Psychological Sciences and Health

SOCIOECONOMIC STATUS AND PRIMARY-AGED CHILDREN'S ACHIEVEMENT IN MATHEMATICS: THE ROLE OF EDUCATIONAL PSYCHOLOGY IN UNDERSTANDING AND ADDRESSING VARIABLES WHICH MITIGATE THE IMPACT OF RELATIVE DEPRIVATION

DOUGLAS C. HUTCHISON

A thesis presented in part-fulfilment of the requirements for the Award of Doctorate in Educational Psychology

7 July 2023

Supervisor: Dr Clare Daly

Declaration of Authenticity and Author's Rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: Douglas Hutchison

Date: 19th March 2023

Word count: 44,691

Dedication

This thesis is dedicated to my wife Kathleen and our three children, Katy, Joseph and Sarah who are making their own way through Higher education. I could not have completed this work without their love and support. We have all been fortunate to benefit from a good education and it is only right that we do all we can to extend that benefit to all of Scotland's children and young people regardless of their family background.

Acknowledgements

I am very grateful to my supervisor Dr Clare Daly for her guidance, encouragement and support throughout this process. My sincere thanks also to Professor Jim Boyle for his wisdom as well as skilful guidance and support on all matters related to statistical analysis and methods.

I am deeply indebted to my colleague Carole Campbell and the entire group of fellow travellers on the DEdPsy group, without whose peer support this would have been a much more difficult journey. I am also very appreciative of the small Doctoral Research Group who met weekly during lockdown for their support.

Finally my sincere thanks to the two teachers in the intervention schools and their very enthusiastic pupils without whom this thesis would not have been possible.

Data statement

Data underpinning this thesis are openly available from the University of Strathclyde research information portal at https://doi.org/10.15129/88672303-ec3e-4228-aa9d-e79cf6d519b8.

Further information about data processing is available from the University of Strathclyde KnowledgeBase at http://doi.org/10.15129/a1234b56.

Table of Contents

List of Tables

List of Figures

Abstract

Attainment for lower SES children tends to be below average. The investigations sought to explore mathematics attainment for lower SES children and the contribution their own attitudes and teachers' perceptions of mathematics make to attainment.

The main hypothesis is that poorer outcomes in maths are partly due to attitudes, expectations and values about maths held by both teachers and children.

Participants in the study on children's attitudes to maths are primary school aged children while participants in the teachers' Perceptions of Mathematics study are primary school teachers.

Study 1 involved analysis of secondary attainment data (n=1,075) using regression analysis to characterise the strength of connection between maths and SES. Study 2 explored the factor structure of the Perceptions of Mathematics (POM) survey using Principal Components Analysis (PCA) to explore teachers' attitudes to maths teaching (n=136).

The method in the main study was quasi-experimental. An intervention group took part in a peer-assisted, games-based learning intervention (n=42) with a control group (n=19) following maths-as-usual. Commercial off-the-shelf maths games were used by the intervention group over 6 weeks with pre post *Maths Attitude and Anxiety Questionnaire (MAAQ)* and *Myself As a Learner (MALS)* measures taken.

Analysis of secondary attainment data found general maths by SES fitted the data best compared to Reading and General Ability.

PCA found a two factor structure in the POM consistent with conceptual and procedural mathematics.

Multiple hierarchical regression analysis of the MAAQ at T1 and T2 found an effect of time by group with no significant effect found for MALS.

Results indicated a connection between SES and attainment with a stronger effect for maths. The POM results suggest teaching approaches for poorer children may disadvantage them and finally, children's attitudes to maths may be positively influenced by a peer-assisted games-based learning intervention which may ultimately improve their attainment.

Introduction

Achievement of Curriculum for Excellence levels in 2021 show that the gap between the most deprived and least deprived children increased following school closures due to Covid (Scottish Government, 2021). The gap increased most in numeracy figures, increasing by just over 27% at P1 (age 5), 22% at P4 (age 8) and 15% at P7 (age 11). The disruption of school closures appears to have impacted to a greater extent on the youngest and the poorest in Scotland. However, there was an existing gap in attainment figures which the Scottish Government and the Scottish education system had been addressing with greater focus since 2015 (Scottish Government, 2022). This thesis aims to make a contribution to the research on what is likely to make a difference to children and young people living in relative deprivation. The aim is to do it by focussing on psychological variables which can have a positive or negative impact on motivation to learn, and subsequently to achieve, by developing a protocol for an intervention that could be implemented in schools.

The fact that Curriculum for Excellence numeracy attainment was more negatively impacted than literacy during the Covid disruption points to an important issue which this thesis aims to explore. It is the question of whether or not maths attainment is more sensitive to relative deprivation than literacy or general ability. Research suggests that early maths skills are more predictive of overall academic success compared to early literacy skills (Romano et al., 2010) and so may be an important indicator of progress in tackling poverty related outcomes gaps in education.

Returning to the issue of motivation to learn and psychological variables, beliefs, values and attitudes to learning are influenced by the community, family and peers (Hentges et al., 2019). It appears that an acceptance of negative attitudes towards maths are more prevalent in relatively more deprived communities and families (Häfner et al., 2017). Beliefs, values and attitudes in turn have an impact on the effort we make in a specific area of learning and appear to have an impact on achievement even when controlling for prior attainment and levels of deprivation (Eccles & Wigfield, 2020; Rosenzweig et al., 2022). The focus therefore of this thesis is on the extent to which psychological variables such as beliefs, values and attitudes towards maths can be measured, influenced and can influence outcomes.

The focus firstly however is on teachers' attitudes to maths and the distinction between a teaching preference for conceptual maths versus a teaching preference for procedural maths. The distinction is of interest because in order to achieve in maths, it is important to have a developed understanding of concepts as well as procedures (Lenz et al., 2020; OECD, 2016). The Organisation for Economic Cooperation and Development (OECD) research suggests that teachers of relatively more deprived children adopt a more procedural approach to teaching, whereas teachers teaching relatively less deprived children adopt a more conceptual approach to teaching. The gap in outcomes therefore may, in part, be explained by lack of exposure to conceptual maths. The first step in exploring the distinction in teaching preferences is developing a reliably validated instrument which can distinguish between teachers' conceptual versus procedural preferences.

Children's values about learning are formed by multiple sources including community, family and peers (Zhang et al., 2020) and have an effect on achievement (Eccles & Wigfield, 2020; Wigfield & Eccles, 2000). In addition, the experience of learning can lead to maths anxiety which in tun may exacerbate low achievement (Suárez-Pellicioni et al., 2016). There is however some debate about whether maths anxiety leads to poorer outcomes or struggles with maths lead to maths anxiety (Suárez-Pellicioni et al., 2013).

A well-established strategy for improving educational outcomes is peer assisted learning which continues to be used effectively to improve reading (Topping et al., 2003; Topping, 1998; Tymms et al., 2011). It is less commonly used in the context of maths. In the current context it will be used with a view to improving children's attitudes towards learning maths and at the same time reducing maths anxiety. By learning in the context of games and through the mediation of peers as more able learners (Stringer, 2018; Walshaw, 2017), the aim is to influence positively children's experience of maths and their attitudes, values and beliefs about maths. By positively influencing their beliefs, attitudes and values the hope is that maths anxiety may also be reduced for those who experience it and ultimately, their motivation to learn and investment in the subject will improve leading to improvement in attainment.

Chapter 1 therefore will focus on setting out the rationale for a focus on the connection between relative deprivation and educational outcomes in the context of the Scottish educational policy priorities. It will also set out the role of educational psychology in addressing the national policy priority of closing the poverty related outcomes gaps in education. The focus throughout is on the applied role of educational psychology and the contribution it makes at local authority and national policy.

Chapter 2 then explores the literature on relative poverty and the influence on educational outcomes as influenced by the community, family, classroom and individual. The scoping narrative literature review is broadly structured in line with Bronfenbrenner's ecological approach which also structures the work of educational psychologists (Bronfenbrenner, 1977; Woolfson, 2017). Finally, the literature on those issues at the level of the individual child that are genetic and neurological in nature is explored.

Chapter 3 briefly sets out the overall epistemological approach adopted throughout the research which is one of critical realism (Bergin et al., 2008). While the general approach is quantitative, it is neither empiricist nor purely socially constructivist. Critical realism accepts the basic premise of constructivism, that much of reality is socially constructed, however, critical realism also accepts that social constructs have a basis in reality and tries to avoid underplaying material realities such as the biological and neurological basis of learning, for example, while not succumbing to biological determinism (Mirzaei Rafe, 2021; Smith, 1998).

Chapter 4 sets out Study 1 which is an analysis of secondary data from a cohort of 1,085 children age 11-12 to characterise the extent to which the data support the view that there is a connection between relative deprivation and outcomes. The data are standardised assessment results for Reading, Mental Arithmetic, General Mathematics and Developed Ability and were available from the local authority which carried out the assessment routinely from 2011-2017. The 2017 cohort was used as the cohort for analysis and regression analyses were carried out to determine the relationship between free meal entitlement and attainment. As expected, the results suggest a connection between outcomes and relative deprivation using free meal entitlement as a proxy for relative deprivation.

Chapter 5 sets out Study 2 which is a validation of the Perceptions of Mathematics survey and the application of the study to two small groups of teachers. The dimensionality of the POM survey, originally published in Canada (Holm & Kajander, 2012, 2020; Kajander & Mason, 2007), had not been explored previously. In Study 2, Principal Components Analysis was used to explore the factor structure of the POM and found a two factor structure which was consistent with a conceptual component and a procedural component. The POM was then used with two small groups of teachers to explore the possibility of different preferences when teaching procedural and conceptual maths to children from more and less deprived backgrounds. The results had limited generalisability due to sample size but suggested a very small effect for conceptual maths preference but no effect for procedural.

Chapter 6 sets out Study 3 which is a peer assisted games based learning intervention involving two schools and three classes which were two intervention groups and a control group. Over a 6 week period, the two intervention classes adopted a reciprocal peer-assisted learning approach and used commercial off the shelf games three times a week for 20 minutes each session. A baseline assessment was taken at T1 using the Maths Attitude and Anxiety Questionnaire (MAAQ) and the Myself As a Learner Scale (MALS) with a follow up questionnaire for the two intervention classes and the control class at T2. Analysis of the MAAQ and MALS results suggested a small positive effect on the MAAQ between groups at T1 and T2 but no effect for the MALS.

Chapter 7 builds on Study 3 and explores the qualitative feedback from children who took part in the peer-assisted games-based leaning intervention. At the end of each session, children were asked to note which game they had played and comment very briefly on how they felt about the session. In addition, on a weekly basis they were asked to note what they had learned that week. Although Study 3 showed a positive effect on the MAAQ, the expectation was that thematic analysis of the responses from children would shed light on why there was an effect, allowing the themes to emerge from what the children said (Braun & Clarke, 2006). The overwhelming view of children was that the games were fun and they enjoyed games as a context for learning. Children commented on specific areas of progress in maths such as problem solving, adding, subtracting, multiplication and division, but they also commented on issues of self-regulation. Self-regulation related to their experience of competition, winning and losing.

Chapter 8 concludes the thesis with the overall discussion and conclusion. Tackling the poverty related outcomes gaps in education is not unidimensional, nor is it simply about 'catching up'. It is the role of psychology in general and educational psychologists in particular to translate research for policy makers and for practitioners. It is also the role of psychology to challenge over-claiming or the use of research that is not warranted. Studies 1 to 4 set out the evidence on the extent of the outcomes gap at P7 and the connection to mathematics and then explore the potential contribution teachers make through their values and attitudes, then finally use a tried and trusted, but often overlooked, intervention to address children's beliefs and attitudes about themselves and about maths with a view to improving their attainment. The evidence suggested an improvement in attitude to maths and a reduction in maths anxiety, as measured by the MAAQ, following the games-based peer-assisted learning intervention. Future research may therefore focus on the extent to which this gain can be translated into an improvement in attainment.

Chapter 1: Rationale for focusing on relative deprivation and poorer outcomes in mathematics

1.1 Why educational attainment matters

Success in formal education as measured by educational attainment is closely related to more positive life-course outcomes such as employment and income opportunities (Eurostat, 2021). The European statistics agency indicate that across EU countries, around 60% of 20-54 year olds with low educational levels were in employment compared to around 86% with high educational levels, and around 44% of 55-64 year olds with low education levels were in employment compared to around 76% who had a high level of education. Educational success is generally held to lead to greater earning capacity and therefore the likelihood of greater financial resources which in turn is likely to improve social mobility (Woessmann, 2016). At the start however, it is worth noting the distinction between human capital and knowledge capital (Komatsu & Rappleye, 2017). Human capital theorists include education or cognitive skills as one factor among several which contribute to poorer life outcomes whereas knowledge capital theorists tend to focus exclusively on cognitive or educational factors, included amongst whom is Woessmann. Favaro and Sciulli (2022) reinforce the view that a human capital theory approach makes more sense in their analysis of cognitive and non-cognitive abilities interacting to influence employment and income prospects for women in youth and in adulthood. Education level and other poverty related indicators not only influence economic potential, but also health related issues (Gil-Lacruz et al., 2020; Ohlsson et al., 2021; Sperandei et al., 2021). Ohlsson et al. (2021) found elevated mortality levels due to heart failure for those with low educational level and non-employed among a sample of 3,874 patients in Sweden. Gil-Lacruz et al. (2020) found that health related quality of life was influenced by educational level in a sample of 244 students in Zaragoza, Spain, with lower educational level correlating to lower health quality of life. Correlation however does not mean there is always a causal link. With this caveat in mind, similar results were found in relation to mental health, where low education level and poor mental health correlate among older adults in a cohort study of over 260,000 over 45 year olds in New South Wales (Sperandei et al., 2021). The human capital theorists, as suggested by Komatsu and Rappley (2017), usefully make the connection between cognitive or educational level and wider issues associated with poverty. Indeed, success in formal education is influenced by relative poverty and relative wealth which means that not all children start their education with the same opportunities to succeed (OECD, 2019; Sosu, 2018). The connection between poverty and poorer educational outcomes is well established across most education systems to varying degrees (DeFlorio & Beliakoff, 2015; OECD 2007, 2016). Children from relatively poorer backgrounds enter school already behind their more affluent peers (Banerjee, 2016) and the gaps in their attainment are enduring or grow over time (Langenkamp & Carbonaro, 2018). Specifically in a Scottish context, the OECD stated as far back as 2007 that 'who you are in Scotland is far more important than what school you attend' (OECD, 2007, p.18) and one of the principal determinants of who you are is socioeconomic status (SES). In this sentence the OECD sums up the challenge facing education systems across the globe, which is to ensure the education system is strong enough to mitigate the impact of deprivation. If the education system is not strong enough to overcome the disadvantages caused by poverty, learners from poorer backgrounds are more likely to remain poor with all of the attendant negative outcomes associated with poverty. A review of data from the European Union suggested lower educational levels of achievement are linked to precarious employment and social vulnerability (Papadakis et al., 2022). At present, contextual indicators are still significant determinants of educational outcomes (Banerjee, 2016) and in order to reduce their influence and allow all learners to achieve at a higher level, it is important to understand more deeply and in detail the connection between relative deprivation and educational outcomes. Education is more than attainment and carries out multiple functions including the social development of children and young people (Biesta, 2015). However, attainment data offer one way of measuring and quantifying the connection between educational outcomes and the lifelong benefits accruing from educational success as measured by attainment.

1.2 Measuring the progress of learners

At the international level, a range of educational attainment measures is used to make comparisons between countries and also to measure how well groups with different characteristics are progressing. One of the main international measures is the

OECD's Programme for International Student Assessment (PISA) [1]. International measures focus principally on progress in literacy and numeracy with some also focusing on knowledge of science. The International Association for the Evaluation of Educational Achievement (IEA) carries out major studies such as the Trends In Maths and Science Study (TIMSS) [2] every four years and the Progress in International Reading Literacy Study (PIRLS)[3] every five years. The OECD has carried out the Programme for International Student Achievement every two years since the year 2000 involving an assessment of 15 year olds' knowledge in mathematics, literacy and science. The measures are a useful benchmark and allow for international comparison of disadvantaged groups and the gap between them and their less disadvantaged peers.

However, these international measures are not without their critics. Mowat (2020) refers to the OECD, World Bank and McKinsey as 'international influencers' with a neoliberal agenda whose measures are performative and at the service of the economy. Indeed, focusing on attainment measures alone risks reducing education to a narrow group of measures rather than focusing on a wider set of outcomes. In the Scottish education system, for example, outcomes include not only successful learners but confident individuals, responsible citizens and effective contributors (Scottish Government, 2008). Even so, the main benefit of international measures is the ability to make comparisons between education systems and the progress they are making in ensuring that all children are able to benefit fully from education, regardless of their socioeconomic status.

In addition to international measures of how well learners are progressing, at a national level annual examination results are used by the education systems across the United Kingdom to measure progress. The annual examination results are used to make year on year comparisons on how well young people are achieving, normally at age 16 to 18, and whether or not the results are improving year on year (Hamilton & Brown, 2005). In Scotland, data published by the Scottish Qualifications Authority, which is the main examination body, indicate a relatively

---

[1] https://www.oecd.org/pisa/aboutpisa/
[2] https://nces.ed.gov/timss/
[3] https://www.iea.nl/studies/iea/pirls/2021

stable gap between the most deprived and least deprived young people at age 16, 17 and 18 who are presented for examinations. Using the Scottish Index of Multiple Deprivation (SIMD) quintiles as an indicator of relative deprivation (Scottish Government, 2020), the gap between Quintile 1, most deprived and Quintile 5, least deprived is consistently between 8 and 9 percentage points between 2018 and 2022. Then at Higher, the exam taken at age 17, the gap increases to between 15 and 16 percentage points over the same time period and reaches a gap of around 30 percentage points at Advanced Higher, the exam taken at age 18. Overall actual pass rates at A to C for National 5, Higher and Advanced Higher show a gap of around 13 to 15 percentage points between Quintile 1 and Quintile 5.

At the stages prior to external examinations, a variety of measures is used to determine how well learners are achieving and progressing. Across the United Kingdom there are a few common features at ages 5 to 15 but limited consistency. In England, Wales and Northern Ireland formal assessment takes place in literacy and numeracy at Key Stages across the age range from 5 to 15 with data publicly available (Standards and Testing Agency, 2016). Scotland has avoided formal assessments at key stages and prefers to rely on teacher professional judgment with the national results published annually in line with the five levels of Curriculum for Excellence (Scottish Government, 2022). In addition to teacher professional judgement, until recently Scottish Government carried out the Scottish Survey of Literacy and Numeracy (SSLN) (Scottish Government, 2016). On alternate years a sample of children and young people across Scotland was assessed, one year in literacy the alternate year in mathematics. However, the Scottish Government stopped the SSLN and introduced the Scottish National Standardised Assessments in literacy and numeracy as a diagnostic tool for teachers but no data are publicly available (Scottish Government, 2022d). The SNSAs are used at Primary 1, Primary 4, Primary 7 and Secondary 3 in line with the four levels of progress through Curriculum for Excellence. Prior to the introduction of SNSAs, teacher professional judgement was not consistently valued (Biesta, 2015) resulting in many local authorities in Scotland using commercially available standardised assessments.

In Curriculum for Excellence measures, economic disadvantage impacts negatively upon children's progress (Scottish Government, 2022a). The fourth United Nations sustainable development goal aims for 'Inclusive and equitable quality education and promote lifelong learning for all' (United Nations, 2015). In order to achieve this goal for all learners, rather than those with the economic means to benefit from the education system, it is essential to have a good understanding of the causes of underachievement (OECD, 2007). Specifically, it is important to understand in some detail the mechanisms between relative deprivation and underachievement in key areas such as literacy and numeracy which have a significant impact on adult socioeconomic status (Ritchie & Bates, 2013).

1.3 Educational progress as measured by attainment and deprivation

Educational progress cannot be reduced to attainment alone. Education involves inputs; participation and progress; outputs; outcomes; and impact (OECD, 2020). Inputs include financial, human and physical resources as well as education policy and legislation. For the learners, education includes participation and progress which come from engaging in the education system and its institutions, central to which are schools and classrooms. One of the key outputs from the education system is attainment which is normally measured using the results of assessments or examinations, central to which are measures associated with literacy and numeracy. Over time the outcome of education is employment and the impact can be measured in quality of life and earnings. Clearly therefore, attainment is not the entirety of the education process, nor can education be reduced solely to examination or assessment results. However, relative performance in attainment can indicate how well different individuals and groups perform and how well the system is performing for them.

In 2016, UNICEF's league table of inequalities found that 'in every single country under review, the likelihood that the least privileged students fall into the bottom achievement group is higher than for the most privileged students' (UNICEF, 2016, p36). On average, the poorest were 18 percentage points more likely to fall into the lowest achievement group with the four best performing countries reducing the likelihood to 10 percentage points. The gap between the best performing countries and all others shows that is possible to reduce the impact of social background in the education system.

1.4 Definition of relative poverty

In order to understand and explore the impact of poverty, it is important first to define what is understood in the context of this study by relative poverty. Defining poverty is necessary in order to make comparisons over time and also comparisons between establishments and education systems. However, before proceeding to defining what is meant by poverty in the current studies it is worth exploring briefly the overall concept of poverty.

Although Pierre Bourdieu did not write extensively about education, his concepts or tools have been used extensively in the context of education (Rawolle & Lingard, 2008). Bourdieu's conceptual tools include Practices which are every day customs; Habitus which are described as 'bodily incorporations of social history' (Rawolle & Lingard, 2008, p. 731); and Social Fields which are the environments in which habitus is expressed, for example gender is an overarching social field. In the context of exploring the influence of poverty in education, using Bourdieu's thinking tools, Rawolle and Lingard (2008) argue that the global education field is influenced by bodies such as the OECD which are part of the neo-liberal economy and lead to what they call policy by numbers. Statistics become one of the central technologies of governance resulting in a move away from the school field to an accountability model and a culture of performativity where an indicator of quality becomes the definition of quality (Biesta, 2015). In a culture of performativity and strict accountability, poorer children risk being marginalised in the pursuit of better statistics in exam results. In short, Bourdieu's tools suggest that education may amplify the effects of poverty.

Another concept commonly used by Bourdieu is social capital which, like actual capital, can be used, exchanged, drawn upon and invested (McGonigal et al., 2007; Mikus et al., 2020). Social capital in a school context becomes a form of power which more affluent groups can use to ensure they retain a degree of social dominance and ensure the education system advantages them and their children. According to Mikus et al. (2020), marginalised groups who do not have the social capital to navigate the education system are seen to be at a disadvantage since schools are middle-class institutions which discriminate against working-class children and replicate inequalities. The research of Mikus et al. (2020) suggested that student characteristics influence teachers' professional judgements which in turn lead to children with already greater social capital achieving more highly. As a result, Mikus et al. (2020) emphasise the importance of weakening the connection between teacher beliefs and attitudes and children's outcomes. They suggest that unless the issue of teacher subjectivity is addressed, poorer children remain at a double disadvantage since they arrive at school with less social capital and are then disadvantaged by teachers' subjective views of them (Mikus et al., 2020; Simmons et al., 2020).

Definitions of poverty themselves are value laden and seen through different lenses or disciplines including economic, sociological, psychological and developmental (Reeves et al., 2020). Generally in the current studies, poverty is considered through an economic lens since it is defined in a school context using locality indicators such as SIMD or income level indicators which trigger entitlement to specific benefits such as free school meals or footwear and clothing grants. However, Reeves et al. (2020) distinguish between a definitional approach to poverty which is taken by those who study it and an outcome based approach which focuses on those who experience poverty. For those who experience poverty, it is argued that there are structural factors which result in them lacking access to resources and the ability to engage in broader society (Reeves et al., 2020; Seale, 2020). However, Seale (2020) emphasises the importance of not pathologizing, stigmatising or misrepresenting people experiencing poverty by referring to a culture of poverty. Returning to Bourdieu, social capital serves to legitimate poverty and structures such as race and gender perpetuate poverty (Brady, 2019).

In the discipline of economics, there are echoes of sociology with Barrett and Carter (2013) describing the Multiple Financial Markets Failure poverty trap (MFMF). Within MFMF, Barrett and Carter (2013) describe the Micawber Threshold (MT) above which an individual is likely to have the means to withstand an economic shock but below the MT they are likely to be pushed into an enduring poverty trap.

To those just above the MT and at risk, an economic shock such as the global pandemic or geopolitical shocks leading to a sharp increase in energy costs can result in them slipping into poverty which may endure. The difference between those who fall below the MT and remain there are the skills and abilities they possess which mean that over time they may return to above the MT. Higher technical skills for example and a higher level of education are more likely to result in those temporarily slipping below the MT returning over time to a higher asset position above the MT. The advantage of the MT as a construct is that it is dynamic rather than a static economic metric and focuses on behaviours which are more likely to result in economic improvement over time for individuals rather than remaining in poverty (Carter & Barrett, 2006). Investing in skills and education therefore could be the difference between those structurally poor and those who are not.

In practical terms, the current study focuses on relative poverty as opposed to absolute poverty with poverty considered largely an economic measure. Absolute poverty is normally linked to having sufficient financial resources to purchase the absolute basics needed in order to survive (Decerf & Ferrando, 2022). Relative poverty is more frequently used in higher income countries and is normally defined as a percentage of the median income for the country. Relative poverty therefore can vary depending on the wealth of the country. UNICEF and the OECD have used a proxy measure for relative deprivation in their surveys which relates to self-report on the number of books in the household. In a digital age this may be difficult to sustain as a proxy measure for relative deprivation. In the Scottish context, a simpler measure is that the household has less than 60% of the median wage of the country (Scottish Government, 2022e).

Entitlement to free school meals has been used as a proxy measure for relative poverty in Scottish schools with Scottish Government, for example, distributing Pupil Equity Funding (PEF) to schools on the basis of a set amount for each child registered for free school meals. PEF is part of the Scottish Attainment Challenge funding and targets additional resources to schools where there are young people attending who are registered for free school meals (Scottish Government, 2022c).

The entitlement criteria for free school meals in 2020 included trigger state benefits which are indicative of relative poverty.

Entitlement to free school meals however is not an uncontested indictor of poverty since a family may only recently have met the criteria for free school meals, whereas another family may have experienced generations of entitlement due to poverty (Gorard et al., 2019). In Scottish local authorities, data are only collected on entitlement or not to free school meals, and so free meal entitlement is considered a binary category and one measure of relative deprivation.

Another measure commonly used to distribute and target resources is the Scottish Index of Multiple Deprivation (SIMD) (Scottish Government, 2020). SIMD however is a geographical measure of relative deprivation based on dividing the country into small data zones and ranking them based on multiple measures of deprivation. Although useful as a broad measure of relative deprivation in an area, the weakness with SIMD is that not all households living within a data zone will experience deprivation. In particular where new housing has been developed or in highly rural areas, SIMD does not fully capture relative deprivation. In the context of widening access to Higher Education, Paterson et al. (2019) capture the essence of the difficulty with SIMD, which is that it misses too much in the way of individual-level characteristics by being area based. When considering relative deprivation at the level of the individual child or family, entitlement to free school meals currently offers a more reliable proxy indicator, capturing individual family level characteristics.

1.5 The Scottish policy context and the role of educational psychology in raising attainment for all

1.5.1 Scottish policy context

The OECD report on the Scottish Education system in 2007 set out clearly that there was a significant gap in outcomes for children from more deprived backgrounds compared to their less deprived peers (OECD, 2007). It was only more recently, from 2014, that Scottish Government made it their ‘defining mission’ to close what they described as ‘the poverty related attainment gap’. The First Minister of Scotland set out her government’s education mission at a keynote speech in Wester

Hailes High School in Edinburgh (McNab, 2015). The Scottish Attainment Challenge is the overarching policy response by the Scottish Government to poverty related attainment gaps, and over the period of the Scottish Parliament 2015-2021, Scottish Government committed £750 million in additional resources to education to address the problem (SPICE, 2016).

Through Scottish Attainment Challenge funding, nine local authorities with the highest levels of child poverty were identified for additional funding while every primary school in Scotland with more than 70% of children registered for free school meals received additional funding. In addition to the local authority and schools programme, each school received a direct award of a fixed amount per pupil registered for free school meals and further funding for children and young people who were care experienced. New legislation in the Education (Scotland) Act 2016 required local authorities to publish an annual plan indicating how they would tackle the poverty related attainment gaps and also report annually on progress. It is in this context that the current study takes place, focusing on primary schools in one local authority.

1.5.2 The role of educational psychology

The role of educational psychology is relevant because educational psychologists work across the local authority education system. Educational psychology focuses on identifying and removing barriers to learning wherever they occur in the entire system that surrounds a learner – at the level of the child, family, neighbourhood, school or education system (MacKay, 2018, p. 725). Poverty impacts at all of these levels and the educational psychologist 'is the collaborative professional working in consultation with schools and organisations at system level' (Bryce et al., 2018, p. 725; MacKay, 2018). The educational psychologist adopts a systemic and collaborative approach to analysing the problem or problems with a view to bringing about better outcomes for learners (Kelly et al., 2017). The importance of educational psychologists in addressing the impact of poverty on attainment therefore is principally their role across the system around the child because poverty impacts on almost all aspects of the child's life.

More generally however, one of the key roles of educational psychologists is research (Scottish Executive, 2002). A research orientation within educational psychology is likely to be valuable to practitioners, service users and policy makers regardless of whether the method is qualitative, quantitative or mixed (MacKay et al., 2016).

Greene (2022) suggests that the replication crisis in psychology as well as system inequalities demand reform which in turn demands greater methodological rigour. Greene (2022) further indicates that educational psychology ought to be working towards parsimony in the theories used by reviewing existing and effective theories rather than constantly seeking novelty. Part of Greene's solution lies in making clearer connections between theory and the empirical work published in peer reviewed journals. The following literature review aims to root the later studies reported below in the existing research on the connection between deprivation and outcomes for learners. The subsequent studies are not intended to be replications but are close to conceptual replications in field conditions (Plucker & Makel, 2021). The review of the literature explores empirical evidence on what already has an existing evidence base and an indication of potential effectiveness and aims to seek parsimony over novelty.

Chapter 2: Scoping review of the literature on the impact of relative poverty on children's and young people's attainment

A scoping review of literature relating to the impact of deprivation on attainment, particularly attainment in mathematics, was carried out. The advantage of a more systematic review of the literature over a traditional narrative literature review is that it reduces the likelihood of bias and increases transparency (Boyle et al., 2016). The current scoping review does not fully meet the criteria for a systematic review which would require inclusion and exclusion criteria; date ranges for inclusion of all studies along with a rationale for dates selected. Nevertheless, the aim of the current review is to provide a synthesis of the current research to establish the extent of the relationship between variables – in this case socioeconomic status and educational outcomes, particularly in maths (Dunst & Trivette, 2012). In addition, sufficient detail on the searches carried out is provided to allow replication of the searches and identify potential bias.

Searches were carried out for peer reviewed journal articles to ensure consistently high quality evidence. Books and book chapters were largely excluded for practical reasons as the library was closed for much of the period the literature review was taking place due to Covid restrictions. Searches were carried out in the British Education Index; APA Psych articles; Applied Social Sciences Index and Abstracts; and the University of Strathclyde SUPRIMO library catalogue. Initial search terms included educational attainment AND poverty; mathematics (math*) AND socioeconomic status / low income / disadvantage / disadvantaged; attainment gap; attainment; achievement; literacy or reading numeracy; brain AND math*. The search covered the period from 2011 to 2022 and useful references were also identified from the reference section of articles identified through the initial searches. As the thesis developed and the intervention became clearer, search terms were widened to include peer tutoring; mentoring; peer instruction; peer learning; gamification; games based learning; peer assisted learning in math*; paired learning; computer assisted learning; games and math*; educational psychology.

Underlying the current research is the role of educational psychologists who are well placed in the education system to work across the various aspects of a child's life likely to impact on their educational outcomes. Bronfenbrenner (1977) advocated the importance of analysis in terms of 'all possible subsystems (i.e. dyads, triads etc) and the potential second and higher order effects associated with them' (Bronfenbrenner, 1977, p.520). What has been described as Phase 1 of Bronfenbrenner's ecological approach focuses on the entire system in which a child develops (Rosa & Tudge, 2013). It is beyond the scope of the current project to explore all systems influencing children, including the microsystem (child's immediate environment); the mesosystem (interacting microsystems such as home, school, peer group); exosystem (major institutions); macrosystem (the blueprints of how a system works, cultural or subcultural patterns) (Bronfenbrenner, 1977). However, adopting a systemic approach, broadly in line with Bronfenbrenner's approach, to analyse the problem of underachievement which is linked to deprivation, is also consistent with current educational psychology practice. The Integrated Framework of Practice 'can be used to inform work at any ecological level within the class, school, family or wider community' (Woolfson, 2017, p. 161). Educational psychologists do not work in isolation but work with a variety of professionals such as class teachers and take account of the child's perspectives and wishes. The Integrated Framework of Practice has the advantage of taking account of the various systems in which children operate while also including and involving children as participants and wider professionals as partners. In the words of Woolfson (2017), the model

> *enables problem analyses and intervention solutions to be identified at the levels of child, class, school, family and community in order to help EPs take account in assessment and intervention phases of the different micro- and meso-systems that may influence the presenting problem* (Woolfson (2017), p.153).

The literature review therefore will be structured around the main systems within which the child or young person operates, that is the community; home and parents / carers; school, classroom and teacher; and finally influences at the level of the individual child, or young person. The approach is broadly consistent with a critical realist approach since social constructivist approaches, at times, underplay the importance of biological determinants of behaviour (Bergin et al., 2008; Mirzaei Rafe, 2021; Mirzaei Rafe et al., 2019). At the level of the child there will also be reference to potential genetic determinants of educational outcomes.

2.1 The influence of the community[4]

Research consistently identifies a connection between poverty and poorer educational outcomes with the work of Chmielewski (2019) showing a gap in educational outcomes attributable to socioeconomic status over a 50 year period based on 30 large scale international studies of reading, maths and science. Similar results have been identified in England and the United States based upon longitudinal cohort studies of children's progress through school (Gorard, 2016; Gorard & Siddiqui, 2019; Hentges et al., 2019). Table 1 summarises the main findings of the studies mentioned.

