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Masterclass network

Secondary Mathematics Masterclass Development

Attending a Secondary Mathematics Masterclass series is an invaluable mathematical experience for the students as they have the opportunity to see mathematics as an exciting discipline driven both by the need to solve real-world problems and by investigations into interesting ideas and concepts to see where they lead.

Aims

Masterclasses should:

- Contribute to each student's mathematical reasoning, investigative, problem solving and communication skills.
- Allow students to gain confidence and motivation, especially in regards to mathematics.
- Be challenging and involve real mathematical depth, with the opportunities for exploration and discovery.
- Give students the opportunity to work on open-ended and real-world problems, showing them the relevance of mathematics and how it is used day-to-day. Even if your Masterclass is more abstract, show them links to how the subject is used, current research, or famous unsolved problems – allow them to see the relevance and excitement in the subject. Are there any ethical, environmental, or societal issues which your topic relates to? Discuss this with the students – it is good for them to see the bigger picture.
- Introduce students to new ideas or different applications of more traditional maths in order to extend and enrich their mathematical experience.
- Be outside the normal curriculum – Masterclasses are not an acceleration course and are not for exam support. They are to inspire and engage students with ideas beyond the standard curriculum topics, giving them the opportunity to use their existing skills in challenging and unfamiliar contexts.

Particular things to think about

Some maths topics can be more difficult to turn into a Masterclass as it can be harder to think of hands-on or practical activities. Use existing resources to help you – do a search online for activities within your topic and see what you can use and adapt. NRICH and the rest of the Millennium Maths Project sites are very useful (https://nrich.maths.org/).

Make sure you really are including investigative activities, not just a series of questions or calculations to answer. Open-ended questions are great. Try to vary the type of activity if possible – students can get 'worksheet fatigue'.

Make sure you introduce maths as a creative and collaborative subject. You will probably need to encourage the students to talk to each other and work together – let them know that it's rare for any maths to be done by one person in isolation, in the real world people work collaboratively.

Make sure you tell them that they don't have to have a 'right answer' – it's better to get things wrong and find out why they are wrong than be 'correct' first time. Also, a lot of questions have many different answers, and there are definitely lots of different approaches to the same problem. Make sure the students know to respect others' ideas.

Ensure you allow the students to see different approaches within the Masterclass – see how one student has arrived at a solution to a problem, and then see who has a different way of doing it.

Also ensure that you have different types of problems within the class – some students will think very algebraically, some will think very geometrically, and so on. Often we can't see a different approach to doing things than our own preferred method – NRICH is a great place to go to see how this can be done, as many of their activities have solutions which have been worked out in very different ways.

Do introduce notation and technical terms, just ensure you explain this clearly and thoroughly – use examples etc. Don't go too fast with your explanations and risk losing students – ensure there are opportunities to ask questions and that you make it clear that it's OK to ask. See the slides from the 'presentation skills' section of the training.

All technical aspects around the standard curriculum should be explained in the class and students should be reminded of theory which will be needed in the session that they may have already covered. Ask the Masterclass team for help on what the students may cover in the curriculum.

Questioning

It is easy to ask questions which have a 'right answer' in maths – here are some more tips on questioning:

If you would like the students to discuss their ideas, make sure you give them some concrete questions to think about. For example, ask them to come up with some rules which a method/model/idea seems to follow rather than just asking them to discuss it, and asking 'Can you describe what is different between these two methods?' is better than 'What do you think about the methods?'.

Tell them how you expect them to answer questions – do you want hands up, shouting out, or volunteers to write something on the board?

Remember that many teenagers are shy - if you are having problems getting answers from more than a few students, try the following:

- Mention that you would like to ask someone who hasn't answered yet
- Ask them to discuss the question with the person next to them before asking for responses; you could give them some thinking time before this. You could also ask them to volunteer their partner's idea.
- Ask each table for an answer (where the question is suited to having multiple ideas)
- If you have asked them to discuss something, go round and listen to what they were saying – that way you can pick on a table/group to share a particularly interesting idea which you heard them talking about. Don't pick on individuals in case they are very shy.

If you are working something through with the group as a whole, you could ask for volunteers to show how they would do it (after some thinking/working time), or you could ask the group to tell you what to do next – this allows them to have input, but without needing the confidence to show everyone their working on the entire problem.

Below are different ways of eliciting understanding/ideas from students with specific questions:

- Ask students to construct an example of something that demonstrates their understanding, and then ask them to explain to the others what it is about their example that makes it work. Where there are multiple examples, this sort of questioning allows students to be creative.
- Ask them what could be changed to make something work/not work and explain why, to draw their attention an important feature. Alternatively ask them 'what can change, and what must still stay the same' in order for something to continue to work.
- Ask them to sort particular objects/ideas by whichever criteria they choose – this will show you what aspects they are attending to. For example, in a Masterclass on sequences it might be interesting to see how they sort several different sequences. Can you bring out of them ideas about divergence or convergence?

- Ask them 'what is the same and what is different' between particular mathematical objects/methods/ideas. This may help them gain understanding of different aspects of the topic.

Each of these general questioning techniques are taken from 'Questions and Prompts for Mathematical Thinking' (Anne Watson and John Mason, February 1998), where more details can be found.

Group size

Bear in mind group sizes and room layouts when deciding on your structure. Most Secondary Mathematics Masterclass groups are for between 40-60 students, but some are larger. Likewise, some are restricted to tiered lecture theatres rather than classrooms with tables and chairs which can be grouped.

This will also have an impact on the activities you can do, and it is also unlikely that there will be access to computers for the students. You will need to carefully consider the scalability of any activities (both in terms of kit and time – it can take a very long time for groups to present their ideas, particularly in a large class, and the other students may bet restless while waiting). Ensure any consumables you are using are cheap, quick and easy to produce.

