RESEARCH ARTICLE

Pre-university informal engagement with mathematical activities and the decision to study mathematics at university

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Abstract

A survey was created to investigate the experiences of mathematics undergraduates with informal mathematical activity prior to starting university, and links these with the decision to study mathematics. A questionnaire was completed by a small sample of first-year undergraduates at two UK universities. Generally, incoming undergraduates are shown to have a high level of enjoyment of mathematics and engagement with informal mathematical activity. Popular activities included mathematical puzzles and games, and online videos about maths. Students were often engaged with family or via social media, playing computer, tablet or phone games, watching TV game shows with mathematical aspects and participating in organised competitions. Only around half engaged via talks or workshops organised through school and watching more structured documentaries or videos of lectures. Few participated in organised clubs. It seems there was greater engagement with 'fun' aspects of mathematics than with activities which demonstrate mathematics linked to career choice. The link to goals of outreach and similar initiatives is discussed, with further research indicated.

Keywords: outreach, university, engagement, informal learning.

1. Introduction

The study of effective outreach practice in STEM is relatively new and developing, but is still under-studied in mathematics in particular. We sought to understand informal engagement with mathematical activity experienced by mathematics undergraduates prior to arriving at university, and to examine any links with the decision to study mathematics at university. A significant feature of this research is that it draws on the experience of a successful freelance maths communicator with many years' experience (KS) to establish potential experiences and activities, and is completed in collaboration with authors who have experience of outreach and public engagement projects (PR) and a formal outreach role in a university mathematics department (AU). A survey was designed, with the aim to gather data on students' recollections of informal mathematical activities and the decision to study mathematics at university.

Informal mathematical activity in universities often takes the form of public engagement and outreach. Public engagement is *"the myriad of ways in which the activity and benefits of higher education and research can be shared with the public"* and is *"by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit"* (NCCPE, 2018). University outreach activities are undertaken in order to promote public awareness and understanding of subjects and make informal contributions to education (Varner, 2014), usually with a secondary goal of creating and maintaining relationships with schools and colleges and encouraging young people to continue to higher education in the subject (University of Sheffield, 2019). A related concept is widening participation, which directs outreach and marketing activities to particular under-represented demographics. In addition to university activity, there is much amateur

and freelance maths communication. In this article, we consider any activity outside of school and formal education which encourages participants to engage with mathematical ideas and techniques. These activities may cross over one or more of the above categories, and from the point of view of the recipient may be indistinguishable.

The remainder of the article is structured as follows: a discussion of the types of informal mathematics activity, based on our experience, is followed by a discussion of background literature. Details of method are followed by results and discussion.

2. Types of informal mathematics activity

Separate from formal school curricula, we consider informal engagement with mathematics through a huge variety of activities, ranging from organised extra-curricular activities participated in at school through to measurements and calculations performed as part of activities around the home. Based on our experience, we listed relevant activities. This was particularly informed by the professional practice of KS via a review of freelance outreach/public engagement projects and other activity she has been involved with. This list of activities was then sorted into broad categories: organised; independent; online/digital; and, other media.

Organised activities are tangential to formal schooling. This might include visits to a school from STEM professionals for talks and lectures, organised workshops such as Ri Masterclasses, maths/STEM clubs and school trips to STEM institutions.

Independent activities might include talks and lectures visited with family or other non-school organisations, mathematical or logic-based toys or board games, reading maths books in their own time, or mathematical activities at home, such as measuring/calculating in order to perform DIY or cooking tasks. We argue that these are distinct from ‘organised activities’ because either they take place informally in the home, or if they are arranged, they are not for a specific group of students.

The category of online/digital activities includes online courses, YouTube videos, mathematical apps/games, and maths/logic puzzles shared on social media. This is distinct from ‘independent activities’, as they take place online and are largely self-directed by the student.

The final category concerns ‘other media’, and includes mathematical television documentaries or lectures, radio shows or segments, and TV game shows with a mathematical basis. We have this as separate because mass media is fundamentally different to social media and other digital activities.