Table 1

Longitudinal studies on the connection between SES and educational outcomes

Authors	**Sample**	**Age**	**Country**	**Measures / effect size**
(Hentges et al., 2019)	1,536	10, 12 and 14	United States	Correlation between maths grades and economic disadvantage = -.29 (p<.001)
(Gorard, 2016)	Census of all mainstream school pupils 1989-2014	5-16	England	Level of segregation correlation with Free School meals (ever) = -0.96

[4] The term parents is used throughout to refer to all those who have the primary caring role for children and is not limited to biological parents.

(Chmielewski, 2019)	5.8 million students in 30 large scale international studies of reading, maths and science		International	Gaps based on parent education increased by 50% over the 50 year period; parent occupation education outcome gaps grew by 55%; gaps based on household books increased by 40%
(Gorard & Siddiqui, 2019)	550,000	5-16	England	SES status age 5 correlates with outcomes age 16, R=0.90. FSMe & outcomes ES = -0.68.

Despite the consistent finding of a connection between educational outcomes and SES, it is important to guard against what Meaney (2014) refers to as homogenising children living in poverty. Homogenisation refers to first labelling children living in relative poverty as abnormal and then working to change them somehow into 'normal' children. The risk in so doing is missing what strengths children bring with them and instead focusing on their deficits. Nevertheless, in order to mitigate the gap in attainment, it is necessary to understand it. The first step towards understanding it is broadly describing its impact and the possible reasons behind the difference in progress and attainment between relatively more deprived children and their better off peers.

The place where children live and grow up can have an effect on their educational outcomes beyond what might be related to their immediate family's economic circumstances (Wolf et al., 2017). Wolf et al. (2017) found that the concentration of high poverty households in an area leads to issues linked to safety and quality of space; fewer options for high quality childcare; toxins, noise pollution and other environmental stressors such as potential violence can all have a negative impact on a child's readiness to learn by the time they start school. The research by Wolf et al. (2017) carried out in the USA identifies a negative impact on reading and maths which they associate with the neighbourhood and interestingly, the impact is greater on maths.

A similar study set in Turkey however did not find a significant link between community level poverty and school participation (Gumus, 2014). The Turkish research found that there was a clear link between family level poverty and level of adult education in the household but no clear link with neighbourhood poverty levels in addition to family level. In the case of Turkey as opposed to the US, it may be hypothesised that the toxic influences associated with neighbourhood poverty which are likely to have an additional impact beyond family level poverty are not as consistently prevalent. What matters from the comparison of the Turkish and US study is that poverty of itself is not the key factor, but the issues associated with poor neighbourhoods such as those identified in Wolf et al. (2017).

Pearman (2019) found that living in a high poverty neighbourhood leads to the equivalent of losing three quarters of a year's learning over a five year period. The findings of Pearman (2019) echo those of Wolf et al. (2017) in that they identify downward pressures on attainment due to fewer opportunities for children; lower quality schools and healthcare and increased stress as a result of the place where they live. Pearman (2019) concludes that even after controlling for other key variables, neighbourhood poverty of itself is an additional negative influence on educational attainment which he quantifies as 1 standard deviation increase in neighbourhood poverty resulting in -0.18 of a standard deviation in maths attainment. Children from higher deprivation neighbourhoods would require an additional six weeks of mathematics learning to keep up with their better off peers. It is not simply that living in an area with greater density of poverty limits the acquisition of skills, it also appears that children from poorer communities have lower ability to apply the limited skills they have in the school context (Casey et al., 2011).

2.2 Family influences

Children are part of a community or neighbourhood, but they spend most of their time with their immediate family. The influence of parents and the wider family context is significant, especially in the pre-school years. Several studies have found that poorer children are already behind their better off peers by age 3, the point where in the United Kingdom most will start attending a formal pre-school setting (Banerjee, 2016; Deflorio & Beliakoff, 2015; Duncan et al., 2007; Romano et al., 2010). Parents are in effect the first teachers of their children and are likely to pass on their beliefs about learning, especially in relation to literacy and numeracy (OECD, 2016). Duncan et al. (2007) carried out analysis of 6 longitudinal data sets from the United Kingdom, USA and Canada to determine which pre-school readiness indicators were predictive of future success in learning at age 7 and 11. They found that early mathematical skills were the most powerful predictors of later academic achievement, indeed more accurately predicting future reading ability than early reading skills. The study by Duncan et al. (2007) was replicated soon after on a Canadian national survey and the findings remained the same, that early mathematical skills were overall most predictive of later academic success (Romano et al., 2010).

The link between early maths skills and later academic success should not be surprising in view of research in the area of executive function (EF). EF broadly includes working memory, inhibitory control and attention switching (Harvey & Miller, 2017). Brain systems that take longer to develop after birth, such as the prefrontal executive system, may be susceptible to the impact of limited resources in a more deprived family environment when compared to the earlier developing brain systems such as the occipito-temporal and parietal (Nesbitt et al., 2013). In addition, Nesbitt et al. (2013) suggest that stressors in the first three years of life which are associated with deprivation and race, particularly among African-Americans, are also associated with lower EF in children. Their research involved a longitudinal study of 206 children to explore the influence of executive function and their conclusions are similar to research with larger groups indicating that EF age 5 strongly predicts academic success age 12 (Ribner et al., 2017).

Ribner et al. (2017) found in a study involving 1,292 children, that while both early and later maths vary as a function of EF, those with higher EF can catch up to peers who performed better in early maths assessments. In effect, higher EF can compensate for limited maths knowledge prior to school entry. Related to the issue of limited resources in the family environment is research suggesting a connection between motor competence and EF as well as fine motor skills and EF (Pitchford et al., 2016; Willoughby et al., 2021). Willoughby et al. (2021) found that improvements in motor competence were associated with improved EF and maths problem solving. They suggest that early movement challenges and the resolution of the challenges contribute to the emergence of cerebellar-cortical networks that support EF development. Pitchford et al. (2016) similarly linked motor and cognitive development in a study of 60 children aged 5-6. They concluded that a focus on visuo-spatial skills requiring fine motor integration was likely to lead to improved EF and contributed unique variance to early maths but not to early reading. In summary, EF appears to contribute unique variance to later maths development but itself can be impacted negatively by SES through available resources and environmental and family stress.

The evidence that children from poorer households enter school behind their peers is strong, however, the explanations for the gap are more varied. Evidence on the root causes of the gap include parental beliefs about mathematics and social acceptance of a negative view of mathematics (Deflorio & Beliakoff, 2015; Goforth et al., 2014); fewer play opportunities leading to less understanding of patterns, shapes, spatial relationships, magnitude and counting (OECD, 2016); low academic level of parents and lack of stimulating interaction with adults (Banerjee, 2016; Burnett & Farkas, 2009).

Related to parental attitudes are parental optimism and subjective social mobility (Zhang et al., 2020). Zhang et al. (2020) based their findings on a study of 815 Chinese 9-12 year olds and found that where parents are optimistic about their child's chances to improve they are more likely to have an internal locus of control and teach their child that they can progress through diligence and persistence. Overall however, Häfner et al. (2017) report that families from a lower socioeconomic background show lower levels of motivation and achievement. Of greater interest however is the fact that based upon an intervention with 1,916 students they were able to demonstrate a long term effect based upon a motivational intervention to improve attitude to maths to the extent that they found no SES differential effect 5 months after the intervention. Häfner et al.'s 2017 study is a timely reminder that the impact of SES is not immutable.

None of the factors that influence a child's educational outcomes sits in isolation from other factors. When overall levels of poverty in a country increase, as measured by GDP, the gap between better off and poorer children tends to increase (Nonoyama-Tarumi et al., 2015). The increased gap appears to be related to the better off families in poorer countries still having lower overall educational outcomes compared to richer countries where parents are able to use their cultural capital to benefit their children by, for example, reading to them (Mikus et al., 2020). Analysis of maths attainment in Iran using Trends in International Mathematics and Science Study (TIMSS) (IEA, 2023) data from 1999 found that background factors including home background and educational aids at home were influential but factors at the level of the individual learner played a greater role - 19.9% of the variance compared to 6% (Kiamanesh & Ali Reza, 2005). However, before considering factors at the level of the individual learner, the next significant influence after the community and home is the school itself.

2.3 The influence of the school

In this section it is important to distinguish between the school as a whole and the way the school is structured, which means the approach adopted by the school to groupings in which children are taught and the criteria by which they make progress. Traditionally children are taught with their same age peers for example and progress chronologically each year. However, the way the school is structured may also include approaches to tracking, also known as selection or setting by ability. Children may only progress for example once they have reached a required level of achievement. In the Scottish context, selection by ability for admission to a school no longer happens in local authority operated schools, however, setting by ability within schools is still relatively common (Muijs & Dunne, 2010). Early tracking, whereby children are streamed according to their ability into different classes or different schools, leads to poorer outcomes for more deprived learners with 54% of the variability in maths outcomes due to early sorting by 'ability' (Francis et al., 2020; OECD, 2016). Early grouping of children by ability is likely to lead to relatively disadvantaged children being over-represented in lower ability groups. As highlighted by Muijs and Dunne (2010) using logistic regression, social background was found to be a significant predictor of probability of which ability set a young person was allocated to. Once in the lower ability school, group or class, approaches to learning and teaching and the way classes and schools are organised begin to become important. The OECD analysis of PISA results (OECD, 2016) found that learners in lower ability groups are exposed to less pure mathematics and more procedural mathematics which in turn has a negative impact on their longer-term attainment. As has been identified earlier, children from poorer backgrounds start school at a disadvantage which is then locked in the earlier they are tracked into lower ability groups. The issue highlighted here is that it is not so much the school itself that is influential, but the extent to which learners are tracked or selected by ability.

Considering the school itself, Brow (2018) examined predictors of literacy and mathematics attainment and found that schools account for 19% of maths variance in Canada and 25% in the USA. Baird (2012) found that schools serving better off children had better classroom and school resources while the OECD (2016) highlight higher quality learning opportunities, both formal and informal, available to better off learners. In addition they point to parents who are better able to navigate the system to their children's advantage. Gorard and Siddiqui (2019) reinforce this when they state that 'schools are largely defined by who attends them. Once that is accounted for, there is no great difference between the outcomes of any of them' (Gorard & Siddiqui, 2019, p. 12).

The fundamental question Gorard and Siddiqui (2019) are addressing is specific to the English context where there are multiple types of schools including Academies, Free schools, Studios and University Technical Colleges as well as local authority run schools and private schools (Gorard et al., 2019). Their argument is that once they have controlled for entry level skills and abilities, the differences in performance between types of schools is much less than may appear to be the case. Although they find a small, negative school composition effect, they argue this could be addressed by a greater mixture of intake. The composition effect they found was that where there is a higher proportion of less deprived students, this had a slightly positive effect on all other students. So, their argument is that if schools were more comprehensive in their makeup, there would be less variability in outcomes for children which is consistent with the OECD view that early tracking further disadvantages poorer children. Gorard and Siddiqui (2019) are not arguing that attainment is not influenced by poverty, rather that the solution is not immediately in the type of school, as there are limited differences in outcomes once they have controlled for entry level ability.

Similarly, Dicke et al. (2018) found that attending a high achieving school had no peer spill over effect and may have had a slight negative impact on self-concept. Their findings support Gorrard and Siddiqui's view that once you control for other variables, making schools selective is unlikely to lead to closing the poverty related attainment gaps. If the school itself does not make a decisive difference then approaches to learning and teaching are worth exploring as alluded to earlier when referencing the OECD view that more deprived learners are exposed to less pure mathematics which ultimately has a negative impact on their attainment.

It is important to state that Gorard and Sidiqui's argument is not that there is no effect from schools, but that the type of school is not the determining factor. Reynolds et al. (2014) set out a brief history of school effectiveness literature which they state started in reaction to the view that schools make little difference. In a review of school effectiveness research from the 1970s up to 2014 Reynolds et al. (2014) indicate that, in summary, schools have a greater impact on individual young people's outcomes where the school is high achieving; has a higher number of girls; and has a high proportion of higher socioeconomic status young people. However, they also state that school effects vary and are greater for largely school based subjects such as maths and science compared to reading.

2.4 Teacher and classroom level variables

If the view articulated most clearly by Gorard et al. (2019) is broadly accepted, that the 'type' of school itself may make limited difference, yet the outcomes are variable within and between schools, then analysis at the classroom level is worthy of investigation. One of the criticisms of earlier school effectiveness studies, according to Reynolds et al. (2014), is that they tended to focus on the school and ignore important variables such as the classroom, the teacher and indeed the local authority.

The component most schools are divided into is classes and at primary school level, children spend most of their time with an individual class teacher. The question therefore is to what extent do individual teachers make a positive difference to children from poorer backgrounds? In their landmark paper, Baumert et al. (2010) indicated that the impact of teacher quality in the first three years of schooling is greater for lower socioeconomic status children than it is for their higher socioeconomic status peers. They speculate that this is due to what they call the 'creaming effect' whereby more competent teachers are more likely to be in higher socioeconomic status schools. Their research focused on the teaching of maths and the extent to which three key teacher level variables influence the quality of mathematical learning for children. The three variables are mathematical content knowledge (CK); pedagogical content knowledge (PCK); and generic pedagogical knowledge (GPK). They found that deep content knowledge is necessary but not sufficient for good mathematical learning by children. Good pedagogical content knowledge is also necessary and they define it as:

> *The choice of representations, explanations, the facilitation of productive classroom discourse, the interpretation of student responses, the checking of student understanding and the swift and correct analysis of student errors and difficulties.* (Baumert et al, 2010, p.139)

The same researchers also identified three key classroom variables associated with good PCK. These are cognitively challenging and well-structured learning opportunities; learning support through monitoring of the learning process and feedback at individual level and adaptive instruction; and efficient classroom and time management. The central and important finding in their research is that content knowledge and pedagogical content knowledge make a unique contribution to learner outcomes, meaning teachers not only need a deep knowledge of mathematics in order to ensure better outcomes for their learners, they also need a deep pedagogical content knowledge specific to mathematics. The question then becomes about the extent to which the quality of teaching and learning differ for children who are relatively more deprived or who attend schools with a higher number of deprived children.

As noted, the OECD (2016) identified one of the main differences between lower SES learners and higher SES learners as differences in opportunities to learn and specifically exposure to conceptual maths learning as opposed to greater exposure to procedural maths learning. Conceptual knowledge can be defined as 'knowledge of concepts and relations which are fundamental in a certain domain' (Lenz et al., 2020, p. 811), while procedural knowledge is 'knowledge of operations in the sense of a sequence of steps, or partial actions which are performed to achieve a specific goal' (Lenz et al. 2020, p.811). Lenz et al. (2020) used confirmatory factor analysis on student level data to confirm empirically that conceptual and procedural knowledge of fractions are two separate constructs.

With regard to the central question of how conceptual and procedural teaching of maths relate to children from poorer backgrounds attaining less well in mathematics, the OECD identified six key areas in which lower SES learners were relatively weaker. The six are as follows:

1. Communication, central to which is reading
2. Mathematising – transforming problems into maths
3. Representations – graphs, tables, diagrams, equations, formulae
4. Reasoning and argument
5. Devising problem solving strategies
6. Using symbolic, formulae and technical language and operations.

The second and sixth are responsible for the largest variance in performance between lower SES learners and their higher SES peers and are the two areas which are more closely linked to conceptual learning of mathematics.

Yet this view on exposure to more conceptual mathematics is challenged by Covay-Minor (2015) who found that all students in their study received a similar mix of both conceptual and procedural instruction across all socio-economic groups. They found that procedural learning goals were used more often than conceptual learning goals, but similarly for all students regardless of socioeconomic status. The findings however are based on teacher self-report and may suffer from inherent flaws such as social desirability bias as self-report relating to values, such as treating students equally regardless of SES, is more likely to suffer from social desirability bias (Fisher & Katz, 2000).

The OECD finding that procedural approaches are favoured is consistent with the findings of Holm and Kajander (2019). Regardless of the approaches to learning and teaching, Covay-Minor (2015) found that poorer children generally had teachers with less teaching experience and who were less well qualified which is consistent with what Baumert et al. (2010) referred to as the ‘creaming effect’. What is clear however, is that teacher level practices and teacher level abilities in both content knowledge and pedagogical content knowledge influence outcomes for learners. The values teachers hold and the decisions teachers make in the classroom are likely to have a positive or negative influence on learners’ outcomes.

The choices teachers make in the classroom are also influenced by the values they hold about maths education, an area explored in research by Kajander and others (2010; Holm & Kajander, 2012; Kajander, 2010b; Kajander & Holm, 2013; Kajander & Mason, 2007; Kajander et al., 2008). In addition to exploring teachers’ basic mathematical competence, these authors explored the extent to which pre-service and in-service teachers valued conceptual approaches to teaching over procedural approaches. Their work tends to be smaller scale qualitative work that may benefit from quantitative exploration in order to apply more widely. However, their research demonstrated a significant reliance on procedures rather than conceptual maths among pre-service teachers.

Qualitative research into classroom practices supports the view that teacher level practices can have the effect of lowering attainment for lower SES learners. Practices that democratise learning through project based learning, group collaboration and student driven curricula can have the effect of reducing maths anxiety for learners (Hann, 2020). The research by Hann (2020) is consistent with a qualitative strand in maths teaching research. A similar view to teaching and learning emphasises the importance of 'relational equity' which is described as learners treating each other with respect and fairly taking account of different viewpoints (Boaler, 2008). Boaler's view is that a multidimensional maths classroom which includes multiple abilities, promotes group work and encourages listening to each other and mutual support and respect is more likely to be one where lower SES learners thrive. Multidimensional classrooms are places where teachers and learners recognise that there is more than one way to solve a mathematical problem and there is not 'one right way'. Interestingly, the 'one right way' approach is likely to be consistent with an over-emphasis on procedural as opposed to conceptual approaches to teaching and learning maths.

In educational settings with high levels of deprivation therefore, relational interactions would appear to be as important as content knowledge and pedagogical content knowledge (Battey, 2012). The importance of learner participation and sense making in a context of high deprivation is seen as key to addressing issues of disempowerment and agency in South Africa (Graven, 2014). Graven (2014) states that too often learners equate success with a pedagogy of compliance which is teacher led and passive. Democratising learning is what Rincon-Gallardo (2020) describes as 'transforming the pedagogical core', the relationship between teacher and learner which he believes will substantially improve learning.

So far, the analysis of teacher level influences on outcomes for lower SES learners has focused on an over emphasis on procedural as opposed to conceptual mathematics. In relation to how the class is organised, research suggests that a more democratised learning environment is more conducive to better progress by marginalised learners, included those who are relatively more deprived. One further issue which takes us closer to the level of the individual learner is the issue of ‘expectations’. Qualitative analysis of classroom dialogue comparing lower streams with higher streams identified low expectations being communicated to learners from relatively more deprived backgrounds in pedagogic classroom dialogue (Straehler-Pohl et al., 2014). The research identified what they describe as the dominant western view that mathematics is about innate ability rather than hard work which is what they consider the eastern view. Talking about messages given to learners as part of the classroom dialogue with the teacher they say ‘we strongly believe that the revealing of structural phenomena which are ingrained in social interactions is the very first step to changing them’ (Straehler-Pohl et al. 2014, p.197). The question of teacher expectations communicated to learners takes the discussion closer to the level of the individual learner which is the next area which will be explored.

2.5 Influences at the level of the individual learner including neurological

2.5.1 Social-cognitive influences

The focus of this study on attainment in mathematics for lower SES learners is not at the level of the individual learner but examines the complex interplay of factors (Graven, 2014) that lead to poorer outcomes for more deprived learners. Nevertheless, there are factors at the level of the individual that are important influencers in educational outcomes including social and cognitive factors as well as genetic and neurological factors. This section will explore social and cognitive factors which operate at the level of the individual including reference to dyscalculia and a brief overview of genetic factors and the extent to which brain structures influence maths learning. Maths anxiety will be addressed as a subsection of brain related issues,

First is a review of the complex social and cognitive processes that lead to the formation of children’s beliefs about their ability in maths. Children’s self-perceived ability or mathematics self-concept has a significant influence on their attainment in maths which in turn influences their interest in the subject (Tosto et al., 2016). Indeed, the knowledge trajectory starts pre-school with key skills such as knowledge of counting; non-symbolic quantities; and repeating patterns significantly influencing later outcomes (Fyfe et al., 2019). The importance of early knowledge gains is underlined by the social-cognitive theory of Eccles and Wigfield (2020) who earlier stated that ‘today’s choices and performance become tomorrow’s past experiences’ (Wigfield & Eccles, 2000, p. 3). Their research highlights the way in which performance is influenced by academic self-concept and in turn academic self-concept is informed by performance. In relation to early intervention, this leads to the obvious question of the importance and value of an early experience of success.

Eccles and Wigfield’s situated expectancy value theory underlines once more the interactive or reciprocal nature of the relationship between children, their environment and their educational outcomes. The importance of situated expectancy value theory is that it combines into a single model a variety of influences including culture, beliefs, behaviour, aptitudes, prior achievement, expectations of success and subjective task value. They also provide clear evidence that an individual child’s beliefs about their ability and their expectations of success in the future combine with the value they place on a subject and together all influence their achievement. Their findings are stark, stating that:

> *even when previous performance is controlled, children’s beliefs about their ability and expectancies for success are the strongest predictors of subsequent grades in maths, predicting those outcomes more strongly than either previous grades or achievement values* (Wigfield & Eccles, 2000, p. 77).

Wigfield and Eccles (2000) based their findings on three longitudinal studies exploring the connections between maths outcomes and motivation (Meece et al., 1990; Wigfield & Eccles, 2000). Their earlier research has been supported by more recent work which explored the potential multiplicative effect between expectancy and task value using data from three cohorts of Trends in International Mathematics and Science Study (TIMSS) (Guo et al., 2015). Guo et al. (2015) explored the link between SES, expectation of success and valuing of the subject, in this case maths. Given parents influence their children socially and emotionally Guo et al. (2015) hypothesised that since parental beliefs are linked to SES, there would be an effect on children’s motivation to learn which in turn impacts on their educational performance. Over three cohorts of TIMSS students, generally aged 15, they found an effect for SES and that maths self-concept had a mediating and interactive role.

Their research further validated the focus of Wigfield and Eccles (2000) expectancy value theory on motivation to learn and outcomes, especially for lower SES learners.

An understanding of an individual child's motivation, self-belief, expectations of success are key to unlocking success for all, especially those living in relatively higher deprivation. Perceived cost, including effort, opportunity and emotional cost are also flagged by Eccles and Wigfield (2020) as central to understanding children's progress in learning and their attainment.

Consistent with Eccles and Wigfield (2020) is the Robin Hood effect on motivation in maths where lower socioeconomic status children tend to have lower motivation in maths and the consequent lower levels of achievement (Häfner et al., 2017). Hentges et al. (2019) found that lower SES young people considered maths learning to have a higher cost to them which had an indirect effect over time resulting in lower overall attainment. The findings of Hentges et al. (2019) are consistent with Eccles and Wigfield's references to values and costs (Eccles and Wigfield, 2020). Hentges et al. (2019) define costs as what an individual needs to give in order to pursue a task as well as the effort required to be good at that task. They found that poverty impacts on attitudes and values and children are more likely to focus on what is 'immediate due to the uncertainty of future pay-offs' (Hentges et al., 2019, p.344) which they suggest is consistent with expectancy value theory and what they refer to as life history theory. According to Hentges et al. (2019), life history theory suggests that growing up in a harsh environment leads to a present-oriented perspective rather than a focus on longer term goals.

All of this is consistent with recent research by Putwain et al. (2021) who found that a greater sense of control and value of the subject being studied are directly related to higher maths test scores while there is an indirect relationship between maths scores and enjoyment and lower anxiety. Intrinsic value amplifies the direct positive relationship between control and attainment in maths.

In summary, the complex social-cognitive links between lower SES and maths attainment play out at the level of the individual child in terms of their motivation, expectations and valuing of maths. The way in which a child's environment influences their early success or lack of success in numeracy as well as their subsequent expectations and value of maths all have a direct influence on their maths outcomes.

2.5.2 Genetic contributions to maths and Developmental Dyscalculia

A significant body of research exists on developmental dyscalculia (DD), much of which focuses on brain structures associated with number and number processing (Agostini et al., 2022). Developmental dyscalculia is defined in DSM-V and includes significant difficulties in number and number processes that cannot be attributed to a lack of learning, any other cognitive impairment, inadequate education or environmental disadvantage (American Psychiatric Association, 2013). The definition rules out the cause of maths difficulties being environmental disadvantage which would include economic disadvantage. Nevertheless, it is worth exploring dyscalculia briefly to ensure it is not confused with environmental or contextual contributors to difficulties with maths and consequent poorer outcomes.

Butterworth et al. (2011) focus on a ‘core deficit’ in DD related to understanding sets and their numericities. Understanding sets and their numericities has also been referred to as numerical magnitude perception or the approximal number system (ANS) (Wilkey et al., 2020). Wilkey et al. (2020) however point out that more recent studies extend from a simple ‘core deficit’ model of dyscalculia to include executive functions and their role in acquiring numerical skills. Their research focused on inhibitory control demands from incongruent visual cues in a non-symbolic comparison task where children were asked to compare two sets of dots and indicate which was bigger. In a study involving 628 students they found that ANS and executive function mechanisms are both involved in what they describe as a dynamic interplay. Their conclusion is that a focus on ANS, or a core deficit, is not enough to explain the relationship between number processing and maths outcomes. They suggest that the role of executive function, including inhibitory control, spatial processing, verbal and visuospatial memory, sustained visual attention and inattentive behaviours contribute and interact to some degree with the likely neurological deficit in the intraparietal sulcus. The involvement of executive functions in DD makes it clearer why there is a high comorbidity between DD and other neurological developmental conditions such as ADHD (Von Aster & Shalev, 2007).

In a study involving 1,303 children, 47 with DD and 895 typically developing, Mamarella et al. (2021) suggest that the children with DD are on a continuum and that searching for a core deficit is simplistic. While the evidence suggests there may not be a simple core deficit operating in isolation from executive functions, the neuropsychological underpinnings of DD appear to be in part determined by the structure of the parietal areas, especially the intraparietal sulcus and frontal brain areas which are under activated in children with DD (Agostini et al., 2022; Von Aster & Shalev, 2007).

DD has also been related to alterations in brain regions associated with short term and long term memory as well as structural deficits in core regions of the brain associated with number processing (Michels et al., 2022). The work of Michels et al. (2022) was consistent with that of McCaskey et al. (2020) who found reduced grey and white matter volumes in the number processing regions of the brain. Both the work of Michels et al. (2022) and McCaskey et al. (2020) involved relatively small sample sizes with 37 and 35 children respectively, however their work based on functional Magnetic Resonance Imaging is consistent. Agostini et al. (2021) carried out a systematic review involving 46 studies of DD and found that some general cognitive domains were compromised in children with DD including executive functions, working memory, attention and processing speed. Dyscalculia is not an explanation for poorer outcomes in mathematics among economically disadvantaged children and young people, however it highlights the importance of understanding the brain structures related to learning maths and to be alert to the possibility of dyscalculia amongst all children, including those living in relative deprivation, given a prevalence of 3-6% in the general population (Decarli et al., 2022).

At a very basic level, Banerjee (2016) indicated that early nutrition can have an influence on later maths outcomes which is a reminder that the social and cognitive are built on the very basics of biology and the structure of the brain. Skeide et al. (2020) indicate that around 20% of maths ability is heritable and identify the ROBO1 gene in particular as associated with the right parietal cortex which is in turn a key region of the brain for representation of quantity (Kuhl et al., 2020; Skeide et al., 2020). Studies using fMRI were first carried out on children only as recently as 2001 and along with more recent research have identified areas of the brain associated with mathematics. The studies found that the pre-frontal cortex is important for the 'maths brain' and the insula is involved but is also linked to intrinsic motivation while the claustrum integrates motivation top-down and bottom-up and the cingulate gyrus is key for attention and working memory. The intraparietal sulcus builds amodal, language independent semantic representations of numerical quantity (Arsalidou et al., 2018).

However, even if 20% of maths ability is linked to genetic factors, that leaves 80% open to the influence of other factors both within the individual and in their environment, including the educational environment. Hart et al. (2009) explored the genetic overlap between maths ability and reading, and identified genetic overlap between maths ability, reading ability and general ability in different measure with maths fluency the only measured maths ability with unique genetic influences. Nevertheless, their study did not fully explore the complex relationship between the genetic realm and the real world of teaching and learning.

Setting aside the genetic components, cognitive psychology indicates that executive functions such as inhibitory control, working memory and cognitive flexibility are influenced by SES and in turn have an impact on numeracy outcomes (Ellefson et al., 2020). Developmental cognitive neuroscience of numeracy consistently emphasises the role of the central executive and working memory in the key tasks required in numeracy tasks including comparison of numerical properties, fact retrieval, and calculation (Dulaney et al., 2015; Menon, 2010).

2.5.3 Maths anxiety and its impact on the individual

At the intersection of both the biological or neurological basis of maths ability and the psychology of maths learning and teaching is the subject of maths anxiety. Maths anxiety (MA) is a contested area but it is worthy of noting since it is related to the previous section in as far as maths anxiety impacts on tasks requiring executive function and therefore working memory which is central to progress in maths (Suárez-Pellicioni et al., 2013; Suárez-Pellicioni et al., 2016). The contested issues include first, the extent to which gender stereotyping contributes to MA and second the debate around whether low ability leads to MA and consistent low achievement or whether MA itself leads to poor performance. The general view as set out by Suarez-Pellicioni et al. (2016) is that MA leads to poor performance and global avoidance, however, there is also evidence that MA without low ability does not result in low achievement. Suarez-Pellicioni et al. (2016) also outline an alternative theory which is that a deficit in maths learning leads to ruminating and using working memory capacity.

Maths anxiety involves the same brain structure as other types of anxiety but is triggered by maths, particularly under timed conditions (Suarez-Pellicioni et al, 2016). Brain areas linked to fear processing such as the amygdala are triggered as are those linked to disgust / pain processing such as the insula.

Teachers themselves who experience maths anxiety have been identified as contributing to children's MA through particular learning and teaching approaches (Ramirez et al., 2017; Ramirez et al., 2018) such as an over-emphasis on rote learning and procedural maths rather than a more conceptual emphasis. Ramirez et al. (2017) build on earlier work which had already identified ways in which teaching techniques increase maths anxiety. Such techniques include giving the same work to all learners; rigidly working through a textbook; teaching as if there is only one way to solve a problem; and focusing on basic skills rather than concepts.

The overall conclusion from reviewing maths anxiety literature is that MA is more likely to be a result of the interaction between the learner and their environment rather than an intrinsic deficit within the learner. Often it is rooted in a negative experience at an early stage in a maths teaching context resulting in fear of being publicly humiliated (Suárez-Pellicioni et al., 2016). MA is therefore not inevitable and is open to being moderated by tackling gender stereotyping with parents and teachers and using known and well established anxiety remedies such as systematic desensitisation, anxiety management and conditional inhibition training (Gülşah, 2021; Patkin & Greenstein, 2020; Pizzie et al., 2020).

So far this literature review has set out the connection between socioeconomic status and educational outcomes. The literature review then highlighted the complex interplay between factors at the level of the community, family, school / teacher and at the level of the individual child which together impact upon mathematical outcomes. In addition, at the level of the individual the literature review explored the biological basis for maths learning at the level of brain structure and touched on developmental dyscalculia and maths anxiety. The focus of the literature review now turns to potential interventions to address the gap in outcomes based on SES.

2.6 Interventions to improve outcomes for children experiencing economic and social deprivation

Identifying the root causes of lower outcomes in mathematics and education more generally remains insufficient in the context of educational psychology. One of the key roles of educational psychology is to identify and implement appropriate interventions to bring about improvement (Scottish Executive, 2002). To that end, this section of the literature review considers some of the evidence to evaluate interventions which may be appropriate to mitigate the impact of relative deprivation on educational outcomes, and specifically maths outcomes. However, given the causes of poorer outcomes are multiple including community, family, school and individual child level, consideration needs to be given to criteria which will help narrow the focus of any intervention.

2.7 Criteria for interventions

Criteria for the evaluation of interventions include utility, feasibility, propriety and technical adequacy (Robson, 2002). Elaborating on Robson's criteria, utility requires the intervention evaluated to be of use to an identified group; feasibility requires that the intervention being evaluated can actually be carried out and is cost-effective; propriety demands that the evaluation can be done in a manner that is fair and ethical; technical adequacy means the intervention being evaluated can be done with 'technical skill and sensitivity' (Robson, 2002, p209). Taking account of these criteria, the focus is on interventions that can be carried out in a school context and which tackle issues as identified by Eccles and Wigfield (2020) who described the interaction between the child's attitudes, belief and experiences which in turn influence their expectations, the value they put on learning a subject and ultimately as a consequence their outcomes.

Research consistently highlights the complex interplay of different factors which impact upon educational outcomes in general and more specifically on maths outcomes. Taking account of the criteria set out above, an intervention focusing on teachers would be useful but in the context of the current study may not be feasible. An intervention focused on teachers may indeed result in changes to practice which benefits learners, however, the length of time required to deliver professional learning to teachers and then to ensure faithful and consistent implementation as well as confirming any change was the result of the professional learning would be challenging. The potential confounding variables, not least the teacher's overall competence, limit the feasibility of a teacher led intervention. Table 2 therefore sets out in summary the issues identified in the literature relating to socioeconomic status and the impact on maths attainment. The table also sets out the potential connection between SES related maths outcome and why games based peer assisted learning may be an effective intervention.

