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A pilot study of the effectiveness of the *Maths For Life* programme for children with Down syndrome

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Background: Beyond educational achievement, mathematics is essential for everyday living, e.g., telling the time, paying with money, using timetables. However, many children from neurodiverse populations fail to acquire basic mathematics skills in school.

Aims: The aim of this study was to investigate *if* and *how* the *Maths For Life* programme, a new mathematical curriculum designed to help struggling learners, influences mathematics performance in children with Down syndrome.

Methods and procedure: Participants included 32 individuals with Down syndrome aged 5-to-24 years (Mage = 12.92 years, SD = 5.8). The study had a pre-post intervention design. The intervention group (n = 15) completed the *Maths For Life* programme (administered by parent/guardian) in addition to their normal school classroom activities and the business-as-usual control group (n = 17) completed their school mathematics classes only. Both groups completed a mathematics assessment pre/post the 4-month intervention period.

Results: Following the programme, the intervention group had higher accuracy and independence scores compared to the business-as-usual control group.

Conclusions and implications: The *Maths For Life* programme can help individuals with Down syndrome to improve their mathematical ability and independence, evidence that supports further testing this programme in schools. Improving children's accurate and independent application of mathematics is vital for everyday living.

KEYWORDS

***Maths For Life* programme, Down syndrome, Mathematics Intervention, Mathematica independence, Parent-led intervention**

Highlights

- The *Maths For Life* programme was evaluated using intervention and business as usual control groups
- After completing the *Maths For Life* programme, people with Down syndrome showed improved mathematics performance
- After completing the *Maths For Life* programme, people with Down syndrome showed greater mathematical independence.

1 Introduction

Down syndrome (DS) is a genetic condition attributable to an extra copy or translocation of genes on chromosome 21 and occurs in 1 in every 400–1,500 births in the United Kingdom (Public Health England, 2020). It is characterized by physical and cognitive differences including intellectual disability that affects educational learning (Grieco et al., 2015). In this study, we investigate difficulties learning mathematics for children and young people with DS.

Beyond educational achievement, acquiring mathematics skills is essential for everyday living, e.g., managing time such as using timetables, appreciating value and budgeting money, understanding quantity and applying this to decision making. However, many children from neurodiverse populations fail to acquire basic mathematics skills in school (Hunt et al., 2021). The *Maths For Life* programme is a new mathematical curriculum designed to help struggling mathematics learners improve their skills. *Maths For Life* is a targeted programme that uses a baseline assessment to ensure that the math content presented to children is individualized and within their zone of proximal development. Additional active ingredients that make this programme unique include the embedding of mathematics content in real-world examples, the use of repetition before the introduction of new concepts, and the one-to-one scaffolding provided by a parent/other adult. The objective of this pilot study was to investigate *if* and *how* the *Maths For Life* programme influences mathematics performance in children with Down syndrome.

1.1 Mathematics abilities in children with down syndrome

The acquisition of mathematical skills is delayed for children with DS (Brigstocke et al., 2008), who have lower performance than mental age-matched typically developing children for counting (Nye et al., 2001), discriminating quantities (Sella et al., 2013) and learning number strings (Porter, 1999). However, for other skills, Morris et al. (2024) reported no overall group difference in mathematics abilities (geometry, arithmetic and problem solving) when comparing individuals with DS and a mental age-matched typically developing control group. That said, individuals with DS appeared to reach a plateau in mathematics development suggesting that people with DS may struggle to improve their mathematics skills beyond a certain point (Morris et al., 2024). Beyond comparisons with typically developing children, mathematics is also a weakness in individuals with DS, compared to their other cognitive/academic abilities. Mathematics skills are reportedly delayed by 2 years compared to literacy skills (Buckley, 2007), suggesting that improving mathematics in people with DS is of particular importance.

1.2 Mathematics interventions for children with down syndrome

For children with DS, there are barriers to learning mathematics within the typical classroom, e.g., insufficient teacher feedback especially conceptual feedback when students with DS make mistakes (or even when their answer is correct) so the students do not improve their conceptual understanding of math (Rietveld, 2005). This suggests that specialized mathematics programs may be required to support achievement for DS groups. The *Maths For Life* programme evaluated here provides one-to-one scaffolding with feedback.