The categories are not totally distinct. It might not be very different, say, for a parent to share with their child a mathematical board game or a mathematical app, or to watch a video on YouTube or one on iPlayer, but we have these as separate activities. For this reason, the categories are mainly a useful division to break up the survey questions and analysis.

3. Background

Our list of reasons students give for studying mathematics at university is drawn from a study by Robinson, Thomlinson and Challis (2010). They surveyed 223 students on arrival at mathematics departments in *“a handful of diverse institutions”* (p. 8), and do not claim the sample as representative. They found that around three quarters of students chose maths as a degree subject due to their interest in, enjoyment of or ability in mathematics, with around a third saying their choice was due to maths having a good reputation as a subject with high earning potential that could lead to good jobs. Of those who had an interest, enjoyment or ability, they note that these categories range from *“being the ‘only subject I was good at’ through to a student talking about their ‘passion’ for maths”* (p. 11).

Robinson, Thomlinson and Challis do not report asking students about their experience of pre-university extracurricular engagement with maths. The Smith Inquiry 'Making Mathematics Count' reports that outside of the school and college system, *"the UK has a tradition of independent small-scale voluntary initiatives to support particular aspects of the teaching and learning of mathematics"* and recognised the need to evaluate these (Smith, 2004).

Archer et al. (2013) highlight *"participation in science-related activities outside of school"* and *"parental attitudes to science"* (p. 17) as some important factors relating to aspirations in science among 10-14 year olds. Cooper (2011) warns of the impact of formal school settings on *"our perspectives of mathematics"*, with *"most students"* experiencing *"isolated instruction that prepares them to perform well on standardized tests"*, but not opportunity to apply mathematics in real situations or integrate this in other areas such as the other STEM disciplines (p. 48). She explains (p. 51)

"It is important for young learners to realize that mathematics is more than counting and number facts, or recognition of geometric shapes, and the application of mathematical procedures. They also need to see the mathematics that makes up the world they live in, such as the growth patterns in nature, the steepness of a slide, why something is pleasing to the eye (symmetry, proportion), and other important connections that informal learning environments might allow learners to explore."

Stirling et al. (2009) suggest that outreach work to show that *"mathematics is more interesting or applicable"* or that *"it leads to more appealing and varied careers"* can help encourage more school students to continue with the subject (p. 5). Johnson and Mulligan (2016) recommend outreach can address *"a common misconception that there are limited career opportunities within the field of mathematics"* by relating learning to *"real life situations and potential career paths"*, with particularly high potential impact for girls (p. 31). They also recommend designing engaging activities using puzzles, games and challenges.

In terms of research into outreach and informal learning, there is relatively little available. UPMAP (Hofkins, 2017), took place in 2008-2011 and surveyed 23,000 UK school students at different ages, asking them about their intentions to study maths post-16 and their current experience. The questionnaire included a section on engagement in enrichment activities - including maths clubs, masterclasses and competitions. A number of research papers have resulted from this study, but most have a main focus on other factors and have not analysed the contribution of such activities beyond statistical correlation.

Stirling et al. (2009) offer sample feedback sheets for asking about the effectiveness of a maths outreach activity at the point of delivery. This type of evaluation is common, but cannot effectively determine whether the activity has resulted in an increased likelihood of further education as it rarely includes any long-term follow up of participants (Rodd, Reiss and Mujtaba, 2011). Cooper offers some insights, but suggests the need for further research into how mathematical thinking can be enhanced through informal learning experiences. Denson, et al. (2015) suggest there is value in informal learning environments, making a link to learning *"outside the constraints of standards-based testing and state-wide curriculums"* (p. 14), and again suggest more research is needed.

We did not find a study of the range of informal experiences with mathematics among students who eventually chose to study mathematics at university, which our project attempted.

