Evaluation of the Royal Institution Secondary Mathematics Masterclasses programme – Summary Report

Patrick Barmby, Karen Jones, Dimitra Kokotsaki, Francis Ndaji, Jeff Searle and Paul Skinner
CEM Centre, Durham University

Introduction

In December 2007, the Royal Institution commissioned the Curriculum, Evaluation and Management (CEM) Centre to carry out the evaluation of the Secondary Mathematics Masterclass programme. These masterclasses are series of events run in different regions of the UK (see Figure 1), designed “to encourage, inspire and engage young people in the art and practice of mathematics by introducing them to aspects, including applications, which may not usually be covered in the school curriculum.”

The evaluation was to be carried out over the period of January to July 2008. The aims of the evaluation were in three strands:

- An initial background strand to inform the evaluation, including desk-based research on existing STEM-based programmes in mathematics and an examination of the Royal Institution’s own documentation to clarify the aims and objectives of the masterclasses.
- A quantitative strand to the evaluation, looking mainly at student perceptions of masterclasses through questionnaire data. Course organisers were asked to complete an online questionnaire as well.
- A qualitative strand to the evaluation, in order to gather formative opinions from a range of stakeholders, including interviews with students, masterclass organisers, presenters, teachers, Heads of Mathematics in schools, and other stakeholders with an interest in STEM initiatives (e.g. a DCSF representative, a university representative). This strand also included case study visits to a variety of masterclasses, in order to observe the kind of activities being carried out during the sessions.

This document provides a summary of the findings of the evaluation. However, a more detailed report is available, describing the evaluation’s findings in full.

1 From the Royal Institution’s Secondary Mathematics Masterclasses website http://www.rigb.org/contentControl?action=displayContent&id=00000001857
Figure 1: Location of masterclasses around the UK (This work is based on data provided through EDINA UKBORDERS with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown, the Post Office and the ED-LINE Consortium.)

Mathematical enrichment and the aims of the masterclasses

The evaluation of the Royal Institution secondary masterclasses began by looking at the background to STEM initiatives and mathematical enrichment, and related these to the overall aims of the masterclass programme. The need for mathematical enrichment activities is highlighted by ongoing concerns over students’ attitudes towards mathematics. For example, despite a rise in recent years of students taking A-level mathematics, the numbers in 2005/06 were still about 6000 students down on the numbers taking the subject in the 1990s (Smith, 2004; Sainsbury, 2007). In addition, the London Mathematical Society (1995) raised concerns that students entering higher education lacked the necessary ability and skills that might be expected on university mathematics courses. Therefore, it would be hoped that mathematical enrichment programmes tackle these two problems of attitudes towards maths and students’ mathematical skills.

When we examined the research literature on mathematical enrichment however, one of the issues that emerged was the difficulty of defining exactly what we mean by enrichment. Despite this difficulty, Feng (2006) put forward four ‘paradigmatic positions’ on enrichment in order to show the different types of mathematical enrichment activities:

1. Development of mathematical talent, including extending mathematical skills and heightening interest in the subject;
2. Popular contextualisation of the subject, including tackling negative stereotypes and deepening mathematical understanding;
3. Enhancement of mathematical learning processes, including developing learning skills, and
4. Outreach to the mathematically underprivileged, including widening student access to mathematics.

We can contrast these with the overall aims of the Royal Institution secondary masterclasses. There are 10 primary objectives for the masterclasses, which we can categorise under the following areas of impact:

a) Attitudes towards mathematics;
b) Doing mathematics;
c) Participation in masterclasses;
d) CPD opportunities from masterclasses;
e) Facilitation of the masterclasses.

The first three areas (a to c) pertain to the students themselves, the fourth area (d) to teachers that are involved, and the final area (e) to organisers, presenters and the general profile of the masterclasses. We see the aims of the masterclasses to be consistent with the above views of enrichment. Tackling attitudes is certainly part of the first two views of enrichment, and one would hope that the doing of mathematics would result in developing talent, understanding and skills. Participation in the masterclasses themselves can be seen as widening access to mathematics.
In trying to match the aims of the masterclasses to the views of enrichment, we had to be careful to differentiate between what can make up enrichment activities (one could say the input) and the desired outcomes from such activities (the output). In the definitions of enrichment, these inputs and outputs are somewhat mixed together (e.g. an input of popular contextualisation together with an output of deepening understanding). Therefore, in order to further clarify our view of mathematical enrichment, especially with regards to the secondary masterclasses, we put forward the following model:

**Figure 2: Diagram of the mathematical enrichment process**

In the model, we split up the inputs and outputs of mathematical enrichment, and we have already given some examples of these (the aims of the masterclasses are given in bold in the outputs). We also needed to examine how the enrichment process, or more specifically the masterclasses, can be facilitated and also how they could be developed. There would also be additional outputs not directly linked to those of enrichment for students. This model helped us to identify the elements that we needed to examine as part of the evaluation of the masterclasses. We therefore began by looking at the identified outputs from the masterclasses.