Table 2

Summary of research relating to SES and maths outcomes aligned to possible interventions addressing the deficit or problem

Issue / problem identified Maths learning and achievement and socioeconomic status.	**Reference**	**Potential intervention research Games based learning / peer assisted learning.**	**Reference**
Home learning environment impacts maths knowledge with lower SES households having fewer and less complex maths interactions with children.	(Deflorio & Beliakoff, 2015)	Games based learning has positive behavioural and neural effects on improving computational fluency with numbers.	(Çakır et al., 2016)
Impact is on number and arithmetic; spatial and geometric reasoning; measure; pattern recognition.		Commercial off the shelf games can deliver positive effects when learning is active; experiential; situated; problem based.	(Connolly et al., 2012)

Lack of cognitive stimulation in home environment has a modest but significant negative effect on younger children.	(Burnett & Farkas, 2009)	Maths concepts or vocabulary in a game context leads to payers being motivated to recall or use information to progress in the game. Game playing in maths context increases motivation and heightens attention leading to retaining information.	(Hassinger-Das et al., 2017)
Linked to poverty, exposure to chronic stress in home environment combined with low parental education impacts upon attitude and values which are among the strongest predictors of academic success.	(Hentges et al., 2019)	Maths computer games have a positive impact on motivation, in part due to immediate feedback and the ability to make mistakes without losing face.	(Bakker et al., 2015)
		Peer tutoring in maths has an overall effect size in maths of 0.78. Improvement in cognition were found but also in reduced anxiety, improved self-esteem and in attitude to maths.	(Alegre et al. 2019)
Early harsh home environment fosters a present orientation, focusing on here and now, limiting investment in longer term learning as required by maths.	(Hentges et al. 2017)	Games based learning focuses on immediate reward and feedback to engage the learner.	(Bakker et al. 2015)
		Enjoyment of maths and self-concept are closely linked.	(Topping et al. 2003)

Lower SES families tended to have lower motivation and achievement in maths.	(Häfner et al., 2017)	Peer tutoring increases self-esteem for tutor and tutee.	(Topping et al. 2003)
		Peer tutoring effect size of 0.48 on maths self-concept with same age reciprocal tutoring more effective on self-concept.	(Moliner & Alegre 2020)
		Motivational and learning benefits of playful games based learning lead to capitalising on learners non-symbolic magnitude knowledge to support their symbolic magnitude knowledge.	(Scalise et al. 2017)
Key areas in early maths learning are number / numerical operations; patterns / functions; algebra.	(Baumert et al. 2010)	Maths games based learning in primary schools promotes adaptive number learning. Knowledge in a new context leads to adaptive and efficient problem solving.	(Brezovszky et al. 2019)
Pre-school knowledge predicts attainment, in particular knowledge of counting; non-symbolic quantities; repeating patterns.	(Fyfe et al. 2019)	After brief exposure to maths games, low income children show significant improvement in numerical skills.	(Scalise et al. 2021)

Spatial skills and number sense are supported by multiple representations – dual coding theory.	(Carr et al., 2020)	Games use spatial, motor, auditory representation, not only semantic representation. Children preferred 3D commercial off the shelf games.	(Topping, 1998)
Classroom stress promotes motivational forgetting of maths knowledge. Classroom stress is linked to SES and chronic stress.	(Ramirez et al., 2017)	Peer tutoring in maths led to moderate effects and enhances intrinsic motivation. It may also reduce anxiety, build maths self-confidence and encourage positive attitudes.	(Martí Arnándiz et al., 2022)
Trauma and PTSD in early life lead to hyper alertness and impaired recruitment of central executive network in learning.	(Herringa, 2017)	Playful learning experiences such as simple card games promote executive function skills.	(Scalise et al., 2019)
		In games children compete according to rules leading to intrinsic motivation; self-efficacy; challenge; control; fantasy; curiosity and interactivity.	(Hassinger Das et al., 2017)

Traumatic stress may lead to negative impact on key memory processing and executive function, both key brain areas in learning.	(Bücker et al., 2012)	Executive function links to maths ability. Games found to be a way of developing executive function.	(Scalise et al. 2021)
Lower SES children have a deficit in executive functions, especially attention and working memory.	(Dulaney et al., 2015)	Playing linear board games promotes lower income children's numerical development.	(Siegler & Ramani, 2008)
Executive function mediates socioeconomic status.	(Lawson & Farah, 2015)		
The values individuals hold about maths and their expectations of success strongly predict achievement in maths.	(Eccles &Wigfield, 2020)	Utility value interventions work for lower SES children. Learning experiences that support feelings of competence, connectedness and autonomy.	(Eccles & Wigfield, 2020)
Control and value emotions are linked to achievement in maths.	(Putwain et al., 2021)	Analysis of 113 primary studies found a small mean effect size of 0.12 in the relationship between attitude to maths and attainment in maths.	(Ma & Kishor, 1997)

Executive functions (inhibitory control; working memory; cognitive flexibility) mediate the link between SES and numeracy skills.	(Ellefson et al., 2020) (Harvey & Miller, 2017) (Nesbitt et al., 2013) (Lawson & Farah, 2015)	Games require self-regulation; rule following; turn taking; social interaction; communication.	(Ramani et al., 2012)
		Games based learning has a marginally significant effect on maths achievement.	(Tokac et al., 2019)

Taking account of the evidence set out in Table 2, in particular the research from Eccles and Wigfield (2020), and the criteria set out by Robson (2002), the choice of focus is on an intervention which potentially results in children experiencing success which may influence self-concept as a learner and consequently attitude to learning and potentially reduce anxieties about learning. A review of literature on games-based learning and peer-assisted learning follows as a potential route for effective and feasible interventions.

2.8 Games based learning

Online or computer based maths games have a rich evidence base of demonstrating improvement (Connolly et al., 2012; Deng et al., 2020; Hartley, 2008; Rich et al., 2017; Weiss & Headlam, 2019). Interestingly, Bakker et al. (2015) found the greatest effect when games were played at home followed by a debriefing in school. In common with other research, they found that computer games impacted positively on motivation due to immediate feedback and the possibility of making mistakes without losing face. However, the shift from declarative knowledge, such as number facts, and procedural knowledge, such as numerical operation skills, to conceptual knowledge was brought about through the reflection in-school after the games were played at home. The reflection in class showed that children made progress from declarative and procedural knowledge to higher order thinking skills and conceptual knowledge.

A meta-analysis of game based learning found a small but marginally significant effect for games where video games were used for teaching (Tokac et al., 2019). More generally, a game-based learning environment in primary schools helped children to develop flexibility in number and number operations (Brezovszky et al., 2019). Participants were able to apply their knowledge of numbers and number operations in a different context demonstrating a rich repertoire of number problem solving, and an ability to switch adaptively between procedures. Specifically in the computer games environment, Connolly et al. (2012) explored commercial-off-the-shelf game-based learning and found effective learning when the learning was active, experiential, situated, problem based and provided immediate feedback.

For lower income families, there is evidence that playing linear numerical board games promotes the numerical development of children (Siegler & Ramani, 2008). Siegler and Ramani's work is based on a mental number line being the central conceptual structure which underlies early numerical understanding. Simple games such as snakes and ladders can promote a mental number line but may be less likely to be played in lower income households. Siegler and Ramani (2008) then extended their work from a research led context to a small group learning activity in a classroom setting and found that children who played a board game in groups using a number line from 1 to 10 improved in key measures of numerical knowledge (Ramani et al., 2012). Using optical brain imaging, Çakır et al. (2016) found that gamification allowed for arithmetic learning which allowed learning to be engaging and reduced anxiety among children learning maths.

Interestingly, Scalise et al. (2018) explored what specific learning it is that children from lower income families are less likely to have and which may limit their progress in maths (Scalise et al., 2018, 2021). They found a greater gap in symbolic number tasks than in non-symbolic number tasks, suggesting that income related differences are quantitative in nature. This view reinforces the value of games based learning since it is suggested that children from higher SES groups are more often exposed to counting in games, cooking and a range of everyday activities. The research of Scalise et al. (2021) suggests that some children can be good at complex maths tasks but relatively weak at fundamental numeracy which in turn reinforces the view that focusing on procedural maths at the expense of conceptual maths may disadvantage already disadvantaged children.

Scalise et al. (2018) capitalised on children's non-symbolic maths knowledge to support their symbolic learning. Critically however, this was embedded in the context of a card game to motivate children through the learning benefits of playful game based activities. Their findings indicated that children using multiple redundant cues in card games may improve their early maths skills. Hassinger-Das et al. (2017) found a similar effect and propose games as part of playful pedagogy. Along with free play and directed play, they propose games as a way of learning that taps into intrinsic motivation and self-efficacy but that also includes challenge, self-control, fantasy, curiosity and interactivity. The element of fantasy allows children to switch off reality and enter the game thus reducing some of the normal anxiety that may be connected to learning in a classroom context.

Hassinger-Das et al. (2017) found that games increased motivation and heightened attention to content while helping retain information, particularly in maths concepts and vocabulary. They cautioned however that there is a potential negative effect of children expecting fun, which is the risk that children expect to be entertained in educational settings. They suggest addressing this concern through focusing on learning goals, learners' needs and the games available for a particular purpose.

More recently Scalise et al. (2017) tried to determine if playing card games at home might improve learning in maths, however, results were unclear. Part of the problem was implementation fidelity and inconsistency in the home environment. However, the work of Scalise et al. (2017) on the value of using games to establish an initial number sequence is reinforced by research which emphasised the importance of children progressing from pre-numerical to establishing an initial number sequence and progressing to a tacitly nested number sequence (Wilkins et al., 2021). Their findings corroborate the theoretical basis for a staged theory of development where children progress from pre-numerical to an initial number system based on one to one counting and connection then progress to a tacitly nested number system, that is the ability to understand that seven for example, includes 7 ones and it is possible to count on from there. The progress from pre-numerical to a tacitly nested number system forms the basis of multiplicative reasoning and understanding fractions.

Overall therefore, there appears to be evidence to support a games based approach to try and improve maths outcomes for children from lower socioeconomic status households and bring them closer to their higher SES peers. One particular approach to games based learning is peer assisted learning using games as the context for learning (Topping et al., 2003).

2.9 Mediated Learning

At the core of peer assisted learning is an understanding of learning and teaching as a fundamentally social process involving interaction with a more capable other (Elliott et al., 1996). Vygotsky and post-Vygotskyian theorists use the overarching title of a sociocultural theory of development to describe the work of Vygotsky and the approaches that emerged from his work (Hedges, 2021). Hedges (2021) talks of a dialectic approach that intertwines intellect and affect rather than a staged approach to learning and development. Learning leads development with a more capable other involved as a mediator rather than waiting for something almost magical to happen as the child becomes 'ready to learn'. Consistent with Vygotsky is Feuerstein's theory of Structural Cognitive Modifiability and Mediated Learning Experience (SCM-MLE) in which the basic assumption is that the structure of the brain is modifiable, so learning potential matters more than the fixed notion of intelligence (Tzuriel, 2013, 2021). For the current research, the key issue in the context of mediated learning is, first, the view that intelligence is not fixed, so children who have had limited exposure to stimulating numeracy experiences at home due to socioeconomic disadvantage are not destined to remain at a disadvantage. Secondly, peer assisted learning offers the opportunity through a more-able peer to improve maths skills and develop a more positive attitude to maths.

Interestingly, Study 1 below uses standardised assessment data to explore the potential gap between children entitled to free school meals and those not entitled to free school meals. Tzuriel (2021) suggests that the problem with standardised assessment is not what it does, but what it doesn't do, which is explore a child's learning potential. Particularly for low SES children who may have had poor mediation from their parents and who have not been exposed to learning strategies, the issue is they may have inefficient approaches to learning rather than a fixed difficulty. In addition, standardised assessments do not focus sufficiently on issues of personality, emotion or motivation which are key factors in learning. Tzureil (2021) argues therefore that a sociocultural approach to learning is more effective than the structuralist approach of Piaget and Dewey for example.

In a moderated learning experience such as peer assisted learning, the emphasis has to be on the learning process and on the individual's ability to modify cognitive functions rather than basing cognitive ability on previous learning or the final product in a standardised assessment (Passig et al., 2016). Intelligence therefore is not a fixed trait but is considered as 'ability to learn' (Stringer, 2018).

2.10 Peer assisted learning

One of the most commonly used definitions of peer assisted learning or peer tutoring is that of Topping (2003) who described peer tutoring as 'people from similar social groupings who are not professional teachers helping each other to learn and learning themselves by teaching' (Topping et al., 2003; Topping, 1996, p. 322). In addition to individual research papers, a number of reviews and meta-analyses attest to the positive impact of peer tutoring (Alegre et al., 2019a, 2019b; Alegre et al., 2020; Leung, 2019; Moliner & Alegre, 2020; Mundelsee & Jurkowski, 2021). The research focuses not only on cognitive gains but on the positive effect on psychological variables such as self-concept, anxiety and attitude to learning (Lidón & Francisco, 2020; Moliner & Alegre, 2020). The meta-analysis carried out by Leung (2019) focuses on the benefits to tutors and found a weighted standardised mean effect size of 0.43 (p<.001). The view is that tutors learn by explaining (Alegre et al, 2020) while in a qualitative analysis of student learning in Finland, Oikarinen et al. (2022) found a significant amount of pedagogical knowledge in conversations between tutor and tutee which benefit both. The Finnish research with 9-11 year olds found children using language of instruction, thinking aloud, feedback, support, new ideas and reflection. In effect the tutors and tutees were externalising their internal mental representations in the context of digital maths lessons.

Nevertheless, while Topping et al. (2003) claim that peer tutoring 'yields significant achievement gains on both criterion and norm referenced maths tests plus gains in attitudes to maths; self-concept and social interaction' (Topping et al., 2003, p. 295), Topping later emphasizes the importance of implementation fidelity (Topping et al., 2011; Topping, 2020). Peer assisted learning appears to result in greater effect sizes in some circumstances than others. Alegre et al. (2019a) for example carried out a review of effect sizes and moderators and found that using children of the same age was more effective than cross age peer assisted learning; programmes lasting less than 8 weeks achieved better results; individual sessions lasting 30 minutes or less was optimal; three sessions or less a week achieved greatest effect sizes (Alegre et al., 2019a). They also found that peer tutoring out-of-school was less effective than in-school hours while there were also gains in reducing maths anxiety; increasing self-esteem and a more positive attitude to maths as a subject. Although they described optimal circumstances for gains they also concluded that 'practitioners should also find academic benefits in any scenario, as academic gains have been documented overall under any condition' (Alegre et al., (2019a), p6).

A note of caution however is required in relation to the connection between attitude to mathematics and attainment in mathematics. Ma and Kishor (1997) reviewed 113 primary studies in a meta-analysis and found a mean effect of 0.12 which they considered to have no meaningful implications for educational practice. They concede however that the weakness may be in defining and measuring attitudes rather than there being no connection in the real world between attitude to maths and attainment in maths. Moliner and Alegre (2020) for example make the connection between the way in which self-concept influences attitudes which in turn influence motivation and behaviour in a classroom setting, including on-task behaviour. Peer tutoring was also found to improve male students' intrinsic motivation and female students' motivational force (Martí Arnándiz et al., 2022).

2.11 Conclusion from the literature review and the research questions.

So far, the literature suggests a link between relative deprivation and poorer academic outcomes for children. Children appear to start school at a disadvantage and the gap grows throughout their time in school. The literature identifies multiple contributors to the educational progress gap between relatively more deprived and relatively more affluent children. Contributory factors include the community, neighbourhood, family and parental influences on a child as well as school level influences and individual child level factors. In addition to lower educational attainment levels of parents and fewer resources available to support learning, there may be lower expectations as well as negative beliefs and attitudes passed on by parents, family and community. In particular, Eccles and Wigfield (2020) highlight the important role of social and cognitive processes that influence a learner's beliefs and attitudes to a subject. Negative attitudes, beliefs and anxiety towards a subject such as maths are predictive of outcomes in that area. The literature also highlighted the potentially negative impact of teachers and teaching. The OECD (2016) for example, suggested that teachers of children from more relatively deprived backgrounds tend to put a greater emphasis on procedural maths at the expense of more conceptual maths which may exacerbate the effects of deprivation. In addition, children are less likely to attain at a higher level in maths without a sound grasp of mathematical concepts.

Taking account of the literature on deprivation and educational outcomes, the focus on literature around potential interventions was narrowed to focus on games based learning through peer assisted learning with a view to improving the learner's attitudes and self-concept as a learner. Peer assisted learning potentially removes the negative influence of teachers' beliefs and attitudes as well as removing the potential for the teacher's own anxiety about maths to impact negatively on the learner. The literature review therefore leads to areas of investigation and the following research questions:

Research question 1: What is the scale and nature of a negative correlation between relative poverty and academic attainment in primary schools in the local authority which is the focus of the investigation?

> Hypothesis 1: Using Free Meal Registration as a proxy measure for relative deprivation, children registered for free school meals will attain at a lower level than their peers.

Research question 2: Is attainment in mathematics more negatively impacted by relative deprivation than reading attainment or general ability?

> Hypothesis 2: Maths attainment is more sensitive to relative poverty than are literacy attainment and general ability as measured by standardised assessment scores.

Research question 3: Are teachers who teach in schools characterised by relatively higher levels of deprivation more likely to prefer procedural maths learning and teaching over conceptual maths learning and teaching?

> Hypothesis 3: Teachers in schools characterised by relatively higher levels of deprivation are more likely to prefer procedural maths learning and teaching rather than conceptual maths learning and teaching as measured by the Perceptions of Mathematics (POM) survey for teachers.

Research question 4: Can psychological variables, including attitude and anxiety, associated with improving outcomes in maths be positively influenced through peer-assisted, games-based learning in a group of relatively deprived children?

> Hypothesis 4: Using Mathematics Attitude and Anxiety Questionnaire and Myself As A Learner Scale as measures, a peer-assisted, games-based learning intervention will:
>
> a) improve children's attitude to maths
> b) reduce maths anxiety
> c) improve self-concept as a learner

Chapter 3: Methods section

3.1 Epistemology and methodological approach

The aim of this investigation is to characterise the link between relative poverty and attainment in mathematics at primary school level in one Scottish local authority and to identify an intervention or class of interventions addressing psychological variables which may impact upon attainment among a relatively more deprived group of children.

The overall approach in this investigation is informed by critical realism (Robson, 2002; Smith, 1998). Critical realism is rooted in the work of Roy Bhaskar which involves a realist ontology and a constructivist epistemology, that is, that there is a reality which exists independently of our description of that reality but our knowledge of that reality is socially constructed (Scollon, 2003). Critical realism distinguishes itself from theoretical realism or constructivism which argues that not only is knowledge socially constructed, but reality is also socially constructed (Fleetwood, 2014). A critical realist approach is not fully empiricist so it does not adopt the view that social sciences gather and progress knowledge and understanding in the same way as the natural sciences through a strictly experimental method. Working with real people in the real world makes that level of control, even if it was desirable, difficult to achieve. Burden (2008) argues that educational psychology is a social rather than a natural science 'and owes as much to arts as it does to scientific methodology' (Burden, 2008, p. 291). A critical realist approach however is not entirely anti-foundational along the lines of Barthes, Foucault and Derrida for example (Smith, 1998) who take the view that 'all forms of representation can be rearticulated and transformed' (Smith,1998, p.253) so there can be no firm foundations.

Realists consider that social relations operate differently from natural sciences and they look for complex social structures and mechanisms which lead to an understanding of social events. Realism starts from the premise that there are real things with properties to observe and experiment upon, including the social structures which we inhabit. These social structures are produced, reproduced and transformed through human agency, therefore it is important and valid to investigate social structures, such as a classroom, to determine how things work (Smith, 1998).

The realist approach adopted in the current investigation therefore could be considered a systematic mixed method (Boyle, 2012). The systematic mixed method incorporates elements of experimental design integrating the use of quantitative data gathering to determine the effectiveness of interventions as well as qualitative data which offers an insight from the perspective of the participants to determine the 'acceptability and feasibility' of interventions for stakeholders (Boyle, 2012, p.54). The current investigation therefore, in addition to gathering qualitative data through written feedback and semi-structured interviews, principally adopts a quasi-experimental time-series design where measures are obtained pre and post intervention. It is quasi-experimental because participants are not randomly allocated to groups, but form naturally occurring groups. In this case classes within a school are used so that there are two intervention groups and one control group, therefore there is no randomised allocation of participants as would happen in an experiment.

Despite Burden (2008) urging educational psychologists to 'shake off their positivist shackles' (Burden, 2008, p.292), the realist, quasi-experimental mixed method adopted in the current study is sufficiently empirical to be replicated and challenged while at the same time acknowledges that educational psychology is deeply situated and mediated through participants with all the complexity of a real world context such as a busy classroom in a busy school.

3.2 Study outlines

The initial investigation in Study 1 is quantitative, first using regression analyses to characterise the relationship between relative deprivation and lower attainment based upon secondary attainment data consisting of standardised assessment results in Reading, General Mathematics, Mental Arithmetic and Developed Ability. Following initial analysis of data to characterise the possible relationship between relative deprivation and attainment, a survey methodology is used in study 2 involving the Perceptions of Mathematics survey as the instrument to determine whether or not teachers working in schools with higher levels of deprivation are more likely to adopt teaching and learning approaches which prefer procedural mathematics over conceptual mathematics, thus potentially disadvantaging lower socioeconomic status children. In study 3 a quasi-experimental method is used involving an intervention group and control group in a time series design with the experimental group exposed to a games-based peer-assisted learning intervention to determine if the intervention improves attitude to maths, reduces maths anxiety and improves self-concept as a learner.

The intervention, although principally quantitative in approach, also adopts elements of design-based research (Anderson & Shattuck, 2012) in that it is situated in a real educational context and is focused on the design and testing of an intervention. The intervention therefore also involves gathering and analysing qualitative data relating to the children's and teachers' experience of the intervention which is characteristic of design-based research. The results of the qualitative analysis, which involves children reflecting on the games-based learning intervention, will be set out in Study 4. In addition, the intervention involved a collaborative partnership between the researcher and the class teachers and a brief semi-structured interview took place with one of the teachers and is set out without analysis to incorporate the voice of the teacher who implemented the games-based peer-assisted learning intervention. Studies 1 to 3 are set out using the American Psychological Association reporting style for quantitative methods (Appelbaum et al., 2018) while study 4 adopts the approach set out by the APA for qualitative methods (Levitt et al., 2018).

Chapter 4: Study 1 - Characterising the link between relative deprivation and attainment using existing standardised assessment data for a population of 11-12 year olds in the primary schools of one Scottish local authority.

4.1 Introduction

As discussed in Chapter 1 and 2, contextual indicators remain significant determinants of educational outcomes (Banerjee, 2016) with socio-economic status being one of the principal contextual determinants influencing outcomes (OECD, 2020). In Scotland's education policy context, the Scottish Government has committed significant funding to addressing what has been called the poverty related attainment gap (Scottish Government, 2022). Children from more deprived families appear to start school at a disadvantage and the attainment gap between them and their better off peers persists. Understanding the extent of the gap between children from relatively more deprived contexts is a starting point in identifying ways in which the gap can be reduced. National data sets at primary school level focus only on the percentage of children who have achieved a particular level in *Curriculum for Excellence* and as such, the data are categorical indicating which children have achieved a threshold measure. No data are published which explore in detail the strength of connection between Reading, General Mathematics, Mental Arithmetic and Developed Ability - Developed Ability being a measure of general ability. The current study aims to make more explicit the potential strength of relationship between relative deprivation and specific measures of reading, mathematics and general ability using a secondary dataset of standardised assessment results.

The study used a secondary dataset of standardised assessment results from a single cohort of Primary 7 (age 11-12) children dating from 2017. The assessments are commercially purchased by the local authority education department from the Centre for Evaluation and Monitoring who were based at the University of Durham, now based at the University of Cambridge. The standardised assessments are age-appropriate tests of general ability, reading, mental arithmetic and general mathematics and were undertaken online. The test producer considers the actual tests commercially sensitive and so examples are not available. The results are available with a fully anonymised dataset for 2017 stored on the Open Science Framework[5] and the University of Strathclyde PURE data repository[6].

The main hypothesis for study 1 is that there is a connection between relative deprivation and children's attainment in standardised assessments of Reading, General Mathematics, Mental Arithmetic and Developed Ability. Research suggests however that early mathematic skills are more predictive of academic ability than early reading skills (Duncan et al., 2007; Romano et al., 2010; Wolf et al., 2017). A secondary hypothesis therefore is that attainment in general mathematics is more likely to be impacted to a greater extent by relative deprivation.

The hypotheses will therefore be explored using regression analyses (Field, 2013; Tabachnick & Fidell, 2014) to determine through hierarchical multiple regression first of all, the extent to which indicators of relative deprivation impact upon the outcome measures of Reading, Developed Ability, Mental Arithmetic and General Mathematics. Free school meal entitlement is triggered by a family being in receipt of specific state benefits which in turn are income related. Free school meal registration therefore is considered a proxy measure for relative deprivation. The extent to which attainment in Reading, Developed Ability, Mental Arithmetic and General Mathematics can accurately predict the odds ratio of a child being entitled or not entitled to free school meals is considered a useful indicator of the extent to which deprivation impacts upon attainment. Hierarchical logistic regression therefore will also be carried out, with attainment scores as predictor variables and likelihood of entitlement to free schools meals being the dichotomous categorical outcome variable.

4.2 Method

4.2.1 Participant characteristics

The data set included all primary 7 children in 2017 who completed the CEM assessments (Cambridge University Press, 2022) and for whom standardised assessment data were available in all four measures. The total number who

[5] https://osf.io/6fg7a/files/osfstorage
[6] https://doi.org/10.15129/88672303-ec3e-4228-aa9d-e79cf6d519b8

completed the CEM assessments was 1,085, however 7 children did not complete all of the standardised assessments and so were removed from the analysis. Analysis of the 7 cases with missing data suggests they are Missing At Random (Tabachnick & Fidell, 2014), coming from a broad range of schools; ability levels; and SIMD vigintiles. Only one of the seven is entitled to free school meals and footwear and clothing grant, with one other entitled to clothing grant but not free meals. The 7 children removed represent only 0.65% of the data set with Tabachnik and Fidell (2014) suggesting that where less than 5% of a large data set are missing, it is acceptable to drop the missing data points. The seven missing data points were deleted giving an overall data set of 1,078.

Characteristics of the cohort are summarised in Table 3:

Table 3

Characteristics of P7 Cohort, 2017

Gender	**Free Meals Status**	**Footwear and clothing grant**
51.5% Female	17% entitled	24.2% entitled
48.5% Male	83% not entitled	75.8% not entitled

Ethnicity of the cohort is not available, however at the 2011 census, 98.6% of the local authority population identified as white with only 1.4% identifying as any other ethnic origin (Scottish Government, 2012). The expectation is that the cohort broadly reflects the local population. The mean age of the cohort was 11 years and 8 months with the youngest 11 years and 2 months and the oldest 12 years and 11 months.

4.2.2 Sampling procedure

The cohort of children who completed the assessments includes all children at Primary 7 in mainstream schools. Those not taking part included a very small number in the age group who attended specialist schools for children with complex additional support needs, including learning disabilities. The Primary 7 cohort was chosen due to them being at the end of their primary school years, having completed almost 7 years of primary education. The investigation is focused upon differences in attainment due to relative poverty and the end of the primary years is considered an appropriate stage to assess any gap arising from relative deprivation.

4.2.3 Data gathering and ethical considerations

Children completed the assessments individually in their classroom or in a computer suite in their school using computer based assessments which are adaptive and delivered on-line. The data are secondary data gathered for assessment purposes by the local authority. When parents / carers consent to their child taking part, they also consent to the use of data for research purposes. Ethical approval was granted for the analysis of the data by the ethics committee of the School of Psychological Sciences and Health at the University of Strathclyde (see Appendix A).

4.2.4 Sample size, power and precision

An a priori power analysis was carried out using G*Power version 3.1.9.7 (Faul et al., 2007) for sample size estimation. No previous studies of the data were reported, therefore a conservative effect size of .15 was considered appropriate using Cohen's criteria (Cohen, 1988). Adopting a significance criterion of $\alpha = .05$ and power = .80, the minimum sample size needed with this effect size is 602 for linear multiple regression, fixed model R^2 increase. As such, the obtained sample size of N=1,078 was judged to be adequate to test the study hypothesis.

4.2.5 Measures and covariates

The measures are standardised test results for four assessments used to measure attainment in Reading; Developed Ability (a measure of general ability); Mental Arithmetic and General Mathematics. All four test results are standardised, with a mean of 100 and a standard deviation of 15.

4.2.6 Instrumentation

The assessments for Reading, Developed Ability, Mental Arithmetic and General Mathematics are commercially available from Cambridge University's Centre for Evaluation and Monitoring (Cambridge University Press, 2022). At the time the tests were used, the Centre for Evaluation and Monitoring was located at Durham University, but subsequently transferred to Cambridge University in 2019. The tests used are part of the Interactive Computerised Assessment System (InCas)

(Cambridge University Press, 2022) which assesses reading; spelling; general mathematics; mental arithmetic; and attitudes. The data for spelling and attitudes were not used in the current study for two reasons, first the data provided were not standardised but an age equivalent score, and secondly, the local authority did not require the attitude surveys to be completed so the data were incomplete.

The assessment of reading includes ‘word recognition’; ‘decoding’; and ‘comprehension’. General mathematics includes ‘counting’; ‘arithmetic’; ‘fractions’; patterns’; ‘algebra’; ‘measures’; ‘shape and space’; and ‘data handling’. Mental arithmetic assessment includes ‘addition’; ‘subtraction’; ‘multiplication’ and ‘division’. ‘Developed ability’ is a measure of general ability and is assessed using ‘picture vocabulary’ and ‘non-verbal reasoning’.

The InCAS assessments used in the current study were validated against an existing assessment, PIPS, which had been standardised against a nationally (UK) representative sample (Merrell & Tymms, 2007). The correlations between the InCAS assessments and the PIPS assessments are all significant (p=.01). In addition, Merrell and Tymms (2007) carried out correlation analysis between the InCAS assessments and these were also significantly correlated (p=.01).

4.2.7 Conditions and design

The data were secondary data gathered during routine standardised assessments each year in all mainstream primary schools in the local authority. The advantage of this secondary data set is the size of the cohort since carrying out the assessments to obtain primary data would be extremely costly and likely result in a more modest sample with limited statistical power and generalizability (Cave & Stumm, 2021; Siddiqui, 2019). The assessments were carried out annually at Primary 1, Primary 4 and Primary 7, so the participants were used to carrying out the assessments and staff experienced in administering the assessments. The data therefore were not gathered for the purposes of the investigation but are being used as a dataset which can be analysed to characterise the nature of the relationship between relative deprivation and attainment using these standardised assessment data.

4.2.8 Data diagnostics

As indicated above, the data were already available as standardised scores with a mean of 100 and standard deviation of 15. The approach adopted for missing data has already been outlined and only 7 cases out of the entire data set had missing values, so the 7 cases which appear to be Missing At Random have been removed as they represent 0.65% of the entire data set (Tabachnick & Fidell, 2014). Standardised residuals greater than 3 were examined and considered for removal if considered to be introducing bias into the regression analyses (Field, 2013).

4.2.9 Analytic strategy

The data were analysed first to determine whether there was a significant difference between children entitled to free school meals and those not entitled. Secondly, multiple hierarchical regression were undertaken to determine which of the three assessments had greatest influence and was most influenced by markers of deprivation. Finally, hierarchical logistic regression was used to characterise the extent to which assessment data could be used to predict the odds or log-likelihood that a child was entitled or not to free school meals.

H1 = Using Free Meal Registration as a proxy measure for relative deprivation, children registered for free school meals will attain at a lower level than their peers.

H2 = Maths attainment is more sensitive to relative poverty than are literacy attainment and general ability as measured by standardised assessment scores.

4.3 Results

A table setting out the flow of participants is not considered relevant since the total cohort of eligible children took part in the assessments and only 7 cases have missing data. Therefore 1,085 undertook the assessments and 7 were excluded from the analyses due to missing data with the 7 considered to be Missing At Random. The assessments were undertaken between 18 April 2017 and 9 June 2017. The 2017 cohort was chosen because after 2017 no standardised assessment data were available as the local authority started using the Scottish National Standardised Assessments and no data were publicly available for these assessments. Earlier cohort data was available but does not include data on characteristics such as free meal status.

All analyses across all studies were carried out using IBM SPSS Statistics (version 28) predictive analytics software. Descriptive statistics for the group not entitled to free school meals are set out at Table 4, then descriptive statistics at Table 5 for the group entitled to free school meals.

4.3.1 Descriptive Statistics

Table 4

Descriptive statistics for Standardised Assessments, P7 2017 Cohort not entitled to free school meals

	N	Range	Min.	Max.	Sum	Std Deviation	Variance	Skewness		Kurtosis	
									Std Error		Std Error
Developed ability	895	90	55	145	94845.70	14.25	203.11	-.257	.082	.602	.163
Reading	895	90	55	145	89371.52	17.19	295.47	.559	.082	.409	.163
Mental Arithmetic	895	90	55	145	84424.81	16.13	260.07	.259	.082	.552	.163
General Maths	895	90	55	145	84769.93	17.02	289.56	-.060	.082	-.214	.163

[a]FME=No

Table 5

Descriptive statistics for Standardised Assessments, P7 2017 Cohort entitled to free school meals

	N	Range	Min.	Max.	Sum	Std Deviation	Variance	Skewness		Kurtosis	
									Std Error		Std Error
Developed ability	183	87.33	57.67	145	18240.13	15.1	227.99	.149	.180	-.036	.357
Reading	183	87.15	55	142.15	16957.80	17.78	316.27	.211	.180	.571	.357
Mental Arithmetic	183	74.86	55	129.86	15596.68	15.89	252.54	.312	.180	.075	.357
General Maths	183	78.15	55	133.15	15463.09	17.71	313.65	.411	.180	-.537	.357

4.3.3 Independent sample t-tests

Exploring the data further, independent t-tests (Field, 2013) were carried out to compare the mean attainment on all four assessments between P7s not entitled to free school meals and P7s entitled to free school meals. There was a significant difference in Developed Ability scores between Not-FME entitled (M = 105.97, SD = 14.25) and FME entitled (M=99.67, SD=15.09; t(1076) = -5.393, *p*<.001, two-tailed); similarly for Reading scores between Not-FME entitled (M = 99.86, SD = 17.19) and FME entitled (M = 92.66, SD = 17.78; t(1076) = -5.126, *p*<.001, two-tailed); and Mental Arithmetic scores for Not-FME entitled (M = 94.33, SD = 15.89) and FME entitled (M = 85.23, SD = 15.89; t(1076) = -6.974, *p*<.001, two-tailed); and finally General Mathematics scores for the Not-FME entitled group (M = 94.71, SD = 17.02) and the FME entitled group (M = 84.50, SD = 17.71; t(1076) = -7.349, *p*<.001, two-tailed). The magnitude of the differences in the means represented a medium effect size across all scores (Developed Ability Cohen's d = -.438; 95% CI -.598 to -.277; Reading Cohen's d = -.416; 95% CI -.576 to -.256; Mental Arithmetic Cohen's d = -.566; 95% CI -.726 to -.405; General Mathematics Cohen's d = -.596; 95% CI -.757 to -.435). Field (2013) suggests carrying out a Bonferroni correction in order to control *Type I error rate* when carrying out multiple tests. The acceptable adjusted *p*-value for the four tests just listed would be .0125 which all of the individual *p*-values exceed, meaning the findings are statistically reliable. Table 6 summarises the results of the t-tests.