4. Method

The survey was conducted as a questionnaire, emailed to first year mathematics students at Sheffield Hallam University and Sheffield University, and is available in the appendix.

It included four main questions about types of informal experience of mathematics prior to attending university. These questions were written based around the discussion given in section 2 above, with one question for each of the four categories of activity giving checkboxes to indicate which activities the respondents recalled participating in, with the options 'Yes', 'No', 'I think so' and 'I don't know'. Each question also contained a free text field to allow respondents to expand on or clarify their answer, including the prompt *"For example, what do you particularly remember about the activities you took part in? What did you most enjoy?"* A fifth free-text question asks for activities not already covered.

A final question explored the reasons for studying mathematics at university, giving students a list of reasons based on an analysis of free-text responses given by Robinson, Thomlinson and Challis (2010, p. 11) and discussed earlier in this article.

There is much more that could have been asked, but the decision was made to balance thoroughness against the length of the survey. The idea was to obtain coverage of the topic for the surveyed audience, in hopes of highlighting particular areas that might form the basis of further investigations.

Ethics approval for the questionnaire in the appendix was granted by the Sheffield Hallam University research ethics committee in March 2019. The survey was promoted to first year undergraduate students in class and by email over two weeks in March and April 2019 and data collected over a five week period.

5. Results

The questionnaire was completed by 33 students, 23 from Sheffield Hallam University and 10 from the University of Sheffield, all of whom consented to participate.

5.1. Organised activities

Responses to question 1a about organised activities are given in table 1. The most popular response was to competitions and challenges, with 70% of respondents saying 'Yes' or 'I think so'. Otherwise, around half of participants reported engaging in a school trip to a maths lecture or workshop, and around half reported a talk or activity by an external person at their school. Around a third of respondents reported attending a careers event that involved meeting mathematicians, scientists or engineers, and around a third reported a school trip to a relevant museum, centre or exhibit.

One free-text response reported attending a *"'getting girls into STEM' style day"* and said *"I found the talks from female mathematicians motivating to go into maths"*, and also taking part in UKMT challenges and that these *"built on my confidence in my maths ability at different ages"*. Another commented on UKMT challenges, saying *"I loved all the UKMT stuff, because it was maths that made you think, rather than memorise."*

Table 1. Responses to 'Please indicate which of the following organised activities you took part in before starting university'.

Activity	**Yes**	**No**	**I think so**	**I don't know**
Someone visited my school and gave a maths talk or ran an activity.	13 (39%)	16 (48%)	3 (9%)	1 (3%)
School trip to maths lecture or workshop.	16 (48%)	15 (45%)	2 (6%)	0

School trip to science/engineering/maths museum, STEM centre or exhibit.	9 (27%)	23 (70%)	1 (3%)	0
School trip to industrial site/factory/business to learn about how they apply maths/science.	4 (12%)	29 (88%)	0	0
I attended a careers event involving meeting mathematicians/scientists/engineers (in or out of school).	12 (36%)	21 (64%)	0	0
I participated in Maths Club/STEM Club activities.	6 (18%)	26 (79%)	1 (3%)	0
I participated in STEM activities through Scouts/Guides or similar.	2 (6%)	29 (88%)	2 (6%)	0
I attended CodeClub/Coderdojo/Hackday events or any other events to learn coding.	1 (3%)	32 (97%)	0	0
I participated in STEP prep sessions.	3 (9%)	30 (91%)	0	0
I visited Sheffield Hallam for the PopMaths quiz.	2 (6%)	31 (94%)	0	0
I participated in another maths competition/Olympiad/quiz/UKMT challenge - through school or individually.	21 (64%)	10 (30%)	2 (6%)	0

5.2. Independent activities

Responses to question 2a about independent activities are given in table 2. The most popular responses are puzzles (85%), board games (76%), sharing mathematical puzzles/ideas with friends and family (67%) and toys (58%). 42% had visited a relevant museum, centre or exhibit not with school, and around a third had attended a maths lecture or workshop not with school, participated in an escape room or read popular maths books.

