

Maths Sparks engagement programme: investigating the impact on under-privileged pupils' attitudes towards mathematics

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Abstract

In this paper we explore the attitudes of under-privileged secondary school pupils in Ireland towards mathematics and investigate the impact of attending a 4-week engagement programme on these attitudes. The pupils involved in this research attended schools recognized by the Department of Education & Skills as socio-economically deprived. Pupils attending these schools, known as Delivering Equality of Opportunity in Schools (DEIS), are 40% less likely than their counterparts in non-DEIS schools to pursue mathematics at a higher level in state examinations (Smyth, E., Mccoy, S. & Kingston, G., 2015, *Learning From the Evaluation of DEIS*. Dublin: Economic and Social Research Institute). However, little research has reported on these pupils' experiences of and attitudes towards mathematics at senior secondary level. An engagement programme entitled 'Maths Sparks' was purposefully designed for secondary pupils from DEIS schools, with the aim of positively influencing their attitudes towards and confidence in mathematics. The programme consisted of weekly out-of-school workshops exploring extra-curricular mathematics topics, designed and delivered by undergraduate mathematics students. Questionnaires were utilized to evaluate pupils' attitudes towards mathematics before and after their participation in the programme. Despite its relatively short time frame, qualitative and quantitative analysis suggests an increase in participating pupils' attitudes towards, enjoyment of and self-confidence in mathematics due to their participation in the programme. Findings also suggest that while these pupils liked the subject of mathematics, their experience of learning the subject in school was not always positive and was sometimes hindered by the absence of higher-level mathematics as an option in school. The high-stakes examination content and teachers' beliefs in the ability of their students also sometimes negatively impacted learners' intentions to pursue mathematics at a higher level. Findings suggest that longitudinal mathematics engagement programmes, which focus on problem solving, involve extra-curricular mathematical concepts and are presented

by undergraduate mathematics students, may provide a valuable way of positively impacting pupils' intentions to pursue the subject.

I. Introduction and Educational Rationale

Over the past 10 years educational and economic policies in Ireland and around the world have emphasized the importance of mathematics education for secondary school pupils and have highlighted the need to encourage more learners to pursue Science, Technology, Engineering and Mathematics (STEM) courses at third level (STEM Education Review Group, 2016, Department of Education & Skills, 2017, Darlington and Bowyer, 2017). While mathematics is not a compulsory subject for secondary pupils in Ireland, the vast majority of students (98%) studies mathematics for the duration of their secondary education (SEC, 2019). Education is not compulsory after the age of 16 in Ireland, but 91.2% of pupils participate in senior secondary education and sit the high-stakes Leaving Certificate examination (equivalent to A-levels or baccalaureate), which also governs entry into higher or third-level education (CSO, 2019a,b). Although Leaving Certificate scores (or points) are calculated from a total of a pupils' highest six scoring subjects, research demonstrates that attainment in mathematics is a key determinant of entry to higher education in Ireland (McCoy *et al.*, 2010). In this system mathematics can be taken at three levels (higher, ordinary or foundation) and there is a particularly positive association of pursuing higher-level mathematics with third-level university admittance (Byrne and McCoy, 2017).

In 2011 only 15.8% of the national pupil cohort sat the higher-level Leaving Certificate Mathematics examinations in Ireland. With a revision of the secondary school mathematics curriculum in 2010, the Department of Education & Skills (DES) aimed to increase the numbers of pupils taking higher-level Leaving Certificate Mathematics to 30% (Project Maths Implementation Support Group, 2010). To encourage pupils in this regard, the DES advised that 25 bonus points be added to the 100 achievable points awarded for subjects assessed at higher level by the Central Applications Office (CAO), the system by which the majority of pupils enters into third level education. With this incentive, coupled with the revised secondary mathematics curriculum known as 'Project Maths' (Jeffes *et al.*, 2013), Ireland saw a rise in higher-level mathematics participation similar to the UK (Noyes and Adkins, 2016) and in 2019 32.9% of students completed the higher-level Leaving Certificate Mathematics examination (SEC, 2019). However, while these numbers may be seen to be a positive outcome of the secondary mathematics curriculum reform, when the socio-economic status of pupils is taken into account, the distribution of the proportion of pupils choosing to study higher-level mathematics shows much inequality (McCoy *et al.*, 2019, Smyth *et al.*, 2015).

A scheme focusing on improving the educational attainment of pupils with challenging socio-economic backgrounds was introduced to the Irish education system in 2006. This Delivering Equality of Opportunity in Schools (DEIS) scheme aimed to address 'the educational needs of children and young people from disadvantaged communities' (Department of Education & Science, 2005). Schools under the DEIS scheme (approximately 680 primary and 194 secondary schools of a national total of 3,111 and 710 schools, respectively) are provided with additional resources to, among other targets, reduce class sizes, improve pupils' educational achievements and reduce the number of pupils leaving school early. Focusing solely on mathematics, pupils from low socio-economic backgrounds in Ireland are, more often than not, found to be in lower level mathematics classes (Byrne and McCoy, 2017). While there is evidence that some elements of educational disadvantage have been met through the DEIS scheme (Weir *et al.*, 2014), research has shown that secondary school pupils from DEIS schools are only 40% as likely to take higher-level mathematics than their counterparts in non-DEIS schools (Smyth *et al.*, 2015).

Furthermore, [McCoy et al. \(2019\)](#) found that these patterns of inequality have been exacerbated by the recent policy decision to award the bonus points for higher-level Leaving Certificate Mathematics.

It is in this context that an extra-curricular mathematics engagement programme, entitled ‘Maths Sparks’, was designed for senior secondary pupils from DEIS schools. This programme aimed to positively impact pupils’ attitudes towards and self-confidence in mathematics, thereby encouraging them to pursue higher-level mathematics and, leading on from this, other STEM subjects in their future education. While there is a large body of research on DEIS schools in Ireland, little is known about these pupils’ perceptions of their own learning, particularly in relation to senior secondary mathematics. Building on previous studies ([Ni Shuilleabhain and Cronin, 2015](#), [Cronin et al., 2017](#)), we therefore aimed to answer the following research questions:

1. How do senior secondary pupils attending DEIS schools reflect on their experiences of learning mathematics?
2. How does participation in a specifically designed mathematics engagement programme impact on pupils’ attitudes towards mathematics?