Table 6

Independent sample t-tests between P7s entitled to free school meals and P7s not entitled to free school meals

	Levene's Test for Equality of Means		**t-test for Equality of Means**							
					Significance				95% CI of the Difference	
	F	Sig.	t	df	One-sided *p*	Two-sided *p*	Mean difference	Std Error Difference	Lower	Upper
Developed Ability[a]	1.685	.195	-5.393	1076	<.001	<.001	-6.30	1.17	-8.59	-4.01
Reading	.153	.696	-5.126	1076	<.001	<.001	-7.19	1.40	-9.94	-4.44
Mental Arithmetic	.002	.969	-6.974	1076	<.001	<.001	-9.10	1.31	-11.66	-6.54
General Maths	3.492	.062	-7.349	1076	<.001	<.001	10.22	1.39	-12.95	-7.49

[a] All equal variances assumed

4.3.4 Regression analyses

Regression analyses were considered appropriate to investigate the relationship between the dependent variable (DV) and independent variables (IVs) of interest (Tabachnick & Fidell, 2014). Standard multiple regressions can be used to explore whether prediction of a DV from one set of IVs is better than prediction from another set. In addition hierarchical multiple regressions were carried out to determine if Footwear and clothing grant status or vigintile of the Scottish Index of Multiple

Deprivation improved the fit of the model when used as an independent variable compared to Free Meal Entitlement status. Hierarchical multiple regression therefore was used to explore Research question 1: *Is there evidence of a negative correlation between relative poverty and academic attainment in primary schools in the local authority which is part of the investigation?*; and the related Hypothesis 1: Using Free Meal Registration as a proxy measure for relative deprivation, children registered for free school meals will attain at a lower level than their peers. The regression analysis was intended also to shed light on Research question 2: *Is attainment in mathematics more negatively impacted by relative deprivation than reading attainment or general ability?;* and the associated Hypothesis 2: Maths attainment is more sensitive to relative poverty than are literacy attainment and general ability as measured by standardised assessment scores.

Specifically in this study, regression was being used to explore the relationship between the four sets of standardised scores of Reading, Developed Ability, Mental Arithmetic and General Mathematics and how they are affected by relative poverty as measured by free school meals status which is used as a proxy measure for relative deprivation. The data set and participants are exactly as described above. Free school meals status (FME) was dummy variable coded as 'FME_Yes' and 'FME_No' for entitled and not entitled to free school meals respectively. A series of hierarchical multiple regressions was planned using each of the standardised assessment results as the DV in turn to determine which set of IVs best predicts the result in either developed ability, reading, mental arithmetic or general mathematics taking account of relative deprivation.

4.3.5 Preliminary analysis

Prior to analyses, the IVs of standardised scores in Mental Arithmetic, General Mathematics, Reading and Developed Ability were examined through various IBM SPSS procedures to check for missing values and fit between the distribution of scores and the assumptions of multivariate analysis. As mentioned already, the 7 cases with missing data were examined and considered to be cases where data was missing at random. In addition the cases accounted for 0.65% of the overall number of cases and at considerably less than 5% of cases (Tabachnick and Fidell, 2014) were removed from the analyses. Three cases were identified using Mahalanobis distance (p<.001) as multivariate outliers as they exceeded the critical value of 18.47 (Tabachnick and Fidell, 2014). Examination of the 3 cases showed they had a pattern of attainment that could not be easily explained, such as Developed Ability score around 3 SD below average and a general mathematics score 1.5 SD above average, and so they were removed from the analyses resulting in overall N = 1,075. One further case was just outside the critical value at 18.55, but inspection of the case suggested an acceptable pattern of scores so it was left in the analyses. With 1,075 cases remaining in the analyses the ratio of cases to IVs was judged to be adequate. Skewness and kurtosis for each of the variables was less than plus or minus 1 and using IBM SPSS scales and examination of the histograms suggests they are within tolerable limits of being normally distributed (Miles & Shevlin, 2001). An examination of the data suggested no suppressor variables could be identified as there are no negative Betas and the semi-partials squared and added together for each Model amount to significantly less than the R^2 for each model (Darlington & Hayes, 2017; Smith et al., 1992).

The standardised assessments for General Mathematics and Mental Arithmetic were a concern for multicollinearity. The Mental Arithmetic assessment included assessment of addition, subtraction, multiplication and division, while the General Mathematics assessment included assessment of counting, arithmetic, fractions, patterns, algebra, measure, shape and space and data handling. Pearson's correlation indicated a correlation between mental arithmetic and general mathematics of R = 0.767 and Tabacknick and Fidell (2014) and Pallant (2020) suggest removing variables which correlate above R = 0.7 to minimise the risk of multicollinearity. As a result of the high level of correlation and the risk of multicollinearity, Mental Arithmetic was removed from the regression and General Mathematics retained as it assessed a broader range of relevant skills than Mental Arithmetic.

A standard hierarchical multiple regression analysis (Tabachnick and Fidell, 2014) was carried out to characterise the relationship between the three remaining sets of standardised scores (Developed Ability, Reading and General Mathematics) and Free Meal Entitlement status as a proxy for relative deprivation. The expectation, in line with Hypotheses 1 and 2, was that general mathematics would have the strongest relationship with free meal entitlement and it would be a negative correlation.

4.3.6 Regression results

In the first regression analysis, Model 1 included General Mathematics as the DV and FME_yes as the IV; Model 2 General Mathematics was the DV with FME_yes and Developed Ability as the IVs; in Model 3 General Mathematics was the DV and FME_Yes, Developed Ability and Reading as the IVs. Table 7 reports the correlations between variables and shows a stronger correlation between General Mathematics and FME status than either Developed Ability or Reading scores (r=-.217 for Maths and FME versus FME and Developed Ability (r=-.153) and FME and Reading (r=-.153). Table 8 shows the mean and standard deviation for each of the variables which were, as expected, close to 100 for the mean and close to a SD of 15. Table 9 shows the R, R^2 and adjusted R^2 for each model with Model 3 showing an improvement in fit over Model 1 and 2 with an adjusted R^2 = .518. Model 3 accounts for 51.8% of the variability in the model compared to 21.7% in Model 1 and 46.3% in Model 2. Table 10 shows the Betas, standardised Betas and semipartial correlations (Part) indicating that the independent variables account for 21.4% unique variability leaving 30.2% shared variability in Model 3.

Table 7

Correlations between variables (standardised scores)

		General Mathematics	**Reading**	**Developed Ability**	**Yes_FME**
Pearson Correlation	General Maths	1.00	.596	.671	-.217
	Reading	.596	1.00	.602	-.153
	Developed Ability	.671	.602	1.00	-.153
	Yes_FME	-.217	-.153	-.153	1.00
Sig. (1-tailed)	General Maths		<.001	<.001	<.001
	Reading	.000		.000	.000
	Developed Ability	.000	.000		.000
	Yes_FME	.000	.000	.000	
N	General Maths	1075	1075	1075	1075
	Reading	1075	1075	1075	1075
	Developed Ability	1075	1075	1075	1075
	Yes_FME	1075	1075	1075	1075

Table 8

Mean and standard deviations for each variable

	Mean	Std Deviation	N
General Mathematics	92.97	17.51	1075
Reading	98.65	17.50	1075
Developed Ability	104.93	14.47	1075

Table 9

R, R^2 and adjusted R^2 for each variable

Model Summary[d]

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std Error of the Estimate	R Square Change	F Change	df1	df2	Sig F Change
1	.217[a]	.047	.046	17.10	.047	53.25	1	1073	<.001
2	.681[b]	.464	.463	12.84	.416	831.85	1	1073	<.001
3	.719[c]	.518	.516	12.18	.054	119.97	1	1073	<.001

[a] *Predictors (Constant), FME*
[b] *Predictors (Constant), FME, Developed Ability*
[c] *Predictors (Constant), FME, Developed Ability, Reading*
[d] *Dependent Variable General Mathematics*

Table 10

Beta, standardised Beta and semipartial correlations

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients			95% CI for B		Correlations			Collinearity Stats.	
Model		B	Std Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	74.34	2.61		28.53	<.001	69.23	79.45					
	FME	10.17	1.39	.217	7.30	<.001	7.44	12.91	.217	.217	.217	1.00	1.00
2	(Constant)	-.020	3.24		-.006	.995	-6.37						
	FME	5.49	1.06	.117	5.18	<.001	3.4	7.56	.217	.156	.116	.976	1.02
	Developed Ability	.790	.03	.653	28.84	<.001	.737	.844	.671	.661	.645	.976	1.02
3	(Constant)	-5.30	3.11		-1.71	.088	-11.40	.798					
	FME	4.64	1.01	.099	4.61	<.001	2.67	6.62	.217	.139	.098	.971	1.03
	Developed Ability	.581	.03	.480	17.99	<.001	.517	.644	.671	.482	.382	.633	1.58
	Reading	.292	.03	.292	10.95	<.001	.240	.345	.596	.317	.232	.633	1.58

[a] *Dependent Variable: General Mathematics*

In addition to the above hierarchical standard multiple regression analysis, further regression analyses were undertaken to explore whether the set of variables had a different relationship than was demonstrated in the regression with General Mathematics as the DV, Developed Ability and Reading were used in turn as the DVs.

With Developed Ability as the DV and FME_yes, Reading and General Mathematics as the IVs, the outcome was broadly similar with a very slight reduction in adjusted R^2. Similarly with reading as the DV, there was a reduction in adjusted R^2. The outcomes are summarised in Table 11 and suggest that the only outcome variable where FME status is making a significant difference is General Mathematics. The 4th line in Table 11 shows the results of a further regression using entitlement to footwear and clothing grant to determine if it was a better fit for the model. However, the overall difference was marginal and analysis of collinearity diagnostics showed two condition index measures over 15 (dimension 3 = 17.448; dimension 4 = 23.049) suggesting a greater level of collinearity than in other models. Finally, SIMD Vigintile was used as an independent variable in place of FME to determine if it was a more effective measure of relative deprivation. Table 11 shows that there was almost no difference.

Table 11

Outcomes of model fitting analyses for each dependent variable

DV	**IVs**	**R**	**Adjusted R^2**	**Standardised Beta**	**SR^2 (unique)**
1. General Maths	FME_Yes; Developed ability; reading	.719	.516	Reading: .292*** Developed ability: .480*** FME_yes: -.099***	Reading: .0538 Developed ability: .1436 FME_yes: .0062
2. Developed ability	FME_Yes; General maths; reading	.717	.512	Reading: .314*** Gen Maths: .484*** FME_yes: .000	Reading: .063 Gen Maths: .147 FME_yes: .000
3. Reading	FME_Yes; Developed ability; general maths	.656	.429	Developed Ability: .314*** Gen Maths: .484*** FME_yes: .000	Developed Ability: .0745 Gen Maths: .0640 FME_yes: .000441

4. General Maths	Clothing grant_yes; developed ability; reading	.717	.513	Developed Ability: .478*** Reading: .292*** Cloth grant_yes: -3.725***	Developed Ability: .1436 Reading: .0538 Cloth grant_yes: -0062
5. General Maths	SIMD Vigintile; developed ability; reading	.718	.515	Developed Ability: .482*** Reading: .289*** SIMD Vigintile: .092***	Developed Ability: .1474 Reading: .0524 SIMD Vigintile: .0084

In summary, the hierarchical standard multiple regression analyses performed between General Mathematics as the DV and FME_Yes, Reading and Developed Ability as the IVs result in R for regression significantly different from zero, F (3, 1071) = 383.05, p<.001, with R^2 at .518 and adjusted R^2 at .516. The adjusted R^2 value of .516 suggests that around half the variability in General Mathematics scores is predicted by Free meal entitlement status, Developed Ability scores and Reading Scores. The unique variability of the three independent variables is calculated at 21.4% with a further shared variability of 30.2%. The Model where General Mathematics was the DV and FME status, Developed Ability and Reading as IVs had the highest R^2 compared to other models.

In the regression analyses where Reading was the DV and Developed Ability, General Maths and FME status were the IVs, the FME variable did not show a significant change in the regression line (t = .012, p = .607). The same was true with Developed Ability as the DV and Reading, General Maths and FME status as the IVs (t = .014, p = .989). Overall therefore, the hierarchical multiple regression tends to indicate a slight negative relationship between free meal entitlement and attainment, with the impact being stronger on General Mathematics than Reading and Developed Ability.

In addition, the regression analyses carried out indicated that Footwear and Clothing Grant status as well as SIMD vigintile, essentially postcode, were no more effective at predicting attainment than FME status. Now that FME status has been identified as the most useful predictor of attainment through standard hierarchical multiple regression and General Mathematics has been found to have a stronger relationship with FME than Developed Ability and Reading, further analyses of the relationship between General Mathematics and FME can be explored using hierarchical logistic regression in order to characterise further the relationship between relative deprivation and attainment.

4.3.7 Hierarchical logistic regression analysis

Standard hierarchical multiple regression indicated a correlation between General Mathematics scores and free meal entitlement. Logistic regression however can offer an odds ratio of being in the category of entitled to free meals (Free meals_yes) or not entitled to free meals (Free meals_no) based on predictor variables. Having reduced the predictor variables by removing Mental Arithmetic due to high correlation with General Mathematics and established a relationship by model fitting using standard multiple regression, logistic regression allows for predicting outcomes for new cases on a 'probabilistic basis' (Tabachnick & Fidell, 2014, p. 485). Hierarchical logistic regression therefore was carried out with Free meal entitlement as the categorical outcome variable representing a proxy for relative deprivation. The predictor variables were Reading scores, Developed Ability scores and General Mathematics scores. Reading and Developed Ability were entered as predictors in Block 1 with General Mathematics entered at Block 2 to determine if the addition of general mathematics improved the fit of the model.

4.3.8 Preliminary analysis

The ratio of cases to variables is adequate with 1,075 cases and four variables overall. For consistency, the data set is the same as for standard multiple regression, so the 7 cases with missing data were removed and the 3 cases remained deleted from the previous analysis that were identified using Mahalanobis distance ($p<.001$) as multivariate outliers as they exceeded the critical value of 18.47 (Tabachnick and Fidell, 2014). Studentized residuals (SRESID) were checked for outliers as SRESID 'makes a correction based on the estimated variance of the residual at that value of the predicted variable' (Miles & Shevlin, 2001, p.93). On checking SRESID there were no outliers.

4.3.9 Hierarchical logistic regression results

In order to characterise the relationship between relative poverty and General Mathematics, a hierarchical logistic regression analysis was performed on Free Meal Entitlement as the outcome with attainment scores in Reading and Developed Ability as predictor variables at Block 1 and General Mathematics added to these two predictor variables at Block 2 to check if the addition improved the fit of the model. Data from 1,075 Primary 7 children, 894 not entitled to free meals and 181 entitled to free meals, were used in the analysis. A test of Model 1, with Reading and Developed Ability as predictors, against a constant only model was significant, χ^2 (2, n=1,075) = 32.34, p<.001, indicating that together, the two predictors in the model significantly distinguished between children entitled to free school meals and children not entitled to free school meals. Table 12 shows regression coefficients, Wald statistics, odds ratios, and 95% confidence intervals for odds ratios for each of the three predictors at Block 1 and Block 2. A test of Model 2 with General Mathematics scores added to Reading and Developed Ability as predictors against Model 1 with only Reading and Developed Ability in the model was significant, χ^2 (3, n=1,075) = 52.91, p<.001, indicating that the addition of General Mathematics to the model significantly improved the fit of the model.

Table 12

Logistic regression of free meal entitlement as a function of attainment scores

Block 1 Variables	***B***	**Wald chi square**	**Odds ratio**	**CI 95%: Lower**	**CI 95%: Upper**
Developed Ability	-.017	5.869 (p=.015)	.983	.969	.997
Reading	-.017	6.958 (p=.008)	.984	.971	.996
Block 2					
Developed Ability	.001	.005 (p=.945)	1.001	.985	1.017
Reading	.006	.775 (p=.379)	.994	.981	1.007
General mathematics	-.032	19.529 (p<.001)	.969	.955	.983

As can be seen at Table 12, according to the Wald criterion at Model 2, only General Mathematics significantly predicted free meals status, χ^2 (1, n=1,075) = 19.529, $p<.001$. This indicates that General Mathematics attainment score is the only statistically significant predictor of free meals status from the other candidate predictors of Developed Ability, Reading and General Mathematics. However, caution is required as an odds ratio of .969 in the likelihood of being entitled versus not entitled to free school meals was based on a one unit change in General Maths score.

Nevertheless, what is evident in the standard multiple regression and the hierarchical logistic regression is that General Mathematics attainment scores have a stronger and more sensitive relationship with free school meals status as a proxy for relative poverty compared to Developed Ability and Reading Scores.

4.3.10 Post-hoc analysis

A review of the cases incorrectly classified by the regression shows that they were all entitled to free school meals but were wrongly classified as not being entitled to free school meals. All cases scored above average for children entitled to free school meals. No cases were actually classified as entitled to free school meals who were not entitled to free school meals. The cases were evenly spread by gender and were spread across 20 schools amounting to around half of the schools in the local authority. There was no pattern by rural urban split, however the schools tended to be schools serving relatively less deprived areas with one exception. School C had 7 pupils all of whom scored above 100, three were one full SD above average and one over 2 SDs above average. The school served an area of significant deprivation, with over 70% of the school entitled to free school meals. The school had a particular focus on maths and was an early adopter of the concrete, pictorial, abstract teaching method (Jaciw et al., 2016) which may have had a positive impact on maths attainment.

4.4 Discussion

Multiple regression and hierarchical logistic regression analyses both support H1 that using Free Meal Registration as a proxy measure for relative deprivation, children registered for free school meals will attain at a lower level than their peers who are not entitled and registered for free school meals. The adjusted $R^2 = .516$ for the standard multiple regression model suggesting that 51.6% of the overall variance in General Maths scores was predicted by FME status, Reading and Developed Ability scores. While the unique variance contributed by FME is very small at 4.7%, the only model where there is a significant relationship between FME and an attainment score is when General Maths is the dependent variable and FME status, Developed Ability and Reading are the predictor variables (reading t=10.953, $p<.001$; developed ability t=17.985, $p<.001$; Yes_FME t= -4.609, $p<.001$). With Developed Ability as the outcome variable FME is not significant (Yes_FME, t= -.014; $p=.989$) and with Reading as the dependent variable, once again FME is not significant (Yes_FME, t= -.897; $p=.370$). The analyses therefore also support H2 that maths attainment is more sensitive to relative poverty than literacy attainment and general ability as measured by standardised assessment scores.

Similar to the standard multiple regression, the hierarchical logistic regression indicated a significant relationship between General Mathematics attainment scores and relative deprivation as measured by free meals status. At Block 1, General Mathematics alone, B = -.035, $p<.001$. The addition of reading results in General Mathematics B = -.031, $p<.001$ and the Reading B = -.006, $p = .367$. Similarly, adding Developed Ability at Block 3, Developed Ability B = .001, $p=.945$. The conclusion is that General Maths attainment scores can predict with a significant degree of accuracy whether or not a child is entitled to free school meals, thus supporting Hypothesis 1 and 2. There does appear to be a significant connection between relative deprivation and poorer attainment outcomes and mathematics attainment is more sensitive to relative deprivation than reading or general ability.

4.5 Limitations and future research

The current study used secondary data from standardised assessments of General Mathematics, Reading and Developed Ability. Although the assessment publishers work hard to limit cultural bias, they are still likely to suffer from a degree of cultural bias which may disadvantage relatively more deprived children as suggested by Mikus et al., 2020. The only potential mitigating factor is that the assessments had been in use for over 6 years in the local authority and teachers who administered the assessments had become skilled at ensuring language idioms unfamiliar to a west coast of Scotland child were explained in advance.

A further potential issue is the use of Free Meal Entitlement as a measure of relative deprivation. FME is a binary category and does not indicate the length of time a child has been entitled to free school meals and so does not distinguish between a family who have been entitled to free meals for generations and one who has recently become entitled due to recent job loss of a parent for example. Regression analyses using SIMD and footwear and clothing grant as potential substitute variables however did not suggest a significant difference which may indicate FME is broadly reliable as a proxy measure for relative deprivation.

Finally, while the overall sample size is considered reliable, the number of children entitled to free school meals is considerably smaller than the overall population. It is nevertheless consistent with the Scottish average, however a national sample would be useful to explore in future research. Future research may also usefully explore the relationships between deprivation and maths outcomes using a more detailed measure of relative deprivation and the length of time a family has experienced deprivation. Further research may also explore whether there is a correlation between teacher professional judgement as expressed in *Curriculum for Excellence* levels, standardised test results and measures of deprivation. Equally the single measure of relative deprivation used, that is free school meal entitlement, is limited. Future research may explore further children's experiences of trauma, adversity and stress due to factors associated with extreme deprivation such as substance misuse and the impact of these on their attainment. Taking account of these limitations, the findings are considered sufficient to explore interventions which may have a positive impact on the connection between relative deprivation and outcomes in maths.

Study 1 has established that there is a connection between relative deprivation and attainment in mathematics. It remains however to explore empirically what contributes to the differential attainment by SES and what may be done to mitigate the impact of deprivation. Study 2 explores the potential link between the teacher and the way they teach and relatively poorer outcomes in mathematics. As outlined previously, there are multiple factors contributing to lower educational outcomes, however, in order to try and identify an appropriate and feasible intervention it is important to identify more precisely the factors contributing to lower attainment due to SES as identified through regression analyses.

Chapter 5: Study 2 - Exploring the factor structure of the Perceptions of Mathematics (POM) Survey using Principal Components Analysis and a comparison of teachers in low deprivation schools and higher deprivation schools.

5.1 Introduction

Research indicates that the values and perceptions children hold about maths and their expectations of success are predictive of future achievement (Hentges et al., 2019; Lazarides et al., 2020; Tosto et al., 2016; Wigfield & Eccles, 2000). However, teachers' values and attitudes to maths may also influence the way they teach which in turn influences their students' own attitudes, values and beliefs about maths (Ramirez et al., 2018). The focus of this study is on identifying teachers' maths values and the extent to which these may differ depending on their students' levels of deprivation. In particular this study will focus on the distinction between teaching principally procedural maths to lower SES children as opposed to a balance between procedural and conceptual maths (Baroody et al., 2007). The distinction between procedural and conceptual maths has been in existence for many years in maths educational research with Hiebert and Lefevre (1986) summarising the research to that point and establishing definitions which have remained useful. They define conceptual knowledge as 'knowledge that is rich in relationships. It can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information' (Hiebert & Lefevre, 1986, p.3). They then define procedural knowledge as having two parts , the first being the formal language and symbols in maths and the second being the algorithms or rules required to complete mathematical tasks. Interestingly they state early on 'We do not believe however that the distinction provides a classification into which all knowledge can or should be sorted' (Hiebert & Lefevre, 1986, p.3). The relevance of the distinction however is in the view that lower SES children are more likely to be exposed more consistently to procedural rather than conceptual maths which may limit their ability to achieve at a higher level (Bachman et al., 2015; Organisation for Economic Co-operation and, 2016). Table 13 sets out some of the reported distinctions between procedural and conceptual maths.

Table 13: Reported distinction between procedural and conceptual maths

Procedural	Reference	Conceptual	Reference
Knowledge of sequences or steps or actions that can be used to solve problems	(Rittle-Johnson et al., 2001)	Knowledge of general principles and knowledge of the principles underlying procedures	(Crooks & Alibali, 2014)
Knowing what to do	(Crooks & Alibabi 2014)	Knowing what to do and why	(Crooks & Alibabi 2014)
Knowledge that enables the application of rules, algorithms and procedures for solving problems but may not generalise.	(Voutsina, 2012)	Conceptual allows for evaluating which procedure to use; flexible problem solving; generalising to new context; deeper and longer lasting understanding	(Voutsina, 2012)
Knowledge – how?	(Baroody et al., 2007)	Knowledge – how and why?	(Baroody et al., 2007)

However, it has also been argued that conceptual and procedural knowledge exist on a continuum and what matters is depth of knowledge in either procedural or conceptual understanding (Baroody et al., 2007; Voutsina, 2012). Knowledge quality matters with deep procedural and conceptual knowledge being adaptive, that is able to be used in a new and different context whereas superficial or routine procedural or conceptual knowledge are unlikely to be applied out of context. Nevertheless, flexibility and adaptability require procedural knowledge but are generally only possible where there is conceptual knowledge which can give meaning to the steps involved in a procedure. Conceptual knowledge enables the learner to select the appropriate procedure. If conceptual knowledge is key to progressing in maths, lower SES children being exposed to less conceptual maths and more procedural maths may place them at a disadvantage.

Contextual variables such as family and community level poverty remain important to the progress children make in school (Martínez Garrido et al., 2020). In a systematic review, Banerjee (2016) identified 771 studies between 2005 and 2014 which explored the connection between relative deprivation and outcomes in Science Technology Engineering and Maths (STEM) subjects for young people. A synthesis was carried out of 34 studies which were large scale, involved a comparator group and had robust methods. From the systematic review, Banerjee (2016) identified community effects which included lack of role models and quality of schools while at family level, lack of parental involvement and low academic achievement of parents were significant influencers of outcomes for children. However, a key question for teachers and educators is whether the formal education system then mitigates or amplifies the influence of the family context where it is one of deprivation. Baker et al. (2015) warn against focusing on child level effects without attending to the ecological context, especially the impact of the school and the teacher (Baker et al., 2015; Bronfenbrenner, 1977). For example, analysis of PISA results in Canada identified that the school accounted for 19% of the variance in maths results while in the USA it was 25% (Brow, 2018).

Teachers' intentional or unintentional classroom practices, expectations, attitudes and beliefs about learning, teaching and the success of children have a significant impact on outcomes for learners (Banerjee, 2016; Battey, 2012; OECD, 2016). The work of Battey (2012) focused on the importance of relationships in the maths classroom between teacher and learner as well as between learners. To ensure learners from disadvantaged backgrounds progress well, the teacher's maths content knowledge is not enough, the values which influence their pedagogical approaches are also influential of outcomes for learners (Baumert et al., 2010; Holm & Kajander, 2012; Kajander & Mason, 2007).

The importance of focusing on 'relational equity' in the teaching of mathematics has been highlighted over many years (Boaler, 2008; McKinney & Frazier, 2010). Boaler (2008) distinguishes between unidimensional maths classrooms where learners 'are valued for executing procedures and nothing more' (Boaler, 2008, p.172) as opposed to multidimensional maths classrooms where different methods, questioning, discussion and different ways of representing maths are valued. The connection has been made between teacher practices such as project based learning, group collaboration and a student driven curriculum and better maths achievement (Hann, 2020; König et al., 2021; Reddy et al., 2020). McKinney and Frazier (2010) conclude that lecture and drill practices do not prepare learners for rigorous maths. Overall, classrooms that support feelings of competence, connectedness and autonomy are more likely to lead to better outcomes for learners (Eccles & Wigfield, 2020). Teachers and teaching in maths classrooms therefore make a difference to engagement and therefore to outcomes for learners.

Analysis of the OECD PISA results in maths (OECD, 2016) picks up the themes of distinguishing between 'lecture and drill' or 'unidimensional classrooms' and concludes that learners from more disadvantaged backgrounds are more likely to be exposed to this type of learning and teaching. In large part, the difference in approach is due to early tracking which refers to children being put into schools, classrooms or groups depending on their 'ability'. Setting or tracking by ability reduces opportunities to learn for more disadvantaged learners who 'never get an opportunity to develop a taste for, and some means of independent thinking' (OECD, 2016, p.36).

In order to perform at the top level in maths, learners cannot rely on memory alone but need to make connections and develop alternative solutions when solving problems. As highlighted by Boaler (2008), knowledge transmission is necessary but learners need to work independently as well as collaborate in order to become strategic learners and achieve at a higher level in maths. The OECD concluded that across all education systems, socioeconomically disadvantaged learners have less access to maths content and are more likely to be exposed to procedural learning rather than conceptual learning. Making explicit the extent to which teachers' values are principally conceptual or principally procedural when teaching maths may help to address the issue identified by the OECD that more disadvantaged learners are more often exposed to procedural teaching and learning.

The OECD highlight two key conceptual skills that more disadvantaged learners are developing less well which are firstly, mathematising which is transforming problems into mathematics and secondly, using symbolic, formal and technical mathematical language and operations (OECD, 2016). The argument in teaching ‘lower ability’ maths groups or classes is that they should use concrete or practical maths, i.e. non-symbolic. However, recent evidence shows that more disadvantaged learners do equally poorly in symbolic and non-symbolic maths, so there is no real case for excluding them from symbolic maths which is the route to higher achievement (Fischer & Thierry, 2021).

In order to ensure an equitable approach to the teaching of maths for all learners, one area of focus may be professional learning for teachers, specifically in relation to understanding the distinction between teaching conceptual maths as well as procedural approaches for all learners. Procedural knowledge is more recently described as ‘knowledge of operations in the sense of a sequence of steps or partial actions which are performed to achieve a specific goal’ (Lenz et al., 2020, p.811) while conceptual knowledge is ‘knowledge of concepts and relations which are fundamental in a certain domain’ (Lenz et al., 2020, p.811).

Kajander (2007) supported by Kajander and Mason (2007) developed a questionnaire to determine the extent to which teachers valued the teaching of procedural knowledge over conceptual knowledge. More recent research has underlined the importance of teachers understanding the value of a focus on conceptual understanding of maths in order to be able to teach effectively and equitably (Holm & Kajander, 2020). Kajander and Mason (2007) have principally used a 20 item survey to explore the values of pre-service and in-service teachers (Appendix B). However, the survey has mainly been used qualitatively and the underlying factor structure has not been explored. The original POM was adapted to the language of the Scottish context and is consistent with the work of Boaler (2008) in relation to challenging concepts related to the notion that some children have a ‘maths brain’ (Anderson et al., 2018; Boaler, 2008; Kachwalla, 2021). Using the adapted POM and exploring the dimensionality of the survey, it may be possible to identify the component structure and gain an understanding of a teacher’s preferences or values in teaching maths and in turn explore the extent to which there is an association between teachers’ maths values and outcomes for learners, especially the most socially-disadvantaged.

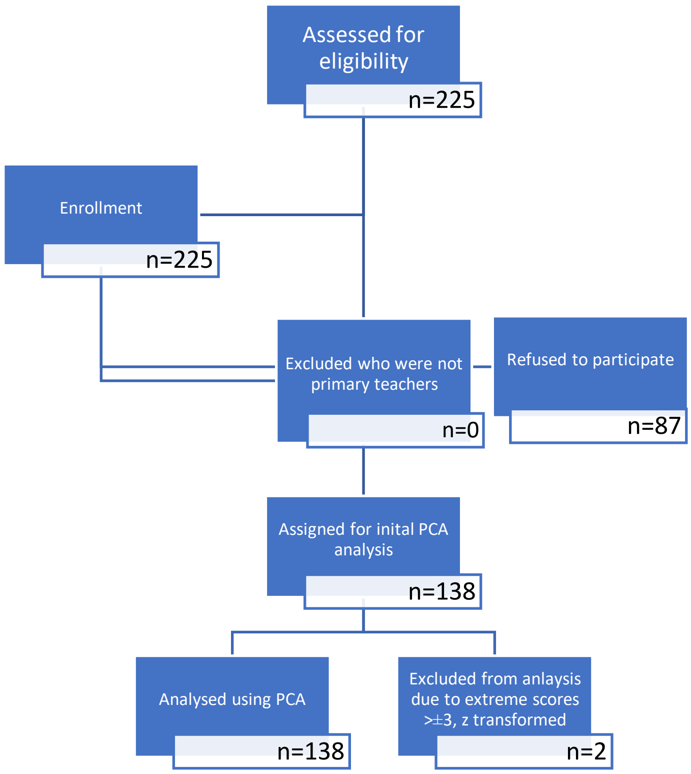
The hypothesis (H3) has been set out already and the focus of study 2 is to explore the psychometric properties of the POM in relation to the underlying component structure and dimensionality and sub-scale reliability. Once complete, if a suitable component structure is identified, the POM may be used to check any possible difference between teachers teaching lower SES children and higher SES children.

5.2 Method

5.2.1 Participant characteristics

The participants were primary school teachers and the only data gathered as part of the survey were consent and scores, no demographic data were gathered. Two targeted groups (n=32) were asked to identify their school for a comparison to be made between two schools. Other than the name of the school for the targeted groups, the survey was anonymous. The participants therefore were all mainstream primary school teachers in one Scottish local authority. The 10 largest primary schools were selected with a view to achieving sufficient respondents to carry out PCA, therefore between 100-150. The data were collected electronically in October 2021 using MS Forms. Participants were invited to complete the survey and were sent the participant information sheet with consent included as part of the electronic survey. Ethical approval was granted by the University of Strathclyde school of Psychological Sciences and Health ethics committee (Appendix A) and through the local authority ethics process. The Flow of participants is set out at Figure 1.

Figure 1: Participant Flow through each stage of analysis of POM Survey



5.2.2 Sample size, power and precision

The total number of primary teachers in the local authority at the time of the survey was 529, which means that out of the total population who could have completed the survey, 26% of all teachers completed it. Of the entire population of primary teachers, only 225 were invited to complete the survey with 138 completing it which is a 61% completion rate.

The local authority has a total of 41 primary schools of which 10 schools had teachers who completed the survey. The participating schools were representative of the entire local authority.

The primary purpose of the survey was to carry out exploratory factor analysis of the psychometric properties of the POM survey. The survey is a 20 item instrument which means that the number of participants (n=138) exceeds the initial broad 'rule of thumb' suggesting 5 participants per item (Tabachnick & Fidell, 2014). MacCallum et al. (1999) are critical of these rules of thumb, suggesting sample size is contingent upon the level of communality and overdetermination of factors, that is six or seven indicators per factor. The mean communality in the analysis was 0.685 with 6 items remaining in a two factor solution which neither meets their criterion of high communality or the criterion of overdetermination at 6 or 7 indicators per factor. However, at an initial ratio of 6.8 participants per item and final communality averaging 0.685 with two factors and a small number of indicators per factor, the sample size is considered adequate for Principal Components Analysis (Tabachnik and Fidell 2014; Field, 2013).

