RESEARCH ARTICLE

Maths Sparks: Investigating the impact of outreach on pupil's attitudes towards mathematics

Anthony Cronin, School of Mathematics and Statistics, University College Dublin, Dublin, Ireland. Email: anthony.cronin@ucd.ie
Aoibhinn Ni Shuilleabhain, School of Mathematics and Statistics, University College Dublin, Dublin, Ireland. Email: aoibhinn.nishuilleabhain@ucd.ie
Emily Lewanowski-Breen, School of Mathematics and Statistics, University College Dublin, Dublin, Ireland. Email: emily.lewanowski-breen@ucdconnect.ie
Christopher Kennedy, School of Mathematics and Statistics, University College Dublin, Dublin, Ireland. Email: christopher.kennedy@ucdconnect.ie

Abstract

In this article, we examine the impact of participating in a series of mathematics workshops on secondary-school pupils' attitudes towards mathematics. A six-week program, entitled 'Maths Sparks', was run by a team of lecturers and students at a research-intensive university in the Republic of Ireland. The outreach series aimed to promote mathematics to pupils from schools designated as socio-economically disadvantaged (DEIS - Delivering Equality of Opportunity in Schools), who are less likely to study mathematics at higher level than their non-DEIS counterparts (Smyth et al. 2015). Sixty-two pupils participated in the research and data was generated through pre-post questionnaires based on the Fennema-Sherman (1976) framework of Attitudes to Mathematics. Findings suggest that while male students initially had more positive attitudes towards mathematics, there was a narrowing in this gender gap across several factors on the Fennema-Sherman scale as a result of participation in the programme. The most prominent of these features were: 'Attitudes towards success in mathematics' and 'Motivation towards mathematics'. Findings suggest that the construct and delivery of this Mathematics outreach programme, involving undergraduate students and academic staff, may provide a useful structure in benefitting pupils' attitudes towards mathematics and encouraging their study of the subject.

Keywords: mathematics outreach, widening participation, student-staff collaboration.

1. Introduction

Students from lower socio-economic areas are often disadvantaged in terms of their mathematics education, when compared with their counterparts in higher socio-economic areas (Cox & Bidgood, 2002; Schoenfeld, 2002). In the Republic of Ireland (ROI), pupils in schools designated as disadvantaged (Delivering Equality of Opportunity in Schools – DEIS) have been found to have lower average scores in overall mathematical skills (Shiel, Kelleher, McKeown, & Denner, 2015). In addition, a recent report has found that secondary pupils in DEIS schools are less likely to participate in mathematics at a higher level than their non-DEIS counterparts (Smyth, McCoy, & Kingston, 2015). It has been suggested that this lower participation in higher mathematics is due to pupils' attitudes towards studying mathematics and their perceived usefulness of studying mathematics at higher level for the terminal state secondary examination (the Leaving Certificate).

In this paper, we investigate the impact on pupils' attitudes towards mathematics via participation in a series of mathematics outreach workshops, known as 'Maths Sparks'. Building on results from a previous pilot programme (Ni Shuilleabhain & Cronin, 2015), this research utilizes the Fennema-Sherman framework of attitudes towards mathematics (1976) to analyse the impact of participation in this series of workshops on pupils' attitudes towards mathematics. In addition, we analyse the impact on pupils' aspirations to pursue higher level mathematics as a result of taking part in Maths Sparks.

2. Maths Sparks

'Maths Sparks' is a series of mathematical problem solving workshops, based on content external to the senior-cycle mathematics curriculum. Each workshop is designed to incorporate contextualized and meaningful mathematical activities which encourage students' sense-making and include a range of classroom organizational forms (Schoenfeld, 1992; Verschaffel et al., 1999). A key feature of the workshops is that they are designed by teams of undergraduate students, who collaborate with academics to develop relevant mathematical content for participating pupils. Each workshop is presented by the designing undergraduate team, with pupil learning facilitated by other participating students and lecturers. This construct encourages collaboration between secondary pupils and undergraduate mathematics students in exploring mathematical ideas and developing skills in mathematical thinking.