2. Review of the Literature

2.1. DEIS: a focus on mathematics

The socio-economic status of pupils impacts on their successes in education ([Lucas, 2009](#)) and is a predictor of their achievement in mathematics ([Organisation for Economic Cooperation and Development, 2016](#)). In turn, mathematical achievement and higher levels of mathematics education have been demonstrated as important predictors of earnings and employability in later life ([Adkins and Noyes, 2016](#), [Rose and Betts, 2004](#)).

In the Irish context there is a pronounced correlation between inequalities in income and inequalities in education. Those who have higher household income and higher earnings have associated higher levels of educational attainment, while welfare receipt and dependency are predictors of low levels of educational attainment ([Byrne and McCoy, 2017](#)). While the DEIS programme provides additional resources for such designated schools, studies have demonstrated that in DEIS schools pupils’ learning experiences are more likely to be teacher centric and activities promoting higher-order skills are less prevalent than in non-DEIS schools ([Devine et al., 2013](#), [Perkins and Shiel, 2016](#)). As well as the significant recorded gaps in pupils’ achievement in the state Leaving Certificate examinations and in international tests such as TIMSS and PISA, pupils’ attitudes towards learning in DEIS schools remain significantly more negative than their counterparts in non-DEIS schools ([Weir et al., 2014](#), [Smyth et al., 2015](#)). Furthermore, with regards to continuing education after secondary school, research involving low-income working-class communities found that learners’ sense of university is of that which is unknown, foreign and somewhere they do not belong, thereby inhibiting their pursuit of higher education ([Lynch and O’Riordan, 1998](#)).

Focusing specifically on the subject of mathematics, a number of studies have found that pupils from DEIS schools are 40% less likely than their non-DEIS counterparts to engage with the subject at the higher level ([Smyth et al., 2015](#)). In addition, pupils in DEIS schools demonstrate higher mathematical anxiety and lower self-concept in mathematics ([Perkins et al., 2013](#)). With regards to the new incentivization scheme of 25 bonus points, research by [McCoy et al. \(2019\)](#) demonstrated a widening of the gap between overall points achieved by students in DEIS and non-DEIS schools, further impacting pupils from DEIS schools’ access to third level in the competitive Leaving Certificate

points race. Such findings of inequality are worrying, particularly considering the impact of secondary mathematical achievement on later educational and employment experiences.

2.2. *Attitudes toward mathematics*

Affective factors such as attitudes, beliefs, emotions and values impact a pupil's engagement with their learning of mathematics (Donmoyer, 2000). A pupil's attitude towards the subject is developed through their collective learning experiences over a considerably long period of time (White *et al.*, 2005, Ngurah and Lynch, 2013) and can be impacted by the learning environment, teacher knowledge and approaches to teaching and learning (Prendergast and O'Donoghue, 2014).

Over the past 40 years there has been considerable interest in the study of pupils' attitudes toward mathematics (Lim and Chapman, 2013). A large body of research suggests that pupils' attitudes towards the subject are related to their achievement (Zan *et al.*, 2006, Papanastasiou, 2000, Ma and Kishor, 1997). For example, in a longitudinal study incorporating over 3,000 pupils Ma (2001) found that pupils' attitudes toward Mathematics are one of the most important factors affecting participation in advanced study of the subject. At the other end of the spectrum, pupils' dropout rates in mathematics courses have been found to relate closely to their negative attitudes towards it (Barkoukis *et al.*, 2008).

Attitudes towards mathematics may also provide some explanation for longstanding gender disparities in the subject. Research has demonstrated that female pupils often tend to have more negative attitudes towards the subject than their male counterparts (Leder, 1992, Prendergast and O'Donoghue, 2014), and there is little doubt that the causes of such differences are multifaceted, interactive and dynamic (Good *et al.*, 2012, Beilock *et al.*, 2010, Leslie *et al.*, 2015).

While it may be difficult, and likely unwise, to attempt to generalize pupils' attitudes towards mathematics as a result of their socio-economic status, international studies have demonstrated that pupils from lower socioeconomic backgrounds tend to experience lower self-efficacy and higher mathematical anxiety than their less disadvantaged counterparts (OECD, 2013). In Ireland, pupils in DEIS schools have been found to express lower intrinsic motivation, lower self-efficacy and lower self-concept in their mathematics learning and, as noted earlier, have demonstrated higher mathematics anxiety (Perkins *et al.*, 2013). Such affective factors likely negatively impact pupils' attitudes towards mathematics and obstruct their considerations to pursue the subject at advanced levels in later education.

2.3. *Influencing pupils' attitudes towards mathematics through extra-curricular initiatives*

In order to ensure that learners are better prepared to utilize and apply their mathematical knowledge, Wake (2016) suggests that they are provided with opportunities to develop expanded conceptualizations of mathematics and how it connects with other fields. In classrooms where pupils associate mathematics as an individualized subject focused on repeating procedures demonstrated by a teacher, as has been widely recorded in Ireland (Lyons *et al.*, 2003, Jeffes *et al.*, 2012), extra-curricular activities may provide useful environments for pupils to explore the subject in new contexts that build on collaborative practices, incorporate problem solving and use a wide range of resources.

Research by Vennix *et al.* (2018) has demonstrated that pupils' attitudes towards STEM subjects can improve through their participation in extra-curricular activities, particularly those that take place in the form of workshops outside of school and with peers. In this research pupils enjoyed participating in activities where they were not graded (in a test or exam) and liked engaging with people working or studying STEM (Vennix *et al.*, 2018). Focusing specifically on mathematics activities, research by Lynch

and Kim (2017) demonstrated that targeted out-of-school programmes can positively impact low-income pupils' mathematical learning.

However, while many extra-curricular activities can be aimed at pupils deemed as 'gifted' or already self-identified as interested in mathematics, evidence from higher education institutions across the UK has demonstrated that wider participation in out-of-school activities is necessary to encourage a wider diversity of those choosing to study mathematics at third level (Cox and Bidgood, 2002). Unfortunately, while there are some public engagement and extra-curricular mathematics programmes available in Ireland, the provision of such activities is below the OECD average (Perkins *et al.*, 2013). It is within this context that the Maths Sparks programme was designed and undertaken. The research reported here took place in the third year of the delivery of the programme (in 2017).

