WE STAND FOR AMBITION.

University of Kent

The Gamification of Numeracy

2025

Contents

Introduction

Mathematical attainment at Key Stage 4 is an essential element of educational success and a key determinant of future academic and career pathways. Achieving a grade 4 or above in GCSE Mathematics and English significantly increases the likelihood of progression to further education, apprenticeships, and higher education. However, disparities persist, with students in non-selective schools less likely to achieve these grades than their peers in selective and independent schools. These challenges are further compounded by leaving primary education with gaps in foundational numeracy skills.

In response to these challenges, this report examines the development, implementation, and evaluation of a pilot numeracy programme designed to address gaps in mathematical understanding and foster confidence in mathematics among Year 7 students. Grounded in gamification principles, the programme integrated engaging and interactive learning strategies to support numeracy skill development. The programme sought to create a supportive environment where students could build both their competence and self-efficacy in mathematics.

This report provides an overview of the programme's design, its theoretical underpinnings, and its evaluation methodology. It concludes with key findings, challenges encountered, and recommendations for future iterations.

Context

Attainment of a grade 4 or above in Maths GCSE is a key target for schools and students alike. It is closely linked to progression to level 3 study and Higher Education. In 2019, 95 % of students who achieved grade 4 (formerly known as a grade C) in Maths and English GCSEs went on to further education or apprenticeships, compared to 82 % of those who did not (Education statistics). Of those who achieved grade C or above in English and Maths GCSEs in 2016, 44.3 % were in higher education in 2019, compared to 7.9 % of those who did not. These numbers rose to 57.5 % and 15.6 %, respectively, 5 years after the students sat GCSEs in 2016 (Education statistics).

These disparities are further accentuated in counties where there is a selective education system. Students in non-selective schools are less likely to achieve these key GCSE grades than their peers in selective schools. The latest data available, for 2022, shows that 62% of students in non-selective schools in highly selective areas (including Kent and Medway) achieved grade 4 or above in Maths and English GCSEs, compared to 98.2 % of their peers in selective schools. The national average was 68.8 % for students in state-funded mainstream schools (Education statistics).

It is of note that disadvantaged students, who are disproportionately represented In non-selective schools, are less likely than their peers to achieve a 4 or above in Maths and English GCSEs. In 2023, 39.4 % of students in Kent classified as disadvantaged achieved grade 4 or above in GCSE Maths and English, whereas 74.2 % of students classified as not disadvantaged achieved grade 4 or above. Similarly, 38.5% of students in Medway classified as disadvantaged achieved grade 4 or above in GCSE Maths and English, whereas 72 % of students classified as not disadvantaged achieved grade 4 or above.

There is a correlation between prior attainment in mathematics, namely Key Stage 2 (KS2) attainment, and Key Stage 4 (KS4). The latest data available, for 2022, shows that 96.8 % of high prior attainment students (scaled KS2 score above 110) achieved a grade 4 in English and Maths GCSEs, compared to 28.5 % of low prior attaining students (KS2 scaled score below 100). If we look at disadvantaged students, only 18.7 % of students who were classified as both disadvantaged (DfE definition) and low prior attainment achieved grade 4 or above in English and Maths GCSEs. This figure drops to 2.6 % of those with the lowest score (KS2 scaled score below 80). In contrast, for those who were not classed as disadvantaged, 35.2 % of low prior attainment students achieved 4 or above in GCSE Maths and English, 6 % for those with the lowest score. Disadvantaged students are overrepresented in the low prior attainment group. In 2022, 78% of non-disadvantaged pupils and 56% of disadvantaged pupils met the expected standard in KS2 maths, a significant decline from 2019 figures of 84% and 67%, respectively.