One free-text response referred to the Rubik's cube and speed solving. Three referred to parents and grandparents, including one who enjoyed *"testing my parents"*. One had read biographies of mathematicians and another had read a mathematics study guide.

Table 2. Responses to ‘Please indicate which of the following other activities you took part in before starting university’.

Activity	Yes	No	I think so	I don't know
Attended maths lecture or workshop (not with school).	11 (33%)	21 (64%)	0	1 (3%)
Visited science/engineering/maths museum, STEM centre or exhibit (not with school).	14 (42%)	18 (55%)	0	1 (3%)
I participated in an Escape Room.	12 (36%)	21 (64%)	0	0
I attended a science/maths themed birthday party.	1 (3%)	32 (97%)	0	0
I read popular maths books (covering maths topics, biographies of mathematicians/scientists).	11 (34%)	21 (66%)	0	0
I solved Sudoku and other logic or maths puzzles.	28 (85%)	5 (15%)	0	0
I played maths/logic based board games.	24 (73%)	8 (24%)	1 (3%)	0
I played with maths/logic based toys.	18 (55%)	14 (42%)	1 (3%)	0
I did practical building/measuring/crafting/carpentry/ engineering tasks around the house/with parents.	16 (48%)	17 (52%)	0	0
I shared mathematical puzzles/ideas with friends/family.	21 (64%)	11 (33%)	1 (3%)	0

5.3. Online/digital activities

Responses to question 3a about online/digital activities are given in table 3. Here, participation was generally high, with around 70-75% reporting having watched online videos about maths, accessed mathematical content via social media and played maths/logic based computer games or phone/tablet apps. Around half had watched online lectures/talks about mathematics but fewer than a quarter had studied online courses.

Table 3. Responses to ‘Please indicate which of the following online/digital activities you engaged with before starting university’.

Activity	Yes	No	I think so	I don't know
I watched online videos about maths (Numberphile, Standupmaths, etc.).	18 (56%)	8 (25%)	6 (19%)	0
I watched online lectures/talks about maths (e.g. on YouTube, Ri Channel, a university website, etc.).	15 (45%)	17 (52%)	1 (3%)	0
I studied online courses such as Khan Academy or a MOOC.	6 (19%)	24 (77%)	1 (3%)	0
Mathematical puzzles/ideas shared on social media.	21 (66%)	10 (31%)	1 (3%)	0
I played maths/logic based computer games or phone/tablet apps.	23 (70%)	10 (30%)	0	0

Free-text responses do not add significantly to the details here, simply naming specific games and YouTube channels/presenters.

5.4. Other media

Responses to question 4a about other media activities are given in table 4. Here, around 70% reported having watched TV game shows or quizzes with a mathematical aspect, and around half had watched TV documentaries about mathematics, with lower proportions for the other options.

Table 4. Responses to 'Please indicate which of the following other media activities you engaged with before starting university'.

Activity	Yes	No	I think so	I don't know
I watched TV documentaries about maths.	14 (42%)	17 (52%)	2 (6%)	0
I watched TV game shows/quiz shows with a mathematical aspect (Dara O Briain's School of Hard Sums, Countdown, Golden Balls etc.).	22 (67%)	10 (30%)	1 (3%)	0
I watched Royal Institution Christmas Lectures on TV (or attended a live recording).	6 (18%)	27 (82%)	0	0
I heard maths puzzles on the radio (e.g. Radio 4 Puzzle For Today, or otherwise).	6 (19%)	25 (78%)	1 (3%)	0

One free-text response clarifies that they watched quiz shows rather than game shows.

5.5. Other activities

A free-text question 5 asked for other activities not covered in the questions. Two affirmative responses were received. One referred to UKMT challenges, which *was* included as an option in an earlier question to which this student had answered 'Yes'. The other said *"Tried to do a step exam"*. This respondent had answered 'No' to participation in STEP prep sessions, which are different but related.