The workshops are designed with four aims:

1. To encourage pupils to communicate, reflect on, and build confidence in their mathematical thinking.
2. To impact pupils' attitudes towards mathematics to see it as a viable, interesting, and important subject.
3. To motivate pupils to continue studying mathematics at higher level for Leaving Certificate.
4. To encourage pupils to study courses related to science, technology, engineering or mathematics (STEM) at third level through engaging with undergraduates and graduates of STEM.

The series is aimed towards senior cycle secondary pupils in Transition Year or fifth year (15-17 year olds) and is offered free of charge to participants.

Information on the Maths Sparks series was shared with DEIS schools through the university Access & Lifelong Learning Centre, who have responsibility for providing support to school leavers from socio-economically disadvantaged backgrounds. Seventy-two pupils (forty-one females and thirty-one males) from twelve schools chose to take part in the programme.

The series of workshops took place from March to April in 2016 and introduced 10 topics (from Game Theory to Cryptography) over the course of the six weeks. Workshops were held in the university's Active Learning Rooms (ALE), where the learning environment supported collaborative activities for pupils. On each of the six evenings, a short concluding presentation was given by a mathematics lecturer on a topic related to the workshops.

3. Methodology

Prior to the commencement of the series, pupils were invited to be involved in research on the impact of taking part in Maths Sparks. Permission for pupils' participation was requested from parents/guardians and sixty-two pupils (thirty-seven females and twenty-five males) agreed to take part. Data was generated through pre-post questionnaires, which contained a mixture of open and Likert-scale questions. Open questions were designed to investigate pupils' opinions on studying mathematics and their intentions to study mathematics at higher level for the Leaving Certificate. Likert scale questions on a 5-point scale ranging from "strongly disagree" to "strongly agree" were asked on 12 questions over six of the nine factors of the Fennema-Sherman scale (1976):

1. Mathematics Anxiety (MA),
2. Confidence in Learning Mathematics (CLM),
3. Attitudes Towards Success in Mathematics (ATS),
4. Teacher Scale (TS),
5. Usefulness of Mathematics (UM),
6. Effectance Motivation in Mathematics factor (EMM).

In total, sixty-two pupils (37 females and 25 males) completed the pre-series questionnaire and fifty pupils (23 females and 27 males) completed the post-series questionnaire. Statistical analysis incorporated only matching pre-post pupil responses (forty-four pupils) and qualitative analysis was conducted through a thematic analysis (Braun & Clarke, 2006) of pupils' responses based on the framework of the six Fennema-Sherman factors (1976).

4. Findings

As might be expected from pupils who had opted to participate in a mathematics outreach programme, in the pre-series questionnaires the majority of pupils were positive in their attitudes towards mathematics (all names are pseudonyms):

> *"I like the satisfaction that comes with it as soon as you solve the puzzle it feels very rewarding to me and it makes me feel that I have achieved my objective."* – Cora

> *"I like the challenge associated with it and the feeling of satisfaction when I solve parts of it."* – Sean

Participants' negative opinions of mathematics were, however, generally related to their experiences of learning mathematics at school. Aligning with research from (Lyons, Lynch, Close, Sheerin, & Boland, 2003) on classroom mathematics practices in the ROI, pupils reported on learning rules and formulae, with memorization viewed as an important mathematical skill. In addition, mathematics was often viewed as a topic solely relevant to school.

> *"I dislike all the theorems and things that need to be memorized for the Leaving Cert."* – Lucy

> *"Some chapters can be tedious. Just putting different numbers into the same formula repeatedly."* – Michael

When asked if they intended to study mathematics at higher level for their Leaving Certificate six pupils (all female) reported in the negative and cited a lack of confidence in their own ability as a reason for this decision.

> "*Because I am not good enough."* – Rachel

Following their participation in the Maths Sparks series of workshops, pupils' were asked if they felt more confident in their mathematical ability, with the vast majority of pupils responding positively.