Work with our teaching colleagues in schools has identified two key areas of concern; the first is a picture of significant gaps in primary level learning for students entering year 7, which subsequently limits and hinders their engagement with the Key Stage 3 curriculum and negatively impacts their confidence and self-efficacy. The second is a set of gaps in GCSE knowledge (in some cases linked to learning lost during covid) which similarly impacts confidence and self-efficacy under exam questions and conditions. Given

this, the Outreach and Wiening Particiption Team developed a programme aimed at supporting students with developing numeracy skills to support their development with Key Stage 3. Through developing a theory of change, we anticipate that supporting students in developing foundational skills will foster long-term progress in mathematics, ultimately contributing to higher attainment at KS4.

Gamification Rationale

The pilot programme was developed using gamification principles. Gamification integrates game-design elements such as competition, feedback, and rewards into non-game settings to develop motivation and engagement (Faiella, 2015). In education, gamification has proven effective in increasing student participation and retention of knowledge (Faiella & Ricciardi, 2015). By transforming traditional learning into an interactive and enjoyable experience, gamification addresses cognitive, emotional, and social dimensions of learning (Faiella & Ricciardi, 2015).

As previously highlighted, students in non-selective schools often face challenges stemming from lower prior attainment and gaps in foundational knowledge. Gamification can be particularly suited to these settings, as it reduces anxiety associated with traditional learning and fosters a positive learning environment (Sanchez et al., 2020). Additionally, games can provide students with opportunities for repeated practice without stigma.

It was hypothesized that incorporating gamification into a numeracy programme will foster a positive attitude towards mathematics and encourage active participation among students.

Pilot Structure

The programme was designed to be a 12-week, small group programme where students participated in a range of different games related to multiplication. Students worked in small groups of 3-4 students with one undergraduate ambassador.

The programme looked to incorporate key gamification elements in order to support embedding learning. Apostol et al (2013) identified eight elements that should be used for the gamification of learning, these were: "rules, goals and outcome, feedback and rewards, problem solving, story, player(s), safe environment, sense of mastery." (Apostol et al 2013, cited in Faiella, 2015).

Nand et al (2019), found that gamification improved primary aged children's learning outcomes in numeracy. Their project specifically focused on computer-based games which incorporated characteristics of computer gaming for social pleasure. Through their research, they identified three key game features which were essential to the success of the programme. These were; varying and increasing levels of challenges, incorporation of feedback for example knowing points scored and realistic graphics including colourful images, real-life characters, high definition (Nand et al, 2019).

Given that the department has limited resources suitable to developing games involving technology and that our pilot school had limited access to technology, it was decided to embed the elements of Apostol et al (2013) and Nand et al (2019) using a variety of technology and technology free games. Combining technology-based and low-tech games offers an innovative approach to gamification.

The primary focus of the games implemented within the maths support programme more closely followed that of Nand et al (2019), including increasing levels of challenge, incorporation of feedback and interactive resources. However, the programme also wanted to ensure that students had a safe environment whereby they felt comfortable to participate and could achieve a sense of mastery according to Apostol et al, 2013.

Games and activities were chosen in collaboration with the school who provided access to existing resources that would be familiar to the students. A variety of games were used including computer based games and card games such as bingo multiplication, multiplication snap, 21's and 24. By collaborating with the school, it was hoped that the content of the sessions would be both relevant to their in school learning and incorporate the key elements of gamification outlined above. Additionally, by working with small groups, and a consistent ambassador, it was hypothesised that this would create an environment whereby students felt comfortable to participate and develop a sense of mastery.

Programme Aims

The objective was to raise attainment in identified numeracy topic areas for year 7 in the pilot school, as well as raising students' level of maths confidence and improve their self-efficacy around maths. Therefore the intended outcomes for this programme were as follows:

- Improved maths skills in targeted topics
- Increase maths confidence and self-efficacy

Methodology

A mixed method approach was used to evaluate the effectiveness of the pilot programme. This included pre and post testing, pre and post surveys, alongside incorporating qualitative feedback from practitioners, school staff and student ambassadors.

