Secondary students engaging in a live online enrichment programme

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The study reports on a series of Royal Institution (RI) Mathematics Masterclasses that took place in Wales in Spring 2021. The RI Masterclasses are a popular example of a mathematics enrichment activity and would usually take place in a traditional face-to-face environment, such as a university lecture theatre or school classroom. However, the 2021 series took place online due to Covid-19 restrictions. Through feedback collected after each session we investigate how the design of the online classes influenced students' engagement with mathematics.

Keywords: online; covid-19; enrichment; engagement.

Introduction

The Royal Institution mathematics masterclasses programme for school children was founded in 1981 following the success of the 1978 Christmas Lectures by Sir Christopher Zeeman. The Royal Institution's vision is that the masterclasses offer extended and in-depth exploration of mathematics beyond the classroom, show real-life applications, inspire further engagement with mathematics and allow participants to grow in confidence and make new friends. While the notion of mathematics enrichment has been long debated in literature (Piggott, 2007), the above vision reflect hoped-for-outcomes of mathematics enrichment outlined in various studies (see, e.g., Feng, 2010; Santos & Barmby, 2010)) which are enriched learner experience of mathematics, personal and social gains, support for maths learning at school, impact on the learning and understanding of mathematics but also, sometime, exposure to higher education (Feng, 2010).

Over the years the programme had grown with 180 series of 1050 workshops attracting as many as 6500 students in 2018/19. However, due to the pandemic, some series did not take place and others had to move classes online in 2020/21 cycle. The present study reports on the Swansea 2021 programme and is concerned with how students engaged with the 2021 series. In this series the main differences to the traditional approach to masterclasses were: the classes were held online rather than on a university site; students aged 13-14 and 14-15 were mixed together rather than attending separate programmes of classes; and students from across Wales were invited to attend a single programme of classes rather than having regional programmes organised separately. Additionally, no limit was placed on the number of students that each school could select to attend the classes where normally schools would be restricted to select only 2 students due to space restrictions.

Design of the 2021 series

A series of four 1.5 hour live online sessions took place on four Saturdays in April and May 2021. Due to a high number of applicants (234) and for safeguarding reasons

each session was run twice for a different group (group 1 and 2) of students, thus in total, eight sessions were delivered.

The Microsoft Teams platform was used for the masterclasses with presenters sharing a pre-loaded powerpoint with students. Students could use the chat box to ask and answer questions posed by the presenters. No student video or audio was allowed, and the sessions were not recorded. Presenters were instructed to build breaks within the sessions for students to work on questions and tasks and to encourage students to use the chat box. A collection of follow up materials was sent to students after each session. This contained a pre-recorded video of the presentation and a list of problems and solutions in English and Welsh. The first class was on Combinatorics and included a presentation on Maryam Mirzakhani's advice on doing mathematics, as well as organisers' tips on how to make the most of the online masterclasses emphasising the importance of revising the materials provided after each class as good practice. After the first session students were invited to invent a new problem that could be solved by a method similar to that considered in class and submit their solution via email. Both the second and third sessions were on Topology with the third session (Mobius Strip) having a practical and hands-on emphasis where students were cutting and gluing shapes. The last session on Codes and Ciphers involved 'an escape room' created using a Google document containing puzzles to do during and after the session.

Research question and methodology

To investigate how students responded to the online mathematics masterclasses, we follow Santos and Barmby (2010) who consider student engagement about mathematics as the key output of mathematics enrichment. In view of engagement believed to have three dimensions, behavioural, emotional and cognitive (Fredricks et al., 2004), we mapped elements of the main sources of data available onto each component of engagement. These sources were: attendance data, student feedback collected in a survey after each session, competition entries and organisers' observations discussed after each session. The feedback survey asked participants what about the masterclasses they enjoyed the most and least and asked them to rate statements about various aspects on a Likert scale.

In investigating the behavioural component, we paid attention to student attendance, competition entries and observed behaviour patterns in sessions (e.g, chat participation) and between the sessions (communicating with organisers by email). Attendance data including geographical spread, gender split, school demographics and entries into the competition were also considered as an insight into the behavioural component of engagement. Answers to open ended questions concerning participants developing interest, motivation and appreciation of mathematics and survey questions about participants' enjoyment of the sessions were considered in relation to the emotional dimension. The content of competition entries, survey comments on their own learning revealing metacognitive strategies and approaches and comments about mathematical content of the sessions and motivational goals was considered for investigating the cognitive dimension.

In this preliminary study we report on the findings from each source of data separately. In the second phase of the research, which will be reported separately, participants were invited to give an interview and some 26 responded.