**Main outputs from the masterclasses**

The evaluation clearly identified particular student outcomes from the secondary masterclasses, both from the quantitative results of the student questionnaire, and from the qualitative interviews with students carried out during case study visits to masterclasses. The student questionnaire, completed by 971 students, produced the following key findings:
• 64.2% of the students agreed or strongly agreed that their attitude towards mathematics had improved due to the masterclasses;
• 69.6% of the students felt that their ability in mathematics had improved due to the masterclasses.

Therefore, around two thirds of the students perceived that the masterclasses had directly impacted on their attitudes and attainment in maths, in line with what we would hope from an enrichment programme. The responses to other questions on the questionnaire revealed other related outcomes:

Table 1: How students felt about the masterclasses (selected items)

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>% Agreeing or strongly agreeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>I learnt a lot of mathematics from the classes</td>
<td>80.0</td>
</tr>
<tr>
<td>10</td>
<td>I learnt in the masterclasses how useful mathematics is</td>
<td>79.3</td>
</tr>
<tr>
<td>19</td>
<td>The masterclasses have allowed me to explore mathematical ideas</td>
<td>78.6</td>
</tr>
<tr>
<td>2</td>
<td>The masterclasses showed me the importance of mathematics</td>
<td>76.4</td>
</tr>
<tr>
<td>15</td>
<td>Following the masterclasses, I am more confident that I can learn advanced mathematics</td>
<td>72.3</td>
</tr>
<tr>
<td>3</td>
<td>Following the masterclasses, I now expect to do better in maths courses that I take</td>
<td>70.0</td>
</tr>
<tr>
<td>7</td>
<td>The classes made me feel more confident at solving mathematical problems</td>
<td>69.6</td>
</tr>
<tr>
<td>6</td>
<td>The masterclasses have encouraged me to study maths in the future</td>
<td>59.3</td>
</tr>
</tbody>
</table>

These items again showed that students perceived the masterclasses as benefiting their mathematical knowledge and their attitude towards maths, as well as their confidence in the subject. Almost 60% of the students also agreed that the masterclasses had encouraged them to study maths in the future.

These outcomes of improved attitude, knowledge, confidence and future participation were also highlighted in the interviews with students.

*Masterclasses have made me like maths more and now if I’ve finished, Sir gives me more stuff to do from different books and things.*

*When I was in Primary, I didn’t really get it at all and after coming here I am really good at it.*

*I think it will help a bit later on when you come back to the subject at school, you have a sort of understanding because you’ve been through it carefully here.*

*Yes, I’m more confident in maths now and I seem to enjoy it because I’d like to go on to a maths career when I’m older.*
Interviews carried out with organisers, presenters, teachers and Heads of Maths also confirmed these outcomes.

For the very brightest, it’s instilled in them this sort of extra enjoyment and fascination with the subject that maybe wouldn’t necessarily come true in a large class when we’re maybe doing lower level work. So certainly every year, our brighter students do go along and I do think it has given them just a wider appreciation of the subject.

(Head of Maths)

They learn a new way of approaching a problem, particularly thinking outside of the box. Because of the problems they are given, they have to think outside of the box, and I think in that respect it is particularly good.

(Teacher)

Certainly it made the children I taught a lot more positive. I had children taking A-level maths largely because of the masterclass. They enjoyed the classes, they could see where it might lead. So they wished to continue to study and you can’t get better than that.

(Organiser)

Their confidence grows from it. One of my girls, who is here today, is very quiet, but she is up there saying stuff.

(Teacher)

### Additional outputs from the masterclasses

In addition to those outputs which we would hope from a maths enrichment programme, some additional benefits to the masterclasses were identified as well. From the student perspective, the results from the questionnaire indicate two related areas.