Testing

At the start and end of the programme, students undertook a short maths assessment using 'PiXL'. This is an app that tests students on their maths abilities and was recommended by the school. PiXL is a subscription based service used regularly within the school. At the end of each test, students were given a score out of 60.

Surveys

This survey consisted of attitudinal questions which looked to measure students' perception of maths and their perception of their ability in maths. For example, students were asked to rate their agreement to questions such as, "I find maths easy", and "Maths is important in everyday life". Weighted average scores were calculated from the responses to these questions.

Qualitative Feedback

Feedback from outreach practitioners, school staff and student ambassadors was also collected. This feedback is essential to understanding the practical experiences of running the programme, alongside the successes and challenges that traditional evaluation methods such as surveys and testing cannot capture. This feedback is seldom incorporated into discussions on the impact of the programme, but can often provide rich context as to its value.. It also is most likely to lead to realistic and practical improvements to programme design.

Findings

Given that there were a small number of students who participated, statistical relevance cannot be assumed. Therefore, a degree of caution should be considered when making assertions about the impact of the programme.

Test Scores

A breakdown of average scores is provided in Table 1.

	Number of participants	Number of participants improved scores	%	Average Baseline Score (/60)	Average Final Score (/60)	Average attendance
Group 1	11	8	72.70%	34	37.63	81%
Group 2	12	6	50%	32.08	33.91	76.40%
Total	23	14	60.90%	33	35.69	79%

Table 1: Assessment averages

Although the average scores did increase for both groups, the individual scores were contradictory and as the number of participants is low it is difficult to draw conclusions from.

Surveys

The weighted average responses of the group (n=18) had increased for seven of the ten questions posed to them (figure 2), showing that they more strongly agree with these statements. The biggest positive differences were in their agreement with the statements 'I am confident solving maths problems', 'I like to solve new problems in maths' and 'The challenge of maths is fun to me'. This may suggest an increase in confidence in their maths abilities.