5.3 Psychometric properties using Principal Components Analysis (PCA)

Screening for suitability of analysis took place with factorability of the correlation matrix supported due to inspection of the correlation matrix showing multiple coefficients of .3 and above. In addition, the initial KMO and Bartlett's Test of Sphericity are set out at Table 14 and indicate appropriate factorability with Bartlett significant and KMO exceeding the recommended value of .6 (Pallant, 2020).

Table 14

Tests for Factorability of POM Survey

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.704
Bartlett's Test of Sphericity	Approx Chi-Square	727.38
	df	190
	Sig.	<.001

The data were z transformed to check for outliers beyond plus 3 or minus 3. Eight cases had at least one score above plus 3 or below minus 3, however 6 of these cases only had one single instance of a score just above the threshold so were kept in the analysis. Two cases were removed as they had multiple instances of z-scores exceeding the criterion of plus 3 or minus 3 resulting in a trimmed data set of 136. The individual items in the survey were all normally distributed (Table 15) with the exception of two items which had a Kurtosis above plus 1.5 or below minus 1.5 (Tabachnick & Fidell, 2014). However, Tabachnick and Fidell (2014) also note that 'To the extent that normality fails, the solution is degraded but may still be worthwhile' (Tabachnick and Fidell, 2014, p.666). Principal components analysis was then undertaken on the remaining data set of 136 cases.

Table 15

Descriptive statistics for trimmed, z-transformed data set – POM Survey

	N	Min.	Max.	Sum	Mean		SD	Variance	Skewness		Kurtosis	
						Std. Error				Std Error		Std Error
Correct_ans	136	-2.91	1.04	-.76	-.006	.086	1.00	1.01	-.673	.208	-.015	.413
Understand_procedure	136	-2.70	.50	8.60	.063	.074	.86	.74	-1.868	.208	2.620	.413
Basic_no_calc	136	-3.40	.73	-.08	-.001	.086	1.00	1.01	-1.348	.208	1.492	.413
Deeply_ustd	136	-3.02	.96	2.06	.015	.083	.97	.94	-.620	.208	-.459	.413
Recall_maths	136	-2.78	1.06	.44	.003	.085	.99	.99	-.607	.208	-.251	.413
Different_approaches	136	-2.12	.71	1.41	.010	.086	1.00	1.01	-1.099	.208	-.167	.413
Teacher_teach_steps	136	-2.65	.96	.49	.004	.086	1.01	1.01	-.869	.208	.163	.413
Several_correct	136	-4.50	.31	6.59	.048	.070	.81	.66	-3.088	.208	9.468	.413
Calculation_skills	136	-3.62	.85	-.22	-.002	.086	1.00	1.01	-.908	.208	.303	.413
Enrich_diff_ways	136	-2.97	.56	5.93	.044	.078	.91	.84	-1.544	.208	1.508	.413
Many_fam_short_ans	136	-2.23	1.20	2.17	.016	.085	.99	.98	-.488	.208	-.429	.413
Connection_models	136	-2.39	.78	6.37	.047	.079	.92	.85	-.829	.208	-.289	.413
Methods_step_by_step	136	-2.09	1.32	-.36	-.003	.086	1.01	1.01	-.320	.208	-.652	.413
Me_how_why	136	-2.97	.85	4.66	.034	.083	.96	.93	-1.022	.208	.552	.413
Calculators_overuse	136	-1.82	1.97	-1.41	-.010	.085	.99	.98	-.010	.208	-.407	.413
Deep_learn_new_probs	136	-1.99	.93	3.99	.029	.082	.99	.92	-.593	.208	-.637	.413
One_best_way	136	-.91	2.69	-4.17	-.031	.083	.97	.94	.861	.208	.042	.413
Small_gps	136	-2.19	1.27	3.23	.024	.084	.99	.97	-.426	.208	-.432	.413
Follow_steps	136	-1.67	1.67	-3.34	-.025	.085	.99	.97	-,127	.208	-.714	.413
Connect_by_multistep	136	-2.15	.97	4.29	.032	.082	.95	.91	-.483	.208	-.627	.413

5.3.1 Analytic strategy

As mentioned already, the data were z-transformed in order to identify outliers. Strictly speaking the data are not continuous, however, while some authors are critical of the fact that researchers use Likert Rating Scales or Likert-type scales as if the data produced are not ordinal and assume continuous variables at interval level (Asún et al., 2016) others accept the data as quasi-continuous. The Perceptions of Mathematics scale was presented horizontally using equally spaced images which Harpe (2015) considers acceptable in order to use parametric analytical approaches. For the purposes of the study, the data were treated as if they were interval (Norman, 2010; Stratton, 2018).

Screening for suitability of the data for PCA had already taken place. Parameters for the PCA were as follows:

- Items with a communality less than 0.4 were removed, lowest item at each iteration of the PCA (Costello & Osborne, 2005).

- The derived components explain 50% or more of the variance in each variable, in effect they have a communality greater than 0.5.
- There is no complex structure in the derived components, so none of the items have loadings greater than 0.40 or higher for more than one component.
- None of the derived components has only one item
- Direct Oblimin rotation was used as there is an expectation of correlation between factors.
- Parallel analysis using Montecarlo PCA for Parallel Analysis[7] (White et al., 2011) was carried out as a guide to determine the number of components.

5.3.2 Results

The 20 items of the Perceptions of Mathematics survey were subjected to PCA using IBM SPSS Statistics version 28. As described already, the results of each PCA iteration were checked for communalities less than 0.4 with the item having the lowest community below 0.4 removed and the PCA run again. Following multiple iterations of the PCA, the PCA revealed the presence of six components with eigenvalues exceeding 1, explaining 70.91% of the variance collectively. Table 16 sets out the detail of the eigenvalues and variance explained in the final PCA. The final solution had a KMO = .696 and Bartlett's Test of Sphericity $p<.001$.

Table 16

Total Variance explained in PCA of Adapted Perceptions of Maths survey

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.250	21.664	21.664	3.250	21.664	21.664
2	2.650	17.667	39.331	2.650	17.667	39.331
3	1.338	8.919	48.250	1.338	8.919	48.250
4	1.254	8.359	56.609	1.254	8.359	56.609
5	1.094	7.291	63.899	1.094	7.291	63.899
6	1.052	7.010	70.910	1.052	7.010	70.910
7	.734	4.895	75.804			
8	.666	4.441	80.245			
9	.561	3.738	83.983			
10	.536	3.572	87.555			
11	.485	3.236	90.792			
12	.443	2.951	93.743			
13	.360	2.402	96.144			
14	.340	2.269	98.414			
15	.238	1.586	100			

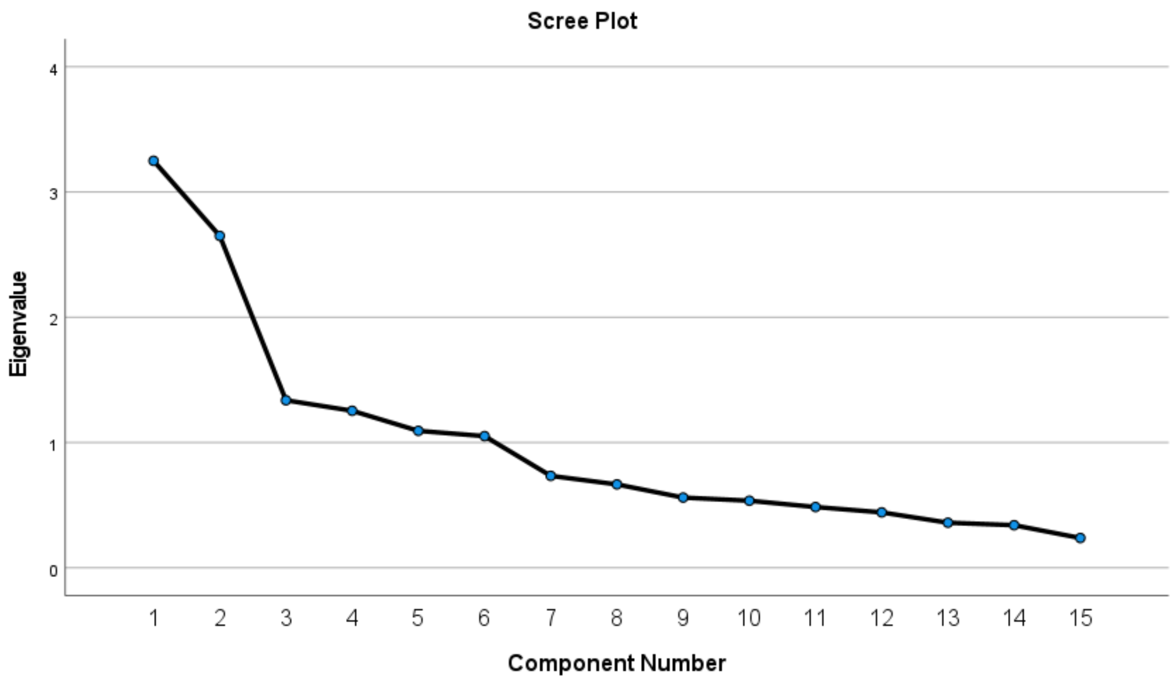
Extraction Method: Principal Component Analysis

[7] Monte Carlo PCA for Parallel Analysis http://edpsychassociates.com/Watkins3.html

However, inspection of the scree plot shows a clear break after component 2 as shown below (Figure 2):

Figure 2

Scree Plot for 6 factor solution, Adapted Perceptions of Maths Survey



In addition, Montecarlo PCA for Parallel Analysis resulted in a mean eigenvalue of 1.352 generated from a random PCA based on 20 items, a sample size of 136 with 500 iterations. The parallel analysis, as recommended by Tabachnick and Fidell (2014), suggests that the two component solution rather than the 6 component solution should be pursued.

Forcing a two component solution required further iterations of the PCA for several reasons. Communalities were now lower than 0.5 and, as can be seen from inspection of the 6 factor solution Component Matrix (Table 17), there is complex loading on a number of items which means the items needed to be removed and further iterations of the PCA carried out.

Table 17

Component matrix for 6 factor solution PCA POM 136 cases

Component Matrix[a]

	Component					
	1	2	3	4	5	6
Correct_ans	.497	.141	.086	.488	-.042	-.204
Understand_procedure	-.346	.469	.242	.226	-.174	-.467
Basic_no_calc	.166	.171	.125	.595	.179	.577
Deeply_ustd	-.162	.720	.030	.032	-.313	-.169
Recall_maths	.558	.095	-.166	.417	-.004	.163
Teacher_teach_steps	.672	.358	.222	-.173	-.072	.071
Many_fam_short_ans	.582	.346	-.462	-.074	-.188	.016
Connection_models	-.185	.596	-.616	-.060	.072	.009
Methods_step_by_step	.740	.313	.144	-.292	-.021	.090
Me_how_why	-.267	.592	.272	.177	-.414	.120
Deep_learn_new_probs	-.381	.575	-.045	-.298	.137	.221
One_best_way	.490	.081	.339	.053	.415	-.459
Small_gps	-.214	.461	.525	-.251	.346	.278
Follow_steps	.780	.115	-.049	-.306	-.002	-.041
Connect_by_multistep	-.184	.489	-.308	.181	.635	-.192

Extraction Method: Principal Component Analysis
[a] *6 components extracted*

Further iterations of the PCA were therefore carried out resulting in a two factor solution with two components which had eigen values greater than the mean of 1.352 arrived at through parallel analysis. The two factor solution had a KMO = .653 and significant Bartlett's test (p<.001). As mentioned in the analytic strategy, Direct Oblimin rotation was used to aid in the interpretation of the two components and the rotated solution showed a simple structure with all variables loading substantially on only one component as set out at Tables 18 and 19:

Table 18

Pattern Matrix for PCA POM survey

Component 1	
Teacher_teach_steps	*0.835*
Methods_step_bystep	*0.887*
Follow_steps	*0.808*
Component 2	
Understand_procedure	*0.727*
Deeply_ustand	*0.811*
Me_how_why	*0.788*

Extraction method: Principal Component Analysis
Rotation method: Oblimin with Kaiser Normalisation
(Rotation converged in 4 iterations)

Table 19

Communalities for final solution, PCA of Adapted POM survey

	Initial	**Extraction**
Understand_procedure	1.00	.575
Deeply_ustand	1.00	.670
Teacher_teach_steps	1.00	.705
Methods_step_by_step	1.00	.785
Me_how_why	1.00	.620
Follow_steps	1.00	.709

Extraction Method: Principal Component Analysis

Correlation between the two components is low at -.057 as can be seen on Table 20 which supports the conclusion that the two components are indeed distinct. Correlation between items varies between .023 and .624 and correlation between components, although low, is not zero, therefore oblique rotation was justified as orthogonal rotations constrain correlation to 0.00.

Table 20

Component Correlation Matrix for adapted POM survey

Component	**1**	**2**
1	1.00	-.057
2	-.057	1.00

Extraction Method: Principal Component Analysis
Rotation Method: Oblimin with Kaiser Normalization

The interpretation of the two components was consistent with the research carried out by Holm and Kajander (Holm & Kajander, 2012, 2020; Kajander, 2010a, 2010b; Kajander & Holm, 2013; Kajander & Mason, 2007) with Procedural mathematics teaching preference loading significantly on Component 1 and Conceptual mathematics teaching loading on Component 2.

A test of reliability was carried out on the three items of the Conceptual component resulting in a Cronbach's Alpha of .676. The reliability score for the three items of the Procedural component resulted in Cronbach's alpha of .803. The overall Cronbach's alpha for all 6 items was .562.

5.4 Analysis of POM results involving two different groups of teachers in two schools serving populations characterised by relatively high deprivation and relatively low deprivation.

With the underlying dimensionality determined, the POM was completed by two groups of staff, School A (n=21) serving an area with relatively lower deprivation and School B (n=11) serving an area with relatively higher deprivation. School B was the school used in the intervention set out in Study 3. Tabachnick and Fidell (2014) describe what they call simplistic methods of estimating factor scores and conclude that 'For many research purposes, this "quick and dirty" estimate of factor scores is entirely adequate' (Tabachnick & Fidell, 2014, p. 703). Factor scores, or in this case component scores, are an estimate of the score a subject would receive on each of the factors had they been measured directly. The scores are only estimates and in this case, rather than estimating the scores of each participant, the unit of interest is the school, so an estimate of the scores is calculated for each school by calculating the mean standardised score for the group of participants in school A and B respectively on the three items of Component 1 and Component 2.

At Table 21, School 1 is School A, less deprived, and School 2 is School B, more deprived. The three items listed at Table 21 correspond to the Component which can be described as a conceptual mathematics preference. Teachers in School A (labelled school 1), relatively less deprived pupil population, have positive mean standardised scores while it is notable that teachers in School B (labelled school 2) have negative standardised scores which may indicate a stronger preference for conceptual maths learning and teaching in the relatively less deprived school. The three items listed at Table 22 correspond to the component which can be described as a procedural maths preference. Based on the item scores, the distinction between the schools is less clear cut at component 2, with a positive scoring for two items at School A, compared to negative scoring at School B and vice versa for the third item.

Table 21

Mean z-score on each item of component 1 – conceptual maths

Descriptive Statistics			
School		N	Mean
1	Undertsand_procedure	21	.0234
	Deeply_ustand	21	.1016
	Me_how_why	21	.1533
2	Undertsand_procedure	11	-.0447
	Deeply_ustand	11	-.1939
	Me_how_why	11	-.2927

Table 22

Mean z-score on each item of component 2 – procedural maths

Descriptive Statistics			
School		N	Mean
1	Undertsand_procedure	21	.0713
	Deeply_ustand	21	.1004
	Me_how_why	21	-.0075
2	Undertsand_procedure	11	-.1361
	Deeply_ustand	11	-.1916
	Me_how_why	11	.0143

5.5 Discussion

The PCA supported a two component solution for the Perceptions of Mathematics survey which is consistent with the original understanding of the survey having a two factor structure as described by Kajander and Mason (2007). The two components are consistent with conceptual maths preference and a procedural maths preference. However, components with three items are generally considered to be weaker and potentially unstable (Costello & Osborne, 2005) with 5 or more desirable. The current POM has three items in each factor which may limit the possibility of generalisability, however three items are held to be adequate (Osborne et al., 2008).

Hypothesis 3 stated that teachers in schools characterised by relatively higher levels of deprivation are more likely to prefer procedural maths learning and teaching rather than conceptual maths learning and teaching as measured by the Perceptions of Mathematics (POM) survey for teachers. Overall, validation of the psychometric properties of the POM supported a two factor solution consistent with procedural and conceptual preferences. Although the sample size was small and lacking in statistical power, the two groups of teachers, one from a relatively affluent school and the other from a school characterised by high levels of deprivation, showed a difference in their preferences in the component relating to conceptual mathematics. Staff in School A, with significantly less deprivation, had overall mean standardised scores which were all positive while staff in School B, with high levels of deprivation had overall mean standardised scores which were all negative. Scores on the component associated with procedural maths were more variable and difficult to interpret.

Taking into account the small number of participants and unequal group sizes, it is difficult to reach a definitive conclusion, however, the results of the POM survey involving two groups of staff appear to partially support Hypothesis 3, that teachers teaching children in a less deprived school have a stronger preference for conceptual mathematics. However, the differences in relation to procedural maths are less clear but worthy of further exploration.

5.6 Limitations and future research

The obvious limitation in this study for both the validation study and the comparison of two groups of teachers is the small sample size. In part this is due to the context since the study had to be carried out entirely remotely due to Covid restrictions. Nevertheless, the validation study is close to a sufficient sample size but, as with all exploratory factor analyses, more participants would improve reliability. The comparison of two groups of teachers suffers significantly from the sample size and is more an indication of what could be done using the POM Survey in future. Caution therefore needs to be exercised when generalising from the study or using the POM survey. Nevertheless, it serves to strengthen the original research carried out by Kajander and Mason (2007).

The Perceptions of Maths survey was used with teachers who were all mainstream primary teachers and no demographic data were collected. Future research may include repeating the survey with a larger sample size and a broader range of demographic data such as length of time in teaching; gender; stage taught; highest level of mathematics attained. With a broader range of demographic data it may be possible to explore in more detail the extent to which teachers prefer procedural or conceptual teaching and what the characteristics are of those teachers. In addition, a larger sample size and more diverse group of teachers may allow for more detailed item analysis to take place (Reise et al., 2005).

The Study exploring the extent to which teachers hold maths values that are mainly conceptual or procedural was about the extent to which teachers influence the values children hold about themselves as learners. Children's values are also shaped by their home environment and community. The next Study explores the extent to which it is possible to influence positively the values children hold about themselves as learners with a view to mitigating negative views about themselves as learners and about maths as a subject with a view to improving their attainment.

Chapter 6: Study 3 - Maths paired learning intervention designed to improve lower SES children's attitude to maths

6.1 Introduction

Children from relatively more deprived backgrounds have poorer outcomes in mathematics for a variety of reasons which are related to family, neighbourhood, school and individual level issues as outlined at sections 2.1 to 2.4. The purpose of the current study is not only characterising the connection between relative poverty and outcomes in maths, but also to focus on feasible interventions an educational psychologist may propose which a school can implement in order to mitigate the effects of social and economic disadvantage. The intervention needs to be feasible and deliverable in a normal, busy primary school environment. To that end, criteria for potential interventions may include that they are familiar, easily understood and easily implemented with minimal intervention from the educational psychologist. A systematic review and meta-analysis of interventions for lower SES learners found an average effect size of 0.05 for psychological interventions and 0.22 for cooperative learning (Dietrichson et al., 2017; Dietrichson et al., 2021). Despite a relatively low average effect size for psychological interventions, the systematic review demonstrated that it is possible to mitigate the impact of relative deprivation through well-designed interventions involving cooperative learning and including psychological variables. Such psychological variables include attitude to maths, anxiety about maths and associated to both is motivation to learn, all precursors to and predictors of learning and outcomes in maths (Alegre et al., 2019a).

Central to any discussion on motivation to learn is Bandura's core position that 'the beliefs people hold about their capabilities and about the outcomes of their efforts powerfully influence the ways in which they behave' (Bandura, 1977; Usher & Pajares, 2008, p. 751). Bandura's core position on motivation and learning is developed further in expectancy value theory (EVT) (Fielding-Wells et al., 2017; Wigfield & Eccles, 2000) and the more recent situated expectancy value theory (SEVT)(Eccles & Wigfield, 2020). Wigfield and Eccles (2000) established empirically that children's beliefs about their ability in a specific academic domain, their expectancy of success and the value they placed on a task have a significant impact on their likelihood of success and overall attainment in the specific academic domain. They concluded that:

> *even when previous performance is controlled, children's beliefs about their ability and expectancies for success are the strongest predictors of subsequent grades in math, predicting those outcomes more strongly than either previous grades or achievement values* (Wigfield & Eccles, 2000, p.77).

In his original work, Bandura (1977) established a central role for self-efficacy in determining outcomes for individuals. Efficacy expectations, he indicated, are estimates that a behaviour will lead to an outcome while outcome expectations are the conviction the individual has that they can execute successfully the behaviour needed to produce outcomes. The former therefore is the belief that the behaviour will achieve an outcome and the latter is the belief that I am capable of the behaviour (Bandura, 1977). It is important to note that Bandura also stated that expectation alone is not enough if the basic competence is not there. However, with skills and motivation, expectations become a major influence of choices, effort and persistence. In the present context, the focus is on expectations a child has which will make a difference when learning maths. It is also worth noting, that Bandura argued that self-efficacy measures should be subject specific rather than generalised (Kirschner & Hendrick, 2020).

Meece et al. (1990) concluded that subject specific measures of self-efficacy are a strong predictor of attainment. Wigfield and Eccles (2000) go beyond expectancy, which is closely aligned to Bandura's efficacy, and explore value. They distinguish attainment value which is the importance of doing well on a task; intrinsic value which is enjoyment of the task; and utility value which is the way in which the task fits into the individual's future plans and is closely related to cost. Cost involves the decision on whether or not to engage in the activity and the extent to which engaging limits opportunities for other activities as well as the emotional cost to the individual.

Wigfield and Eccles (2015) carried out longitudinal studies to test EVT, initially suggesting that expectancies for success, subjective task values and academic self-concept are indistinguishable in their analysis. More recently however, in the context of SETV, they reach the view that it would have been possible through careful analysis to distinguish the two (Eccles and Wigfield, 2020).

The key point however in both the work of Bandura (1977) and the subsequent work of Wigfield and Eccles (2015) is that outcomes can be influenced by an individual's beliefs about themselves and their expectation of success as well as the value they place on a particular task or challenge. The difference between EVT and SEVT is that SEVT takes greater account of the many messages children receive from various socialisers including their family, school, teacher and crucially in the current context, their peers. Wigfield and Eccles (2015) conclude that further research might usefully focus on aspects of the classroom 'that support feelings of competence, connectedness, and autonomy' (Wigfield and Eccles, 2015, p.9). Indeed their research supports connections between changing children's experiences in the classroom resulting in changes for better and for worse in children's academic self-concept, expectancies for success and subjective task values. Finally they indicate that further work is needed on other social influencers such as media, culture and crucially, peers.

Tosto et al. (2016) also found that maths self-efficacy was the strongest predictor of achievement in maths and recommended identifying environmental mechanisms for enhancing maths self-efficacy as a research priority. Self-efficacy beliefs in maths problem solving were found to be more predictive of actual problem solving than maths self-concept, beliefs on utility of maths, prior experience or gender (Pajares & Miller, 1994). Similarly, Putwain et al. (2021) focusing on the achievement emotions of control and value found that higher control and value were related to higher maths scores and reduced anxiety. Crucially, they suggest that 'control and value are malleable and, when enhanced, can have downstream benefits for achievement' (Putwain et al., 2021, p.362). Approaching the same issue from an evolutionary perspective, Hentges et al. (2019) reached the same conclusion that interventions to target children's perceived 'cost' of learning maths can have a positive impact. Of particular relevance is the fact that Hentges et al (2019) focus on children living in relative economic disadvantage.

However, just as there are critics of Bandura who claim for example that self-efficacy can have neutral or negative effects (Tryon, 1981), so there are critics of the multiplicity of concepts and constructs in expectancy value theory. Marsh et al. (2019) distinguish between test related self-efficacy and functional self-efficacy, claiming that although there are various self-belief constructs such as generalised self-efficacy, outcome expectations, and self-concepts, these are indistinguishable with correlations mostly greater than .9. Despite their critique, they still conclude that self-concept that is domain specific rather than generalised can be used to operationalise the expectancy construct in Bandura and in expectancy value theory.

In relation to specific interventions, Moliner and Alegre (2020) focus on the psychological effects of a peer tutoring intervention. In a review of 22 studies focused on psychological variables such as self-concept, anxiety and attitude, they found that 16 of the studies reported improvements in psychological variables with the greatest improvement found in self-concept. In addition, they found that reciprocal tutoring, that is tutoring where peers alternate being tutored and taking on the role of tutor, had more positive effects at an overall level compared to fixed peer tutoring, that is where normally an older child takes on the role of tutor with a younger child. Moliner and Alegre (2020) concluded that peer tutoring is potentially beneficial at primary school level in mathematics from a psychological perspective.

Situated expectancy value theory very usefully therefore incorporates the psychological as well as social and cultural factors which influence children's outcomes in primary school level maths (Fielding-Wells et al., 2017) and also explains learning in game based environments (Rachmatullah et al., 2021).

The following intervention therefore is rooted in Eccles and Wigfield's situated expectancy value theory aimed at promoting children's self-concept as maths learners through a reciprocal peer-assisted games based learning intervention (Eccles & Wigfield, 2020).

The approach takes account of the view expressed that too many interventions have focused on utility value and not enough on other constructs in the model such as interventions aimed at improving learners' intrinsic value of maths, perceived cost, expectancies for success and ability beliefs or combinations of these situated expectancy value constructs (Rosenzweig et al., 2022). Rosenzweig et al. (2022) recommend targeting competence related beliefs which are likely to affect performance and achievement as early as elementary school in order to help children learn strategies for self-regulated learning and experience success to help them learn that abilities can always improve.

Hypothesis 4 therefore is that, in line with Eccles and Wigfield's situated expectancy value theory, using the Myself As A Learner Scale (MALS) (Burden, 1999) and Mathematics Attitude and Anxiety Questionnaire (MAAQ)[8] as measures, a peer-assisted, games-based learning intervention will improve children's attitude to maths; reduce maths anxiety; and improve self-concept as a learner.

6.2 Method

6.2.1 Inclusion and exclusion

Inclusion criteria for the study were that the participants attended the Scottish local authority primary schools in the overall study and were at the Primary 5 stage (age 8 and 9). The two primary schools included were selected on the basis that the majority of the children in the school were entitled to free school meals and that the school served a majority of families who lived in Decile 1 and 2 data zones of the Scottish Index of Multiple Deprivation. No children included were care experienced, that is none was currently nor had been under a statutory or voluntary supervision order (Scottish Government, 2011). In addition to the aforementioned criteria, one of the schools was required to have two classes at the Primary 5 stage in order to have a control group. Once two schools had been selected which met the criteria, no children were excluded and all who were in attendance were able to participate.

6.2.2 Participant characteristics

All participants (n=61) were children at the Primary 5 stage of two primary schools in one local authority. Demographic data were not collected relating to the children

[8] Mathematics Attitudes and Anxiety Questionnaire (MAAQ) - Oxford University Innovation

as the inclusion criteria only included that they were at the particular stage in a mainstream primary school. The total number of participants was 61, of whom 34 were male and 27 female.

6.2.3 Sampling procedure

Once the criteria for inclusion and exclusion had been identified as set out above, two schools met the criteria. One school was the most deprived in the local authority as measured by free school meal entitlement and number of children living in Decile 1 and 2 data zones of the SIMD. The other school, although not scoring as high for deprivation, was a school located within 1 km of the first school and had two classes at the Primary 5 stage. The percentage of children entitled to free school meals in the second school was well above the local authority and national average and the two Primary 5 classes were representative of the school as a whole. All children in the three classes were able to participate, although some were absent at T1 and T2 when the MAAQ and MALS were administered. During the intervention, Covid 19 infection rates were particularly high. Data were collected in the schools at January 2022 and April 2022 with the intervention taking place between January and April 2022. The data were collected in person by the researcher using paper and pencil questionnaires (MAAQ and MALS) (Appendix C and Appendix D) administered to each class as a group with the class teacher present. The study was approved by the University of Strathclyde School of Psychological Sciences and Health ethics committee (Appendix E). Gatekeeper consent was provided by the head teachers in both schools and opt-in parental consent was sought for all participants and verbal consent sought from participants before the start of the intervention following a verbal briefing by the class teacher

6.2.4 Sample size, power and precision

The total number of potential participants was 70, however due to higher than average absence rates at T1 and T2 the total number of participants was 66 with only 61 eligible for the analysis. G Power analysis (Faul et al., 2007) using version 3.1.9.4 was carried out for fixed model R^2 deviation from zero. Using an expected effect size of $\rho^2 = .15$; $\alpha = .05$ and Power = 0.80 with 3 predictor variables, G Power analysis indicated that an initial sample size of 77 was required. Given the sample in the present study is 61, caution needs to be exercised in generalizing the results.

6.2.5 Measures and covariates

Primary measures collected were the results of the MAAQ and the MALS. Both were collected at T1 and T2 with timepoint by group membership (intervention v control) and timepoint by gender analysed. In addition, qualitative data were collected which will be set out at Study 4 and are not reported in this study.

6.2.6 Data collection

The MAAQ was printed for participants and set out using the answer sheet provided by Oxford University Innovation Limited (Appendix C) consisting of symbols which were age appropriate for 8 year old children. The symbols used included ticks and crosses, faces with smiles or frowns, wasps and sweets, with all the symbols set out horizontally in a Likert type sequence. The MALS was similarly set out using only faces with smiles and frowns in a Likert type horizontal sequence for each of the 20 items. The surveys were issued over the course of two days by the researcher to each of the three class groups in their own classroom both at T1 and T2. Attendance varied over the two days which is why there are different participant numbers for the MAAQ and the MALS. The decision to use symbols rather than written codes such as strongly agree, agree, was taken in consultation with the class teachers and took account of the literacy levels of the participants. The surveys were distributed and the researcher took the class through each item and explained the possible responses. The pre-intervention (T1) data were collected in January 2022 at a point when Covid 19 levels were high. The intervention then started two weeks later and continued for 6 weeks. Following a two week school holiday period, the MAAQ and MALS were completed again at T2 in April 2022 in the same format as at T1. Completion of the surveys at T1 and T2 was carried out by the researcher following the same format, removing the possibility of variation between data collectors.

6.2.7 Instrumentation

The MAAQ is used under license from Oxford University Innovation[9] and is a survey which includes 28 items focused on seven domains aimed at measuring the respondents' views of maths. The seven domains are:

[9] Mathematics Attitudes and Anxiety Questionnaire (MAAQ) - Oxford University Innovation

1. Maths in general
2. Written maths calculations
3. Mental maths calculations
4. Easy maths
5. Difficult maths
6. Maths assessments
7. Understanding the teacher

The participants are asked the same 4 questions for each of the 7 domains:

1. *How good are you?* which is a self-report question answered using the symbols of ticks and crosses ranging from very good to very bad.
2. *How much do you like?* which is rated using symbols for wasps and sweets ranging from like very much to hate very much.
3. *How worried are you about?* which relates to anxiety and is answered using facial expressions from very relaxed to very worried.
4. *How happy are you about?* which uses frowning or happy faces rating from very unhappy to very happy.

Krinzinger et al. (2009) report the results of a standardisation study they carried out on the MAQ as it was referred to at the time. The original MAQ was developed by Thomas and Dowker (2000)[10] and reported at a British Psychological Society conference in 2000. However their original study does not appear to be published, only the validation study by Krinzinger in 2007 as reported in Krinzinger (2009). The 2007 Krinzinger study is only available in German, but as reported in Krinzinger (2009), the Cronbach's alpha measuring internal consistency of the MAQ ranged between .83 and .9 depending on the age of participants. The MAQ is aimed at 6-9 year old children and the analysis reported led them to conclude that the first two questions in the MAQ related reliably to general maths attitudes while the second two questions reliably related to anxiety about maths.

[10] Thomas, G. & Dowker, A. (2000) Mathematics and anxiety related factors in young children: Paper presented at British Psychological Society Developmental Section Conference, Bristol, September

The *Myself-As-Learner Scale* (MALS) (Burden, 1999) is aimed at measuring general academic self-concept in children aged 9-16. It is a 20 item scale with a five point Likert type scale for respondents to choose from. The five point scale ranges from definitely agree to strongly disagree. The statements can be read to a group to avoid any literacy difficulties and to ensure respondents understand the five negatively worded items. Details of the standardisation and validation process were published by Burden in 1998 and showed internal reliability using Cronbach's alpha of 0.85 (Burden, 1998).

6.2.8 Conditions and design

The experimental manipulation involved a peer-assisted games-based learning intervention where children took part in three 20 minute sessions a week of games based peer-assisted learning over a six week period, total dosage being 6 hours. The unit of assignment was the class group that children belonged to, with three class groups in total taking part (n=61). Two of the class groups were the intervention groups and one of the class groups was a control group who followed their normal maths programme but did not take part in the peer assisted games based learning. The choice of control group was randomly based on teacher availability. One of the two class teachers in the two-stream school was absent at the start of the intervention and could not take part in briefings related to the intervention, therefore her class became the control group. At T1, participants were all equally unaware of the nature of the intervention. At T2 the intervention groups were aware that they had been part of the games based learning and the control group were not informed but are likely to have been aware of the intervention through contact with their peers in the school. Their teacher was aware that the games were going to be made available to the control group after the intervention concluded.

6.3 The Intervention

The two class teachers involved in the intervention group were given a verbal briefing as well as written instructions (Appendix E, Annex 13) on the nature of the intervention and how to implement the games based peer assisted learning. They were given freedom to decide the three points over the course of the week they would carry out the 20 minute sessions. Reciprocal peer-assisted learning involves children taking turns at being the tutor then being the tutee in alternate sessions. The tutors and tutees were children from within the same class because Covid restrictions meant that children could not mix with other classes.

As well as teachers having freedom to choose the timing of the three 20 minute slots, they were given freedom to choose the pairings for the peer assisted activities. The pairings were carefully chosen by the teachers to take account of ability levels of the children and social compatibility. Children were given a briefing by the class teacher and a script was provided to ensure consistency (Appendix E, Annex 8). The teachers introduced the games to the children and allowed time for the children taking on the role of tutor to familiarise themselves with the games in advance of the peer assisted learning session. In this way the child acting as tutor was more able to the extent that they introduced the game to their tutee and demonstrated how to play it. The teachers took overall responsibility for processes such as identifying who would be the tutor, who would be the tutee to ensure a balanced and fair approach to taking on the role of tutor and tutee. Staff generally only intervened where asked to by the children.