> "*Yes, because I'm no longer afraid answering questions*" – Paul

> "Y*es, I give up less easily when tackling Maths problems and I see the problems through - attempt them to the best of my ability*" - Nicholas

All pupils in the post-series questionnaires intended to pursue mathematics at higher level in their Leaving Certificate and, while thirteen pupils (12 females and 1 male) in the pre-series questionnaire noted they were not considering a STEM related course or career after secondary school, in the post-series questionnaire this was reduced to five pupils (3 of whom were female). Pupils also had a broader perspective on the usefulness of mathematics across a variety of applications and careers:

> "*I've discovered several different things the students studied in relation to maths that interested me that I didn't even know I could study.*" – Ciara

> "*My opinion of maths has greatly changed as I thought it was only used in school and business but I later found out it could be used in game mechanics and measuring waves.*" - John

The quantitative analysis of the data further explores the impact of the Maths Sparks series on pupils' attitudes towards mathematics. Following pupils' participation in Maths Sparks, there were statistically significant results over three features of the Fennema-Sherman scale (1976): 'attitudes towards success in mathematics', 'usefulness of mathematics' and 'effectance motivation in mathematics' scales (results are included in the Appendix). Differences in pupils' responses across the two genders were evident, with male pupils' responses differing to those of female pupils in both pre- and post-series questionnaires and male pupils demonstrating a statistically significant change in their 'confidence in learning mathematics' post series. Differences in gendered responses were, however, reduced across 'attitudes towards success' and 'effectance motivation': male responses were significantly higher at the 5% and 10% level in the pre-survey (p-values for the Mann-Whitney U test 0.0151 and 0.06832 respectively) and these differences were no longer significant in the post survey.

Taking one of the features demonstrating a statistically significant change, we consider one of the twelve questions related towards 'attitudes towards success in mathematics'. Pupils were asked to rate their agreement with the statement "I don't like people to think I'm smart at maths". While in the pupils' pre-series responses thirty pupils disagreed or strongly disagreed with this statement, this increased to thirty-six in the post-series response. This change was related to the additional female pupils who strongly disagreed with this statement in the post-series questionnaire.

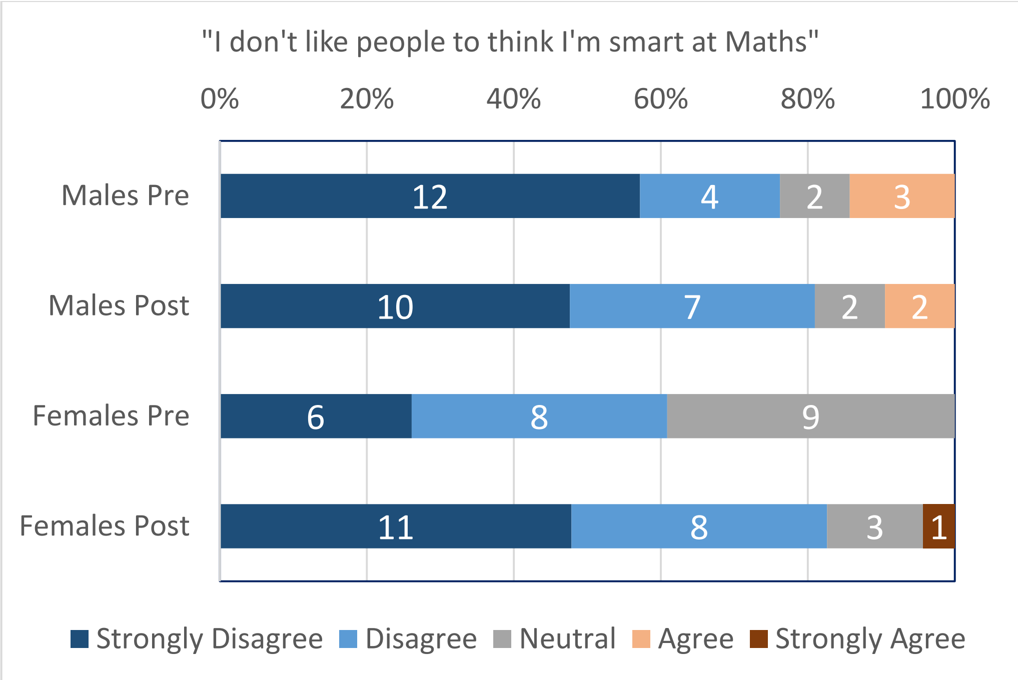

Figure 1. Responses to the question “I don’t like people to think I’m smart at maths.”