Mathematics interventions can lead to positive outcomes for individuals with DS (for a synthesis see Lemons et al., 2015). Porter (2022) found that quantity discrimination improved after a 4-week intervention with digital and non-digital games targeting magnitude understanding (identifying more and less), in children with DS ($n = 8$). This suggests that targeted intervention may improve math skills in DS. However, this study is weakened by the small sample size and lack of control group. Lanfranchi et al. (2015) also found that specific numerical skills training (targeting lexical processing, semantic processing, pre-syntactic processing, counting, and mental calculation) improved basic mathematics ability and logical thinking in children with DS ($n = 27$) compared to a control group ($n = 9$). However, for both studies the range of mathematics skills assessed was limited.

In another example, Sella et al. (2021) found that the use of a computer-based intervention "The Number Race" which targets basic number concepts and arithmetic, improved specific numerical skills, e.g., mental calculation in children with DS ($n = 30$) compared to a control group ($n = 31$). However, there were no differences in overall numeracy between the groups. In a follow-up study, Lanfranchi et al. (2021) found that the same intervention improved various measures of numerical skills, including overall numeracy, encompassing lexical, semantic, counting and pre-syntactic skills, regardless of whether it was administered by parents or researchers. These improvements remained 3 months after the training. Both these studies show the promise of mathematics interventions for improving basic numerical skills in individuals with DS.

1.3 Current study

The evidence suggests that mathematics abilities are malleable in children with DS. However, most previous training studies have specifically targeted basic numerical skills instead of a wide range of mathematical content. Furthermore, few studies provide individualized learning that is scaffolded by one-to-one adult interaction. The aim of the current study is to investigate, for the first time, whether parent delivery of the *Maths For Life* programme improves mathematics outcomes in people with DS compared to a business-as-usual control group. *Maths For Life* is a targeted programme that is individualized to a child's ability not their age, i.e., within their zone of proximal development. Unlike other interventions, children are supported throughout by adult scaffolding and encouraged by the use of real-world examples.

2 Methodology

2.1 Participants

Participants included 32 young people with DS aged 5–24 years ($M_{age} = 12.92$ years, SD = 5.8, gender = 17 males, 15 females). A further 11 children participated but were excluded due to missing data for either Time 1 and/or Time 2 assessment. Following exclusions, the final sample size was $N = 15$ for the intervention group ($M_{age} = 12.92$

years, SD = 5.65, 73% male) and $N = 17$ ($M_{age} = 13$ years, SD = 6.1, 35% male) for the control group. Participants were recruited through the Down Syndrome Oxford (DSO) charity group, and DS community groups on social media. Participants recruited through DSO were allocated to the intervention group and participants recruited from social media were allocated to the business-as-usual control group.

2.2 Design and procedure

All aspects of recruitment, data collection and administration were completed by the *Maths For Life* organization. All participants completed the *Maths For Life* Mathematics assessment both pre- and post the intervention period. The intervention period lasted 3 months during which participants in the intervention group completed the *Maths For Life* programme in addition to their normal school mathematics activities. The business-as-usual control group completed normal mathematics learning in their schools but did not receive any additional instruction. These participants were offered the opportunity to engage with the *Maths For Life* programme after the intervention period.

Maths For Life is a limited company. The founder and author of the programme is the majority shareholder. It is an entirely self-funded organization. The mission of the company is to bring love to maths, offering a pathway to students for whom the standard mathematics national curriculum is unattainable. The goal of *Maths For Life* is—simple maths done accurately, independently and in real life scenarios.

The *Maths For Life* programme was led and administered by a parent/caregiver. Based on the pre-intervention mathematics assessment, a report was completed, identifying the participant's areas of strengths and weaknesses and highlighting core missing skills. Targets were then set based on a report produced by the *Maths For Life* organization. Parents/carers were provided with a copy of the relevant *Maths For Life* educator guide(s) to enable them to understand how to break down targets into incremental micro-steps. The *Maths For Life* resource library could be accessed by the parent/carer at any time, including worksheets that could be used to help students reach their targets and records of progress that could be used intermittently to review students' progress. For more details on the *Maths For Life* programme see the Supplementary material and the programme website https://www.mathsforlife.com.