Children were also provided with simple instructions for each of the games (Appendix E, Annex 15) all of which were commercially available off the shelf games (Appendix E, Annex 2). The games chosen focused on numerical operations including adding, subtracting, multiplying and dividing as well as simple mental manipulations involving mathematical thinking. As such the games focused on developing procedural maths skills as opposed to conceptual maths. The focus of this intervention however was on psychological variables in children such as attitude and anxiety which may impact on children's perseverance and attainment rather than on teachers' attitudes and beliefs.

After the MALS and MAAQ had been administered around mid-January 2022, the class teachers were free to choose when to start the intervention, and both started mid-February. The expectation was that the intervention would be complete by the school holiday break at the end of March 2022. Both intervention classes completed three sessions per week over a continuous six week period meaning dosage was 6 hours each class. The MALS and MAAQ were then administered at T2 which was around mid-April, one week after the school holiday and three weeks after the final games based learning session.

6.3.1 Implementation fidelity

The overall purpose of the intervention was to try and identify whether or not peer-assisted games-based learning was likely to improve children's attitude to maths and reduce maths anxiety. The intervention was taking place in the real world, so it was important that the intervention was not strictly directed by the researcher. The researcher briefed the teachers involved before the intervention and arranged online discussions with the teachers to check for any problems and answer any queries. Two online meetings took place during the intervention period to provide support and remind the teachers of the purpose and aims of the intervention as well as address any practical issues arising.

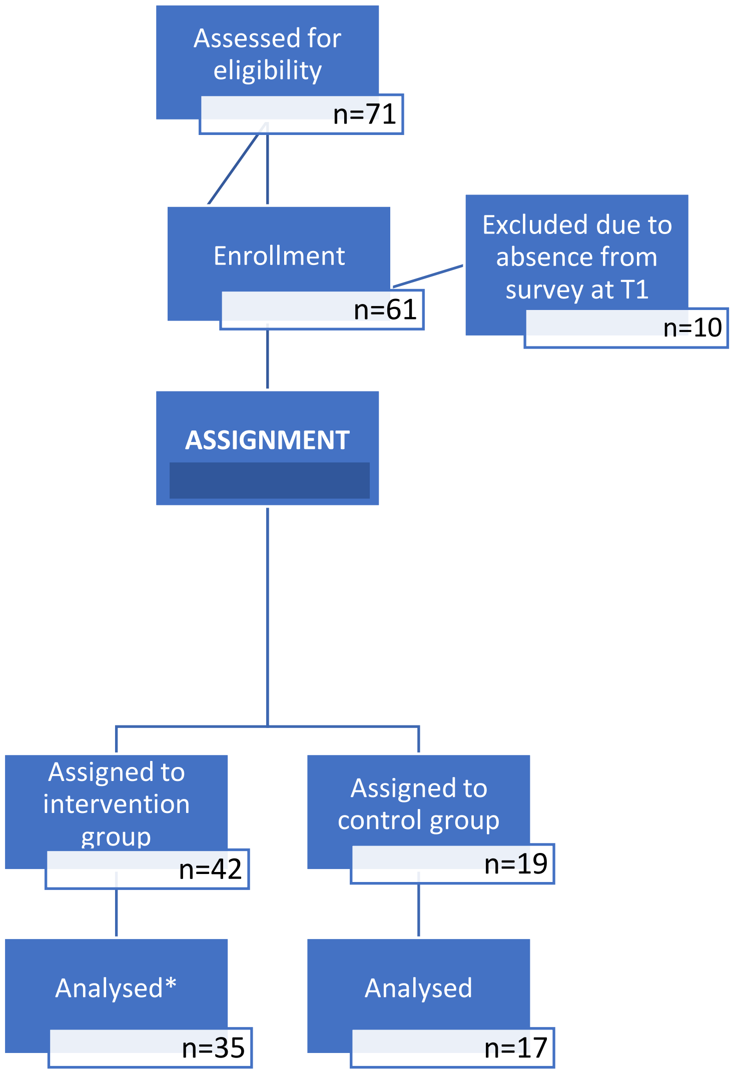
6.3.2 Data diagnostics

Regression analysis was used to determine any effect with time, gender and group membership (intervention or control group) as predictor variables and scores on MALS and MAAQ as outcome variables. Missing value analysis was carried out with multiple imputation being used in the event of more than 5% of cases missing values.

6.4 Results: MAAQ

6.4.1 Maths Attitude and Anxiety Questionnaire

Figure 3: Participant flow – Maths Attitude and Anxiety Questionnaire



*52 in whole case sensitivity analysis, 61 analysed using multiple imputation for missing T2 values.

6.4.2 Missing value analysis

Due to high participant absence as a result of Covid, nine children who completed the surveys at T1 were absent at T2. Children completing at T2 who did not have T1 scores were discounted from the analysis and were counted among the 9 in total excluded (Table 23). Table 23 shows the pattern of missing values:

Table 23

Overall summary of missing values

	Variables	Cases	Values
Complete data	3 (75%)	52(85.25%)	235(96.3%)
Incomplete data	1(25%)	9(14.75%)	9(3.7%)

As can be seen at Table 23, 14.75% of values are missing and these have the characteristics set out at Table 24:

Table 24

Missing data profile

Tabulated Patterns												
		Missing Patterns[a]					***SCHOOL***[d]		***GENDER***[d]		***GROUP***[d]	
	School	Gender	Group	Total_post	Complete if...[b]	Total_post[c]	SchoolA	SchoolB	F	M	1	2
Number of cases												
52					52	99.04	15	37	22	30	35	17
9				X	61		6	3	6	3	7	2

[a] Variables are sorted on missing patterns
[b] Number of complete cases if variables missing in that pattern (marked with X) are not used
[c] Means at each unique pattern
[d] Frequency distribution at each unique pattern

The missing values are evaluated as missing at random due to Covid related school absence. The proportions missing from each school are similar at around 15% although a slightly higher proportion is missing from the intervention group at around 16% as opposed to 10.5% of the control group. A higher proportion of girls are missing compared to boys overall. Analysis of the pattern of missing values suggested it was appropriate to carry out multiple imputation for missing values based on intention to treat (Gorard, 2020; White et al., 2011). Multiple imputation was carried out with 10 imputations of the T2 scores using all school, group, gender and T1 scores as predictors.

6.4.3 Descriptive statistics

Pooled data from the multiple imputation will be reported rather than data for each imputation unless there is a reason for reporting a specific imputation. Table 25 below shows mean scores at T1 and T2 for the intervention group (Group 1) and the control group (Group 2), including the original scores and the pooled scores from 10 imputations.

Table 25

MAAQ descriptive statistics, mean scores for group by timepoint with imputations (Group 1= intervention group; Group 2= control group)

Imputation	**Group**	**Timepoint**	**Mean**	**SD**	**N**
Original data	1	T1	97.46	18.33	35
		T2	101.63	17.86	35
	2	T1	98.35	22.40	17
		T2	93.71	16.78	17
Pooled	1	T1	96.36		42
		T2	100.88		42
	2	T1	95.37		19
		T2	91.52		19

Table 26 below shows descriptive statistics including mean scores of the interactions by gender as well as timepoint. Figure 4 sets out the mean scores by gender for the intervention group (1) and control group (2) at T2 with 95% confidence intervals.

Table 26

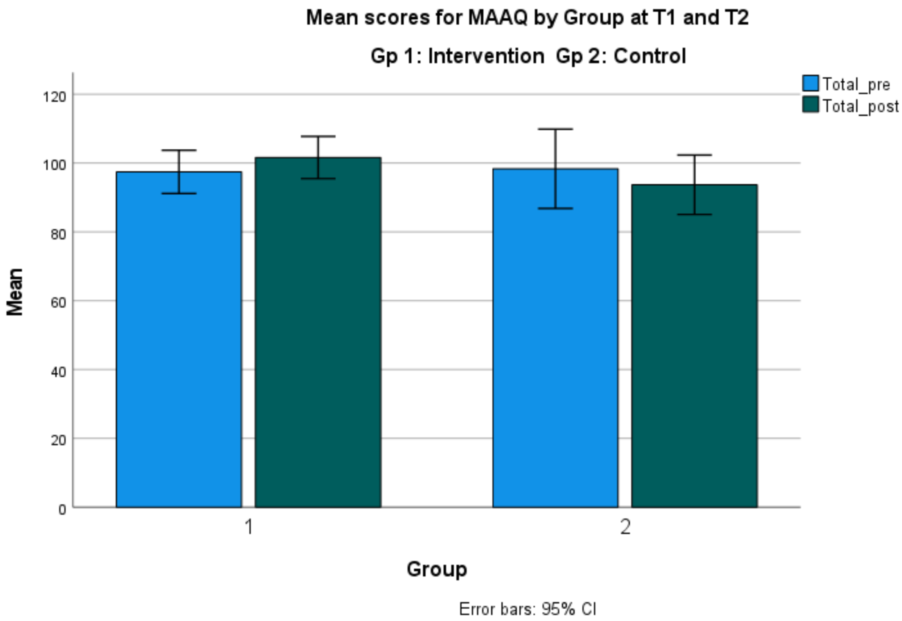
MAAQ descriptive statistics – Mean scores for MAAQ, gender by timepoint by group, original and multiple imputation

				Mean	**Std. Error**	**95% Confidence Interval**		**Fraction Missing Info.**	**Relative Increase Variance**	**Relative Efficiency**
Imputation Number	Group[a]	Gender	Timepoint			Lower Bound	Upper Bound			
Original data	1	F	1	90.72	4.37	81.94	99.51			
			2	94.44	3.87	86.66	102.23			
		M	1	104.59	4.50	95.55	113.63			
			2	109.24	3.98	101.23	117.24			
	2	F	1	82.75	9.27	64.11	101.39			
			2	84.00	8.21	67.49	100.51			
		M	1	103.15	5.14	92.81	113.49			
			2	96.69	4.55	87.54	105.85			
Pooled	1	F	1	91.73	4.17	83.54	99.91	0.00	0.00	1.00
			2	95.51	3.76	88.13	102.89	0.06	0.06	0.99
		M	1	101.45	4.38	92.87	110.03	0.00	0.00	1.00
			2	106.78	3.89	99.15	114.41	0.03	0.03	1.00
	2	F	1	78.50	7.99	62.83	94.17	0.00	0.00	1.00
			2	80.31	7.56	65.44	95.17	0.15	0.17	0.99
		M	1	103.15	5.43	92.51	113.80	0.00	0.00	1.00
			2	96.69	4.75	87.38	106.00	0.00	0.00	1.00

[a] Group 1 – intervention group; Group 2 – Control Group

Figure 4

Mean scores for the Intervention Group (1) and Control Group (2) at T1 and T2



6.5 Hierarchical multiple regression analysis

6.5.1 Preliminary analysis

Tabachnick and Fidell (2014) suggest a rule of thumb sample size formula of 50+8 times the number of independent variables which in this case would be a required sample size of 74 cases. Although the original survey population was 71, the number used in the analysis including multiple imputation was 61, which suggests caution should be exercised when generalising from this analysis. A check for outliers using Mahalonabis distance with a critical Chi Square value of 16.266 (Tabachnick and Fidell, 2014) indicated no issues with the highest value reaching 11.27. The highest Cooke's distance was .009 also suggesting no issues. None of the IVs showed a correlation above .3 which is lower than the threshold of .7 at which there is concern for multicollinearity or singularity (Pallant, 2020). Checks for multicollinearity using VIF greater than 10 and Tolerance less than .10 indicated no issues. An examination of the residuals scatterplots also gave no cause for concern and so, with the exception of sample size, the data were considered appropriate for hierarchical multiple regression.

6.5.2 Regression analyses (MAAQ)

Regression analysis explored the effects of timepoint (with T2 as DV and T1 as covariate) and both group and gender as covariates. Hierarchical regression analysis was carried out using T2 scores as the dependent variable with T1 scores added as covariate at Block 1; T1 and Group added as covariate at Block 2; and T1, Group and Gender added as covariate at Block 3. Group significantly improved the fit of the model ($F(1, 49) = 9.085$; $p=.004$) while Gender did not significantly improve the fit ($F(1,48) = 1.053$; $p=.310$). Table 27 summarises the results of the hierarchical regression analyses and includes the multiple imputation data because Model 3, which includes gender, was significant at imputation 3.

Table 27

Model summary hierarchical regression analysis of MAAQ scores with multiple imputation – timepoint, group, gender

***Model Summary*[d]**

Imputation Number		**R**	**R Square**	**Adj. R Square**	**Std. Error of the Estimate**	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
Original data	1	.815[a]	0.664	0.657	10.388	0.664	98.85	1	50	0.000
	2	.847[b]	0.717	0.705	9.638	0.053	9.085	1	49	0.004
	3	.850[c]	0.723	0.705	9.633	0.006	1.05	1	48	0.310
1	1	.834[a]	0.695	0.690	10.425	0.695	132.2	1	58	0.000
	2	.863[b]	0.746	0.737	9.605	0.051	11.32	1	57	0.001
	3	.868[c]	0.754	0.741	9.534	0.008	1.85	1	56	0.179
2	1	.829[a]	0.688	0.682	10.331	0.688	129.9	1	59	0.000
	2	.865[b]	0.748	0.739	9.367	0.060	13.76	1	58	0.000
	3	.868[c]	0.753	0.740	9.345	0.006	1.28	1	57	0.262
3	1	.746[a]	0.556	0.549	11.850	0.556	73.96	1	59	0.000
	2	.791[b]	0.625	0.612	10.982	0.069	10.69	1	58	0.002
	3	.813[c]	0.661	0.643	10.538	0.036	5.998	1	57	0.017
4	1	.835[a]	0.697	0.692	10.300	0.697	135.7	1	59	0.000
	2	.859[b]	0.738	0.729	9.657	0.041	9.13	1	58	0.004
	3	.861[c]	0.741	0.727	9.692	0.003	0.57	1	57	0.451
5	1	.819[a]	0.671	0.665	10.453	0.671	120.3	1	59	0.000
	2	.849[b]	0.722	0.712	9.699	0.051	10.53	1	58	0.002
	3	.852[c]	0.725	0.711	9.722	0.004	0.727	1	57	0.398
6	1	.833[a]	0.695	0.689	10.439	0.695	134.1	1	59	0.000
	2	.856[b]	0.732	0.723	9.861	0.037	8.110	1	58	0.006
	3	.856[c]	0.733	0.719	9.927	0.001	0.233	1	57	0.631
7	1	.830[a]	0.689	0.684	9.873	0.689	130.7	1	59	0.000
	2	.860[b]	0.739	0.730	9.125	0.050	11.08	1	58	0.002
	3	.863[c]	0.744	0.731	9.107	0.005	1.22	1	57	0.273
8	1	.840[a]	0.705	0.700	10.721	0.705	140.9	1	59	0.000
	2	.868[b]	0.754	0.745	9.875	0.049	11.53	1	58	0.001
	3	.872[c]	0.761	0.748	9.826	0.007	1.58	1	57	0.214
9	1	.837[a]	0.701	0.696	10.175	0.701	138.5	1	59	0.000
	2	.863[b]	0.744	0.735	9.496	0.043	9.735	1	58	0.003
	3	.868[c]	0.753	0.740	9.415	0.009	2.01	1	57	0.162
10	1	.811[a]	0.658	0.652	10.765	0.658	113.6	1	59	0.000
	2	.855[b]	0.730	0.721	9.643	0.072	15.53	1	58	0.000
	3	.863[c]	0.745	0.731	9.461	0.015	3.25	1	57	0.077

a. Predictors: (Constant), Total_pre
b. Predictors: (Constant), Total_pre, Group
c. Predictors: (Constant), Total_pre, Group, GENDER=M
d. Dependent Variable: Total_post

Table 27 shows as expected that at Model 1, T2 scores are predicted from T1 scores. Given the fact that the majority of the children completing the surveys were the same at T1 and T2, it is to be expected that the relationship would be significant. However, Model 2 includes Group as part of the model and significantly improves the fit of the model. R^2 = .664 for Model 1 and R^2 = .717 for Model 2, indicating that group membership significantly improves the overall fit of the data, explaining a further 5.3% of the variance. However, for gender R^2 = .723, suggesting gender explains 0.6% of the overall variance and does not add significantly to the fit of the model.

Table 28 sets out the coefficients from the regression models and once again shows that gender does not significantly improve the fit of the data with non-significant t-tests in Model 2 and 3 for gender.

Table 28

Coefficients for Hierarchical Multiple Regression – original data and pooled data from 10 imputations of MAAQ

Coefficents[a]

			Unstandardised coefficients		**Standardised coefficients**			**95% Confidence interval for B**		**Correlations**			**Collinearity Statistics**	
	Model		B	Std Error	Beta	t	Sig.	Lower	Upper	Zero-order	Partial	Part	Toler-ance	VIF
Original data	1	(Constant)	26.68	7.42		3.60	.00	11.78	41.58					
		Total pre	0.74	0.07	0.81	9.94	.00	0.59	0.89	0.81	0.81	0.81	1.00	1.00
	2	(Constant)	37.64	7.78		4.83	.00	21.99	53.28					
		Total pre	0.74	0.07	0.82	10.78	.00	0.61	0.88	0.81	0.84	0.82	1.00	1.00
		Group	-8.59	2.85	-0.23	-3.01	.00	-14.32	-2.86	-0.21	-0.40	-0.23	1.00	1.00
	3	(Constant)	39.83	8.07		4.94	.00	23.61	56.05					
		Total pre	0.72	0.07	0.79	9.57	.00	0.57	0.87	0.81	0.81	0.73	0.85	1.17
		Group	-9.43	2.96	-0.25	-3.18	.00	-15.39	-3.47	-0.21	-0.42	-0.24	0.92	1.08
		Gender	3.12	3.04	0.09	1.03	.31	-2.99	9.22	0.32	0.15	0.08	0.79	1.26
Pooled	1	(Constant)	27.38	7.91		3.46	.00	11.66	43.10					
		Total pre	0.74	0.08		9.22	.00	0.58	0.89	0.82	0.82	0.82		
	2	(Constant)	39.57	8.69		4.56	.00	22.57	56.88					
		Total pre	0.73	0.08		9.66	.00	0.58	0.88	0.82	0.84	0.82		
		Group	-8.94	2.85		-3.14	.00	-14.54	-3.35	-0.25	-0.40	-0.23		
	3	(Constant)	41.35	9.14		4.52	.00	23.05	59.65					
		Total pre	0.70	0.08		8.33	.00	0.53	0.87	0.82	0.82	0.74		
		Group	-9.69	3.00		-3.23	.00	-15.59	-3.79	-0.25	-0.42	-0.24		
		Gender	3.41	3.19		1.07	.29	-2.91	9.74	0.30	0.16	0.09		

[a]Dependent Variable: Total_post

In conclusion, analysis of the Mathematics Attitude and Anxiety Questionnaire results at T1 and T2 suggest that there was a small positive effect related to the intervention which can be determined by Group status, i.e. intervention or control group and cannot be accounted for by gender which was not a significant factor despite there being clear differences in gender scores overall.

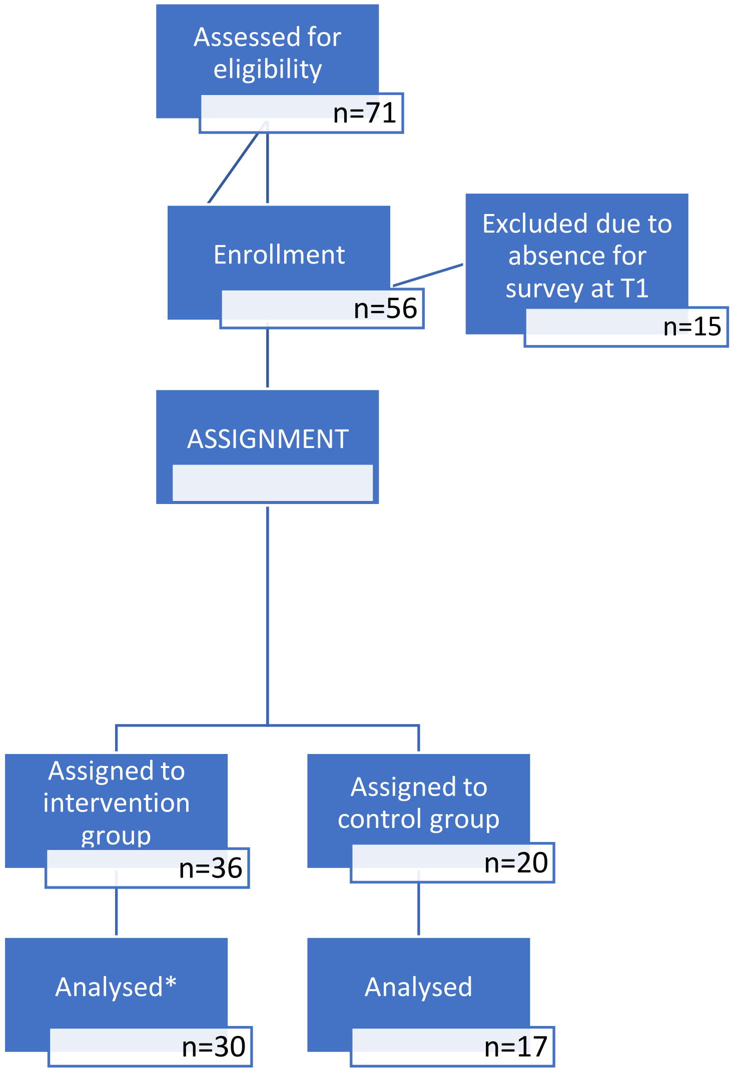
Whole case sensitivity analysis is provided in the analysis of the original data provided at Table 27 above. Research involving longitudinal intention to treat studies found that a single imputation or complete cases analysis could be sensitive to missing data and provide poor estimates of a treatment effect (Yamaguchi et al., 2018). However, the complete cases analysis of the MAAQ data suggests that there is no large difference with the multiply imputed results as can be seen at Table 27. With the exception of imputation 8, where the gender effect is significant, there is only a slightly stronger effect as a result of each imputation for timepoint by group.

6.6 Results: MALS

6.6.1 Myself As A Learner Scale (MALS)

Figure 5

Participant Flow Myself As A Learner Scale



*Whole case sensitivity analysis of the 47 cases present at T1 and T2 with 9 cases who were absent at T2 being imputed through multiple imputation.

Table 29

Participant Characteristics – MALS

	Gender		**Group**		**School**	
	Male	Female	Intervention	Control	A	B
N	29	27	36	20	41	15

Table 30

Missing Value Analysis: MALS

	Gender		Group		Class			School	
	M	F	Intervention	Control	P5B	P5Ja	P5Jb	School A	SchoolB
Number	5	4	6	3	4	2	3	5	4
%	14.7	12.9	14.3	13	17	8	13	10.9	21

The pattern of missing data set out at Table 30 suggested it was missing at random but not completely at random. It was at random due to missingness principally being about school absence caused by high levels of Covid19 infections. However, it is not completely at random as there appear to be more missing from School B proportionately and fewer missing from class P5Ja proportionately. The data are nevertheless considered suitable for multiple imputation (Gorard, 2020; White et al., 2011).

6.6.2 Descriptive statistics

Table 31 sets out the mean, SD, skewness and kurtosis for the overall group at T1 and T2, while Figure 6 shows the mean scores for MALS at T1 and T2 by group.

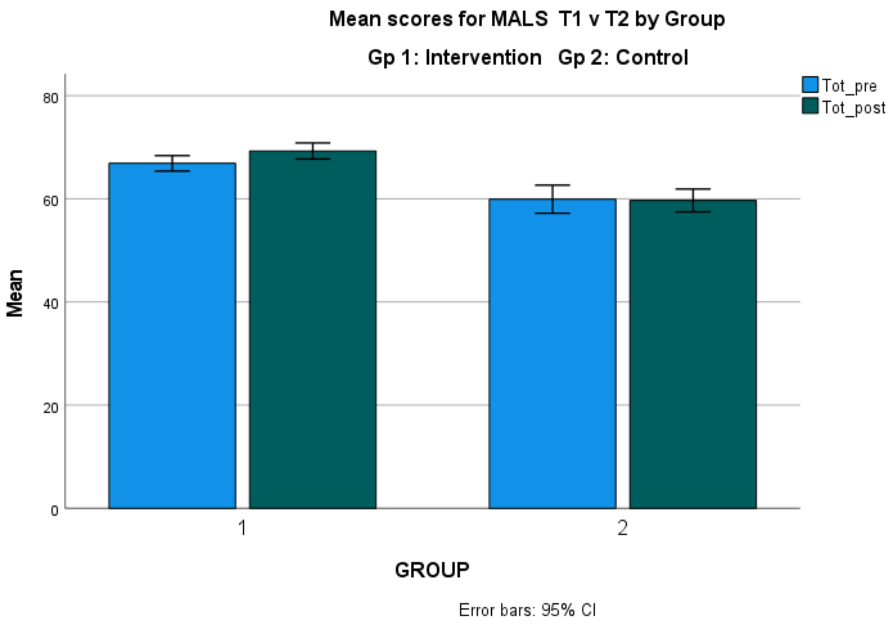
Table 31

Descriptive Statistics: MALS (original data set)

	N	Min	Max	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
							Statistic	Std. Error	Statistic	Std. Error
T1	56	20	100	64.27	17.58	309.18	-0.224	0.319	0.031	0.628
T2	47	31	98	66.77	16.15	260.75	-0.301	0.347	-0.560	0.681

Figure 6

Mean scores for MALS by group at T1 and T2.



6.7 Hierarchical regression analysis using multiple imputation

6.7.1 Preliminary analysis

As indicated above, Tabachnick and Fidell (2014) suggest a rough sample size formula of 50+8 times the number of independent variables which in this case would be a required sample size of 74 cases. Although the original survey population was 71, the number used in the analysis including multiple imputation was 56 which suggests caution should be exercised when generalising from this analysis. A check for outliers using Mahalonabis distance with a critical Chi Square value of 16.266 (Tabachnick and Fidell, 2014) indicated no issues with the highest value reaching 10. The highest Cooke's distance was .009 also suggesting no issues. The correlation between T1 and T2 was .773 which is higher than the suggested .7 (Pallant, 2020), however checks for multicollinearity using VIF greater than 10 and Tolerance less than .10 indicated no issues. An examination of the residuals scatterplots also gave no cause for concern and so, with the exception of sample size, the data were considered appropriate for hierarchical multiple regression.

The rationale for multiple imputation was the same rationale as for the MAAQ outlined at Section 6.4.2 as this was almost all of the same group of children completing the MALS within a day of completing the MAAQ. As with the MAAQ, regression analysis explored the effects of timepoint (with T2 as DV and T1 as covariate) and both group and gender as covariates. Regression was carried out using T2 as the dependent variable (DV) with T1 scores added as covariate at Model 1; T1 and Group added as covariates for Model 2; and T1, Group and Gender as covariates at Model 3. As expected, Model 1 was significant ($F(1,45)=62.113$, $p<.001$) because the group of children completing the T2 survey was broadly the same group of children who completed the T1 survey, so it is expected that T1 results would predict T2 results. The addition of Group to the model however made almost no difference ($F(1,44)=2.061$, $p=.158$). Adding gender at Model 3, having created a dummy variable of gender and using Gender_M with Gender_F as reference group, also resulted in almost no change ($F(1,43)= .130$, $p=.720$). Table 32 sets out the Model summary for Model 1, 2 and 3 with the original data and imputation 8 only as there was no difference due to multiple imputation with the exception of imputation 8. The original data at Table 32 offer a whole case sensitivity analysis of the 47 cases minus the imputation. In line with the analysis involving multiple imputation, there is still no significant difference between intervention and control group.

Table 32

Model summary, Hierarchical multiple regression of MALS scores using multiple imputation

Model Summary[d]

Imputation Number	Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics: R^2 Change	F Change	df1	df2	Sig. F Change
Original data	1	.761[a]	0.58	0.571	10.58	0.580	62.11	1	45	0.000
	2	.774[b]	0.599	0.580	10.46	0.019	2.06	1	44	0.158
	3	.775[c]	0.60	0.572	10.56	0.001	0.13	1	43	0.720
8	1	.769[a]	0.592	0.584	10.60	0.592	78.30	1	54	0.000
	2	.794[b]	0.631	0.617	10.18	0.039	5.55	1	53	0.022
	3	.795[c]	0.632	0.611	10.26	0.002	0.22	1	52	0.637

a. Predictors: (Constant), Tot_pre

b. Predictors: (Constant), Tot_pre, GROUP

c. Predictors: (Constant), Tot_pre, GROUP, Gender=M

d. Dependent Variable: Tot_post

Although multiple imputation was carried out to account for the missing values at T2, this still did not result in any significant change with the exception of Imputation 8 ($F(1,53)=5.55$, $p=.022$).

Table 33 sets out the regression coefficients from the multiple regression and shows the data fit poorly with no significant effect for either gender or group. The only significant effect was for T1 score which is unsurprising since it is broadly the same children completing the survey at T2.

Table 33

Regression coefficients for MALS

			Unstandardized Coefficients		Standardized Coefficients			95% Confidence interval for B		Correlations			Collinearity Statistics	
	Model		B	Std Error	Beta	t	Sig.	Lower	Upper	Zero-order	Partial	Part	Tolerance	VIF
Original data	1	(Constant)	17.37	6.45		2.69	0.10	4.37	30.37					
		Total_pre	0.75	0.09	0.76	7.88	<.001	0.56	0.94	0.76	0.76	0.76	1.00	1.00
	2	(Constant)	25.34	8.46		3.00	0.004	8.29	42.39					
		Total_pre	0.72	0.09	0.74	7.57	<.001	0.53	0.91	0.76	0.75	0.72	.97	1.03
		Group	-4.64	3.23	-0.14	-1.44	0.16	-11.15	1.87	-0.27	-0.21	-0.14	.97	1.03
	3	(Constant)	25.16	8.56		2.94	0.005	7.90	42.42					
		Total_pre	0.73	0.10	0.74	7.40	<.001	0.53	0.93	0.76	0.75	0.71	0.92	1.09
		Group	-4.45	3.30	-0.13	-1.35	0.18	-11.11	2.23	-0.27	-0.20	-0.13	0.94	1.06
		Gender	-1.15	3.18	-0.04	-0.36	0.72	-7.56	5.26	0.09	-0.05	-0.03	0.94	1.06
Pooled	1	(Constant)	18.23	7.19		2.54	0.014	3.79	32.67					
		Total_pre	0.74	0.11		6.97	<.001	0.50	0.93	0.77	0.77	0.77		
	2	(Constant)	26.05	9.18		2.84	0.006	7.75	44.34					
		Total_pre	0.71	0.11		6.64	<.001	0.50	0.93	0.77	0.77	0.74		
		Group	-4.60	3.23		-1.42	0.155	10.95	1.74	-0.28	-0.21	-0.13		
	3	(Constant)	25.96	9.21		2.82	0.006	7.62	44.30					
		Total_pre	0.72	0.11		6.63	<.001	0.50	0.94	0.77	0.76	0.72		
		Group	-4.48	3.27		-1.37	0.17	-10.89	1.94	-0.28	-0.20	-0.12		
		Gender	-0.73	3.13		-0.23	0.81	-6.89	5.42	0.10	-0.03	-0.02		

[a] Dependent Variable: Total_post

In conclusion, analysis of the MALS results at T1 and T2 suggest that there was no positive effect related to the intervention.

6.8 Discussion

Hypothesis 4 stated that using the MAAQ and the MALS as measures, a peer-assisted, games-based learning intervention would

a. improve children’s attitude to maths
b. reduce maths anxiety.
c. improve self-concept as a learner

The results suggest that for the intervention group, the MAAQ results show a small but significant improvement in attitude to maths and reduction in maths anxiety, whereas there was no such change for the control group. In relation to the improved broader self-concept as a learner, the MALS results suggest there was no significant change in either the intervention group or the control group between T1 and T2. The results may be consistent with the view that self-efficacy is domain specific rather than generic and the improvement in attitude to maths and reduction in maths anxiety may be associated with the fact that the games were maths games.

6.9 Limitations and future research

As with the previous study, the overall sample size is relatively small and the study would be more reliable with a larger sample size. With multiple imputation, the sample size is sufficient to demonstrate that a wider roll out of the overall approach would be worth investing in and investigating further. Even with a larger sample size, the study still relates to attitudes, so further research might usefully consider whether the change in attitudes observed in the study might progress to improved outcomes. The value of the current study is demonstrating that it is possible to influence positively children's attitudes and anxiety about maths. In the overall context of the Scottish Attainment Challenge this has been a relatively unexplored area and the study demonstrates that it is worth exploring further to help in addressing the gap between the most and least deprived in the area of maths.

Future research, free from the restrictions associated with Covid19, might make greater use of qualitative methods such as focus groups to explore children's attitudes to maths and maths anxiety. In addition, the current intervention used games which developed children's procedural skills in maths. Further research may explore the promotion of conceptual understanding through adult mediation, for example the teacher supporting children to reflect on their learning and make connections between procedures and the underlying concepts.

Exploration of the children's views and the teachers' views through qualitative analysis of their comments and reflections during the intervention may provide further insight into the results. Study 4 explores the children's reflections on the intervention and includes one teacher's reflections.

Chapter 7: Study 4 - Qualitative analysis of children's reflections on a games-based, peer-assisted learning intervention aimed at improving attitude to maths, reducing maths anxiety and improving self-concept as a learner in 8 and 9 year olds in schools serving a lower socioeconomic status area.[11]

7.1 Introduction

The study explores the reflections of children (n=48) and one of their teachers who took part in a peer assisted games based learning intervention aimed at reducing maths anxiety and improving attitude to maths. The participants were all mainstream primary school children aged 8 or 9 in two different schools situated in areas of relatively high deprivation. The quantitative results of the intervention were measured using numerical scores from the Mathematics Attitude and Anxiety Questionnaire and Myself As A Learner Scale. While the quantitative analysis showed an effect in relation to improving attitude and reducing anxiety, the analysis did not include any sense of how the change happened. A thematic analysis of children's and teachers' views was carried out to explore their thinking and feelings about taking part in the peer assisted games based learning intervention. Children's views were captured through a comment sheet which they completed after each of the 18 peer assisted games sessions as well as through a weekly comment on what they had learned (Appendix E, Annex 16). One of the two participating teachers also took part in a 45 minute semi-structured interview following completion of the intervention to offer her reflections. The data from the interview were insufficient to carry out thematic analysis, however key themes are noted.