3. Research Methodology

3.1. Maths Sparks programme: design and delivery

The Maths Sparks programme was designed with the aim of encouraging participating senior secondary pupils from DEIS schools to continue their studies of mathematics at a higher level and, furthermore, to encourage these students to consider pursuing mathematics or STEM-based courses in higher education. The construct of the 4-week programme is outlined here using the framework provided by Vennix *et al.* (2018) to describe extra-curricular STEM activities: context, location, objective, teaching approach and participant selection.

3.1.1. Context. The mathematical content included within the Maths Sparks programme was chosen for its potential to be (1) interesting and (2) relevant to participating pupils, but (3) external to their school mathematics curriculum. It was important to delineate Maths Sparks as a public engagement activity and not an additional classroom tutoring or 'grinds' (private tuition) facility for pupils, since many Irish secondary learners only experience mathematics in a school (and hence examination) context (Perkins *et al.*, 2013). Thirteen undergraduate mathematics students were recruited by the first and second authors (directors of the Maths Sparks programme) and volunteered to collaboratively design and facilitate the workshops included in the programme. Furthermore, academic staff (including the first and second authors) participated in the workshops both as resources for the undergraduate students in the design and facilitation of workshops, and/or as guest presenters showcasing their research during a workshop.

3.1.2. Location. Out-of-school STEM activities have demonstrated greater success in impacting learner attitudes than school-based programmes (Vennix *et al.*, 2018). In addition, the university campus can often be considered as foreign and daunting for pupils from DEIS schools (Lynch and O'Riordan, 1998). Therefore, it was decided to locate the Maths Sparks programme on the university campus and workshops were held in an active learning environment in the University College of Science. These classrooms are equipped with large circular tables to seat 8–10 people and are furnished with a large number of white boards. This learning environment, largely differing to that of the traditional classroom, was intended to allow for creative and collaborative explorations of the content during workshops (Chittum *et al.*, 2017). Workshops were held on an evening after school and, remaining cognizant of the socio-economic backgrounds of pupils, an evening snack and free buses to and from the university to the schools were provided (funded by SFI Discover).

Logic Times
Bringing you the top activities since 2015 3rd April

Who Robbed Kim in Paris

Several suspects have been brought forward regarding the robbing of Kim Kardashian in Paris last week. Each suspect told one truth and one lie, but we don't know which is which. Their claims are reported below:

Kanye: 'It wasn't Jay-Z, it was Beyoncé'
Beyoncé: 'It wasn't Trump, it wasn't Jay-Z'
Trump: 'It was Jay-Z, it wasn't Kanye'
Michael D: 'It was Trump, it was Beyoncé'
Jay-Z: 'It was Michael D, it wasn't Kanye'

Image credit: huffingtonpost.com

Can you figure out who robbed Kim based on the suspects' claims?

FIG. 1 Sample task in the Maths Sparks 'Logic' workshop.

3.1.3. Objective. As outlined above, the objective of the programme was to encourage participating pupils to continue their pursuit of mathematics at higher level for Leaving Certificate and to consider mathematics as a part of their third-level education. It was hoped this objective could be met by broadening pupils' considerations of the subject of mathematics, as advised by Wake (2016), and by introducing them to applications of mathematics outside of the school curriculum. Furthermore, by meeting and engaging with undergraduate students, it was hoped that pupils would be encouraged about the accessibility of mathematics (Vennix *et al.*, 2018) by engaging with positive role models who were close to their age as peers (Chittum *et al.*, 2017).

The Maths Sparks programme was delivered in a series of 2-hour workshops over 4 weeks, each workshop consisting of 1- or 2-hour themed lessons. Undergraduate student volunteers worked in groups of two to four to design their themed lesson, under the guidance of university lecturers (including the first and second author). Each workshop was peer reviewed by the student volunteers and again by the first and second authors before the programme began. Students were encouraged to design workshops that would foster positive beliefs about mathematical problem solving (Verschaffel *et al.*, 1999, Wake, 2016) and for each workshop they were asked to:

- (1) encourage pupils to communicate their mathematical thinking as part of a variety of classroom organizational forms (i.e. pupils should have a varied experience of working individually, in pairs or in groups and should have to communicate their mathematical thinking both verbally and in notation)
- (2) incorporate contextualized and meaningful problems (these could be abstract, but introduced in a motivational way for pupils)
- (3) promote positive beliefs and attitudes about mathematics (perhaps through focusing on history of mathematics, mathematicians or the application of mathematics).

In this iteration of the Maths Sparks programme workshops were held in the topics of Probability and Statistics, Number and Trigonometry (all workshop material is freely available to download at <https://>

Logic: Workshop Appendix

Note 1: Solutions to Activity 1

The following table summarises the suspects' claims regarding the robbing of Kim's ring.

	KANYE TELLS US	BEYONCÉ TELLS US	TRUMP TELLS US	MICHAEL D TELLS US	JAY-Z TELLS US
Kanye			✗		✗
Beyoncé	✓			✓	
Trump		✗		✓	
Michael D					✓
Jay-Z	✗	✗	✓		

✓ = robbed Kim ✗ = didn't rob Kim

Fig. 2 Sample answer to task in the Maths Sparks 'Logic' workshop.

www.ucd.ie/mathstat/mathsparks/). A sample task from one workshop can be seen in Fig. 1 with a sample answer to the task from the associated worksheet in Fig. 2.

During each week of the programme one group of undergraduate students took the lead on presenting a workshop, while the remaining student volunteers acted as facilitators of pupils' learning. This environment provided opportunities for the secondary pupils to be involved in near-peer communities and also provided opportunities for informal conversations between secondary pupils and undergraduate students (Chittum *et al.*, 2017). Furthermore, during each session an academic member of staff gave a short presentation on their research (10 to 15 mins) to conclude the session.

3.1.4 Participant selection. Secondary school pupils from fourth (transition) year and fifth year were invited to participate in the programme through their teachers and were therefore self-selecting in choosing to take part in Maths Sparks. This was an important factor in ensuring that pupils felt they had autonomy in taking part in the programme (Vennix *et al.*, 2018). Ten senior-cycle pupils from each of 10 urban DEIS schools in the vicinity of the university were invited to take part in the programme, with provision for additional numbers if more pupils were interested in taking part.