2.3 Mathematics assessments

The *Maths For Life* Mathematics assessment was administered by a parent/caregiver who recorded responses using the answer sheet provided. There are two forms of the test (Form A and Form B) and each is comprised of two levels: Foundation (Figure 1a) and Level 1 (Figure 1b). Questions across both levels measure the same topics: developing prenumber skills and concepts, using numbers and the number system, using common measures, shapes and space, and handling information and data. It was recommended that all participants start the assessment at the Foundation level. If the student completed this with ease, they progressed to the Level 1 assessment. The child progressed through the assessments until they could not continue, based on the parent/caregiver's judgment. Participants completed Form A and B of the assessment at Time 1 (pre-intervention) and Time 2 (post-intervention) respectively. The items in the tests differed to reduce practice effects.

For each item, parents/caregivers recorded their child's answer as either *Answered correctly*, *Attempted but not 100% correct*, or *Not attempted*. Performance was measured in three ways. First, accuracy was calculated as the number of items answered correctly divided by the total number of items [120 items (Form A); 121 items (Form B)]. Second, a non-attempt score was calculated as the number of non-attempts, divided by the total number of items. Finally, parents/caregivers recorded the amount of help that participants were given for each item using *The Hierarchy of Independence Key* (Figure 1c) ranging from 1 being "completed independently" to 6 being "demonstrated." An accuracy including independence score was created by combining accuracy with how much help the participant received. For correct items where independence was 1 or 2 (independent and assisted reading) the child got full marks (score = 1). For correct items where independence was scored as 3 or 4 (indirect prompt or direct prompts used) the child's accuracy was reduced to 0.75. For items where independence was 5 or 6 (direct model provided or adult demonstrated how to answer the question) the child's accuracy was reduced to 0.5.

2.4 Analysis strategy

2.4.1 Generating variables

Pre-test scores were calculated as a percentage of the total of Foundation and Level 1 items at pre-test. At pre-test 91% of participants did Foundation and 31% did Level 1. If participants did not do Level 1 they were marked 0 for these items. If a participant did not do Foundation but did do level 1, they were marked correct for all Foundation questions. For non-attempts, if a participant did not do Level 1, we did not adjust their non-attempt score. At post-test 78% of participants did Foundation and 31% did Level 1. Post-test scores were calculated in the same way as pre-test.

2.4.2 Analyses

We compared the groups at Time 1, using independent samples *t*-tests, testing whether the groups had approximately similar ability prior to the intervention. We analyzed the effect of the intervention using ANCOVAs, with pre-test scores and age as covariates, and group as a between-subjects factor. The Bayes Factors reported can be interpreted using the following benchmarks: Bayes factors <1 = limited/no support; between 1 and 3 = weak/ anecdotal support; Bayes factors between 3 and 10 = substantial support; Bayes factors between 10 and 100 = strong evidence; Bayes factors greater than 100 = very strong/decisive evidence (Jarosz and Wiley, 2014).

3 Results

3.1 Time 1 performance

At Time 1, there were no significant group differences for any measure (see Table 1; Figure 2) including overall accuracy, $t(30) = 0.31$, $p = 0.759$, $d = 0.110$, $BF_{10} = 0.349$, accuracy including independence,