While only male pupils’ responses demonstrated a significant change in their ‘confidence in learning mathematics’, there was an increase in the numbers of pupils who strongly disagreed with the statement “For some reason even though I study, maths seems unusually hard for me”.

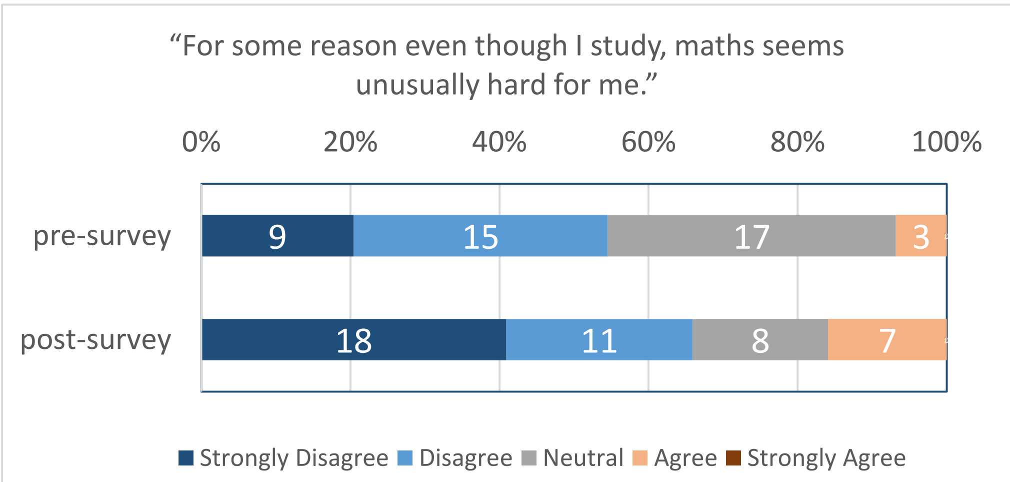

Figure 2. Negatively phrased question from CLM factor showing increase in positivity for the whole cohort

There were also increased numbers of pupils who agreed with the statement “I think I could handle more difficult maths” (further details included in the Appendix).

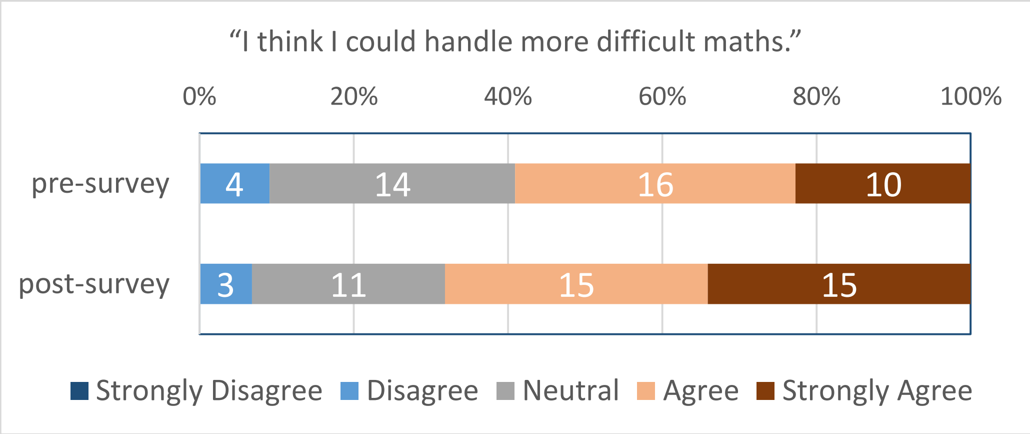

Figure 3: CLM questions showing increased positivity for the whole cohort in the post survey

Returning to pupils' open responses, participants were asked if their opinion of mathematics had changed due to their participation in Maths Sparks. Their responses were very positive and, in the majority, were related to their perceived relevance of the subject:

> *"It made me admire mathematicians and maths because of how much importance it has in our world."* - David

In addition, many pupils commented on the contrasting way mathematics was introduced in the Maths Sparks workshops when compared with their classroom experiences. Pupils also enjoyed learning new topics outside of the mathematics curriculum.