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>% Agreeing or strongly agreeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>I enjoyed being part of a group that is enthusiastic about mathematics</td>
<td>70.5</td>
</tr>
<tr>
<td>4</td>
<td>I have enjoyed the social side of the masterclasses</td>
<td>69.3</td>
</tr>
<tr>
<td>14</td>
<td>I made new friends at the masterclasses</td>
<td>58.9</td>
</tr>
</tbody>
</table>

First of all, students enjoyed being part of an enthusiastic group about maths. Secondly, students enjoyed the social aspect and possibly making new friends within the masterclasses. These additional outputs were confirmed by comments from student and teacher interviews.

It’s also nice to meet other people who enjoy maths.
Evaluation of the Royal Institution Secondary Mathematics Masterclasses programme

(Student)

Because you get to meet new people and make new friends.

(Student)

I think that one of the most important things is that the children can meet children from other schools, with similar interests. Sometimes you get five children in the school and they are on their own. They do meet and continue the relationship with some of the children that they meet.

(Teacher)

In addition to these more social benefits for students, benefits for teachers attending the masterclasses, especially in terms of professional development and providing materials that they could use in the classroom, were identified in interviews.

There are always plenty of ideas! We always come with a book and write things down and come back to school and try and use some of the things that we have picked up.

(Teacher)

What is really nice is the teachers coming, because they can then take it back to school. What my teachers in [town name] usually do is, the two or three students that have been go back and teach the rest of the class. Not all the topic, but bits of the thing.

(Presenter)

The same benefits were identified by PGCE students involved in the masterclasses.

When you are thrown in with so many pupils that you don’t know, it is how you adjust to the environment and to helping out and things like that.

Yes, it’s given me so many ideas to do things with higher groups, higher sets, at school which make it more interesting for the children.

Additional benefits were identified as well for organisers. The questionnaire to organisers identified their enjoyment of working with enthusiastic students, and that the masterclasses also provided networking opportunities for them.

I have had some very interesting and enjoyable sessions. Indeed, I would say that in all my professional life some of the most satisfying activities have been masterclass activities. It has made me aware that young people can understand many mathematical concepts which are perceived to be advanced, provided that concepts are discussed in a language familiar to Year 9 pupils.

Tremendous support from teachers, lecturers & RI. Extending my mathematical knowledge increases job satisfaction. The support gives me a whole range of people to "bounce ideas off" when developing further events to encourage young mathematicians.
Main inputs into the masterclasses

The masterclasses were therefore perceived very positively by students, teachers and organisers, and we have been able to identify important outputs from the programme. The next step was to identify why the masterclasses were perceived positively, and the evaluation highlighted three factors: That the masterclasses involved engaging, practical activities for students, that they obtained a broader view of the subject, and that the activities showed the relevance of mathematics to students.

From the questionnaire to students, we were able to combine items referring to how students found the masterclasses into an overall ‘measure of mathematical enrichment’. When we examined the degree to which this measure was related to the quality of three particular inputs, namely that of the presenters, the activities in the sessions and the facilities where the masterclasses were held, we found that the quality of activities correlated most highly (correlation of 0.44). This was followed by the quality of the presenters (0.38). This supports the idea that the activities carried out in the masterclasses were an important contributor to their success. The role of the activities were also identified by the researchers during their visits to various masterclasses, where practical activities were seen to enthuse students and get them involved in ‘doing mathematics’. Engaging activities were also highlighted by students in their interview comments.

_I just like puzzles, sometimes in maths you just get told stuff or you just have to work out things, whereas in those ones you’re actually making things and doing things that are imaginative._

_You learn yourself through experimenting rather than just being told something._

_It is different methods and stuff and we put into practice Pythagoras’ theory and type of stuff. You cover it at school, but here you actually do it._

In addition to the activities being practical, the evaluation highlighted that the activities were different to what students were doing in school, and therefore providing a broader view of mathematics.

**Table 3: Items concerning the maths in the masterclasses being different and useful**

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>% Agreeing or strongly agreeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>I have had the opportunity to tackle new mathematical problems in the masterclasses</td>
<td>91.1</td>
</tr>
<tr>
<td>10</td>
<td>I learnt in the masterclasses how useful mathematics is</td>
<td>79.3</td>
</tr>
<tr>
<td>2</td>
<td>The masterclasses showed me the importance of mathematics</td>
<td>76.4</td>
</tr>
<tr>
<td>18</td>
<td>Much of the mathematics in the masterclasses was new to me</td>
<td>70.0</td>
</tr>
<tr>
<td>13</td>
<td>The masterclasses have shown mathematics in a new light</td>
<td>68.2</td>
</tr>
</tbody>
</table>
Again, that this was an important characteristic of the masterclasses was supported by student comments.