5.6. Decision to study mathematics at university

Responses to question 6a about the decision to study mathematics at university are given in table 5. Considering a response of '5', '6' or '7' as indicating that this reason was important, the most important reasons were wanting to learn more maths (97%), enjoying maths (94%), being good at maths (84%), finding maths a challenge (72%) and career prospects (72%).

There were two free-text responses giving other reasons. One said *"To improve my ability to communicate maths to others"*, and the other said *"To put off getting a proper job for a while! I just want to mess around with maths for a career, if that's possible."*

Table 5. Responses to ‘Please indicate how important the following were in your decision to study mathematics at university’.

Reason	1 - least important	2	3	4	5	6	7 - most important
I enjoy maths/maths is my favourite subject	1 (3%)	1 (3%)	0	0	7 (22%)	6 (19%)	17 (53%)
I wanted to learn more maths	0	0	1 (3%)	0	9 (28%)	12 (38%)	10 (31%)
Maths is a challenge	0	3 (9%)	2 (6%)	4 (13%)	8 (25%)	11 (34%)	4 (13%)
I am good at maths/best at maths compared with other subjects	1 (3%)	1 (3%)	1 (3%)	2 (6%)	6 (19%)	9 (28%)	12 (38%)
Good job prospects/Wide range of jobs open to maths graduates	2 (6%)	1 (3%)	3 (9%)	3 (9%)	5 (16%)	9 (28%)	9 (28%)
Maths is a prestigious/valued degree	2 (6%)	2 (6%)	2 (6%)	7 (23%)	5 (16%)	11 (35%)	2 (6%)
Maths fits into my specific career plans	6 (20%)	1 (3%)	4 (13%)	8 (27%)	3 (10%)	6 (20%)	2 (7%)
Earning potential	5 (16%)	2 (6%)	5 (16%)	5 (16%)	6 (19%)	6 (19%)	2 (6%)

5.7. Links between experiences and the reason to study

The small sample size precludes meaningful statistical analysis, and also many students rated several options as ‘7 - most important’, meaning we don’t have distinct groups with different motivations. However, it may be interesting to explore two cases in greater detail, chosen for apparently different motivations. While not necessarily representative of particular groups within the cohort, these two cases illustrate combinations of attitudes we saw in the responses which may be of interest – many students were positive about their attitude to mathematics, but some were less likely to be motivated by its impact on their career prospects, like Student A. We are planning a further study which will investigate the connections between these attitudes more closely.

Student A

Student A is a first year student at Sheffield Hallam University. In terms of reasons for studying mathematics, they rated ‘I enjoy maths/maths is my favourite subject’ and ‘I wanted to learn more maths’ as ‘7 - most important’, and all other reasons less important. They rated ‘Good job prospects/Wide range of jobs open to maths graduates’, ‘Maths fits into my specific career plans’ and ‘Earning potential’ as ‘1 - least important’. It seems reasonable, therefore, to classify student A as motivated by enjoyment of the subject and not at all by future career prospects.

In terms of organised activities, student A engaged with none of the activities in question 1a, nor did they engage with informally-organised talks or visits in question 2a. It is clear, then, that this student’s enjoyment of the subject did not arise from organised extracurricular activities. They answered ‘Yes’, however, to reading popular maths books and playing with mathematical games, puzzles and toys, and to engaging mathematically with family members. In question 2b, this student reported teaching themselves to solve the Rubik’s cube, playing Sudoku, Chess, Othello and other games with their dad and grandad, and doing woodworking projects with their dad. This student also reported engaging with all the online activities in question 3, as well as some engagement with TV documentaries and the Ri Christmas Lectures. In question 3b, they report watching YouTube videos

by Numberphile, Matt Parker, Grant Sanderson, Sal Khan, Michael Stevens and others, and playing the Euclidea mobile game.