3.2. Research design

As outlined above, the research attempts to answer the two following questions:

1. How do senior secondary pupils attending DEIS schools reflect on their experiences of learning mathematics?
2. How does participation in a specifically designed mathematics engagement programme impact on pupils' attitudes towards mathematics?

The research was conducted during the Maths Sparks programme held in the Spring of 2017. Eighty-three pupils signed up to the programme, with an average attendance of 75% over 4 weeks. With consent

of schools and parents, 64 pupils volunteered to participate in the research and personally consented to their data being utilized in the research.

Thirteen undergraduate mathematics student volunteers were recruited through a competitive process to design, develop and deliver the mathematics workshops, and six lecturers (including the first two authors) participated in mentoring undergraduate student teams, delivering a short lecture, and/or facilitating at workshops.

In an attempt to find out more about these pupils' experiences of learning mathematics at secondary level and to investigate the impact of participation on pupils' attitudes towards mathematics, pre- and post-programme questionnaires were distributed at the beginning and end of the programme. These questionnaires, which combined both quantitative and qualitative questions, composed of three sections. Section A established participants' demographic information, enquired about their subject choice for their senior cycle of secondary school and asked participants about their aspirational career choice. Section B focused on pupils' experiences of learning mathematics in school. Section C consisted of a pre-validated quantitative scale to measure attitudes toward mathematics, namely the attitudes toward mathematics inventory (ATMI), which comprises 40 items divided into four sub-scales: self-confidence (15 items), value (10 items), enjoyment (10 items) and motivation (5 items) (Tapia and Marsh, 2004).

3.3. Data analysis

Sixty-four secondary pupils completed the pre-questionnaire and, as pupils from one of the schools did not attend the final session due to a school event, 48 completed the post-questionnaire. Analysis on the impact of the Maths Sparks programme was therefore only conducted on the 48 pupils who participated in both the pre- and post-questionnaires. Overall, the sample composed of mainly female students (69%) and ages ranged between 16 (70%) and 17 (30%) years, which was representative of the pupils attending the programme.

Qualitative analysis was conducted on pupils' answers to open-ended questions within the questionnaire. Questions related to pupils' experiences of learning mathematics in school were coded using thematic analysis (Braun and Clarke, 2006), maintaining a focus on their interpreted classroom experiences. Questions related to the Maths Sparks programme were coded utilizing the ATMI framework under the categories of: self-confidence, value, enjoyment and motivation. In relation to pupils' experiences of learning mathematics at school, coding was initially undertaken by two of the three authors and the thematic framework was revised until agreement was reached on coding of the data. In analysing pupils' experiences of Maths Sparks, two authors coded a section of pupils' responses according to the ATMI framework and coding criteria were agreed upon before the entire set of data was analysed.

In relation to the quantitative ATMI questions, respondents were asked to indicate their level of agreement or disagreement with each item: 1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree. Scoring on negatively worded items was reversed and, thus, a high score indicated a more favourable attitude towards the subject. Twenty-nine of the statements in the ATMI were worded in the direction of a favourable attitude and the other 11 in the direction of an unfavourable attitude towards mathematics. The maximum score that could be achieved by a respondent was 200. To assess internal consistency, the Cronbach alpha coefficients for the overall ATMI scale and each of the four subscales was first calculated. This allowed the alpha coefficients to be compared with those in the original Tapia and Marsh (2004) study, where the ATMI was first validated (see Table 1).

As evidenced in Table 1 very high Cronbach's alpha values, which were similar to the values reported by Tapia and Marsh (2004), were obtained for the overall scale and the self-confidence and enjoyment scales. The 0.78 score for the value scale is also higher than the cut-off point of 0.70 for reliability (Hair *et*

TABLE 1. Cronbach alpha scores

	Overall Scale	Self-confidence	Value	Enjoyment	Motivation
Original study	0.97	0.95	0.89	0.89	0.88
Maths Sparks	0.95	0.95	0.78	0.88	0.63

al., 2006). However, the 0.63 Cronbach's alpha score for motivation inferred poor reliability and assumed that the statements in this subscale were not all measuring the same underlying construct for the pupils participating in Maths Sparks. This was taken into account when analysing and reporting findings of the data from this sub-scale.

4. Findings & Discussion

Findings related to participating pupils' experiences of learning mathematics in school are initially explored and reported on utilizing the framework of analysis arrived on through thematic coding of pupils' open responses to the pre-programme questionnaire. Examination of pupils' responses following their experience of Maths Sparks is then outlined according to the ATMI framework, incorporating both qualitative and quantitative analysis. Any impact related to pupils' consideration of a STEM career following their participation in Maths Sparks is then noted and reference to gender is also included.

4.1. Pupils' experiences of learning mathematics in school

4.1.1. *Mathematics as a positive challenge.* In the pre-programme questionnaire pupils were asked to describe their mathematics classes in their own words. The majority (36) of pupils was positive about their learning experiences, with many of these referencing maths class as 'fun', 'interesting' and 'engaging'. It was noteworthy that a number of these pupils (7) specifically referenced their enjoyment of being challenged in their learning and having to work hard in class:

'I find my maths classes interesting but also challenging. I like maths a lot and enjoy class each day'. Pupil 40.

'Challenging, but not so much that I cannot understand it. I prefer to understand concepts rather than memorise'. Pupil 6.

Pupils also noted the benefit of working with their classmates on mathematical tasks, a feature of learning promoted in the implementation of the revised curriculum (National Council for Curriculum and Assessment, 2012).

'[Maths class is] interesting, many questions can be asked and students are involved'. Pupil 1.

'They aren't boring because we do a lot of group work and activities. We learn from each other'. Pupil 21.

In particular, a small number of pupils noted working with classmates in a structured problem-solving approach (Hino, 2007), where learners compare solutions as part of the learning process.

'My maths class in school is very interactive and everyone gets involved. We share different ways of doing questions'. Pupil 7.

'Really enjoyable in working out the right answers. Me and my classmates discuss the answers as we are going along'. Pupil 41.