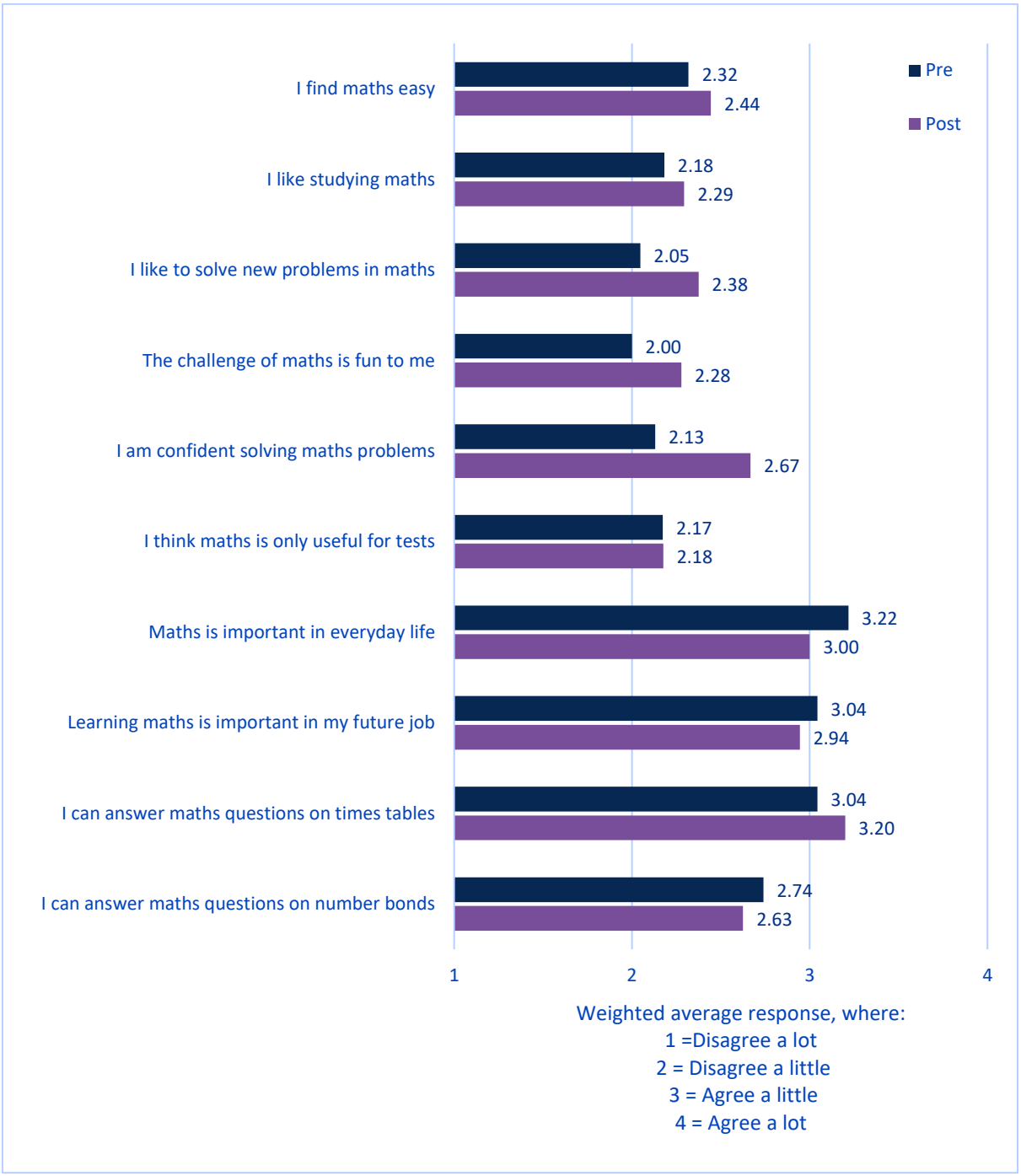

Figure 2. Weighted average response showing how strength of agreement to a series of statements has changed from the start of the programme to the end

However, the weighted average responses were lower for the following statements at the end of the programme than at the beginning:

- 'Maths is important in everyday life'
- 'Learning maths is important in my future job'
- 'I can answer maths questions on number bonds'

There are a number of extraneous variables which may influence participant's responses to survey questions and therefore assertions cannot be made based on these results. Qualitative data or follow up with students may be able to provide further insight into their rationale behind the scores.

Discussion

Increased engagement

There was anecdotal evidence to suggest that gamification improved students' attitudes towards engaging in maths related activities. Student ambassadors mentioned that students were apprehensive about participating in the activity related to maths, however, after participating they saw the activities as games, and this increased their engagement with the session. One ambassador noted:

"I think for them it was a mindset thing and they didn't want to work. That's maybe why they were struggling in class. And then when we came and did it, it was like a game. They forgot that they're actually doing maths and got really good at it." – Student ambassador

A second ambassador noted that students enjoyed participating in the programme because the sessions were distinct from typical school lessons. Students perceived them as enjoyable and fun rather than as traditional studying. This feedback supports the potential of gamifying numeracy to enhance engagement. However, further investigation is needed to determine whether this positive attitude toward maths carries over into the classroom.

An ambassador asserted that the iPad based games were especially effective in creating opportunities for all students to succeed, particularly those students who were less confident in their abilities or competing against others. The ambassadors mentioned that the online games created opportunities to measure success in different ways. The ambassador listed things such as aiming for the fastest time or being the most accurate. One particular ambassador mentioned that this was particularly important in maintaining engagement with the competitive environment. They stated:

"[The online games] were really good, like I said, because even if they weren't as confident, they were still able to engage and it didn't set them apart from anyone else… So there were different levels they could engage at and I've seen times where the competition element has gone really wrong in schools and they didn't happen at all."- Student ambassador

The ambassador mentioned the idea that competition is not always suitable for all students, and this is something that the programme did experience. This will be elaborated on in a discussion on the group environment.