> *"Learning the different things to maths. In school, it's just "Find XYZ", here there are millions of different ways to show maths."* - Janette

> *"Yes. I learned that there are different options in maths. It's not like the maths we do in school. You can take the part in maths that you enjoy and find interesting to study."* - Marion

Many pupils also commented on being more aware of their capacity to work through problems with different strategies, rather than only having 'one way' to do a question:

> *"I know that I have to look at every question in other ways to get an answer*" – Cora

When asked to describe what they enjoyed about Maths Sparks, pupils commented on the social element of the workshops, where pupils engaged with undergraduate mathematics students and met and worked with pupils from other schools.

> *"Interacting with University students and getting to ask them questions."- Nicolas*

> *"Got to meet and befriend people I wouldn't normally have got the chance to meet."- Karen*

Pupils responded positively to both the content and construct of the Maths Sparks workshops:

> *"I really really enjoyed the maths we learned and now enjoy maths again. Thank you for doing this for us and offering it to us, it was very enjoyable"*- Michelle

> *"It was the best 8 weeks of my school life"*- Greg

5. Discussion and Conclusion

Participating in Maths Sparks workshops positively impacted on pupils' attitudes towards mathematics and on their intention to pursue mathematics at higher level in their secondary school studies. Analysis demonstrates that there were statistically significant changes to pupils' 'attitudes towards success in mathematics', 'usefulness of mathematics' and 'effectance motivation in mathematics' features of the Fennema-Sherman (1976) attitudes towards mathematics instrument. In addition, there were statistically significant differences in male pupils' responses to their 'confidence in learning mathematics'. Pupils' perceptions of mathematics were impacted and, rather than seeing mathematics as a subject within the school curriculum, pupils' responses included the references to applications of mathematics in the real world and across a number of industries.

Following their participation in the Maths Sparks series, more pupils intended to study mathematics at higher level in the Leaving Certificate and more pupils were considering pursuing a career in STEM.

Based on our findings, we consider that Marks Sparks offers the university an innovative way to attract students from a diverse socio-economic background to mathematics-based courses.

6. Acknowledgements

We like to thank the undergraduate volunteers and the secondary students who participated in Maths Sparks 2016 and would also like to acknowledge our undergraduate co-authors who supported the research as part of a summer internship programme. We would also like to acknowledge Áine Murphy and the UCD Access and Lifelong Learning Centre for their support in liaising with all schools participating in the programme.

This research was supported by a SFI Discover grant: number DP15/018

A booklet detailing each of the Maths Sparks workshops has been published and is free to download at https://www.ucd.ie/mathstat/mathsparks/ for any group wishing to commence a Maths Sparks programme at their own institution.

7. Appendix: Tables and Charts

Table 1. Summary of testing differences in the median results between and within genders

	Test	Result	p-value	U-Value	Z-value
MA	Males vs Females Pre Survey	Males had a higher median score on average	0.01169*	111	-2.5039
	Males vs Females Post Survey	Males had a higher median score on average	0.02184*	103	-2.0703
	Male Pre vs Male Post	No Significant Difference	0.625	2.5	-1
	Female Pre vs Female Post	No Significant Difference	0.6875	7	-0.8165
CLM	Males vs Females Pre Survey	Males had a higher median score on average	0.001851**	117	-3.0211
	Males vs Females Post Survey	Males had a higher median score on average	0.001111**	119	-3.1333
	Male Pre vs Male Post	Confidence was statistically significantly higher in the post survey	0.03125*	0	-2.2361
	Female Pre vs Female Post	No Significant Difference	0.625	2.5	-1
ATS	Males vs Females Pre Survey	Males had a higher median score on average	0.0151**	106	-2.1835
	Males vs Females Post Survey	No Significant Difference	1	73.5	-0.0982
	Male Pre vs Male Post	No Significant Difference	1	2	-0.5774
	Female Pre vs Female Post	No Significant Difference	0.125	0	-1.7321
TS	Males vs Females Pre Survey	Males had a higher median score on average	0.00062**	105	-2.2958
	Males vs Females Post Survey	Males had a higher median score on average	0.01015*	103.5	-2.171
	Male Pre vs Male Post	No Significant Difference	0.1875	12	1.3416
	Female Pre vs Female Post	No Significant Difference	0.25	3	1.4142
UM	Males vs Females Pre Survey	No Significant Difference	0.155	96	-1.8459
	Males vs Females Post Survey	Males had a higher median score on average	0.04535*	106	-2.1319
	Male Pre vs Male Post	No Significant Difference	0.5	0	-1.4142
	Female Pre vs Female Post	No Significant Difference	0.25	0	-1.7321
EMM	Males vs Females Pre Survey	Males had a higher median score on average	0.06832*	94	-1.9579
	Males vs Females Post Survey	No Significant Difference	[-]		
	Male Pre vs Male Post	No Significant Difference	0.125	6	1.7321
	Female Pre vs Female Post	No Significant Difference	0.5	0	-1.4142