However, in contrast to the positive comments on the challenging and interactive nature of their maths classes, a number of pupils (10) were very negative about their mathematical learning citing it as *'boring'* and *'tedious'*. Pupils did not like classes where they were *'on my own just doing exercises'*. It is interesting to note that these comments were related to classes that seemed to follow a pattern of direct teaching (Boaler, 1998), focused on repetitive tasks from the textbook.

'Very busy, always trying to do chapters as quickly and as thoroughly as possible'. Pupil 22.

Others referenced the fact that they felt they were being taught for an exam rather than for understanding and this was seen as negative by pupils with regards to their own learning.

'It's rushed and focuses on exams rather than learning'. Pupil 26.

Pupils' responses suggest that they enjoyed maths class when they felt they were being challenged in a productive way. These findings provide unique insight into the mathematics experiences of senior secondary pupils from DEIS schools and, for this small sample of schools, challenge the common direct-teaching approaches found in mathematics classrooms in DEIS schools (Perkins and Shiel, 2016).

4.1.2. The role of the mathematics teacher. When asked to describe their mathematical learning experiences, many pupils referenced their teachers and confirmed the important role that teachers play in shaping pupils' attitudes towards mathematics. Pupils were positive about teachers who contextualized mathematical concepts and made an effort to engage pupils in their learning.

'Recently, they are very interesting and the teacher relates the maths to real life situations and tries to make it fun'. Pupil 42.

Such responses align with the intentions of the revised mathematics curriculum in Ireland, which promotes the use of real-life examples where appropriate (National Council for Curriculum and Assessment, 2012). Pupils were also positive about the subject when they perceived the teacher as helpful and willing to answer questions in class.

'My maths classes are great. The teacher does help you if you are finding anything difficult'. Pupil 8.

In contrast, other pupils were very negative about their learning when they did not feel there was any opportunity to ask questions in class. This, again, suggests a direct teaching approach in these classrooms, which goes against the teaching and learning approaches espoused by the revised curriculum (Ni Shuilleabhain and Seery, 2018).

'We have maths classes everyday but I still think that it is not enough. Each class is 40 minutes long and we never get time to ask questions'. Pupil 10.

Related to not having opportunity or time to ask questions in class, 17 of the 48 respondents referenced the fast-paced nature of maths lessons, which seemed to negatively impact their learning.

'Our maths class is quite fast and with a lot of course content it's hard to get extra time to spend on difficult topics if needed'. Pupil 17.

Such a direct approach to teaching, emphasizing the need to finish the curriculum, seemed to impact on pupils' considerations of equating success in mathematics with finishing the textbook.

'They are quite fast paced and move through the chapters of the book quite quickly and efficiently'. Pupil 20.

While teachers have highlighted the breadth of the curriculum and lack of time to teach it at senior cycle (O'Meara and Prendergast, 2019), such reported classroom emphasis on 'covering content' highlights the negative influence of the high-stakes, terminal Leaving Certificate examination on pedagogical practices within the mathematics classroom.

4.1.3. Intentions to study higher-level mathematics. From the pre-programme questionnaire, the majority (82%) of these pupils had taken higher-level mathematics for the Junior Certificate and a similar number

(81%) intended to study the subject at higher level for the Leaving Certificate. While many pupils noted their enjoyment of the subject and their confidence in their own ability, a large number of pupils (16) highlighted the bonus points in their reasoning for studying mathematics at this level:

'I will study Higher-Level Maths for Leaving Cert because leaving cert is only a race for points and doing HL maths will give me 25 extra points'. Pupil 9.

'You only need 30% to pass and if I get 40% I would get 25 extra points. So it would really benefit me'. Pupil 8.

It is notable, however, that higher-level mathematics was not offered in all participating schools. One pupil noted that *'the school does not allow it'* (Pupil 13) and this lack of choice for pupils in some DEIS schools, which has negative implications for their accessibility of third-level education (Byrne and McCoy, 2017, McCoy *et al.*, 2019, Smyth *et al.*, 2015), has not yet been reported on in the research literature and is a significant finding in the context of Irish education. Furthermore, another pupil specifically mentioned their teacher's perceived lack of belief in the pupil's ability as a reason not to pursue mathematics at this level:

'Because my teacher thinks it will be much too difficult'. Pupil 14.

The implications of the subject not being offered at higher level in all DEIS schools and the impact of teachers' attitudes towards their learners require further research in the context of equality and inclusion in the Irish education system.

Overall, participating pupils from DEIS schools reflected positively on their experiences of learning mathematics in school. These positive experiences related to mathematics being taught in a way that challenged the learners, but where they felt equipped for such challenges within an environment where the teacher could be a resource for their learning and where they could discuss and collaborate in their learning with their classmates. It is encouraging to note that these experiences of mathematics in the school classroom largely align with the intended curriculum reform approaches to teaching and learning (National Council for Curriculum and Assessment, 2012, Ni Shuilleabhain and Seery, 2018).

However, despite the fact that these pupils were self-selecting in their participating in the Maths Sparks engagement programme, many reported negative experiences of learning Mathematics in school. These experiences related to a lack of encouragement in their mathematical ability communicated directly to them by a teacher or indirectly by lack of option of higher-level mathematics within the school. The impact of these experiences are very serious when considering the future educational prospects of these pupils and this lack of equity in mathematical offering in DEIS schools should be researched in more detail.

4.2. *Participating in Maths Sparks: impact on pupils*

Both qualitative and quantitative analysis of the data demonstrated positive effects of pupils' engagement in the Maths Sparks programme on their attitudes towards mathematics. These findings are reported on below according to the ATMI framework (Tapia and Marsh, 2004).

4.2.1. Impact on pupils' confidence, value, enjoyment & motivation. Analysis of pupils' responses to the ATMI questionnaire following their participation in the Maths Sparks programme demonstrates a statistically significant increase in pupils' mean self-confidence scores in their mathematical ability (Table 2). There was also a statistically significant increase in pupils' enjoyment of mathematics (Table 2). Furthermore, there were increases (although not statistically significant) in pupils' value of and motivation to engage with mathematics (see Table 2).