Findings

Attendance data

The event attracted 21 schools across Wales with 37% of participants being from mid and south, 31% from south central, 26% from north and 6% from south east regions of Wales. More than half (52%) were female. Table 1 represents for the numbers of actual attendees and those who filled in feedback forms. Figure 1 represents participant data split by the type of the institution where schools are categorised according to the number of students in receipt of free school meals.

Session	**1.1**	**2.1**	**1.2**	**2.2**	**1.3**	**2.3**	**1.4**	**2.4**
Attended	113	116	107	104	111	98	106	115
Filled questionnaires, including:	64	67	35	20	37	20	38	23
girls	67.2%	50.7%	66%	48%	72%	48%	77%	39%
ethnic minorities	25.4%	16.9%	2.9%	15%	14%	0%	13%	10%
in receipt of free school meals	3.1%	6%	0%	0%	5.4%	4.3%	2.6%	8.7%

Table 1. Session data on masterclasses attendees and feedback completion in groups 1 (morning sessions 1.1, 1.2, 1.3 and 1.4) and 2 (lunch time sessions 2.1, 2.2, 2.3 and 2.4).

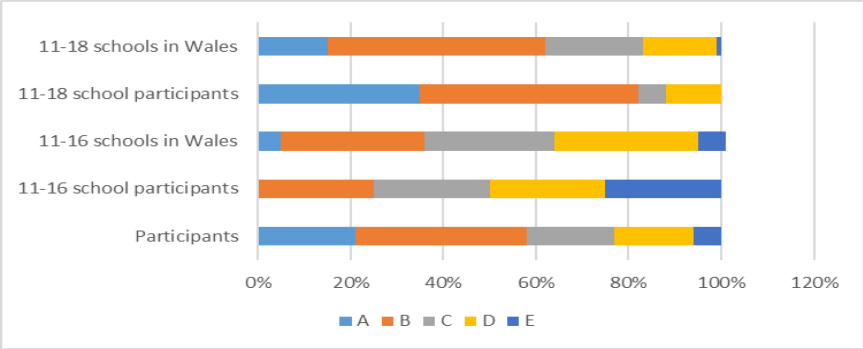

Figure 1. School participant data split by the type of the institution where schools are categorised according to the number of students in receipt of free school meals (FSM). Category A indicates schools with less than 8% of students in receipt of FSM, category B indicates schools not included in A and with less than 16% of students in receipt of FSM, category C indicates schools not included in A or B and with less than 24% of students in receipt of FSM, category D indicates schools not included in the above categories and with less than 32% of students in receipt of FSM and category D indicates schools with at least 32% of students in receipt of FSM. FSM data is not available for colleges.

The feedback was collected via an online questionnaire that students were asked to submit at the end of each session.

Student feedback

Most students who filled the feedback questionnaires felt positive about the classes. Across all the feedback entries, 94% said that they would recommend the sessions to others, 88%, 87% and 89% found, respectively, the content of the session, the materials provided and the quality of delivery excellent or good. There were many more comments about what students enjoyed the most (274 comments in total) rather than what they enjoyed the least (177 comments in total). These came, respectively from 90.1% and 58% of all the respondents.

Comments about what students enjoyed the most

Many students enjoyed learning or doing mathematics, problem solving and especially learning new, contextualised, different or challenging mathematics. They enjoyed learning about mathematics, e.g., learning about "the link between normal everyday things to mathematics advanced questions", how "a simple thing such as a calendar could be used to make a variety of interesting questions" but also that "maths could be used for mostly anything". Learning about new specific areas of mathematics and about mathematicians (both presenters and historical figures) was mentioned as a factor that pushed students to "push harder", "to do and try better" which they enjoyed. For other students, the challenge and interest of the questions (more advanced, going beyond the standard school curriculum or involving more thought or "thinking about maths differently to how we do it in school"), served as a motivator to "push and improve in maths". The problems "didn't have an immediate apparent solutions which led to solving them more rewarding and enjoyable". More emphasis on the method was seen as fun but also something that made students think. Students liked "to think and to solve problems ourselves", to "discover methods rather than just thinking about the answer". The word 'think/thinking' was mentioned in the context of what students enjoyed most 111 times across all comments.

About one third of comments after the first sessions (sessions 1.1 and 2.1) and 74 comments across all sessions were about how much students enjoyed the interaction between the teacher and the students, so they "didn't just have to listen to 1.5 hours". Students enjoyed how involved they could be with answering questions, that they could see the solutions of other students and could draw on screen. They also appreciated that they "could interact with the presenters anonymously" while not feeling "pressured to answer quickly". This seemed to be supported by the pace of the sessions: "[the sessions] were quite interactive allowing people to attempt to figure out the answer before it got explained". More generally, students enjoyed the quality of the teaching (the exercises at the start of the class, the explanations, "the level the work was set", pauses to work on the questions). There was an appreciation from students that they were listed to by the teachers.

