Think about the cost of this (if you would need help to cover the costs, you must run it past the Ri or your local group first. Many will not have any funds for significant contributions to expensive kit).
- Identify what items are reusable and what are consumables. Generate a rough costing that shows price per class in addition to the one-off cost of getting the reusable kit together. Think about consumables. Lots of expensive consumables are generally not feasible in Masterclasses.

It is important that the materials used in sessions are relatively cheap. Can you create a session using basic materials that can be manipulated into an engineering project? Obviously some fields of engineering such as electrical/electronic/robotics may have a cost implication. Discuss with the Ri or the local group you are planning to run the class for how/if this can be funded. If you are thinking of a session that requires a suite of computers, check if the groups you are likely to speak at will have easy access to this.

The students are usually required to bring pens, pencils and a calculator each, so you need not provide these. The organiser can provide paper and worksheets for the theory work. Make sure you liaise with them about this. Do you want extra copies for the teacher helpers?

Remember that some materials and activities will need to be included on a risk assessment, so let the organiser know what you are planning to do in advance.

Activity Examples

Pretty much every aspect of engineering can be turned into a Masterclass. Topics currently taught in engineering Masterclasses include civil and structural, electrical and electronics, submarines, robotics, bioengineering, mechanical, rockets, acoustics, renewable energies, aeronautical, etc.

Some activities are more complex than others. If you think your activity needs more complexity, add some process complexity to it. This also allows you to introduce some realism to the scenario, which is good. You could:

- Introduce the concept of a client. Mention the pressures they would experience in real-life (the need to keep within time/budget; the need to have continued dialogue with client through design and build; the need to incorporate health and safety, etc.). There is also the requirement to understand exactly what the client is asking for – do they want high quality, expensive, slow to produce product or something more 'cheap and cheerful'?
- Present them with a project brief that looks professional and contains all the technical information. This could be on an A3 or A4 piece of paper that has enough space for them to do technical drawing on, and for them to do a cost analysis on too.
- Get them to discuss any ethical and environmental issues that would be pertinent for the project and might impact on their design
- Make them create a design where material costs are minimised (get them to cost up their design on a worksheet)
- Do a Dragons' Den type scenario where they have to present their design ideas (include an incentive - maybe the winner gets more materials?)
- You could create a 'market place' where they have to buy their materials
- Get them to create annotated line drawings of their design
- Introduce a problem half way through that they have to respond to (e.g. a change in design spec or a supply chain problem)
- Create add-on activities for them such as worksheets. These are really useful – you can add them in or remove them to help you manage the time in the class. Provide answer and hint sheets to the teacher helpers present so they can refer to that, get a quick handle on what is required and support the students much more efficiently. These can also go to the students at the end of the session.

Complex Builds

If your activity is quite complex, e.g. for electrical circuit building, coding, etc. You may need to get helpers to come along who have some prior skill and knowledge of the activity (talk to the Masterclass organiser or Ri to see if they can find helpers through their networks). If the students get stuck too often and don't have help on hand to trouble shoot, they may get disheartened. To help all activities start well, write out a clear list of instructions. The students often work very fast when they know what to do but need very clear direction to get going initially. If the instructions are written down, you won't be rushing from one group to the next explaining the same set of instructions each time. Equally if there are common pitfalls, consider creating a trouble-shooting crib sheet which they can reference as they get stuck. This will be extremely useful to teachers and helpers who are supporting you.

Design/make/test projects

Timing

You will have 2½ hours. Just under two of these hours can be dedicated to introduction of theory and the project. The remainder of the time is used for your introduction, refreshment break, tidy up at end and final sum-up. The time line example below has a total of:

45 minutes for theory - maximum (split into two)
65 minutes for project work – minimum (split into two)
40 minutes for all else

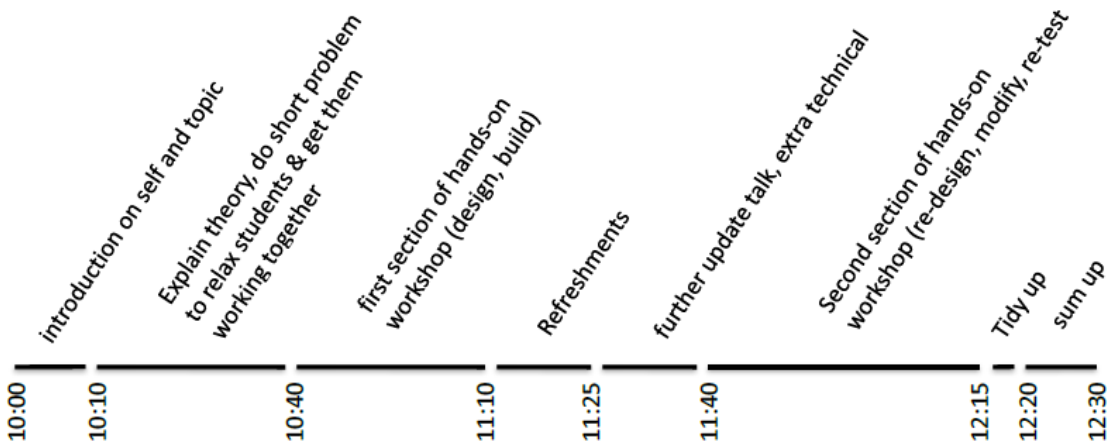
Create your own time-line and remember that this is quite a long time compared to a standard lecture that the students would receive at school. Make sure you have enough to talk about and the students have plenty to do.

Certain activities might take longer than anticipated e.g. helping the students understand the harder theory, so it's better to overestimate times. Have activity modules that can be squeezed out if time is running out, or added in if everything runs faster than anticipated.

Remember to leave adequate time for testing, and have alternative activities for students to do while they are waiting if this will take a significant amount of time. If you have lots of groups' work to test and each test takes several minutes, will the other students get restless?

Always do tidy up before the final sum-up.

Learn from your experience – after your first one, you can tweak the times, but remember: no two Masterclasses are the same so you will always need those modules that can be added or removed.



Example timeline

Advice from other speakers

"In developing the material, put down as many ideas for activities or things to cover as you can related to the topic, and then prune it back to things that work and fit together. If possible, try out sections of the Masterclass with appropriate age groups and see what works, or what needs making easier/harder. Don't be upset if you have to leave something out you really like, if it doesn't go with what you're doing or there's no time. You can always put it in another Masterclass!"

"Prepare material in modular sections, so you can drop things out if you're overrunning or expand on/add in material if the class get through things quickly. While the groups should in theory be at a certain level of ability, 'the best students from each school' can vary wildly in their level of ability - even if they're keen!"

"Even better, have an activity you can give them to work on at the end of the Masterclass, maybe something you've covered briefly but you know they wanted to do more of, so you can turn over the last few minutes of the session to that. This can expand to fill any extra time, or be omitted if needed."

"Use teaching techniques like waiting for silence before you speak."

"Presentations should not be too wordy. Support them with reference or question sheets for focus on any Science, Maths or Technical reference points."

"Include some links in the presentation to Careers and opportunities in the Engineering Industry. Any information on progression routes apprenticeships or University pathways should be referenced for interested students to follow up."

"A session should have a predominance of practical activity supported by short relevant and whizzy plenarys."

"Don't forget to factor in time for clearing up before your big finish. Don't finish on a clear-up; leave them with something to think about at the end."