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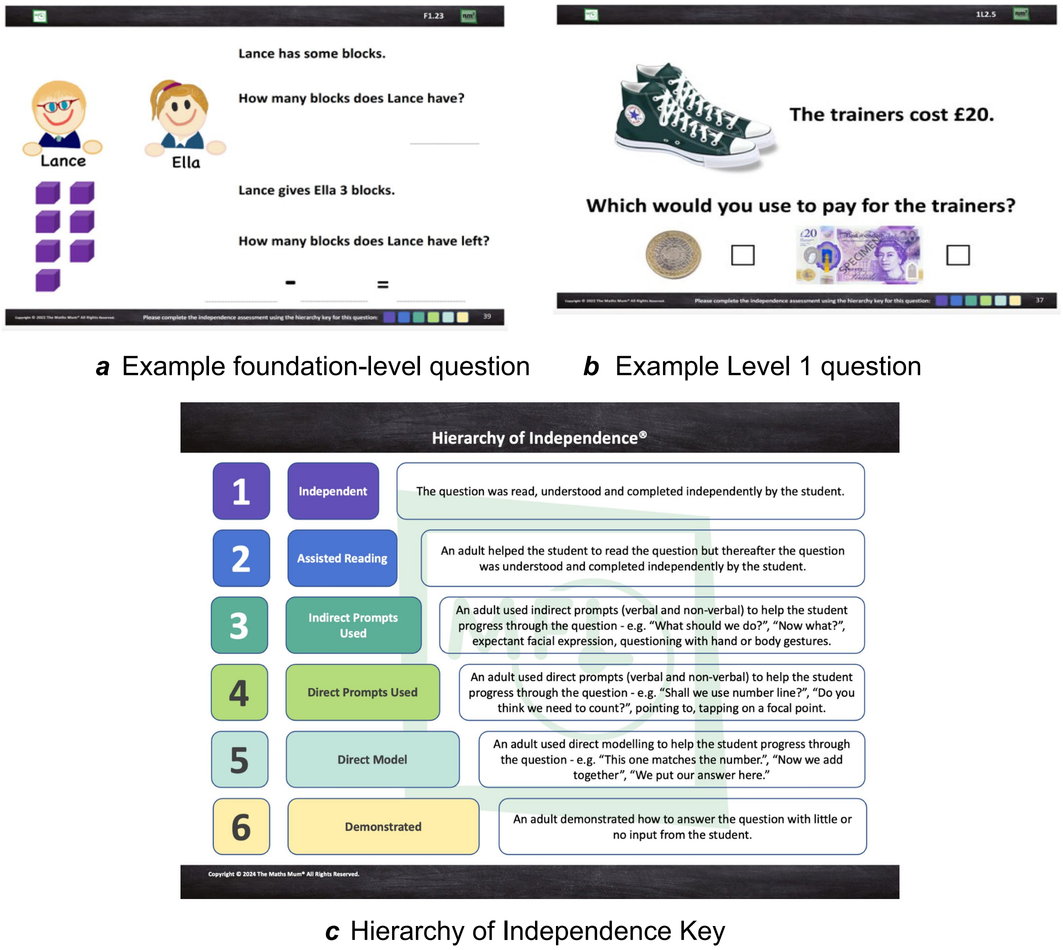

FIGURE 1
(a) Example foundation-level question. **(b)** Example Level 1 question. **(c)** Hierarchy of independence key.

TABLE 1 Performance of each group across the two time points.

Variable	Group	Time 1		Time 2	
		Mean	SD	Mean	SD
Overall accuracy	Intervention	45.2	30.3	53.6	34.1
	Control	48.5	30.1	50.5	28.7
Accuracy including independence	Intervention	40.8	28.9	49.5	32.8
	Control	45.6	30.7	48.3	28.8
Non-attempt scores	Intervention	7.00	9.93	4.13	7.99
	Control	2.10	4.56	1.51	3.62

$t(30) = 0.45$, $p = 0.656$, $d = 0.159$, $BF_{10} = 0.364$, and non-attempt scores, $t(30) = 1.81$, $p = 0.08$, $d = 0.641$, $BF_{10} = 1.14$.

3.2 Time 2 performance

At Time 2, there was a significant effect of group on overall accuracy, F (1, 28) = 5.8, $p = 0.023$, $np^2 = 0.172$, $BF_{10} = 2.524$ and accuracy including independence, F (1, 28) = 6.99, $p = 0.013$, $np^2 = 0.200$, $BF_{10} = 3.710$. In both cases, the intervention group had significantly greater gains in Time 2 scores compared to the control group, i.e., after controlling for Time 1 performance. However, there was no significant effect of group on non-attempt scores, F (1, 28) = 0.873, $p = 0.358$, $np^2 = 0.03$, $BF_{10} = 0.456$.