Generally, then, the picture presented by student A is of someone inspired to an enjoyment of the discipline on the basis of high engagement with individual and informal family activities, rather than organised outreach and public engagement events.

Student B

Student B is a first year student at Sheffield Hallam University. They rated 'Good job prospects/Wide range of jobs open to maths graduates' as their sole '7 - most important' response to question 6a. They answered '5' to the reason 'I enjoy maths/maths is my favourite subject' - still a positive response, but note that 72% of respondents gave a more positive response to this question. (In fact, only two students gave outright negative answers to the enjoyment question and neither appears to be an illustrative case for reasons omitted for space.) It may be fair, then, to characterise student B as more motivated by career goals.

Student B was highly-engaged in organised activities, reporting experience of mathematical events at school, trips to events and locations with school and outside of school, involvement in STEM careers events and involvement in STEM clubs outside of school. They also report involvement with mathematical puzzles, games and toys, and engaging in all online activities in question 3a.

6. Discussion

There is little research on engagement in mathematics by school-age students outside of the formal curriculum. We are interested in engagement in such activities by students who eventually chose to study mathematics at university, and the links between engagement in informal activity and motivations to study mathematics further. A survey of a small group of students at two UK universities gives some insight into such links.

Students have many different reasons for choosing to study mathematics at university. Certainly many are motivated by an interest in or enjoyment of mathematics, while the motivation offered by career prospects varies in our sample. Advice for universities on offering informal engagement activities varies, but often includes a link to applications and career prospects (e.g. Stirling et al., 2009). It is also suggested that there is a role for informal engagement in exploring the true nature of mathematics (beyond standardised testing) and developing mathematical thinking (Cooper, 2011).

The most popular activities among responses were individual ones, playing with mathematical puzzles and games, and watching online videos about maths, all with at least three-quarters participation. Around two-thirds engaged in sharing mathematical ideas with family or via social media, playing online games, watching TV game shows with mathematical aspects and participating in organised competitions. Around half engaged via talks or workshops arranged through school, and watching documentaries and videos of lectures online. Few participated in organised clubs.

It is likely that some of these results reflect societal trends, for example for young people to watch online videos, or around the level of engagement with regular out-of-school clubs. Practicalities also play a role, with free, individual activities more frequently engaged with than paid-for organised events. That said, it is perhaps surprising to note that the most frequently engaged with activities are those which may demonstrate the fun in mathematics (puzzles, games, short videos on YouTube), with lower engagement for activities that may demonstrate mathematics as a career choice.

There may be a link between activities engaged with and motivation to study, though more work is needed to investigate how widespread these results are and to explore causal relationships. It seems

reasonable to highlight that student B has a more career-focused interest in mathematics and that their informal experience of mathematics was more organised and less personal or family-oriented than student A. It may be that playing with mathematical games, puzzles and toys with enthused family and watching YouTube videos about mathematics supports an enjoyment of mathematics, while organised activities have greater focus on applicability and career links.

Further research to explore the links between the goals of different outreach/public engagement methods and student motivations for study would be potentially useful. Activities have myriad goals, including informal learning, furthering engagement in mathematics or broadening public awareness of mathematics. For example, if a project aims to encourage uptake of university mathematics, it would be useful to know whether a focus on applications and career prospects is a reliable approach, or whether fun mathematics is more engaging to the target audience. This is a subtle question; it may be that those who are engaged by fun mathematics are already predisposed to study mathematics further, while those who are uncertain about further study may be more likely to be motivated by applications or career links.

A key limitation of this study is the small, self-selecting sample. It would have been good to ask students to rank their reasons for studying mathematics or at least give a single 'most important' reason, because a lot of students were generally positive across many different reasons. We did not examine the level of engagement in these activities, in order to keep survey completion manageable - for example someone who had engaged in an activity once would give the same response as someone who did so regularly. Given the link to gender revealed by Johnson and Mulligan (2016), perhaps it would have been fruitful to ask for this information.