Positive ambassador-student relationship

The small group environment fostered meaningful interactions between students and student ambassadors which enabled students to develop a good rapport with the student ambassadors. One student ambassador referenced how they were able to get to know the students well and this enabled them to understand each student's strengths and areas to develop.

By forming these personal connections, ambassadors were better equipped to tailor their guidance and support to meet the specific needs of each student. For example, they could adapt the sessions and provide targeted feedback. Additionally, this rapport-building process contributed to a more positive and engaging learning environment.

Sense of mastery

Students demonstrated growth in their multiplication skills, which significantly bolstered their confidence, as shown in fig.2. This was especially evident when engaging with interactive online games that provided immediate feedback and visual progress tracking. Ambassadors observed that students felt a strong sense of accomplishment when they solved problems correctly, further reinforcing their confidence. According to Bandura's self-efficacy theory (1997), experiencing success in tasks enhances students' belief in their ability to succeed, which in turn fosters perseverance and resilience.

Resource limitations

The programme was designed initially to specifically target times tables and multiplication. However, student ambassadors reflected that the students developed substantially relatively quickly and wanted to move onto new topics. It was felt that students began to get bored and distracted after they felt they had mastered times tables. One ambassador identified that students' interest began to dissipate around 4-5 weeks, and they found it challenging to then make sessions more challenging for the students.

It was originally envisaged that a more collaborative approach to resource creation would take place throughout the programme. However, logistical and time constraints meant that this was not feasible. This limited the number of resources which were developed and utilised as part of the programme and meant that the programme did not expand to topics other than times tables and multiplication. Whilst this skill is identified as critical for maths success, it was highlighted by outreach practitioners, student ambassadors and school staff that there was a need to progress this further and incorporate other key areas of maths that students often find difficult to understand or have low confidence in. These include topics such as fractions, decimals, percentages, ratio, proportion. Students did little work on number bonds, which may explain why the students agreed less with the statement 'I can answer maths questions on number bonds' at the end of the programme.

Monitoring progression

There needs to be resources which support tracking the students in session progress. This will enable ambassadors to recognise when a student is ready to tackle more challenging topics while keeping students motivated by allowing them to measure their own progress. For instance, providing clear guidelines on the proficiency levels required to advance to a new topic ensures transparency and consistency. It is equally important to communicate these expectations to students, so they understand

the progression process. One student ambassador highlighted:

"So they were answering questions on an online portal to help with the tracking and the evaluation. I don't think all of the students fully understand it, understood how that worked and it made a little bit hard for us to also figure out like when have they done enough practise for them to log on and do another self-assessment and see how it's going."- Student ambassador

Additionally, this will allow there to be more collaboration between the school and the university, whereby the school can pinpoint individualised development needs, and the university can feedback more regular progress tracking to the school.

Group environment

The small group environment proved challenging for a small number of learners. There were behavioural challenges and for some a lack of confidence to participate. It was felt that this was largely due to a fear of failure in front of peers. This finding aligns with findings from Domínguez et al (2013) who found that some students were not motivated by gamification as they did not want to compete with their peers (Domínguez et al, 2013, cited in Faiella, 2015, p.16).

One ambassador shared their experience with a group of students who preferred playing individual games on iPads rather than engaging in competitive group activities. They described how this initially posed a challenge, making it difficult to connect with the students. Reflecting on the situation, they said, "I didn't know how to handle this at first, but I kept sitting with them and tried to engage as much as I could". Over time, however, the ambassador noted a positive shift, students began seeking their guidance as the programme progressed.

Further research into the fear of failure provides further insight into these challenges. Conroy et al. (2002) identified fear of failure as a psychological construct characterised by the anticipation of negative consequences associated with failing, such as shame, embarrassment, or a diminished sense of self-worth. In learning environments, this fear can manifest as avoidance, reduced participation, and heightened anxiety (Pekrun et al, 2007).