TABLE 2. Means and standard deviations for ATMI sub-scales

Sub-scale	Pre-intervention		Post-intervention		Differences <i>T</i>
	Mean	<i>SD</i>	Mean	<i>SD</i>	
Self-confidence (/75)	50.02	11.31	52.83	10.41	2.22*
Enjoyment (/50)	34.00	6.90	35.96	5.91	2.81*
Value (/50)	39.48	4.67	41.08	5.19	1.49
Motivation (/25)	18.18	2.69	18.46	2.98	0.21

Note: * $p < .05$ (two-tailed).

Pupils' Confidence in Mathematics Pre- Maths Sparks

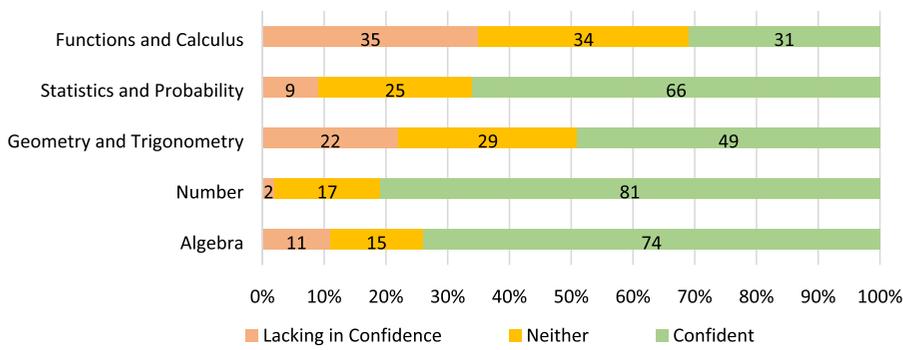


FIG. 3 Pupils' confidence in mathematics strands pre-Maths Sparks.

Of the 40 statements on the overall ATMI scale, the same statement (*I want to develop my mathematics skills*) had the highest mean score in both the pre- (M: 4.63; SD: 0.49) and post- (M: 4.69; SD: 0.47) programme statements, indicating that these participating pupils were motivated to improve in their knowledge of mathematics. Notably, the statement with the lowest mean score (*I am happier in a maths class than any other class*) was also the same on both the pre- (M: 2.61; SD: 0.96) and post- (M: 2.77; SD: 0.97) statements, despite the overwhelmingly positive reporting of math classes by the majority of the cohort. This may indicate that while these pupils may enjoy learning mathematics, their experiences of learning the subject in school pales in comparison to their experiences of other subjects during the school day. This finding correlates with research on the learning experiences of pupils attending primary DEIS schools, where mathematics fared the worst in terms of favoured subjects (Smyth *et al.*, 2015).

Further investigating the impact of participation in Maths Sparks on pupils' learning, we asked pupils to rate their level of confidence in each of the five strands of the secondary syllabus. As evidenced by Figs 3 and 4, the number of pupils who stated that they were confident in mathematics increased in each of the five curriculum strands following the intervention (Functions and Calculus +29%; Statistics and Probability +9%; Geometry and Trigonometry +10%; Number +9%; and Algebra +7%).

Although the content of the Maths Sparks workshops only explicitly dealt with topics within Probability and Statistics, Number and Trigonometry, participating in collaborative, contextualized tasks, under the facilitation of university students and lecturers, seemed to have a positive impact on pupils' confidence in their general mathematical ability.

Pupils' Confidence in Mathematics Strands Post- Maths Sparks

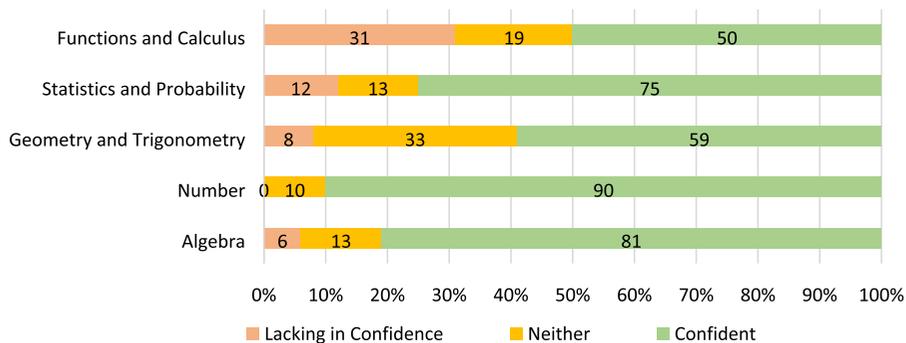


FIG. 4 Pupils' confidence in mathematics strands post-Math Sparks.

In their post-intervention questionnaires, responses related to pupils' self-confidence were most prevalent when students were asked if they thought there were any changes to their knowledge or skills due to their participation in the programme:

'I think that after Maths Sparks, I'm a bit more confident in solving a maths problem. I think more logically when it's about maths now'. Pupil 2.

'I try harder to answer every maths question I get now . . . I think I have gained more knowledge in all of the strands as a result of my participation in Maths Sparks'. Pupil 53.

'I feel as if I've more confidence when I'm doing maths in class rather than lacking it and sitting back in class'. Pupil 19.

These responses not only demonstrated pupils' own beliefs in their increased confidence as a result of participation in the programme but also demonstrated their ability to critically reflect on their own learning.

'I have acquired new skills and approaches when it comes to maths in school. It has deeply helped me'. Pupil 30.

Qualitative responses related to pupils' enjoyment of mathematics were not present in these responses, however, although a number of pupils did describe how they enjoyed *'doing worksheets, learning new things, working with others'* (Pupil 5) during the workshops.

While the quantitative data did not demonstrate any statistically significant changes in pupils' value of mathematics, the qualitative data proved to be different. While only one pupil referenced the value of mathematics in the pre-programme questionnaire, 11 did so when asked about any changes they considered in their knowledge or skills following their participation in Maths Sparks.

'I understand the concept and how numbers are used in real life situations'. Pupil 43.

Another pupil liked *'learning about everyday uses of maths and that it offers a wide range of choices for the future'*, Pupil 17.

Interestingly, a pupil who had been quite negative about their experiences of learning mathematics in school noted following the programme that:

'I think more outside [the box] and can see the relationship between maths and everyday life better now'. Pupil 10.

From the analysis of both pre- and post-programme questionnaires, the motivation to study Mathematics was largely due to *'them bonus points!'* (Pupil 4) rather than an interest in or passion for the

subject. This again points to the inordinate influence of the summative Leaving Certificate examination on pupils' learning and educational decisions. While there were some additional responses related to other motivations to pursue mathematics in the post-intervention questionnaire, the drive to achieve more points for university was the over-riding motivator for pupils when asked why they would pursue higher-level mathematics.