On a more fundamental level, there are goals of outreach and public engagement that cannot be examined via this sample population - for example, an activity may aim to engage those who aren't going to study mathematics at university in taking maths further via A-level or non-mathematics STEM university study, or to engage the general public to see the value of mathematics. Students who considered studying mathematics but chose not to, are not included. It may have been useful to consider whether students had access to opportunities they did not take, or whether some of the activities we listed were not available to them, though recall of childhood activities may not be the method to obtain such information.

Overall, it is pleasing to note that incoming mathematics undergraduates have a high level of enjoyment of mathematics and of engaging with informal mathematical activity, particularly so on an individual basis where presumably they are able to make choices about how to spend their time on a phone or tablet or around the home. The level of engagement in more organised informal mathematical activities is lower, and the link between the goals of such activities and students' motivations warrant further study.

7. Appendix

Pre-university informal engagement with mathematics - Questionnaire Questions

- (Consent to participate question)
- At which university do you study mathematics? *
    - ○ Sheffield Hallam University
    - ○ University of Sheffield
    - ○ Other: [free text]
- 1a. Please indicate which of the following organised activities you took part in before starting university. [Yes/No/I think so/I don't know]

- Someone visited my school and gave a maths talk or ran an activity.
- School trip to maths lecture or workshop.
- School trip to science/engineering/maths museum, STEM centre or exhibit.
- School trip to industrial site/factory/business to learn about how they apply maths/science.
- I attended a careers event involving meeting mathematicians/scientists/engineers (in or out of school).
- I participated in Maths Club/STEM Club activities.
- I participated in STEM activities through Scouts/Guides or similar.
- I attended CodeClub/Coderdojo/Hackday events or any other events to learn coding.
- I participated in STEP prep sessions.
- I visited Sheffield Hallam for the PopMaths quiz.
- I participated in another maths competition/Olympiad/quiz/UKMT challenge - through school or individually.

- 1b. Please use this box to expand on or clarify your answer if you want to. For example, what do you particularly remember about the activities you took part in? What did you most enjoy? [free text]

- 2a. Please indicate which of the following other activities you took part in before starting university. [Yes/No/I think so/I don't know]

    - Attended maths lecture or workshop (not with school).
    - Visited science/engineering/maths museum, STEM centre or exhibit (not with school).
    - I participated in an Escape Room.
    - I attended a science/maths themed birthday party.
    - I read popular maths books (covering maths topics, biographies of mathematicians/scientists).
    - I solved Sudoku and other logic or maths puzzles.
    - I played maths/logic based board games.
    - I played with maths/logic based toys.
    - I did practical building/measuring/crafting/carpentry/engineering tasks around the house/with parents.
    - I shared mathematical puzzles/ideas with friends/family.

- 2b. Please use this box to expand on or clarify your answer if you want to. For example, what do you particularly remember about the activities you took part in? What did you most enjoy? [free text]

- 3a. Please indicate which of the following online/digital activities you engaged with before starting university. [Yes/No/I think so/I don't know]

    - I watched online videos about maths (Numberphile, Standupmaths, etc.).
    - I watched online lectures/talks about maths (e.g. on YouTube, Ri Channel, a university website, etc.).
    - I studied online courses such as from Khan Academy or a MOOC.
    - Mathematical puzzles/ideas shared on social media.
    - I played maths/logic based computer games or phone/tablet apps.

- 3b. Please use this box to expand on or clarify your answer if you want to. For example, what do you particularly remember about the activities you took part in? What did you most enjoy? [free text]

- 4a. Please indicate which of the following other media activities you engaged with before starting university. [Yes/No/I think so/I don't know]

    - I watched TV documentaries about maths.
    - I watched TV game shows/quiz shows with a mathematical aspect (Dara O Briain's School of Hard Sums, Countdown, Golden Balls etc.).
    - I watched Royal Institution Christmas Lectures on TV (or attended a live recording).
    - I heard maths puzzles on the radio (e.g. Radio 4 Puzzle For Today, or otherwise).