*I think it is definitely more outside the box than addition and subtraction!*

*I like maths, but I don’t enjoy it very much in school at the moment ... I think it is just in school, you do not get much chance to learn something new, most of you are just going over the same things.*

*Before this I didn’t think paper folding was maths, so it’s made me see that maths is more than just numbers and algebra. I have seen the wider side of maths.*

Also identified in the table of questionnaire items above was the fact that the masterclasses had shown students the usefulness and importance of mathematics. Once again, student and teacher comments supported this assertion.

*I think they are good because they show you how maths is used in the real world. Used to solve problems.*  
(Student)

*Some kids expected it to be helping them with their SATS. That’s not what it is for, it gets them to think outside of testing, to see how maths influences things in the world. Last time I came there was a session on frets on the guitar and their relationship with maths in that sense. So it just gives them another way of looking at maths. It’s not ‘just sit down, do a test, add this up’, it is how it is actually in the world.*  
(Teacher)

**Areas of development**

Of course, despite the very positive perception of the masterclasses from those consulted, some areas of development were identified. In the student questionnaires, when the suggestions for improving the masterclasses were examined, the following were the most common suggestions

<table>
<thead>
<tr>
<th>Issue</th>
<th>Number of comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shorter sessions</td>
<td>151</td>
</tr>
<tr>
<td>No suggestions for change</td>
<td>129</td>
</tr>
<tr>
<td>More masterclass sessions</td>
<td>92</td>
</tr>
<tr>
<td>More activities in the session</td>
<td>76</td>
</tr>
<tr>
<td>Later start to the sessions</td>
<td>65</td>
</tr>
<tr>
<td>Improvements to presentations</td>
<td>57</td>
</tr>
<tr>
<td>More or longer breaks</td>
<td>52</td>
</tr>
</tbody>
</table>

It should be noted that the second most common suggestion was for no change, and that did not include students who did not provide a response to this question. However, a number of suggestions pertained to the structure of the sessions, namely shorter sessions, later starts, more breaks but also more classes to make up for any
reduction in time. The other suggestions pertained to two important aspects of the masterclasses, namely the amount of activities and the quality of presentations. Students also raised the issue of later starts in their interviews.

_The timings are really bad, because you have to wake up first thing in the morning to come!_

_If it was in the afternoon, because we wouldn’t have to get up early in the morning._

The issue of the masterclasses sometimes being too challenging was also raised in the interviews with students, and also as a possibility from the visits to the masterclasses by the researchers. However, the responses to the relevant items on the student questionnaire suggested that although students generally found the masterclasses challenging, only 14% of them stated that they were too hard.

Table 5: How students felt about the masterclasses

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>% Agreeing or strongly agreeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>I found the mathematics in the masterclasses challenging</td>
<td>72.6</td>
</tr>
<tr>
<td>11</td>
<td>The mathematics in the classes was too hard</td>
<td>13.8</td>
</tr>
</tbody>
</table>

In addition to negative issues identified about the existing masterclasses, positive ways of extending the masterclasses were also suggested. In the student questionnaire, the following three activities were identified as ones that students would be most interested in:

Table 6: Percentage of students replying 'very interested' to various activities

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>% replying 'Very Interested'</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Maths trips and visits</td>
<td>38.2</td>
</tr>
<tr>
<td>1</td>
<td>Masterclasses for older students</td>
<td>29.7</td>
</tr>
<tr>
<td>5</td>
<td>Maths competitions</td>
<td>29.2</td>
</tr>
</tbody>
</table>

Masterclasses for older and younger students were also identified in interviews with students and teachers.

_Maybe primary school children could get something about what we do in high school, similar to what we are getting about university._

(Student)

_I think it would be helpful for perhaps older students as well, because a lot of them are a bit too young to be thinking about university at the moment, so maybe children that are leaving school and not knowing what they are going to do after college ...When it’s fresh in their minds and closer to decision times._

(Student)
The juniors, if you can stimulate the interest when they are younger, and they come into senior school with that confidence already, it’s lovely, if you can catch them when they are young. There is such enthusiasm in junior school. They are not so inhibited as they are in secondary school. They really go at it very positively.

(Teacher)

If something like that could be developed for Yr 11’s, and perhaps, because [university name] is involved, instead of meeting here, the students could perhaps meet on campus, and they could get a feel for what university maths is like, and what university life is like. It might encourage a few more students to take up maths at university, if they experienced that environment.