Time 1 performance was significantly associated with Time 2 performance for all measures, including overall accuracy, F (1, 28) = 310.39, $p < 0.001$, $np^2 = 0.917$, $BF_{10} = 7.39e + 15$, accuracy including independence, F (1, 28) = 413.48, $p < 0.001$, $np^2 = 0.937$, $BF_{10} = 4.16e + 17$, and non-attempt scores, F (1, 28) = 90.36, $p < 0.001$, $np^2 = 0.763$, $BF_{10} = 1.65e + 9$. Age was not significantly associated with Time 2 performance for any measures after accounting for Time 1 performance: overall accuracy, F (1, 28) = 1.56, $p = 0.222$, $np^2 = 0.053$, $BF_{10} = 0.128$; accuracy including independence, F (1, 28) = 1.19, $p = 0.285$, $np^2 = 0.041$, $BF_{10} = 0.098$; and non-attempt scores, F (1, 28) = 0.421, $p = 0.522$, $np^2 = 0.015$, $BF_{10} = 0.130$.

4 Discussion

This study provides the first insights into the efficacy of the *Maths For Life* programme for improving mathematics skills in children with DS. Not only were there significant differences in mathematics

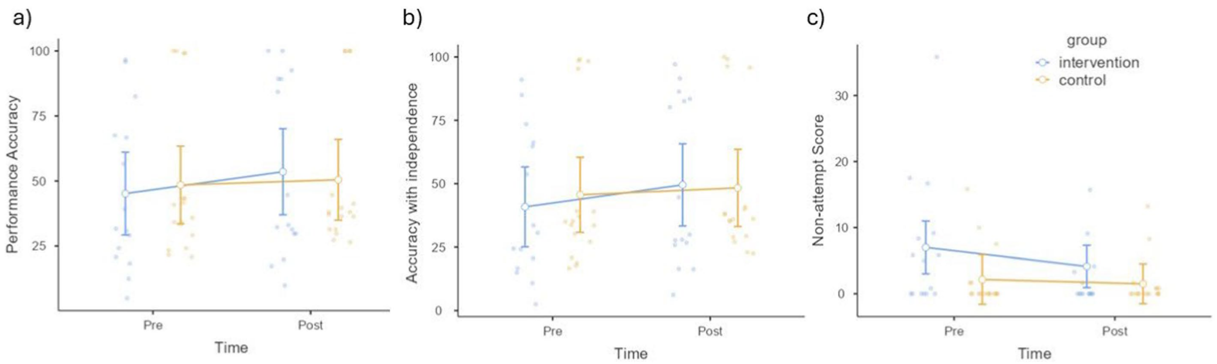

FIGURE 2
Distribution of individual participant scores across groups and time points for overall accuracy **(a)**, accuracy including independence **(b)**, and non-attempt scores **(c)**.

achievement between the intervention and control groups following participation in the *Maths For Life* programme, children's independence in completing mathematics activities also improved significantly after participating in the programme.

As outlined, most previous interventions explore number skills training (Lanfranchi et al., 2015; Porter, 2022; Sella et al., 2021). Our findings align with previous studies showing that mathematics skills are malleable and add support to the fact that improvements in diverse ranges of mathematical competencies are possible to achieve with tailored intervention. In this case, *Maths For Life* ensures that the math content presented to children is individualized and within their zone of proximal development. The results suggest that this approach including the delivery of child appropriate content, the use of repetition before the introduction of new concepts, and the one-to-one scaffolding provided by a parent/other adult are effective in eliciting gains in mathematics.

To our knowledge, this is the first study to assess the effect of a mathematics programme on mathematical independence in children with DS. Mathematical independence is the degree to which students can accurately complete mathematics tasks without support/scaffolding. Based on the pattern of results, it could be that *Maths For Life* consolidates students knowledge leading to increased independence, i.e., not only do students acquire new skills but they also consolidate their understanding to use their skills more independently. The goal of the *Maths For Life* programme is to encourage simple mathematics completed accurately and independently. By providing accessible resources, with lots of repetition, using real life examples, the programme successfully increases children's ability to see mathematics problems in everyday life and solve them with limited scaffolding. Improving mathematical independence has many benefits including the development of future mathematics ability, e.g., independence positively correlates with numerical ability and mathematics outcomes in typically developing children (Sugiarto and Arina Hidayati, 2019). Therefore, over time, increased independence could have further knock on improvements for accuracy. This could be tested by using a delayed follow-up assessment in future studies.