Future iterations of the programme should consider how to mitigate fear of failure for students participating in the programme. Given the additional behavioural challenges, a one-to-one support model which mirrors that of the university's literacy programme could be explored. However, if this is deemed not suitable, consideration should be given to how games or activities can ensure all students can recognise their achievements.

Staff confidence in numeracy

Logistical and timetabling constraints made it impractical to rely solely on maths specialists to deliver the maths support programme. Additionally, it was felt given the level of support needed, that most staff and ambassadors would be capable of delivering this level of maths competently.

Yet, for university staff and student ambassadors who do not have maths experience at a university level, there was an apprehension in their own abilities to support students. This led to challenges in getting the

appropriate sign-up and a general level of maths anxiety for those working on the programme. Maths anxiety is well-documented and often characterised by feelings of tension, apprehension, or fear when dealing with mathematical tasks (Ashcraft, 2002). While often studied in student populations, maths anxiety can also affect educators and facilitators, particularly those without a strong mathematical background. Beilock & Maloney (2015) found that Maths anxiety can undermine confidence, leading individuals to doubt their abilities and avoid engagement with mathematical tasks. This aligns with the university's experience with the staff and student ambassadors which often led to lower sign up from ambassadors, particularly those who were not studying maths at an undergraduate level. Future iterations of the programme should incorporate comprehensive training for university staff and student ambassadors. Training will not only help in developing confidence in delivering numeracy but will also support in developing their professional development.

Recommendations

1. *Amend the programme structure to provide 1:1 support.*

Given the challenges of engagement in the small group environment and the fact that the university has had relative success with 1:1 reading support, it is recommended that the programme amend its format to provide 1:1 support. Whilst gamification principles could still be embedded, it is felt this would remove some of the behavioural and confidence challenges experienced by the students in the group environment.

2. *Support staff and student ambassadors in developing their numeracy confidence and skills.*

Comprehensive training should be provided to support staff and student ambassadors in delivering maths. This would increase the confidence of staff and ambassadors to deliver the programme, whilst simultaneously providing opportunities for professional and personal development. This would also increase the level of support which can be provided to the students.

3. *Utilise content that aligns more closely with secondary school maths curriculum.*

Feedback from the pilot school was that content needed to align more closely to the maths curriculum and incorporate additional topics which students struggle to engage with in class. This includes topics such as fractions, decimals, percentages, ratio, proportion.

4. *Develop a structured system for tracking student progress*

An in programme assessment should be incorporated which supports measuring students' progress each week and identifies when a student can progress to an additional level of difficulty or new topic. This system should be structured, simple to use, accessible and understandable for all parties including students.

5. *Consider new methods of evaluation.*

The evaluation methods implemented were limited, which makes it difficult to accurately assess the impact of the programme. Evaluation methods should be reconsidered as part of the programme redevelopment to provide additional qualitative and quantitative insights into the programme. Where possible, additional experimental methods should be considered such as comparator groups.

Conclusion

The pilot numeracy programme represents an innovative approach to addressing foundational gaps in mathematical knowledge among Year 7 students in non-selective schools. By embedding gamification principles into small group activities, the programme aimed to create an engaging and supportive environment that fostered both skill development and confidence in mathematics. While quantitative results highlighted some improvements in targeted numeracy areas, qualitative feedback revealed significant challenges, including behavioural issues in group settings, fear of failure among students, and apprehension among staff and ambassadors lacking mathematical expertise.

This report underlines the importance of tailoring interventions to meet the diverse needs of students and facilitators. Moving forward, recommendations include transitioning to a one-to-one support model, providing comprehensive training for staff and ambassadors to address maths anxiety, aligning programme content more closely with the secondary school curriculum, and implementing more robust methods of tracking student progress.

Addressing these areas will not only enhance the programme's effectiveness but also ensure its sustainability and scalability. With thoughtful refinement, this initiative has the potential to significantly impact the mathematical attainment and confidence of students in non-selective schools.

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