[11] The study is set out in line with journal article reporting standards for qualitative research Levitt, H. M., Bamberg, M., Creswell, J. W., Frost, D. M., Josselson, R., & Suárez-Orozco, C. (2018). Journal Article Reporting Standards for Qualitative Primary, Qualitative Meta-Analytic, and Mixed Methods Research in Psychology: The APA Publications and Communications Board Task Force Report. *Am Psychol*, *73*(1), 26-46. https://doi.org/10.1037/amp0000151 .

The data used for the thematic analysis of children's views were the collated written comments following each session and their weekly reflection. The expectation was that children's views would demonstrate that they found maths games less threatening than their curriculum as usual in mathematics and enjoyed the games. As a result they would develop a more positive attitude to mathematics. The results indicated that almost all participants enjoyed the games and felt that they improved their maths skills and social skills such as team work and regulating their emotions when losing a game. One theme in the responses was that of a fresh insight into maths as more than just something in a text book, suggesting a more positive attitude to maths. The qualitative analysis was consistent with the quantitative analysis of the Mathematics Attitude and Anxiety Questionnaire which suggested an improvement in scores relating to attitude to maths and maths anxiety.

As outlined at Chapter 2, children from poorer backgrounds tend to achieve less well in education generally and mathematics is more sensitive to relative deprivation than reading for example. Expectancy value theory suggests that if learners expect to do well in a subject and value the subject, they are more likely to succeed in that subject (Eccles & Wigfield, 2020). Peer-assisted games-based learning has a successful track record of improving attainment (Alegre et al., 2019b; Lidón & Francisco, 2020; Topping et al., 2003; Tymms et al., 2011). The focus of the current study however was the step before improving attainment which is improving children's attitude to maths and reducing their anxiety. The method chosen was peer-assisted games-based learning with the expectation that learning numeracy skills in the context of games would reduce threat while peers are more able to understand the challenges of their classmates and therefore support them effectively (Moliner & Alegre, 2020). The intervention involved three 20 minute sessions a week over a six week period. At the end of each session children were asked to note which game they used and how the session had gone for them. In addition, at the end of each week they were asked to say very briefly what they learned over the week.

The purpose of the current qualitative analysis was to explore children's own reflections beyond their scores in a standardised measure in order to explore the richness of their own views and feelings. Analysis of the quantitative scores achieved in the MAAQ before and after the games-based peer-assisted learning intervention indicated an improvement in attitude to maths and reduction in maths anxiety. However, the MALS showed no change before and after the intervention.

Exploring and including the user perspective may enable a more focused and effective intervention in future for a broader group of children. The research question focused on whether psychological variables, including attitude and anxiety, associated with improving outcomes in maths could be positively influenced through peer-assisted, games-based learning in a group of relatively deprived children. Thematic analysis of their written comments and reflections during the intervention was designed to explore the extent to which they themselves as participants felt that they had an improved attitude to maths, reduced maths anxiety and an improved self-concept as a learner.

The children were 8 and 9 year olds, so their reflections and comments were very brief, often a single word. Their comments and statements were tabulated and analysed using thematic analysis (Braun & Clarke, 2006) which is an approach to identifying and analysing themes within the data set. The benefit of using this particular method was the ability to allow themes to emerge resulting in a fit of the data with the views expressed by children which was consistent with the overall qualitative approach 'intended to generate knowledge grounded in human experience' (Nowell et al., 2017, p. 2). The overall approach to the study therefore is critical realist situated within a general constructivist paradigm, allowing the themes to emerge from the data set, in this case the views of the children themselves (Robson, 2002; Smith, 1998).

7.2 Research design overview

Data were collected using a printed template (Appendix E, Annex 16) for each child to complete at the end of each session and at the end of each week, that is after three sessions. The printed template had space for the children to write their name and class, so they were aware it was not anonymous. Writing their name was mainly practical to ensure children were able to identify their own sheet. The only data tabulated however were the comments, and so once tabulated the data were in effect anonymous.

The children were asked to note which game they had played and to answer the question 'How was the session?'. The space provided to answer was small since the children were young and the time allocated to the task was principally the 20 minutes to play the game each session. The amount of space, in effect, limited the length of response. At the end of each week there was a slightly larger space for the children to comment on 'One thing I learned this week'. The completion of the sheets took place in the classroom without the researcher's involvement. The researcher had no direct involvement with the intervention from the point that pre-intervention measures were taken in January until completing post-intervention measures in April.

The class teacher supervised the completion of the sheets and returned these to the researcher at the end of the intervention. The individual sheets were then typed up as a running list of comments, one for School A and one for School B. The comments on each individual session were tabulated first and then the comments on 'One thing I learned this week' as a separate list (Appendix F). The tabulated and anonymised lists then became the data set on which thematic analysis was carried out. Thematic analysis was used in order to ensure the views of the children emerged from the data.

An interview also took place with one of the class teachers involved to review how the sessions had operated in practice and also to gain an insight from an adult perspective. The interview was semi-structured exploring what had worked well, what was challenging and whether there was any evidence of change from the teacher's perspective. Only one teacher was available for interview. The interview was carried out by the researcher and took place online using Microsoft Teams. However, facilities for recording were not available so no transcript was possible and notes were taken by the researcher (Appendix G). The output from the interview will only be used as illustration and is not considered robust.

7.3 Researcher description

The researcher is a qualified educational psychologist registered with the Health and Care Professions Council and is also a teacher registered with the General Teaching Council for Scotland. The researcher's principal role however at the start of the research was as a senior officer of the Council with a leadership role in education. For this reason, as part of the ethical approval, safeguards had been put in place in order to avoid the possibility of coercion. The researcher knew both schools well and was also familiar with both teachers in his role as an educational psychologist. The researcher had not carried out a similar intervention previously but was familiar with the overall approach of peer-assisted learning. The researcher also had extensive experience working in an educational setting at various levels as a teacher, educational psychologist and senior leader in a local education authority.

7.4 Participants

The participants were the intervention groups (two Primary 5 classes, age 8 or 9 years) who took part in a 6 week peer-assisted games-based learning intervention involving three 20 minute sessions each week. School A had 25 children complete or partially complete the comments sheets and School B had 23 children complete or partially complete the forms. The schools are both in areas of relatively high deprivation. The tabulated data are included in full at Appendix F. The researcher did not have any involvement with the completion of the comments recording sheets and simply collected them at the end of the intervention. Participants were recruited as they met the criteria for the intervention, that is they attended the school with a high level of deprivation, that is more than 70% of children entitled to free school meals. Gatekeeper consent and parental consent were sought as part of the ethical approval process agreed by the ethics committee of the School of Psychological Sciences and Health in the faculty of Humanities and Social Sciences at the University of Strathclyde. Participants were aware that they were taking part in a maths related project but had no further information.

7.5 Data collection

The data were collected using a pre-printed form on which children wrote their own comments. The children completed the forms immediately after a games based learning session which means there is the possibility that children copied or shared answers. In addition there is also the possibility that the teacher or support for learning worker supported some children to complete their comments. The comments would be written after the 20 minute session took place and it is likely the class teacher would be keen to move on which means there was limited time to reflect or think about a response.

The comments written by each of the children were collated by the researcher and typed onto a single document for each school once the intervention was completed. In this way, any identifying features were removed with the only distinguishing characteristic being the school the children attended. Thematic analysis then took place using the collated data rather than using the 48 individual sheets completed by the children. In addition to comments, the games each child played were recorded demonstrating the frequency and popularity of each game.

7.6 Analysis

The number of times each game was played was manually calculated using the recording forms completed by participants. Table 34 summarises the results:

Table 34

Analysis of games chosen by children per school

Game	Frequency played: School A	Frequency played: School B
Mobi kids	71	70
Genius Square	101	79
Shut the Box	95	85
Rolling Cubes	55	34
Gangsta Granny	67	64
Mobi adults	2	5

The participant comments were analysed using thematic analysis which includes separate stages of inductive analysis where themes emerge from the data (Braun & Clarke, 2006; Nowell et al., 2017). In order to reduce bias on the part of the researcher, a parallel analysis was carried out by a colleague experienced in thematic analysis. The final thematic analysis was agreed through dialogue and discussion with the second researcher.

Phase 1 - Familiarisation with the data: The researcher manually typed out the comments from all 48 participants which helped with familiarisation (Appendix F). The collated data were shared with the second researcher for parallel analysis. Collating the data was followed by reading through each of the tabulated school data sets. The two schools were initially reviewed separately as there were obvious differences. Participants in School B generally replied with very short responses, often of one or two words such as ‘fun’ while participants in School A tended to write a short sentence such as ‘*I really enjoyed the games’*.

School B

It was immediately obvious that there was a significant amount of overlap between respondents and the responses to the question ‘How was the session?’ mainly resulted in very brief responses of between one to five words such as ‘fun’. The researcher then worked through the data highlighting repeated words or phrases, the word ‘fun’ for example appeared around 85 times which is significantly more than any other word used. It was also evident that there was little change relating to responses as the intervention progressed. Responses to the question on *How was the session?* broadly continued to focus on level of enjoyment and competition between participants. The responses to the weekly reflection continued to be brief, although participants tended to write more than the one or two word comments on the individual sessions. As with the comments on the session, there was also a reasonable amount of repetition and overlap between the participants’ responses. A small number focused on learning about maths in response to the weekly reflection on learning.

School A

Initial familiarisation with the data indicated that participants’ responses were in sentences and frequently started the sentence with ‘I think…’ or ‘I feel…’. Unlike School B, there appears to be a degree of progression in comments on the individual sessions as participants occasionally comment on mathematics skills rather than simply enjoyment or otherwise of the session. The weekly reflection questions appear to have more maths related content and continue to be written in sentences, for example ‘*I am getting better at counting and adding*’.

Phase 2 – Generating Initial Codes: Once again the coding was carried out separately for each school in the first instance.

School A

Coding took place initially for the responses to the question *How was the session?* Codes generated included:

- Enjoyment
- Annoyance
- Difficulty / challenge
- Comparison
- Winning and losing
- Maths learning
- Thrill / excitement
- Confusion
- Competition
- Luck
- Stress
- Team work
- Mastery
- Recommendation
- Tricky
- Intensity
- Boredom
- Engagement
- Intelligence / ability

Coding then took place for the weekly reflection on what the participant learned that week. The following codes were generated:

- Losing / winning
- Anger
- Fun
- Maths learning
- Problem solving
- Team work

- How to deal with winning / losing
- Helping people
- The games
- Friendship
- Improvising
- Resilience
- Thinking
- Luck
- Sportsmanship
- Friendship
- Helping
- Maths skills
- Maths as fun
- “I learned…” and “I am…” statements
- Helping
- Emotions

School B

Coding for School B took place in the same manner as School A with session comments first then weekly comments. The responses for the School B participants were longer than for School A.

How was the session?

- Enjoyment
- Challenge
- Role as teacher / pupil
- Maths
- Improvement
- Maths skills
- I feel...getting better
- Helping others
- Dislike

- Getting better
- Explaining to others
- Boring
- No difference
- Favourite game
- Speed of calculations
- Comment on maths
- Problem solving
- Competition
- Didn’t enjoy
- No learning
- Receiving help
- Explaining
- Pride

One thing I learned?

- Getting better at…
- I am good at…
- I learned…
- View or opinion of maths
- Confidence
- Number talks strategies
- Self-discovery *I found out…*
- Team work
- Not learning
- Speed of calculation
- Accuracy of calculation
- Feeling about maths
- Enjoyment
- Accuracy in calculations
- Specific maths skills – adding, subtracting, multiplying and dividing.

Phase 3: Searching for themes

An initial search for themes took place in the two schools separately and themes were generated for both questions, that is, *How was the session?* and *One thing I learned this week.*

School A

The following themes were identified from an initial review of the codes identified from responses to *How was the session?* The text following the theme represents a few typical examples of what participants said to illustrate the theme.

1. **Enjoyment**: *Really good; fun; really fun; it was cool*
2. **Not enjoyable**: *Not fun; stressful; very annoying; didn't enjoy it.*
3. **Challenge**: *confusing and hard; exciting but challenging; confusing but fun, mind scrambled.*
4. **Competition** (winning and losing): *you win and you lose and that's okay; I learned how to lose and not get angry or sad; you have to win out of luck; I lost all of it.*
5. **Co-operative learning**: *got along with opponent; got to know partner; I learned teamwork.*
6. **Understanding of self**: *I learned how to lose and not to get angry; I'm a master at it.*
7. **Maths learning**: *liked making different sums; helped with multiplication.*

The following themes were identified from an initial review of the codes identified from responses to *One thing I learned this week.* The text following the theme represents a few typical examples of what participants said to illustrate the theme.

1. **Problem solving:** *I'm better at solving problems; solving maths problems.*
2. **Maths learning:** *Maths is more than an explanation; division and some multiplication; multiplication.*
3. **Emotions / social skills:** *Don't get angry if you lose; you win and you lose and that's okay; don't get angry, smile and enjoy the game; how not to be too competitive; how to rage more; tolerance, not to get angry if you lose.*

4. **Helping others:** *I learned to help people; I learned teamwork, I learned how to help people; team work and helping.*
5. **Team work:** *Team work is important; I learned team work; team work is so important; team work is the key; about team mates; team work and how to improve; teamwork and tolerance.*
6. **Friendship:** *Friendship; about teammates, got to become better friends; mostly friendship.*
7. **Resilience:** *It's okay to win and lose; don't get angry, smile and enjoy the game; help by improvising; that maths is always fun, you just have to dig deep; losing is fine; you win you lose, it doesn't matter; teamwork and tolerance; think outside the box.*
8. **Maths as fun:** *Maths is more than an explanation; that maths is always fun; that maths isn't always in a boring text book; maths is fun; maths isn't always in text books.*

School B

The following themes were identified from an initial review of the codes identified from responses to *How was the session?* The text following the theme represents a few typical examples of what participants said to illustrate the theme.

1. **Enjoyment:** (over 70 mentions) *I really enjoyed the game; I really enjoyed this game today it was fun; it was really fun today; I loved this game.*
2. **Lack of enjoyment:** *I didn't enjoy the game; I didn't really like the game today; I didn't like it; I think the games are becoming boring; I don't think this is making a difference to my maths (Shut the Box); this game isn't for me.*
3. **Challenge:** *I found this challenging; I improved my times tables but it was a little hard; I find this game quite difficult; I liked the game but it was hard.*
4. **Role (teacher / pupil):** *I was the teacher today***;** *I was the pupil today; I was a pupil today during the game; I was teaching others.*
5. **Explaining / helping:** *I helped others in my group; I helped others to play; I think I can explain how to play the game really well; I was helping others to calculate; Other pupils helped me; I need a bit of help; I helped other people at my group understand the game today; other people helped me.*

6. **Maths skills:** *I feel my multiplication is getting better; I really improved my skills in maths today; I feel I am making progress in maths; I think I am getting better at adding and subtracting; I felt I can make sums quickly; I think I am getting better at times and division calculations; I am getting better at maths; I improved my problem solving.*
7. **Working with others:** *I feel that I am becoming better at working with others.*

The following themes were identified from an initial review of the codes identified from responses to *One thing I learned this week.* The text following the theme represents a few typical examples of what participants said to illustrate the theme.

1. **Maths skills:** *I am getting better at counting and adding; I learned more times facts; I can calculate quicker; I am calculating quicker; I found out I'm good at problem solving; I learned more division facts; I am very good at solving problems; I am much quicker at adding numbers together.*
2. **View of or feelings about maths:** *I feel happier during maths; I found out that maths can be fun; my opinion of maths has got better; my opinion of maths got way better; maths can be fun.*
3. **Team work:** *I learned how to play as a team.*
4. **Improving / confidence:** *I am getting better at counting and adding; I feel I am becoming more confident with maths;*
5. **Teaching others:** *I learned that I'm a really good mentor* as I helped people *to take part; I think I am really good at teaching others.*
6. **Accuracy in calculations:** *My accuracy is improving.*

Phase 4: Reviewing themes

The data available on which to determine themes is brief, especially from School B where children tended to respond with a single word. School A appear to have been instructed to write in sentences so they tended to write more. However, in both cases there was a significant amount of overlap and similarity between children's responses. In both schools however, despite some negative comments about the games, the overarching theme appeared to be enjoyment or fun when playing the games. On reviewing the themes, it became apparent that one major theme not identified at stage 3 was the games themselves. The overall context was one of games-based learning or gamification of maths. It was at this stage that discussion took place with the second researcher to check for consistency in identifying themes. The second researcher identified the following themes:

School B:

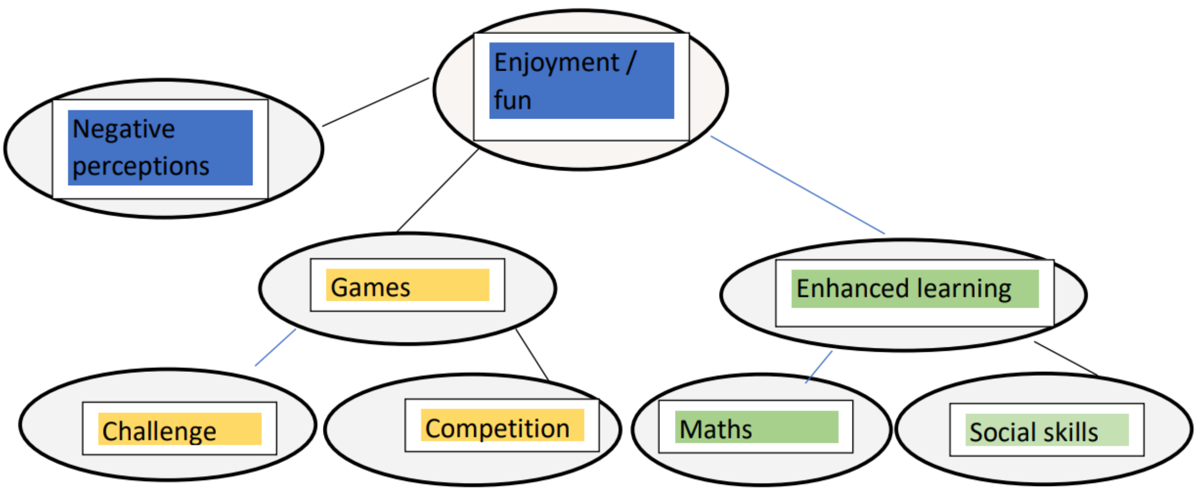
1. Enjoyment
2. Improvement
3. Enhanced learning (including teamwork)
4. Negative perceptions
5. Procedural issues

School A:

1. Enjoyment
2. Improvements in learning
3. Learning
4. Negative perceptions

A review of the themes identified led to the following chart of themes at Figure 7

Figure 7: *Review of themes Games Based Peer Assisted Learning comments*



Phase 5: Defining and naming themes

The overarching theme is one of enjoyment and fun which is consistent with a conceptualization of playful learning set out by Hassinger-Das et al. (2017). Hassinger-Das et al. (2017) extend playful learning from free play and guided play to include games-based learning with games defined as where 'players compete according to rules for the purposes of achieving a predetermined outcome within the game's system' (Hassinger-Das et al., 2017, p195). In this way the games enable children to access their intrinsic motivation as well as supporting and challenging them to progress. In addition, control is not entirely in the hands of the teacher giving instructions so the element of chance as they roll the dice for example, is an important feature of game play and moves control away from adults to peers as well as chance. In this way children have an experience of leading their own learning, at times mediated by their peers and at times impacted by the element of chance in a game. Enjoyment and fun therefore become the canvass or foundation on which learning can take place and attitudes to maths learning can become more positive. Children also benefit from the support of a more able peer who is mediating the learning as described at section 2.9 above.

The next three superordinate themes therefore are, unsurprisingly, teamwork, games and maths. Children mentioned teamwork frequently as well as friendship; School A children - '*teamwork is the key'; 'teamwork is so important';* School B child - '*I helped people at my group understand the game today'.*

In addition to practising their numeracy skills, learning in a games based context where children are leading their own learning, working with and supported by peers rather than direct teaching, can have greater benefits than only engaging in direct teaching led by an adult (Scalise et al., 2018, 2020; Scalise et al., 2022). Games and teamwork as themes go hand in hand because the games required children to work in pairs or threes and fours occasionally.

Linked to games and teamwork are the themes of helping, being helped and friendship. Associated themes are social skills and resilience which also relate to winning and losing, challenge and competition.

The remaining higher order theme is mathematics with a number of sub-themes. Children referenced their feelings about maths, *'my opinion of maths has got better'; 'I found out that maths can be fun'*. However, particularly for School A, children frequently mentioned improvement in problem solving, improvement in maths skills generally and specific reference to numerical operations such as addition, subtraction, multiplication and division. School A in particular also mentioned speed and accuracy in calculations or mathematic operations: *I can calculate quicker; I am much quicker at adding numbers together; my accuracy is improving.*

7.6.1 Themes from interview with class teacher

Only one teacher was available for interview and the output was limited to notes taken by the researcher during a semi-structured interview (Appendix G). The class teacher confirmed in the interview the overall findings of the thematic analysis. Children were very positive about the games, for example, '*they could see the maths games activity coming up and were excited every day'*. The teacher also indicated that at the reflection session the children were all very engaged and there was good dialogue about the games. However, the teacher also indicated that the reflection could have been simplified. In addition, in future the teacher indicated that a differentiated approach for the least able may help, such as limiting their activities to adding and subtracting within 30. However, it was also made clear that some of the least able children had made the greatest gains, for example "*A. detests maths but was so excited with the games*" and "*eight [pupils] who struggle most made big strides*".

7.6.2 Discussion

The research question focused on whether psychological variables, including attitude and anxiety, associated with improving outcomes in maths could be influenced positively through peer-assisted, games-based learning in a group of relatively deprived children. Thematic analysis of their written comments and reflections during the intervention appeared to show that overall, many of the participants felt that they did indeed have an improved attitude to maths which may reduce maths anxiety. There was little in the written output to suggest an overall improved self-concept as a learner since the comments were mainly specific to maths or problem solving.

The themes generated through thematic analysis suggest that the outcome of the intervention is consistent with the literature on peer assisted games based learning. For example, peer tutoring is associated with implicit reward and self-regulation (Topping et al., 2003) which are consistent with the themes identified as *social skills* and *resilience*. Interestingly, Topping et al. (2003) also suggest that children are most motivated by strategy games and prefer 3 dimensional commercially produced games as opposed to two dimensional locally produced games. The data in the current study suggest a consistent outcome with children reporting enjoyment of the games and frequently mentioning *Genius Squares*, a strategy game which develops problem solving skills, as their favourite. In addition, the frequent reference to teamwork, including helping and being helped is consistent with the view that children who have only recently learned the content, in this case how to play a maths board game, are better mediators than adults (Alegre et al., 2019b).

The children's reflections also suggested that their learning was, in part, similar to the findings of Brezovszky et al. (2019) who found games based learning in mathematics helped learners to develop arithmetic flexibility. The current study was limited and could not show evidence of applying knowledge in a new context, but children themselves suggested improvements in their repertoire of arithmetic problem solving.

Overall, children were positive about the intervention, most frequently referencing fun and enjoyment. School A more consistently referenced improvements in specific maths skills but both schools had evidence of a more positive attitude to maths – *maths isn't always in a boring text book; maths is fun; maths can be fun; my opinion of maths has got better*.

The limitations of the study are clear in the output of the children with a significant degree of similarity in the comments which suggests children influenced each other and were potentially influenced by the adults supporting them. The research could have been improved by ensuring that children completed their own reflections rather than what appears to be completion as a class or in groups. Nevertheless, the study took place in the real world context of a busy classroom where the main focus was on three 20 minute sessions of games based learning a week over 6 weeks. The time taken to write comments at the end of each session and then at the end of each week was additional time which the class teacher may not have accounted for. An interview with one of the class teachers indicated that this was indeed the case when she stated that "*for some children the reflection was challenging and they needed some support from the school assistant, their peers or myself*". The rationale for the weekly reflection in particular was that Bakker et al. (2015) found reflection on maths computer games was more likely to develop conceptual maths knowledge. In the current study there is no evidence on which to base such a claim, however, the daily and weekly reflection may have helped to reinforce messages around self-concept in the domain specific area of maths but not in the wider sense of self-concept as a learner.

The research took place at a time when Covid19 infection levels were rising sharply due to the Omicron variant. The overall context of Covid and a rise in infection rates may have resulted in increased levels of anxiety among the children (Watson et al., 2023) which in turn may have been a confounding variable in relation to maths anxiety. A replication of the study in a post-Covid environment may clarify the extent to which Covid anxiety was a factor in study 3 and study 4.

Future research or replications of the current study may also include focus groups of children to explore the themes generated through the qualitative analysis. Focus groups may generate richer data on the intervention and may also address limitations around children being influenced by the teacher or their peers when completing the comment sheets.

Chapter 8: Overall Discussion

8.1 Support for original hypotheses

The aim of this study was to characterise the link between relative deprivation and outcomes in maths at primary school level and explore some of the factors which may contribute to poorer attainment for relatively more deprived children. Once potential factors were identified, the aim was to explore potential interventions for educational psychologists to suggest to schools in order to improve children's outcomes. The research focused particularly on psychological variables making a difference, including the beliefs and practices of teachers relating to the teaching and learning of maths and the beliefs, attitudes and expectations of children related to themselves as learners of maths.

Regression analyses of standardised test data for General Mathematics, Reading and Developed Ability of a cohort of children age 11-12 found a negative correlation between relative poverty and academic attainment in primary schools. Although the effect was small, General Mathematics scores were more sensitive to relative deprivation than standardised Reading scores or Developed Ability scores which were described as a measure of general ability. The regression analyses supported Hypothesis 1 that using free meal registration as a proxy measure for relative deprivation, children registered for free school meals attained at a lower level on average compared to their peers. Hypothesis 2 was also supported by the regression analysis, that maths attainment is more sensitive to relative poverty than literacy and general ability.

8.2 Perceptions of Mathematics and approaches to teaching more and less deprived children maths

While the literature suggests a variety of factors contributing to poorer outcomes in maths linked to poverty at the level of the community, the current study focused on two specific factors which were firstly the influence of the class teacher and secondly the children's perceptions of themselves as learners. The role of teachers in determining outcomes for children living in relative poverty was explored using the Perceptions of Maths (POM) survey which gives an indication of whether a teacher has a preference for conceptual maths or procedural maths teaching. The distinction between procedural and conceptual teaching in maths matters because children exposed to more procedural than conceptual are less likely to achieve at a higher level in maths (OECD, 2016). Principal Components Analysis found that the POM survey did indeed have a two factor structure which distinguished between conceptual and procedural preferences in teaching. Once validated, the POM survey found there was a slight preference for conceptual maths in a small group of teachers who taught in a relatively less deprived school, however the difference between those teaching more and less deprived children was not statistically significant. The current study therefore did not find evidence supporting hypothesis 3 that teachers who teach in schools characterised by relatively higher levels of deprivation are more likely to prefer procedural maths teaching over conceptual maths teaching. While the sample size of those completing the survey overall was sufficient to carry out PCA and show that the survey does distinguish between a conceptual and a procedural preference, the sample of teachers the POM was subsequently applied to was insufficient to show a statistically significant effect.

8.3 Games based peer assisted learning intervention to improve attitude to maths and reduce maths anxiety (H4)

Despite the POM survey not distinguishing between the two groups of teachers, those teaching more deprived and those teaching less deprived children, the potential for teachers to adopt approaches to learning and teaching that amplify rather than mitigate the effects of poverty meant that the focus for intervention in the current study was at the level of the individual child. Specifically, the intervention focused on psychological variables which influence outcomes in maths. A six week, peer assisted, games based learning intervention was designed to influence psychological variables, including attitude and anxiety, which are associated with improving outcomes in maths. The results of the intervention partially supported hypothesis 4, as the results indicate that the peer-assisted, games-based learning intervention improved children's attitude to maths and reduced maths anxiety. However, H4 was only partially supported, as there was no improvement in self-concept as a learner as measured by MALS between T1 and T2 or between the intervention and control groups. Hypothesis 4 stated that using Mathematics Attitude and Anxiety Questionnaire and Myself As A Learner Scale as measures, a peer-assisted, games-based learning intervention will improve children’s attitude to maths; reduce maths anxiety; and improve self-concept as a learner. The results support improvements in the first two but not in self-concept as a learner as measured by the Myself As a Learner Scale.

8.4 Links to existing research

The results of the regression analyses of standardised attainment scores in maths were consistent with existing research such as Fyfe et al. (2019) who used nested regression models to identify that knowledge of counting, non-symbolic quantities and repeating patterns predict future success in maths. Critically however, Fyfe et al. (2019) found that success in maths follows a trajectory for low socioeconomic status children that begins in pre-school, a trajectory where they achieve at a level below their less deprived peers. The current research is consistent with evidence that living in a relatively more deprived neighbourhood, where parents are educated to a lower level means a child is likely to start their education behind their more affluent peers (Banerjee, 2016; Barr, 2015; OECD, 2007, 2016). The current research however considered the possibility that classroom teaching of maths can amplify or mitigate the impact of community and family deprivation depending on the teacher’s preference for teaching conceptually or procedurally.

Although the current study did not find statistically significant evidence of a difference in preference for conceptual versus procedural maths teaching between teachers teaching in schools with higher and lower levels of deprivation, the finding of a two factor solution in the PCA analysis of the Perceptions of Mathematics survey is consistent with work by Kajander and Holm (Holm & Kajander, 2020; Kajander, 2010b; Kajander & Holm, 2013). The findings of the PCA also offer potential areas of future research exploring differences in approaches used in schools where levels of deprivation are higher than average. The OECD report that indicated poorer children are more likely to be exposed to procedural learning than conceptual learning (OECD, 2016) was important because it made the distinction between individual learners’ characteristics and the way maths is taught. They suggest that as learners progress to upper secondary, success in maths is more linked to socioeconomic status and one of the main reasons is the way maths is taught with a greater emphasis on conceptual for learners from more socially advantaged backgrounds. The Perceptions of Mathematics survey, now validated, is a potentially useful tool for exploring the preferences of teachers, however in the current small scale study there was limited evidence of a significant difference.

Recently, Brown and Putwain (2022) focused on the mediating role of expectancy and subjective task value with similar results to the current study. Brown and Putwain's work is rooted in expectancy value theory and focused on the role of expectancy and value in relation to *A Level* results. While their research appears limited to a largely white, middle class group of students, they were able to make a connection between psychological variables such as expectations of success, subjective task value and actual outcomes after controlling for background and prior levels of attainment. Of particular relevance to the current study, they found that high enjoyment and high expectations of success are more likely to lead to better outcomes. The overwhelming theme from the qualitative analysis of children's reflections in the current study was one of enjoyment and fun.

Brezovszky et al. (2019) found that games based learning at primary stages led to more adaptive and flexible number knowledge as well as improved ability to apply number knowledge in a different context. Improved skills in numerical operations such as adding, subtracting, multiplying and dividing were not tested empirically in the current study, however, children frequently referenced improved problem solving skills and improved numerical operations in the qualitative analysis.

In a review carried out by Connolly et al. (2012) it is suggested that effective learning is active, experiential, situated, problem based and provides immediate feedback. The games-based learning context met all of these criteria as evidenced by the children's comments after each session and reflecting on what they had learned over the week. While the children's reflections at the end of each week were quite basic, they were intended to build on the findings of Bakker et al. (2015) who suggest that playing a game alone helps with number fact knowledge and operational skills which is essentially procedural knowledge, however to develop conceptual knowledge children needed a debrief or reflection on what they had learned. It is beyond the scope of the current research to determine whether or not children developed conceptual knowledge, however, the qualitative feedback was encouraging, with children's reflections consistent with Bakker et al. (2015).

While peer assisted learning has been extensively researched by Topping and colleagues and has a substantial evidence base, (Topping et al., 2003; Topping et al., 2011; Topping, 1998, 2020; Tymms et al., 2011) more recent research has focused on psychological variables associated with peer assisted games based learning (Lidón & Francisco, 2020; Martí Arnándiz et al., 2022; Moliner & Alegre, 2020). The current research found results consistent with the more recent work and is in turn supported by the early work of Topping. Moliner and Alegre's 2020 work found that reciprocal peer tutoring was consistently positive in terms of outcomes. While many peer assisted learning studies prefer cross-age peer tutoring, the current study used reciprocal peer assisted as cross-age tutoring was ruled out due to Covid restrictions in place at the time of the intervention. Nevertheless, the results were still positive in terms of improved attitude to maths and potentially reduced maths anxiety.

In addition to reported improvements in their maths skills, children reported improvements in their self-regulation, for example in response to *One thing I learned this week*, children stated *Don't get angry if you lost; you win and you lose and that's okay; to have fun no matter what; sportsmanship; teamwork and tolerance, not to get angry if you lose*.

The children's reflections on their ability to self-regulate as a result of the intervention suggest connections with research on executive functions and in particular, working memory (Dulaney et al., 2015). Dulaney et al. (2015) indicate that working memory requires temporary storage and controlled attention. The temporary storage involves mental coding of incoming information into short term memory, however working memory requires more than short term memory. It requires the central executive to manipulate information through controlled attention and inhibition of irrelevant stimuli. The games-based context as well as working with a peer as mediator supports controlled attention and inhibition of relevant stimuli and may be connected to children's self-reported improvements in self-regulation as well as in their numerical operations. Zhang et al. (2023) recently reported an overall significant medium correlation between arithmetic and working memory from a meta-analysis of 46 studies. Executive function enables a top-down control of attention and behaviour which is important in the context of learning maths (Lawson & Farah, 2015). Lawson and Farah (2015) found evidence to suggest that executive function is a unique mediator between socioeconomic status and academic achievement. Their study also used non-verbal tasks to measure executive functions in order to avoid confounding effects with verbal ability. The current study showed a positive effect in attitude towards maths and self-regulation as a result of learning maths in a games-based context and with the support of peers. Together the improvements in self-regulation and a more positive attitude to maths may be partially explained by improvements in executive functions and would be worthy of further exploration in future research.