Previous studies report that students with DS have poor mathematical outcomes (Van Herwegen et al., 2020). Given the importance of mathematical abilities for daily life, it is important that all children have access to proper resources and appropriate teaching methods to allow them to learn mathematics. This pilot study suggests that children with DS benefit from receiving additional intervention, in addition to standard teaching in school. The *Maths For Life* programme shows promise as a means of achieving this.

Importantly, the results should be interpreted in the context of the study limitations. Our findings rely on self-report methods and parental delivery of assessments which may have reduced systematicity and consequently concealed potential benefits of the programme. To address this, pre and post assessments should be delivered by an independent researcher, especially as parents provided the training as well as delivering the *Maths For Life* programme. Parents may have had expectations that impacted on the results. In future studies, data on implementation, e.g., number of sessions per week, should also be collected.

Second, our sample size ($N = 32$) was small, which limits statistical power and we did not use random allocation of participants to groups. Given that the average effect of educational intervention is typically small (Lortie-Forgues and Inglis, 2019), our small sample size reduces chances of identifying small effects. To address this, we have reported Bayes Factors to support null findings. However, in future, running the *Maths for Life* programme in schools would allow wider participation, e.g., inclusion of children whose parents may not be able to administer the intervention due to time/cost constraints. This would enable a larger sample size and more accurate testing of the efficacy of the programme where random group allocation could be used. Third, the study did not use a standardized mathematics measure and did not include any additional demographic or cognitive measures. Relying on the *Maths For Life* assessment to measure mathematics performance when it has not yet been rigorously tested, leaves uncertainty regarding the reliability and/or validity of the measure. Future research should test mathematics skills using both the *Maths For Life* assessment and a standardized tool, in addition to a wider battery of cognitive measures.

5 Conclusion

This pilot study provides the first evidence on the efficacy of the *Maths For Life* programme for improving mathematics skills in children with DS. The findings from parent administration of the programme suggest that this mathematics programme improves mathematical ability and independence, evidence that lays foundations for further testing this programme in schools. Improving children's accurate and independent application of mathematics is vital for everyday living and independence. This pilot study provides initial evidence that the *Maths For Life* programme may offer one avenue for increasing mathematical independence in those with Down syndrome.

What this study adds?

Acquiring mathematics skills is essential for educational achievement and everyday living/independence, e.g., managing time such as using timetables, appreciating value and budgeting money, understanding quantity and applying this to decision making. However, many children from neurodiverse populations fail to acquire basic mathematics skills in school. This suggests a need for specific intervention programs to promote math achievement in people from neurodiverse groups including those with Down syndrome. This study introduces the *Maths For Life* programme, a new mathematical curriculum designed to help struggling mathematics learners improve their skills. *Maths For Life* is a targeted programme that uses a baseline assessment to ensure that the math content presented to children is individualized and within their zone of proximal development. Additional active ingredients that make this programme unique include the embedding of mathematics content in real-world examples, the use of repetition before the introduction of new concepts, and the one-to-one scaffolding provided by a parent/other adult. The objective of this pilot study was to investigate, for the first time, *if* and *how* the *Maths For Life* programme influences mathematics performance in young people with Down syndrome.

We found that when administered by a parent/caregiver, participation in the programme led to improved mathematics performance and higher mathematical independence scores for the intervention compared to the business-as-usual control group. There were no differences in non-attempt scores between the groups. This pilot study provides the first provisional evidence on the efficacy of the *Maths For Life* programme for improving mathematics ability and independence in children with DS. It provides support for the use of the programme by parents/caregivers to improve their children's abilities in mathematics. The findings also lay the foundations for a larger efficacy trial of the *Maths For Life* programme in school settings with children with neurodiverse conditions. This study provides the first evidence that the *Maths For Life* programme may be an effective and practical tool for closing attainment gaps in mathematics between typically developing and struggling learners.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval for this secondary data analysis was granted by the University College Dublin Ethics Committee. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

KG-L: Formal analysis, Supervision, Writing – original draft, Writing – review & editing. KM: Conceptualization, Investigation, Methodology, Project administration, Resources, Writing – review & editing. HS: Data curation, Formal analysis, Writing – review & editing.

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Conflict of interest

KM is the founder of the *Maths For Life* programme.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1453156/full#supplementary-material

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