Example structures and timelines

There is no 'best' structure for a Secondary Mathematics Masterclass. Options often include the following:

- Set sections of theory/whole-group discussion followed by a longer period of individual/group work, perhaps in a breakout room;
- Short modular sections of teaching/working continuously throughout the Masterclass;
- Mostly discussion in small groups, with the speaker posing new questions to everyone periodically and chatting to them individually before having a whole-group discussion;
- A challenge or competition, starting with some initial practice work and with the majority of the class taken up by students completing a large task in small groups. The end of the class is often dedicated to each group giving a presentation on what they have done.

Some sample timelines (with additional notes) are included below to help you, but remember that you do not have to follow these. The important thing is to keep the students engaged and doing things.

Avoid giving notes or worksheets out before they are needed, as students tend to get distracted by them. Enlist the help of all the adults in the room to give out materials quickly at the time you judge most appropriate.

Make it clear which things the students can keep, and which you would like back. Some students will get distracted by equipment, so you will need to remove this once it is no longer needed, or ask the students to hand it in/put it in a designated place. The students can help with tidying up – remember to include time for this, and to do this before your big finish.

Example timelines:

Short modular sessions (tweak the timings to fit 2.5 hours)

5 minutes	Introduce yourself
5 minutes	First talk: Introduction
10 minutes	First worksheet/activities/discussion
5-10 minutes	Second talk
15-20 minutes	Second worksheet/activities/discussion
5-10 minutes	Third talk
15-20 minutes	Third worksheet/activities/discussion You may wish to briefly discuss their answers/ideas before the break.

10-15 minutes	Break
5-10 minutes	Fourth talk
15-20 minutes	Fourth worksheet/activities/discussion
5-10 minutes	Fifth talk
15-20 minutes	Fifth worksheet/activities/discussion
10-15 minutes	Big finish

Two main Masterclass sections

5 minutes	Introduce yourself Say who you are, what you do, how you use mathematics in your work. Tell them a bit about what a real mathematician is – e.g. how mathematics is important for your role, what mathematics research actually entails, what you do day-to-day. Use pictures, props, etc. to bring your story to life.
5-10 minutes	Introductory problem Give the students a problem to introduce the topic, get them thinking and talking to each-other. Could be used to occupy arriving students.
15 minutes	First talk Introduce the topic and the first ideas you want to cover. Draw on what they have done in the introductory activity and give them different ideas to consider. Remember to involve the students by asking questions, using volunteers during demos, etc.
35 minutes	First worksheet/activities Include questions about the topics you have covered in your first talk. Make sure you have demonstrated how to do things they will be unfamiliar with and don't use the worksheet to introduce anything new. You may wish to include questions that you will use for discussion in your second talk.
10-15 min	Break
15 minutes	Second talk Build on the first talk and take the topic further - you could go more in-depth and look at some harder theory. You could also discuss a related topic and take the class in a new direction. Some students might be getting tired or may be more easily distracted after the break, so you might find it useful to include lots of student interaction.
45 minutes	Second worksheet/activities Include some more in-depth questions based on the second talk. You could also set the students a challenge, perhaps in small groups; for example, ask them to come up with a solution to a real-world problem linked to your topic and get them to present their ideas (this will take quite a while!)
10-15 minutes	Big finish Bring everything together from the Masterclass; link back to the beginning and show how what they have been doing connects. Answer any questions and give answers or feedback on the worksheets/activities. Finish in the last 5 minutes with your 'wow' moment, e.g. an interesting, applicable problem/application or a really good video.

Short introductory ideas, big project

5 minutes	Introduce yourself
5 minutes	Introduce your topic Outline the main ideas and final challenge. Show real world applications, etc.
10 minutes	First talk: idea 1
25 minutes	First worksheet/activities/discussion; practice the ideas and concepts
10 minutes	Second talk: idea 2
25 minutes	Second worksheet/activities/discussion

10-15 minutes	Break
10 minutes	Set your challenge Introduce a challenge for students to solve, based around the ideas and concepts they have met earlier in the class. This could be a practical or real-world problem which they have to develop a solution for. You could also bring in some realism, like providing a professional project brief. You could start with a simple problem and then introduce more constraints, e.g. cost implications, optimising a solution for different priorities, etc. Could they present their ideas as if tendering for a contract or something similar? Remember to give clear guidelines.
20-40 minutes	Challenge work
10-30 minutes* *Time needed will depend on the number of and length of presentations*	Presenting ideas Remember that the students will not be used to presenting to groups, so leave plenty of time for them to speak and for changeover. Work out how many groups you can fit in within the time and balance the group size accordingly. Remember to keep them to an allocated time – how will you do this? Make sure you tell them how long they will have in advance.
5-10 minutes	Big finish Perhaps show your problem/a solution in the real-world; you could also have a discussion on which team's solution is the best or meets a certain condition most successfully.

Advice from other speakers

"When developing your 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 can 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 maths 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 do that during the last few minutes of the session (before your big finish). This can expand to fill any extra time, or be omitted if needed."

"I have found advice from existing and experienced speakers to be invaluable, especially regarding structure and level of difficulty. Visit other sessions and chat to the speakers."

"1. Think carefully about what happens when the pupils enter your room. Will you have something for them to get cracking on right away because they will be curious about your session, and it will help to settle them down? Or do you plan to say hello as they get dropped off and get to know them a little better before you start the session?
2. It's always a good idea to have extension tasks for the activities, just in case someone has seen your task before or really finishes it so much quicker than the others. If you don't get round to using them, they can be take home tasks or saved for next time.

3. My sessions are always evolving, I look out for ideas to add or ways to tweak existing tasks – it keeps the sessions fresh for the pupils but, perhaps more importantly, for me too."