- 4b. Please use this box to expand on or clarify your answer if you want to. For example, what do you particularly remember about the activities you took part in? What did you most enjoy? [free text]

- 5. Are there any other extracurricular maths or related activities not covered in the questions above which you took part in? [free text]

- 6a. Please indicate how important the following were in your decision to study mathematics at university. [Rated from 1 (least important) to 7 (most important)]

    - I enjoy maths/maths is my favourite subject
    - I wanted to learn more maths
    - Maths is a challenge
    - I am good at maths/best at maths compared with other subjects
    - Good job prospects/Wide range of jobs open to maths graduates
    - Maths is a prestigious/valued degree
    - Maths fits into my specific career plans
    - Earning potential

- 6b. If you have a reason for studying maths at university not covered by the list above, please indicate this here. [free text]

8. References

Archer, L., DeWitt, J. and Osborne, J., 2013. *ASPIRES: Young people's science and career aspirations, ages 10-14*. London: King's College London.

Cooper, S., 2011. An Exploration of the Potential for Mathematical Experiences in Informal Learning Environments. *Visitor Studies*, 14(1), pp.48-65. https://doi.org/10.1080/10645578.2011.557628

Denson, C.D., Stallworth, C.A., Hailey, C. and Householder, D.L., 2015. Benefits of Informal Learning Environments: A Focused Examination of STEM-based Program Environments. *Journal of STEM Education*, 16 (1), pp.11-15.

Hofkins, D., 2017. *Understanding Participation rates in post-16 Mathematics and Physics (UPMAP)*. Available at: https://www.ucl.ac.uk/ioe/research-projects/2019/may/understanding-participation-rates-post-16-mathematics-and-physics-upmap [Accessed 10 January 2020].

IMA [Institute of Mathematics and its Applications], 2012. *Maths Outreach Report*. Available at: https://cdn.ima.org.uk/wp/wp-content/uploads/2012/07/National-HE-STEM-Programme-Maths-Outreach-Report.pdf [Accessed 10 January 2020].

Johnson, A. and Mulligan, C., 2016. What makes a successful outreach kit? *MSOR Connections* 14(2), pp.28-33. https://doi.org/10.21100/msor.v14i2.291

NCCPE [National Coordinating Centre for Public Engagement], 2018. *What is public engagement?* Available at: https://www.publicengagement.ac.uk/about-engagement/what-public-engagement [Accessed 10 January 2020].

Robinson, M., Thomlinson, M.M. and Challis, N.V., 2010. Why do students study maths? In: M. Robinson, N. Challis & M. Thomlinson (Eds.), *Maths at University: Reflections on experience, practice and provision*, pp.8-18. Birmingham: More Maths Grads.

Rodd, M., Reiss, M. and Mujtaba, T., 2011. *Undergraduates' stories about why they are studying physics: implications for policy*. Available at: https://www.ucl.ac.uk/ioe/sites/ioe/files/BERA2011RoddReissMujtabaUPMAPpost18physicsS_2.pdf [Accessed 10 January 2020].

Smith, A., 2004. *Making Mathematics Count: The report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education*. Available at: http://www.mathsinquiry.org.uk/report/MathsInquiryFinalReport.pdf [Accessed 10 January 2020].

Stirling, D., 2009. *Outreach to Schools: A Good Practice Guide*. Birmingham: More Maths Grads. Available at: https://www.stem.org.uk/rxue2 [Accessed 10 January 2020].

University of Sheffield, 2019. *Public engagement, outreach and widening participation*. Available at: https://www.sheffield.ac.uk/pre/public-engagement/resources/toolkits/outreach [Accessed 10 January 2020].

Varner, J., 2014. Scientific Outreach: Toward Effective Public Engagement with Biological Science. *BioScience*, 64(4), pp.333-340. https://doi.org/10.1093/biosci/biu021