Having fun was emphasised in the last session on Codes and Cyphers, while enjoying making paper shapes was a popular comment after the third session.

Comments about what students enjoyed the least.

Approximately a third of all these comments were about not being able to understand some parts, feeling confused or not being able to learn well enough. This may have been due to technology, e.g., "My connection dropped out a few times and I likely missed some important information."; or due to the format of the session, i.e., "there was a long pause between each question asked, instead there could be a similar extension question below to work out if you've finished the first one". There were both comments about questions being too easy and too difficult /confusing and pace being slow or fast: "Occasionally the questions were explained too quickly, making it hard to follow what was going on (not very often)." Other comments were about the format of the sessions (Saturday, during lunchtime, homework, sitting down for long for long sessions, not enough breaks) and technology and interaction (chat functionality, the lag during the sessions, unstable internet connection, video being "slightly choppy"). Interestingly, only seven comments out of 177 were made about not being able to attend in person.

In sessions observations

After each session presenters and administrators exchanged remarks on how the sessions went. In all sessions it was noted that students enthusiastically used the chat to answer questions, on average 40+ chat entries were registered to most question. Students who could not access the chat in the first session appeared to be actively seeking help about it, with more than 70 emails exchanged between students and the administrator during the first session. In addition to answering presenters' questions, students also used the chat to ask for technical help from the administrator and, as the sessions, progressed, to seek and give peer help to sort out more subtle technical difficulties, such as when screen notifications prevented them to type in the chat. Only on a few occasions did students use the chat to ask for help with mathematics, such as asking the presenter to go though some bits again. In the second session participants were given the opportunity to volunteer to draw on screen and some 23 volunteering. to do this.

Competition entries

Thirty six students (16% of those attending the first session) entered the competition with 22 entries from girls. All but three entries were valid, that is, clearly written or typed, relevant and mathematically sensible. Most solutions appeared to be well written or typed and well-presented and demonstrated good understanding of the method learnt in class. Some 7 entries contained a problem and an answer (usually correct) but no solution or a statement that the solution method would be the one discussed in class. Finally, 8 entries were more original including questions applied to entirely new situations or contexts or attempting to combine several types of problems considered in class in one new question. Although solutions to these appeared to be incomplete, they were mathematically interesting.

Discussion

The findings of the study are mostly limited to the opinions of those students who completed feedback. They nevertheless indicate that there were students who enjoyed the sessions and found them beneficial. On average 90% attendance across all the sessions and with little variation from session to session is not typical for online delivery. The geographic spread of the attendees, the gender split and the proportion of participants coming from schools with higher proportion of students on free school meals is another positive outcome of the online programme indicating that these students are willing to engage in online outreach during the pandemic.

While only a small proportion of students took part in the competition, the quality of the entries implies that they engaged with the questions in class and were happy to spend extra time doing mathematics and took the trouble to write their solution, to take a picture and send an email. Which may be seen as another positive outcome of the classes.

There is evidence in the study that students could engage behaviourally, emotionally and cognitively in online enrichment. This seemed to be facilitated by the chat function, presenters' ability to 'listen' to students' answers via the chat, the breaks for individual work built in the sessions and the quality of the explanations and the topics being interesting. The factors that students reported as they enjoyed could be seen as typical for mathematics outreach and were what one may expect from a traditional face-to-face session. There are however exceptions, for example no

comments were made about making friends or working with likeminded students and indeed, sessions did not encourage it.

Yet, for some students it may be difficult to construct mathematics knowledge in online classes. Comments about the least enjoyable thing being unable to understand is not typical for face-to-face classes. Such comments may be seen as supported by findings of the studies on teachers teaching online during the pandemic (Crisan et al., 2021) not being able to judge student understanding in online classes as subtle clues they usually use, such as glancing over learners' shoulders or looking at facial expressions are not available in online classes. This represents a challenge for enrichment which is usually designed as a one off session. Studies on remote teaching assume that learning and teaching happens over time allowing for gaps to be filled through subsequent lessons, written work and, assessment and feedback (Senedd Cymru, 2020).

In relation to this, we remark that although the follow up materials were designed to compensate at least partially for the losses of face-to-face environment, there was no evidence of students using these materials at present. This will be addressed in interviews in a follow up study.

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