(Teacher)

The general idea of extending the masterclasses to more people also included disaffected and less able students as well.

What I would really like to do is work with the disaffected. Not necessarily the low ability, but the ones that don’t see the point in mathematics.

(Presenter)

I think that ... if you did interact with different schools and more schools then people would get more of an opportunity to come to it, because not everyone gets a chance to come to it.

(Student)

One of the things I was just thinking about was it would be nice to have something like this for the less able kids, where they can also see that they can do things, where they maybe don’t do so well in the classroom.

(PGCE student)

Turning to comments made by the representative of the DCSF, they seemed to have a view of linking mathematical enrichment more with what was happening in the classroom.

What we are trying to do is bring the outside world into the classroom and the classroom into the outside world. So, in the future, we’re encouraging, particularly at Key Stage 3 where the curriculum is changing in September, that teachers use enhancement opportunities and enrichment opportunities actually during lesson time instead of as an add on. So that’s what we’re after, it’s really bringing the subject to life, making it relevant, and obviously increasing knowledge.

To a degree, this goes against one of the important inputs for the masterclasses that the sessions cover different things to what is being done in the classroom. However, taking the perspective of providing enrichment opportunities for more children, the suggestions from the DCSF representative could be taken on board by trying to link some masterclasses to classrooms through the internet or through video conferencing.
Facilitation of the masterclasses

The final area that was examined was how the whole process could be facilitated and improved, taking a broader perspective from organisers and also from other stakeholders.

The questionnaires to organisers identified a number of drawbacks for them, the main one being the ‘lack of time’, but also the related issue of lack of support and the issue of funding.

<table>
<thead>
<tr>
<th>Areas of drawbacks</th>
<th>Number of organisers stating this drawback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem of time</td>
<td>15</td>
</tr>
<tr>
<td>Inadequate support</td>
<td>5</td>
</tr>
<tr>
<td>Funding</td>
<td>4</td>
</tr>
</tbody>
</table>

Quotes from the organiser questionnaire elaborated on the first of these points.

*The huge amount of time it takes, throughout most of the summer, to make sure that the series goes smoothly: dealing with parents who do not read instructions; dealing with teachers who contact me the day before the series start and ask if there is room for their star pupil to attend.*

*It is time consuming. It is extremely difficult to contact other schools during the day and many schools are very slow to respond to invitations.*

Therefore, considerations need to be made by the Royal Institution as to how the role of the organiser can be made easier in terms of the time required in organising the masterclasses.

The issue of funding was also raised in the case study visits to masterclasses, and also in a face-to-face interview with one of the teachers and in the organiser questionnaire.

*A couple of years ago, we were paid by the Royal Institution, a one off fee for each time we attended, and that was fine, it was sorted. But this year, we have had to find the budget from within school to pay for the teachers to come out.*

(Teacher)

*The main problem is finding the relatively small amount of money needed to meet the costs (mostly payments to the presenters and helpers). Getting sponsorship is not easy and is very intensive for the amounts needed (around £1200 a year). The most help the RI could give us is to use its resources to try and find a few national sponsors who would provide us with a regular income.*

(Comment from organiser questionnaire)

When other stakeholders were asked about the issue of obtaining further funding for mathematical enrichment activities, there was a consensus on the difficulty of doing...
so. The representative from the DCSF highlighted that in the future, the Advisory Committee on Mathematics Education (ACME) may act as the link organisation for funding.

*If there were gaps in particular areas, it may be possible that the lead organisation for enrichment and enhancement, which in mathematics is ACME ... if you’re looking to do something in maths, talk to ACME and ACME might act as the honest broker. That is possible - its not necessarily going to happen, that’s what we’re hoping will happen ... We’re doing it through the directories, which the RI are leading on and basically, ACME will be the coordinating body. They will have strategic overview of all of that, they will have ownership of that directory.*

Therefore, discussing the funding with ACME may be one of the first steps in facilitating funding for the masterclasses.

**Summary**

To summarise the overall findings of the evaluation of the masterclasses, we return to our previous diagram for the model of mathematical enrichment, updating the model with the findings on the masterclasses.

**Figure 3: Updated model for the masterclasses**
Comparing this model with the aims of the masterclasses showed that the aims of the programme were largely being met, in terms of promoting attitudes towards maths, providing opportunities to ‘do maths’, and providing CPD opportunities for teachers. Some consideration of the facilitation of the masterclasses however could still be considered by the Royal Institution.

References