'I want to get higher points and also the extra 25 points'. Pupil 53.

Only a small number of pupils provided an intrinsic reason to continue to study mathematics at higher level in their post-programme questionnaire:

'I'm more inspired and motivated'. Pupil 1.

'It's interesting'. Pupil 37.

This finding may point to a negative impact of the introduction of bonus points in the higher-level Leaving Certificate Mathematics exam. While this initiative was introduced to increase the numbers taking the subject at this level and has succeeded in this (Project Maths Implementation Support Group, 2010, SEC, 2019), there has been no discernible impact in the numbers of students choosing STEM pathways at third level. Intrinsic motivation to study mathematics has been shown to have superior impacts on learners' successes in the subject when compared to extrinsic motivating factors (Murayama *et al.*, 2013), such as the bonus points initiative. Indeed, extrinsic factors can deter learners due to the additional pressures and anxieties of performing well (Chittum *et al.*, 2017, Mueller and Dweck, 1998) and this was evident in some pupils' reporting of their learning during Maths Sparks:

'I was more open to learning because I knew that there would be no exam or test at the end'. Pupil 53.

Treacy (2018) determines that secondary level mathematics education in Ireland must take the potential negative impact of bonus points into account and place greater emphasis on developing student interest and affection for mathematics, rather than offering rewards such as extra points for studying the subject at an advanced level. Based on the findings from our cohort of pupils from DEIS schools, we suggest that further research be undertaken with secondary pupils to better understand their reasoning and motivations to continue their study of mathematics at Leaving Certificate level and beyond.

4.2.2. Impact on pupils' overall attitude towards mathematics. Descriptive analysis of the overall ATMI scale and each of the four sub-scales were carried out and results show that pupils' overall mean attitude score increased from 141.68 (SD: 21.81) to 148.33 (SD: 20.05) from pre- to post-programme, demonstrating that pupils' attitudes towards mathematics improved due to their participation in Maths Sparks. A paired-sample *t*-test found that this increase was statistically significant ($t(48) = 2.881$, $p = .006$, two-tailed). These findings were supported by pupils' open responses when asked if their attitude towards mathematics had changed due to their participation in Maths Sparks:

'Yes. Maths is not that hard, it just needs a little bit of understanding and practice'. Pupil 14.

'Yes, it helped me use my logic on the subject more and not to panic when I look at a maths problem'. Pupil 37.

In response to this same question, it was interesting to note how pupils identified how the emphasis of the Maths Sparks workshops and the environment in which they were learning had an impact on how they perceived the subject.

'Yes, I see how it is used rather than just doing questions to pass an exam'. Pupil 27.

'Yes, it has helped apply the practicality of maths in real life to my study... I feel that the non-traditional environment has really helped me in completely new ways'. Pupil 28.

These findings suggest that participating in a specifically designed out-of-school programme of workshops can positively impact pupils' attitudes towards, confidence in and enjoyment of mathematics. The collaborative environment, where pupils had opportunity to work and engage with other secondary

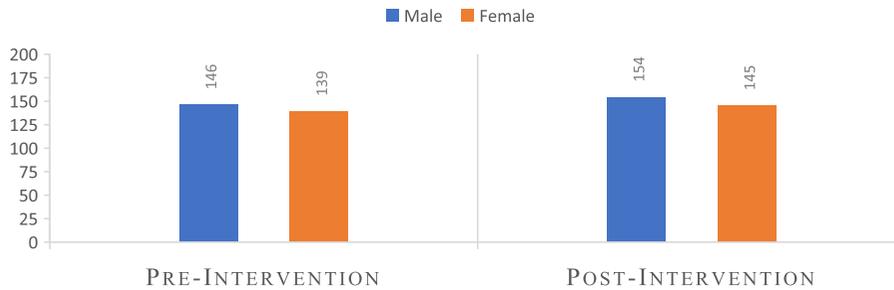


FIG. 5 Mean ATMI scores (out of 200) of male and female students.

pupils and undergraduate peers, seemed to influence their considerations of the subject of mathematics and broaden their learning experiences outside of that of an exam-focused subject.

4.3. Influence of gender on pupils' attitudes towards mathematics

The gender of pupils participating in the research has not been explicitly referenced throughout the findings; however, further analysis was conducted to take into account the many factors that may have affected changes in pupils' attitudes towards mathematics, such as gender, age, school and the baseline level of attitude of each pupil. A mixed design analysis of covariance was conducted with repeated measures of attitude over time, with independent factors of age, gender, school type (mixed or single gender) and a covariate of baseline attitude. This analysis showed that there was no statistically significant effect for these factors ($p > 0.05$). However, concurrent with the literature and as evidenced in Fig. 5, it is noteworthy that males scored higher in the overall ATMI (out of 200), both pre- and post-programme, when compared to their female counterparts.

4.4. Limitations of the research

It is important to keep in mind the short time frame of this intervention and that the pupils participating in the Maths Sparks programme were self-selecting and, therefore, likely had a relatively positive disposition towards mathematics than their other classmates might have. However, it is important that these pupils' experiences of mathematics in school and as part of this extra-curricular programme are reported on, particularly considering the lack of mathematics education research involving senior-cycle pupils from DEIS schools. It is also worthy to note the small number of pupils participating in this research ($n = 48$), and therefore we consider the findings from this research as indicative only. However, when combined with the qualitative analysis, the authors suggest that the findings from this research are both relevant and valid.

5. Conclusion

In this research the mathematical experiences of senior secondary pupils from 10 urban schools in Ireland designated as socio-economically disadvantaged, i.e. DEIS, were investigated. Forty-eight transition year (fourth year) and fifth year pupils participating in a specifically designed mathematics engagement programme, Maths Sparks, volunteered to take part in the research and completed pre-

and post-programme questionnaires recording both quantitative and qualitative data. Pupils' reported experiences of learning mathematics at school and their reflections of participating in Maths Sparks were recorded and analysed using both open coding (Braun and Clarke, 2006) and ATMI (Tapia and Marsh, 2004) frameworks. The research provides a contribution to the scant literature on senior secondary pupils from DEIS schools' mathematical learning experiences. It also provides insight into the impact of pupils' participation in a subject-specific, out-of-school programme facilitated by undergraduate students.