* Significant at the 5% level
** Significant at the 1% level
[-] This test did not give a result as the median responses for males and females were *identical* leading to an NA value for the p-value, the result here is simply that there is zero difference between male and female responses for Effectance Motivation in the post survey

Table 2. Statistically significant results from testing differences between genders

Factor	Test	Result	p-value
ATS	Males Pre vs. Females Pre	Males had a significantly higher median response	0.0151**
	Males Post vs. Females Post	No Significant Difference between the genders	~ 1
EMM	Males Pre vs. Females Pre	Males had a significantly higher median response	0.06832*
	Males Post vs. Females Post	No Significant Difference between the genders	~ 1
UM	Males Pre vs. Females Pre	No Significant Difference between the genders	0.155
	Males Post vs. Females Post	Males had a significantly higher median response	0.04352**

** significant at the 5% level * significant at the 10% level

Table 3. Results showing males having much higher results in several factors, indicating a gender divide.

actor	Test	p-value	Result
MA	Males vs Females Pre Survey	0.01169	Males had a higher median score on average
	Males vs Females Post Survey	0.02184	Males had a higher median score on average
CLM	Males vs Females Pre Survey	0.001851	Males had a higher median score on average
	Males vs Females Post Survey	0.001111	Males had a higher median score on average
TS	Males vs Females Pre Survey	0.00062	Males had a higher median score on average
	Males vs Females Post Survey	0.01015	Males had a higher median score on average

8. References

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Cox, B., & Bidgood, P. (2002). Widening Participation in MSOR. *MSOR Connections, 2*(1), pp.15-19.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to Measure Attitudes toward the Learning of Mathematics by Females and Males. *Journal for Research in Mathematics Education, 7*(5), pp. 324-326. doi:10.2307/748467

Looney, A. (2006). Assessment in the Republic of Ireland. *Assessment in Education: Principles, Policy & Practice, 13*(3), pp. 345-353. doi:10.1080/09695940601035544

Lyons, M., Lynch, K., Close, S., Sheerin, E., & Boland, P. (2003). *Inside Classrooms: The Teaching and Learning of Mathematics in Social Context*. Dublin: Insitute of Public Administration.

Ni Shuilleabhain, A., & Cronin, A. (2015). Maths Sparks: Developing Community and Widening Participation. *MSOR Connections, 14*(1), pp. 43-53.

Schoenfeld, A. H. (1992). Learning to think Mathematically: Problem Solving, Metacognition, And Sense-Making in Mathematics. In D. Grouws (Ed.), *Handbook for Research on Mathematics Teaching and Learning* (pp. 334-370). New York: MacMilan.

Schoenfeld, A. H. (2002). Making Mathematics Work for All Children: Issues of Standards, Testing, and Equity. *Educational Researcher, 31*(1), pp. 13-25.

Shiel, G., Kelleher, C., McKeown, C., & Denner, S. (2015). *Future Ready? The performance of 15-year-olds in Ireland on Science, Reading Literacy and Mathematics in PISA 2015*. Retrieved from Dublin.

Smyth, E., McCoy, S., & Kingston, G. (2015). *Learning from the Evaluation of DEIS*. Retrieved from Dublin.

Verschaffel, L., De Corte, E., Lasure, S., Van Vaerenbergh, G., Bogaerts, H., & Ratinckx, E. (1999). Learning to Solve Mathematical Application Problems: A Design Experiment with Fifth Graders. *Mathematical Thinking and Learning, 1*(3), pp. 195-229.