The research found that the majority of learners from this cohort of self-selecting pupils reported positive experiences of learning mathematics in school. Pupils enjoyed mathematics teaching and learning that challenged their thinking and required them to ask questions. Pupils reported on the importance of having a teacher who was happy to facilitate their learning by answering questions and by providing opportunity for pupils to work together. This finding suggests that, in the majority of schools taking part in the Maths Sparks programme, pupils' mathematical experiences align with the teaching and learning approaches intended by the curriculum reform (National Council for Curriculum and Assessment, 2012, Ni Shuilleabhain and Seery, 2018). However, many of the pupils reported negatively on the fast pace and pressurized nature of mathematics classes, where time always seemed too short to support their learning. This aligns with research recording teachers' opinions of the lack of time to teach the curriculum (O'Meara and Prendergast, 2019, O'Meara and Prendergast, 2018) and connects this research to pupils' negative perceptions of mathematics. It is interesting to note that while the majority of these pupils hoped to pursue mathematics at higher level in their Leaving Certificate, this was motivated by the bonus points available for successful completion of this course, rather than an intrinsic motivation to pursue the subject beyond secondary education. This may indicate a need to review the purpose and outcome of the bonus point scheme for mathematics and a need to review the terminal, high-stakes summative Leaving Certificate examination, particularly in the light of new reforms at the junior cycle of secondary education, which now incorporates continuous assessment through problem solving (National Council for Curriculum & Assessment, 2017).

Pupils' reflections of their mathematical learning pointed to the important role their mathematics teacher plays in developing their attitudes towards mathematics. Pupils who were positive in their attitudes towards and value of mathematics commented on their teacher contextualizing mathematical concepts and making an effort to engage their pupils in their learning. In contrast, pupils who were negative about their experiences of learning mathematics in school described classroom practices that could be described as direct teaching (Boaler, 1998), a reportedly common form of teaching in DEIS schools (Perkins and Shiel, 2016), where the teacher did most of the talking through exposition and where pupils worked on similar repetitious mathematics tasks on their own. The findings align with the literature in indicating that a teachers' approach to teaching and learning mathematics directly impacts pupils' attitudes towards the subject. Similarly, teachers' beliefs in the ability of their learners (both positive and negative) also impact directly on pupils' attitudes towards and self-confidence in mathematics.

While research from Weir *et al.* (2014) shows that only 3.3% of principals of DEIS secondary schools rated their teachers' expectations for pupil achievement as low, pupils' responses in this research demonstrates that some teachers in DEIS schools may have expectations that are too low of their pupils. A number of pupils participating in Maths Sparks were interested in mathematics and wanted to pursue it at a higher level but were discouraged by their teacher. In addition, some of the DEIS schools participating in the Maths Sparks programme did not offer higher-level mathematics as an option to pupils, further disenfranchising them in their abilities to pursue third-level education. This lack of equality of opportunity puts pupils at a disadvantage when compared to their counterparts in other schools (McCoy *et al.*, 2019), particularly considering the additional 25 CAO points available

for this examination, and this finding should be worthy of note to policy makers in Ireland. Further research is required on the number and array of schools who do not offer higher-level Leaving Certificate mathematics to their pupil cohort. Furthermore, teachers' lower academic expectations of their students in general (Devine *et al.*, 2013) may be something for consideration in teacher education.

The majority of pupils participating in the Maths Sparks programme intended to pursue higher-level mathematics for their Leaving Certificate. It was interesting, however, that the motivation for this was largely related to the 25 extra bonus points provided for passing the examination in the subject rather than learners' interest in the subject or willingness to pursue mathematics-based courses at third level. We suggest that a review of the bonus point scheme be undertaken to investigate its influence on learners pursuing mathematics beyond secondary school.

After participating in the Maths Sparks programme, the research demonstrated that there were increases in pupils' self-confidence in their mathematical ability and in their enjoyment of the subject. These quantitative findings were supported by the qualitative responses provided by pupils, who reported on feeling more confident in their overall mathematical ability as a result of taking part in the programme. This is an interesting finding considering the programme content was not related to the secondary mathematics curriculum and considering the short length (4 weeks) of the engagement programme. It was also interesting to note that there were no discernible differences between male and female pupils in this regard. As this was a group of self-selecting pupils who already expressed an interest in mathematics, it would be interesting to conduct similar research with pupils who may not have such positive attitudes or aspirations towards the subject.

Undergraduate students' consistent and positive support throughout the workshops was important in fostering an environment where pupils could offer suggestions or help with struggling peers. These relationships between undergraduate students and secondary pupils proved to be important in providing positive motivational experiences for participants (Chittum *et al.*, 2017). It also seemed beneficial to pupils that there was no test or examination at the end of the programme.

An aim of the Maths Sparks programme was to encourage pupils to continue their study of mathematics and STEM at third level. While this was not a research question addressed by this study, anecdotal evidence from the university access centre has recorded six pupils from the Maths Sparks cohort enrolling in STEM undergraduate programmes. Due to the longitudinal nature of these data, ethical considerations and duration of funding, it was not possible to track pupils' pathways for other third-level courses or universities, but this would be worthy of research in future investigations.

Social inequality in educational outcomes reflects broader inequality in the economic, cultural and social capital possessed by some families. Those from disadvantaged backgrounds deserve resources and experiences that attempt to address the inequality that is present in our society (Smyth, 2017). Based on the findings from this research, we suggest that mathematics teachers in DEIS schools are provided with additional supports to develop and encourage their classrooms as places of collaborative and critical learning, where pupils experience mathematics as a vibrant, contextualized and challenging subject rather than simply an exam to be endured. We also suggest a review of the subjects provided in DEIS schools to ensure all pupils can avail of higher-level mathematics classes at both Junior and Leaving Certificate level. Finally, as well as further researching the impact of mathematics engagement programmes, we suggest that more specifically designed, longitudinal, out-of-school and extra-curricular mathematics workshops be made available to a broad number of pupils across the country, as a way of potentially developing their attitudes towards, self-confidence in and enjoyment of mathematics.

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