8.5 Interpretation of the results

The aim of the current study was to explore what mechanisms may contribute to relatively more deprived children achieving less well than their better off peers with a view to supporting educational psychologists working in schools and education systems to support better outcomes for all learners, regardless of children's backgrounds. The first step in this process was to characterise the difference due to socioeconomic status and the scale of the difference. Regression analyses showed that there is a difference, with poorer children achieving less well in Reading, General Mathematics and General Ability, and that maths was more sensitive to poverty than Reading or General Ability scores. It has to be stated that the scores used are standardised assessment scores and bring with them the concerns associated with standardised assessments. Principally that these tend to be culturally biased and privilege learners with greater cultural capital who in turn tend to be better off (Au, 2016; Helms, 1992; Kruse, 2016). Nevertheless, it is difficult to gather data on the scale of a full cohort of children in a single local authority or at national level without using some form of standardised assessment. The cohort used included approximately 1,800 children which gives a reasonably reliable population from which to draw initial conclusions.

The first step described above was to establish that there is a gap before exploring the mechanisms that may contribute to the gap between less well-off and better-off peers using free school meal entitlement as a proxy for deprivation. The focus for exploring mechanisms was on the interactions taking place in the classroom, looking first at teachers and then at the children and their learning. Existing literature indicated that learners who are taught maths conceptually tend to achieve at a higher level in the long run while those taught principally in a procedural manner tend to achieve less well in the longer term. A tool to explore teachers' preferences for teaching in maths, conceptual or procedural, already existed, called the Perceptions of Mathematics (POM) survey (Kajander, 2010b; Kajander & Mason, 2007; Kajander et al., 2008). However it was limited due to the underlying factor structure not having been defined using exploratory factor analysis. The underlying factor structure of the POM was explored using Principal Components Analysis and indeed, a two factor structure was identified which was consistent with a procedural preference and a conceptual preference. The validated instrument could now be used to explore the preferences of teachers in schools characterised by affluence versus deprivation. Unfortunately the sample size was small and, although there was a difference on the conceptual component in favour of the more advantaged school teachers, no statistically significant difference was found between the two small groups of teachers. Future research might usefully consider using the POM with a much larger group of teachers to determine if there is a difference to be found with a more reliable sample size.

The attitudes and beliefs of teachers about the learning of maths and the capacity of children to learn based upon socioeconomic markers remain an area worthy of investigation. However, in the current study no significant effect was found between two groups of teachers. The second area the study sought to explore was the attitudes and beliefs of children themselves. Based upon the work of Bandura (1977) as developed by Eccles and Wigfield (2020), the starting position was that children's expectations about their success in learning will influence their outcomes after controlling for prior learning and socioeconomic status. Gorard et al. (2012) found some evidence to support a connection between expectations and school outcomes, however they concluded that there is an effect only when socioeconomic status and prior attainment are not accounted for (Gorard et al., 2012). However, the research by Gorard et al. focuses on general outcomes rather than domain specific outcomes.

The current research aimed at bringing about improvements specifically in psychological variables which are associated with poorer outcomes in maths, specifically attitude to maths and maths anxiety.

Attentional bias, for example, due to maths anxiety is considered to be akin to an emotional stroop effect for maths related words (Suárez-Pellicioni et al., 2013; Suárez-Pellicioni et al., 2016) and may well contribute to poorer outcomes in maths. An intervention therefore focused specifically on improving attitude to maths and reducing maths anxiety was designed and targeted towards children in schools with high levels of deprivation.

The games-based, peer-assisted learning intervention results were in fact consistent with both Bandura and the more recent findings of Gorard et al. (2012). The Mathematics Attitude and Anxiety Questionnaire offers a measure of attitude to maths as well as maths anxiety while Myself As A Learner Scale (MALS) offers a measure of overall sense of self as a learner. The former is domain specific while the latter is generic. As expected, the MAAQ results showed a significant change from T1 to T2 for the intervention group and a significant difference between the intervention group and the control group. The MALS showed no significant change between T1 and T2 for the intervention group or between the intervention group and the control group.

The obvious challenge is that there is still a gap between a more positive attitude to maths, reduced maths anxiety and improved attainment in maths for these children. Existing research indicates that subjective task value and expectancy of success lead to better outcomes, even when prior attainment and SES are controlled for (Brown & Putwain, 2022; Eccles & Wigfield, 2020; Meece et al., 1990; Putwain et al., 2021; Wigfield & Eccles, 2000; Wigfield et al., 2020). The overall aim was to explore mechanisms which may contribute to poorer outcomes in maths and the intervention suggests that a focus on psychological variables such as a more positive attitude to maths and reducing maths anxiety are capable of being influenced positively through a simple, peer-assisted games-based learning intervention of limited duration.

The use of weekly reflection sheets proved helpful in understanding the views and experiences of the children themselves. The reflection sheets had two interesting and unexpected features. The first is that at one school, the similarity in several children's reflections and use of whole sentences suggested that there was a degree of direction from the teacher, while the other school's responses were simple and appeared more spontaneous. The level of direction from the teacher calls into question, to some extent, the reliability of the qualitative results. Nevertheless, taking the qualitative results as a whole, a second interesting feature was that the children's reflections pointed in the direction of another potential way in which the intervention can bring about improvements in maths, and that is through improved executive functions. Children reported better self-regulation, which on the face of it may appear to be about emotional self-control, however executive functions are critical to learning, specifically attention, response inhibition and working memory, all of which are important in learning maths (Lawson & Farah, 2015; Zhang et al., 2023). Indeed, executive functions appear to mediate socioeconomic status and learning numeracy skills (Ellefson et al., 2020). Although it was not within the scope of this research to measure executive functions and any change in executive functions, the children's reflections open up an interesting area of further research associated with a relatively straightforward intervention.

8.6 Educational policy implications and educational psychology practice implications

The current research was aimed at supporting educational psychologists in the current Scottish education policy landscape which has a major focus on tackling the poverty related outcomes gaps (Scottish Government, 2022). Initially the policy was known as the Scottish Attainment Challenge (SAC) and associated funding was known as SAC funding. This has recently shifted to the Strategic Equity Fund and the policy intention has shifted slightly to using education to mitigate the effects of poverty. Nevertheless, as recently as December 2022, the Scottish Government reaffirmed their commitment to largely close the poverty related attainment gap by 2026 when the Cabinet Secretary for Education and Skills stated, 'When I talk about substantially eliminating the poverty-related attainment gap, I mean by 2026. We recognise that there are different roles for everyone in the work' (Scottish

Parliament, 2022). So despite slight changes, the main policy intention remains. In this context educational psychologists need the skills and tools to be able to support evidence informed policies as well as offer a view on what is likely to make a difference in the real world of a busy classroom or school environment.

The games based, peer assisted intervention outlined in the current thesis had a high level of ecological validity since it was the class teachers and pupils in question who led the intervention following a brief introduction and training notes from the researcher. Nor did the intervention interfere to any great extent with the normal delivery of the curriculum, with only three 20 minute sessions a week over a six week period. The setting for the intervention was in two local authority primary schools situated in areas of high deprivation but notably during a surge in Covid cases and all the associated restrictions. This limited the options such as cross-age peer tutoring, yet there was still an effect from the less favoured reciprocal tutoring. The Covid restrictions also limited the possibility of visiting the schools regularly to ensure implementation fidelity, however, the increasing and easy use of videoconferencing using MS Teams for example, allowed the researcher to keep in touch with the two class teachers during the intervention. The minimal nature of involvement by the researcher also meant that instructions and training had to be in written form which means the intervention can be replicated easily.

As already mentioned, the aim of this research was to support educational psychology practice to make more use of empirically validated instruments and approaches to addressing the gap between children from poorer backgrounds and their less deprived peers. Educational psychologists have limited time and opportunity to carry out research involving control groups, however, the current research showed that it is possible to carry out evidence based research in challenging circumstances that show promising initial results. The validation of the POM also offers educational psychology a validated instrument to explore further the possibility that teachers adopt different approaches to teaching maths, depending on who they are teaching. Both the POM and the games based, peer assisted learning build on existing research and apply them in a real world context to try and ensure educational psychologists are better placed to tackle the enduring issue of the stratification of educational outcomes by socioeconomic status. Overall, the POM and the intervention also take the focus closer to the level of the classroom rather than situating the issues in the community or in the child. The policy context is the right area for education in Scotland to be tackling, however, it may lack focus and a sufficiently developed evidence base. The current research demonstrates that educational psychology is well placed to steer policy and interventions towards empirically validated approaches that may lead to better use of Strategic Equity Funding and Pupil Equity Funding.

8.7 Limitations and future directions

Study 1 is limited in that the data used for the regression analyses were from standardised assessments with the associated limitations of standardised tests. However, the data used for analyses had the advantage of being secondary data gathered for routine assessment purposes and did not require assessment of over 1,000 children for the purposes of this research. In addition, the standardised scores were age standardised which reduced the possibility of a confounding variable of age. Further research may consider combining teacher professional judgement data published for the cohort to determine if there are similar results, that is, maths attainment is more sensitive to deprivation than literacy. Nationally produced *Curriculum for Excellence* attainment data show a difference by SIMD status (Scottish Government, 2022a). A combination of teacher professional judgement and standardised assessment data may provide a more reliable and ecologically valid measure of children's progress which can be correlated with measures of relative deprivation.

In relation to study 2, the weakness of the Perceptions of Mathematics study is that the POM is still a self-report measure. There may be a degree of social desirability effect in teachers' responses that is not reflected in reality in the classroom. What teachers say and what they do could usefully be cross-validated in future research by classroom observation for example and further qualitative follow up to the POM itself. Further research might also check for any relationship between the POM scores of teachers and the attainment of learners after controlling for SES, gender and age. The POM validation would also benefit from use in a different local authority to check that teachers in the local authority where it was validated were representative of the wider population of teachers across Scotland.

A larger sample size is always desirable for Principal Components Analysis and the current research is no different. However, in addition to a larger sample size, more detailed analysis could be undertaken by gathering additional data relating to the characteristics of respondents and their context such as age; gender; length of service in teaching; highest level of maths achieved prior to teaching; age group taught; demographics of school. These characteristics may enable item response analysis for example, as well as determining whether there are particular markers or contexts in which make a conceptual or procedural approach more likely to be used.

Study 3 was undertaken in challenging circumstances related to Covid with various mitigations in place which limited access to the school and limited the options for children to interact beyond their 'bubbles' which were small groups set up during Covid 19 to minimise spread of the virus. In addition, there were higher than average absence rates as a result of the Omicron variant of Covid impacting on attendance of both staff and pupils in the schools. However, for all these challenges, the research was more 'real world' as a result.

The Covid limitations also meant that the qualitative aspect of the research which is set out in study 4 only used written self-report data. The data suffered from the possibility of direction from adults and the influence of peers, both of which may be mitigated in future research through in-person focus groups led by the researcher to explore further some of the themes generated by the written feedback from participants.

As with any research which seeks to make a connection between attitudes and actions, the research assumes that attitudes and beliefs influence actions and outcomes. The next stage in the research would indeed be to assess the extent to which the reported improvement in attitudes to maths resulted in actual improvement in attainment. Meta-analyses have found however that generally attitudes do influence behaviour and are more likely to influence behaviour when the attitude is easy to recall, stable over time and when the individual has direct experience of the attitude object and report their attitude frequently (Glasman & Albarracín, 2006). Given children at primary stages study maths almost every day, they will have regular contact with the attitude object and an almost daily opportunity to reinforce their attitude. Since attitudes can be changed, and are described as a tendency rather than a fixed state (Eagly & Chaiken, 2007) it would be important to capitalise on the change identified in Study 3 and then follow up on the extent to which it endured over time.

As well as Covid being a limiting factor in Study 3 and Study 4, the Games based peer assisted learning intervention, Covid may also be a confounding variable adding to levels of anxiety among children. Future research therefore in a context without an international pandemic may give an indication of whether or not the Covid context added to children's anxiety.

Study 2 focused on teachers' preference for conceptual or procedural maths teaching and the possibility of teachers' beliefs about children's socioeconomic markers influencing their approach to teaching. Study 3 however did not develop the focus on conceptual versus procedural maths but focused instead on children's beliefs and values about themselves as maths learners. Future research may usefully focus on the extent to which mediation by the teacher following the games based sessions may enable children to progress from procedural learning using games to a more conceptual understanding through the mediation of the teacher enabling children to learn more deeply.

Finally, study 3 used the Myself As A Learner Scale as a measure pre and post intervention and it showed no effect. Given the evidence relating to self-regulation in the qualitative data at study 4, future research may use a measure of executive functions in place of the MALS to check for any effect on EF as a result of the intervention, in particular ability to direct focus and attention.

9. Conclusion

The current study focused on the classroom interactions that have the potential to reduce achievement gaps in maths that can be attributed to socioeconomic status. The POM survey demonstrated that it is possible to distinguish between conceptual preference for teaching maths and a procedural preference for teaching maths. Given the conceptual is likely to lead to higher achievement in maths over the longer term, it would seem important that all children are exposed to conceptual teaching regardless of their SES. Teacher's beliefs and attitudes can influence outcomes for children, so it is important that as educational psychologists we are able to help teachers access what may be latent beliefs and attitudes in order that they teach in a way that does not disadvantage children who may already experience significant disadvantage.

The games-based peer-assisted learning intervention was a low cost and relatively simple intervention which was capable of influencing children's attitudes and anxieties relating to maths which may in turn lead to improved outcomes. Children themselves acted as mediators in the learning process through a reciprocal peer-assisted learning intervention. Focusing on the psychological variables that influence children's learning is one of the central roles of an educational psychologist. Enabling and supporting children to believe they are capable of achieving in maths, view maths more positively and reduce their anxiety may result in improved outcomes in maths and reduce the impact of SES.

The intervention also helped children to develop skills in self-regulation and social skills through peer assisted learning, taking on the role of tutor at one point and then learner at another, thus mediating learning for their peers. More fundamentally, the research sought to demonstrate that it is possible to use psychology more effectively to address what is a central plank of Scottish Government policy, that is to use education to reduce the impact of deprivation on children. The current research underlines the importance and the possibilities of interventions with high ecological validity and evidence of effectiveness.

Making explicit the values and attitudes of children as well as teachers relating to learning and teaching in maths may help children to acquire skills in maths which allow them over time to acquire the assets they need to remain above the Micawber Threshold (Barrett & Carter, 2013). Structural and societal constraints as a result of poverty include a lack of social capital and the potential double disadvantage of negative teacher professional judgement of children who do not possess the same level of social capital as their more affluent peers (Mikus et al., 2020, 2021). Improving children’s attitudes to maths and reducing their maths anxiety as well as surfacing teachers’ attitudes to maths teaching may lead to greater engagement with maths and learning for children experiencing relative deprivation.

Educational psychology is well placed to apply the skills required to ensure more of the budget spent on tackling the effects of poverty is targeted more effectively to ensure children and young people thrive and their future is not determined by their background, but by their willingness to apply themselves to their learning. In short, achievement in learning is not fixed, poverty is not destiny and it is incumbent on those of us working in the education system to ensure we remove the barriers to all of our children and young people thriving.

References

Agostini, F., Zoccolotti, P., & Casagrande, M. (2022). Domain-General Cognitive Skills in Children with Mathematical Difficulties and Dyscalculia: A Systematic Review of the Literature. *BRAIN SCI*, *12*(2), 239. https://doi.org/10.3390/brainsci12020239

Alegre, F., Moliner, L., Maroto, A., & Lorenzo-Valentin, G. (2019a). Peer tutoring and mathematics in secondary education: literature review, effect sizes, moderators, and implications for practice. *Heliyon*, *5*(9), e02491. https://doi.org/10.1016/j.heliyon.2019.e02491

Alegre, F., Moliner, L., Maroto, A., & Lorenzo-Valentin, G. (2019b). Peer tutoring in mathematics in primary education: a systematic review. *Educational Review*, *71*(6), 767-791. https://doi.org/10.1080/00131911.2018.1474176

Alegre, F., Moliner, L., Maroto, A., & Lorenzo-Valentin, G. (2020). Academic Achievement and Peer Tutoring in Mathematics: A Comparison Between Primary and Secondary Education. *SAGE open*, *10*(2), 215824402092929. https://doi.org/10.1177/2158244020929295

American Psychiatric Association (2013). Diagnostic and statistical manual of mental disorders : DSM-5. 9780890425541

Anderson, R. K., Boaler, J., & Dieckmann, J. A. (2018). Achieving elusive teacher change through challenging myths about learning: A blended approach. *Education sciences*, *8*(3), 98. https://doi.org/10.3390/educsci8030098

Anderson, T., & Shattuck, J. (2012). Design-Based Research: A Decade of Progress in Education Research? *Educational researcher*, *41*(1), 16-25. https://doi.org/10.3102/0013189X11428813

Appelbaum, M., Cooper, H., Kline, R. B., Mayo-Wilson, E., Nezu, A. M., & Rao, S. M. (2018). Journal article reporting standards for quantitative research in psychology: The APA Publications and Communications Board task force report. *American Psychologist*, *73*(1), 3-25. https://doi.org/10.1037/amp0000191

Arsalidou, M., Pawliw-Levac, M., Sadeghi, M., & Pascual-Leone, J. (2018). Brain areas associated with numbers and calculations in children: Meta-analyses of fMRI studies. *Developmental Cognitive Neuroscience*, *30*, 239-250. https://doi.org/10.1016/j.dcn.2017.08.002

Asún, R. A., Rdz-Navarro, K., & Alvarado, J. M. (2016). Developing Multidimensional Likert Scales Using Item Factor Analysis: The Case of Four-point Items. *Sociological methods & research*, *45*(1), 109-133. https://doi.org/10.1177/0049124114566716

Au, W. (2016). Meritocracy 2.0: High-Stakes, Standardized Testing as a Racial Project of Neoliberal Multiculturalism. *EDUC POLICY*, *30*(1), 39-62. https://doi.org/10.1177/0895904815614916

Bachman, H. J., Votruba-Drzal, E., El Nokali, N. E., & Castle Heatly, M. (2015). Opportunities for Learning Math in Elementary School: Implications for SES Disparities in Procedural and Conceptual Math Skills. *American educational research journal*, *52*(5), 894-923. https://doi.org/10.3102/0002831215594877

Baker, C. N., Tichovolsky, M. H., Kupersmidt, J. B., Voegler-Lee, M. E., & Arnold, D. H. (2015). Teacher (mis)perceptions of preschoolers' academic skills: Predictors and associations with longitudinal outcomes. *Journal of Educational Psychology*, *107*(3), 805-820. https://doi.org/10.1037/edu0000008

Bakker, M., Van Den Heuvel-Panhuizen, M., & Robitzsch, A. (2015). Effects of playing mathematics computer games on primary school students' multiplicative reasoning ability. *Contemporary Educational Psychology*, *40*, 55-71. https://doi.org/10.1016/j.cedpsych.2014.09.001

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological review*, *84*(2), 191-215. https://doi.org/10.1037/0033-295X.84.2.191

Banerjee, P. A. (2016). A systematic review of factors linked to poor academic performance of disadvantaged students in science and maths in schools. *Cogent Education*, *3*(1), 1178441. https://doi.org/10.1080/2331186x.2016.1178441

Baroody, A. J., Feil, Y., & Johnson, A. R. (2007). An Alternative Reconceptualization of Procedural and Conceptual Knowledge. *Journal for research in mathematics education*, *38*(2), 115-131.

Barr, A. B. (2015). Family socioeconomic status, family health, and changes in students' math achievement across high school: A mediational model. *SOC SCI MED*, *140*, 27-34. https://doi.org/10.1016/j.socscimed.2015.06.028

Barrett, C. B., & Carter, M. R. (2013). The Economics of Poverty Traps and Persistent Poverty: Empirical and Policy Implications. *J DEV STUD*, *49*(7), 976-990. https://doi.org/10.1080/00220388.2013.785527

Battey, D. (2012). "Good" mathematics teaching for students of color and those in poverty: the importance of relational interactions within instruction. *Educ Stud Math*, *82*(1), 125-144. https://doi.org/10.1007/s10649-012-9412-z

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Tsai, Y.-M. (2010). Teachers' Mathematical Knowledge, Cognitive Activation in the Classroom, and Student Progress. *American Educational Research Journal*, *47*(1), 133-180. https://doi.org/10.3102/0002831209345157

Bergin, M., Wells, J. S. G., & Owen, S. (2008). Critical realism: a philosophical framework for the study of gender and mental health. *NURS PHILOS*, *9*(3), 169-179. https://doi.org/10.1111/j.1466-769X.2008.00358.x

Biesta, G. (2015). What is Education For? On Good Education, Teacher Judgement, and Educational Professionalism. *European Journal of Education*, *50*(1), 75-87. https://doi.org/10.1111/ejed.12109

Boaler, J. (2008). Promoting 'relational equity' and high mathematics achievement through an innovative mixed-ability approach. *British Educational Research Journal*, *34*(2), 167-194. https://doi.org/10.1080/01411920701532145

Boyle, J. (2012). Understanding the Nature of Experiments in Real-World Educational Contexts. In B. Kelly & D. F. Perkins (Eds.), *Handbook of Implementation Science for Psychology in Education* (pp. 54-67). Cambridge University Press.

Boyle, J., Connolly, M., & MacKay, T. (2016). Systematic review and meta-analysis. *Education and Child Psychology*, 33 (3). ISSN 0267-1611.

Brady, D. (2019). Theories of the Causes of Poverty. *ANNU REV SOCIOL*, *45*(1), 155-175. https://doi.org/10.1146/annurev-soc-073018-022550

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

Brezovszky, B., Mcmullen, J., Veermans, K., Hannula-Sormunen, M. M., Rodríguez-Aflecht, G., Pongsakdi, N., Lehtinen, E. (2019). Effects of a mathematics game-based learning environment on primary school students' adaptive number knowledge. *Computers & Education*, *128*, 63-74. https://doi.org/10.1016/j.compedu.2018.09.011

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist*, *32*(7), 513-531. https://doi.org/10.1037/0003-066X.32.7.513

Brow, M. (2018). Significant predictors of mathematical literacy for top-tiered countries/economies, Canada, and the United States on PISA 2012: Case for the sparse regression model. *British Journal of Educational Psychology*, *89*(4), 726-749. https://doi.org/10.1111/bjep.12254

Brown, C., & Putwain, D. W. (2022). Socio-economic status, gender and achievement: the mediating role of expectancy and subjective task value. *EDUC PSYCHOL-UK*, *42*(6), 730-748. https://doi.org/10.1080/01443410.2021.1985083

Brown, C., Spiro, J., & Quinton, S. (2020). The role of research ethics committees: Friend or foe in educational research? An exploratory study. *British* *educational research journal*, *46*(4), 747-769. https://doi.org/10.1002/berj.3654

Bryce, T. G. K., Humes, W. M., Gillies, D., Kennedy, A., Davidson, J., Hamilton, T., & Smith, I. (2018). *Scottish education* (Fifth edition. ed.). Edinburgh University Press.

Burden, R. (2008). Illuminative Evaluation. In B. Kelly, L. Woolfson, & J. Boyle (Eds.), *Frameworks for Practice in Educational Psychology: A Textbook for Trainees and Practitioners* (Second ed., pp. 291-308). Jessica Kingsley.

Burden, R. (1998). Assessing Children's Perceptions of Themselves as Learners and Problem-Solvers: The Construction of the Myself-as-Learner Scale (MALS). *School psychology international*, *19*(4), 291-305. https://doi.org/10.1177/0143034398194002

Burden, R. (1999). *Psychology In Education Portfolio: Children's Self-Perceptions*. NFER-Nelson.

Burnett, K., & Farkas, G. (2009). Poverty and family structure effects on children's mathematics achievement: Estimates from random and fixed effects models. *The Social science journal (Fort Collins)*, *46*(2), 297-318. https://doi.org/10.1016/j.soscij.2008.12.009

Butterworth, B., Varma, S., & Laurillard, D. (2011). Dyscalculia: From Brain to Education. *SCIENCE*, *332*(6033), 1049-1053. https://doi.org/10.1126/science.1201536

Bücker, J., Kapczinski, F., Post, R., Ceresér, K. M., Szobot, C., Yatham, L. N., Kauer-Sant'Anna, M. (2012). Cognitive impairment in school-aged children with early trauma. *COMPR PSYCHIAT*, *53*(6), 758-764. https://doi.org/10.1016/j.comppsych.2011.12.006

Çakır, M. P., Çakır, N. A., Ayaz, H., & Lee, F. J. (2016). Behavioral and neural effects of game-based learning on improving computational fluency with numbers: An optical brain imaging study. *Zeitschrift für Psychologie*, *224*(4), 297-302. https://doi.org/10.1027/2151-2604/a000267

Cambridge University Press (2022). *Centre for Evaluation and Monitoring*. Cambridge University. Retrieved 17.07.2022 from https://www.cem.org/incas

Carr, M., Horan, E., Alexeev, N., Barned, N., Wang, L., & Otumfuor, B. (2020). A longitudinal study of spatial skills and number sense development in elementary school children. *Journal of Educational Psychology*, *112*(1), 53-69. https://doi.org/10.1037/edu0000363

Carter, M. R., & Barrett, C. B. (2006). The economics of poverty traps and persistent poverty: An asset-based approach. *J DEV STUD*, *42*(2), 178-199. https://doi.org/10.1080/00220380500405261

Casey, B. M., Dearing, E., Vasilyeva, M., Ganley, C. M., & Tine, M. (2011). Spatial and numerical predictors of measurement performance: The moderating effects of community income and gender. *Journal of Educational Psychology*, *103*(2), 296-311. https://doi.org/10.1037/a0022516

Cave, S. N., & Stumm, S. (2021). Secondary data analysis of British population cohort studies: A practical guide for education researchers. *Br J Educ Psychol*, *91*(2), 531-546. https://doi.org/10.1111/bjep.12386

Chmielewski, A. K. (2019). The Global Increase in the Socioeconomic Achievement Gap, 1964 to 2015. *AM SOCIOL REV*, *84*(3), 517-544. https://doi.org/10.1177/0003122419847165

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd . ed.). Hillsdale, N.J. : L. Erlbaum Associates.

Connolly, T. M., Boyle, E. A., Macarthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661-686. https://doi.org/10.1016/j.compedu.2012.03.004

Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical assessment, research & evaluation*, *10*(7), 7.

Crooks, N. M., & Alibali, M. W. (2014). Defining and measuring conceptual knowledge in mathematics. *Developmental review*, *34*(4), 344-377. https://doi.org/10.1016/j.dr.2014.10.001

Darlington, R. B., & Hayes, A. F. (2017). *Regression Analysis and Linear Models. Concepts, Applications, and Implementation*. The Guilford Press.

Decarli, G., Sella, F., Lanfranchi, S., Gerotto, G., Gerola, S., Cossu, G., & Zorzi, M. (2022). Severe Developmental Dyscalculia Is Characterized by Core Deficits in Both Symbolic and Nonsymbolic Number Sense. *PSYCHOL SCI*, 95679762210979-9567976221097947. https://doi.org/10.1177/09567976221097947

Decerf, B., & Ferrando, M. (2022). Unambiguous Trends Combining Absolute and Relative Income Poverty: New Results and Global Application. *WORLD BANK ECON REV*, *36*(3), 605-628. https://doi.org/10.1093/wber/lhab028

Deflorio, L., & Beliakoff, A. (2015). Socioeconomic Status and Preschoolers' Mathematical Knowledge: The Contribution of Home Activities and Parent Beliefs. *Early Education and Development*, *26*(3), 319-341. https://doi.org/10.1080/10409289.2015.968239

Deng, L., Wu, S., Chen, Y., & Peng, Z. (2020). Digital game-based learning in a Shanghai primary-school mathematics class: A case study. *Journal of*

Computer Assisted Learning, *36*(5), 709-717. https://doi.org/10.1111/jcal.12438

Dicke, T., Marsh, H. W., Parker, P. D., Pekrun, R., Guo, J., & Televantou, I. (2018). Effects of School-Average Achievement on Individual Self-Concept and Achievement: Unmasking Phantom Effects Masquerading as True Compositional Effects. *Journal of educational psychology*, *110*(8), 1112-1126. https://doi.org/10.1037/edu0000259

Dietrichson, J., Bøg, M., Filges, T., & Jørgensen, A.-M. K. (2017). Academic Interventions for Elementary and Middle School Students With Low Socioeconomic Status: A Systematic Review and Meta-Analysis. *Review of educational research*, *87*(2), 243-282. https://doi.org/10.3102/0034654316687036

Dietrichson, J., Filges, T., Seerup, J. K., Klokker, R. H., Viinholt, B. C. A., Bøg, M., & Eiberg, M. (2021). Targeted school-based interventions for improving reading and mathematics for students with or at risk of academic difficulties in Grades K-6: A systematic review. *Campbell Systematic Reviews*, *17*(2). https://doi.org/10.1002/cl2.1152

Dulaney, A., Vasilyeva, M., & O'Dwyer, L. (2015). Individual differences in cognitive resources and elementary school mathematics achievement: Examining the roles of storage and attention. *Learning and individual differences*, *37*, 55-63. https://doi.org/10.1016/j.lindif.2014.11.008

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Japel, C. (2007). School Readiness and Later Achievement. *Dev Psychol*, *43*(6), 1428-1446. https://doi.org/10.1037/0012-1649.43.6.1428

Dunst, C. J., & Trivette, C. M. (2012). Meta-Analysis of Implementation Practice Research. In B. Kelly & D. F. Perkins (Eds.), *Handbook of Implementation Science for Psychology in Education* (pp. 68-91). Cambridge University Press.

Eagly, A. H., & Chaiken, S. (2007). The advantages of an inclusive definition of attitude. *Social cognition*, *25*(5), 582-602. https://doi.org/10.1521/soco.2007.25.5.582

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary educational psychology*, *61*, 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

Education (Scotland) Act 2016, (2016). https://www.legislation.gov.uk/asp/2016/8/contents/enacted

Ellefson, M. R., Zachariou, A., Ng, F. F.-Y., Wang, Q., & Hughes, C. (2020). Do executive functions mediate the link between socioeconomic status and numeracy skills? A cross-site comparison of Hong Kong and the United Kingdom. *Journal of Experimental Child Psychology*, *194*, 104734. https://doi.org/https://doi.org/10.1016/j.jecp.2019.104734

Elliott, J., Lauchlan, F., & Stringer, P. (1996). Dynamic Assessment and its Potential for Educational Psychologists: Part 1 - Theory and practice. *Educational psychology in practice*, *12*(3), 152-160. https://doi.org/10.1080/0266736960120303

Eurostat. (2021). *Education and job type affect over 55s' employment*. Retrieved 04.07.2023 from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210706-1

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). GPower 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191. https://doi.org/10.3758/BF03193146

Favaro, D., & Sciulli, D. (2022). Female long-term labour market outcomes: the role of early-life abilities and education. *Applied Economics*, *54*(3), 340-353. https://doi.org/10.1080/00036846.2021.1962510

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics* (4th ed.). Sage.

Fielding-Wells, J., O'Brien, M., & Makar, K. (2017). Using expectancy-value theory to explore aspects of motivation and engagement in inquiry-based learning in primary mathematics. *Math Ed Res J*, *29*(2), 237-254. https://doi.org/10.1007/s13394-017-0201-y

Fischer, J. P., & Thierry, X. (2021). Are differences between social classes reduced by non-symbolic numerical tasks? Evidence from the ELFE cohort. *British Journal of Educational Psychology*, *91*(1), 286-299. https://doi.org/10.1111/bjep.12363

Fisher, R. J., & Katz, J. E. (2000). Social-desirability bias and the validity of self-reported values [https://doi.org/10.1002/(SICI)1520-6793(200002)17:2<105::AID-MAR3>3.0.CO;2-9]. *Psychology & Marketing*, *17*(2), 105-120. https://doi.org/https://doi.org/10.1002/(SICI)1520-6793(200002)17:2<105::AID-MAR3>3.0.CO;2-9

Fleetwood, S. (2014). Bhaskar and Critical Realism. In *The Oxford Handbook of Sociology, Social Theory, and Organization Studies: Contemporary Currents* (pp. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199671083.013.0009

Flinders, D. J. (1992). In search of ethical guidance: constructing a basis for dialogue. *International journal of qualitative studies in education*, *5*(2), 101-115. https://doi.org/10.1080/0951839920050202

Francis, B., Craig, N., Hodgen, J., Taylor, B., Tereshchenko, A., Connolly, P., & Archer, L. (2020). The impact of tracking by attainment on pupil self-confidence over time: demonstrating the accumulative impact of self-fulfilling prophecy. *British Journal of Sociology of Education*, *41*(5), 626-642. https://doi.org/10.1080/01425692.2020.1763162

Fyfe, E. R., Rittle-Johnson, B., & Farran, D. C. (2019). Predicting success on high-stakes math tests from preschool math measures among children from low-income homes. *Journal of Educational Psychology*, *111*(3), 402-413. https://doi.org/10.1037/edu0000298

Gil-Lacruz, M., Gil-Lacruz, A. I., & Gracia-Pérez, M. L. (2020). Health-related quality of life in young people: The importance of education. *HEALTH QUAL LIFE OUT*, *18*(1), 1-187. https://doi.org/10.1186/s12955-020-01446-5

Glasman, L. R., & Albarracín, D. (2006). Forming Attitudes That Predict Future Behavior: A Meta-Analysis of the Attitude-Behavior Relation. *Psychol Bull*, *132*(5), 778-822. https://doi.org/10.1037/0033-2909.132.5.778

Goforth, K., Noltemeyer, A., Patton, J., Bush, K. R., & Bergen, D. (2014). Understanding mathematics achievement: an analysis of the effects of student and family factors. *Educational Studies*, *40*(2), 196-214. https://doi.org/10.1080/03055698.2013.866890

Gorard, S. (2016). The complex determinants of school intake characteristics and segregation, England 1989 to 2014. *Cambridge Journal of Education*, *46*(1), 131-146. https://doi.org/10.1080/0305764X.2015.1045446

Gorard, S. (2020). Handling missing data in numeric analyses. *International journal of social research methodology*, *23*(6), 651-660. https://doi.org/10.1080/13645579.2020.1729974

Gorard, S., See, B. H., & Davies, P. (2012). Attitudes and aspirations in educational attainment: exploring causality. Joseph Rowantree Foundation.

Gorard, S., & Siddiqui, N. (2019). How Trajectories of Disadvantage Help Explain School Attainment. *SAGE open*, *9*(1), 215824401882517. https://doi.org/10.1177/2158244018825171

Gorard, S., Siddiqui, N., & See, B. H. (2019). The difficulties of judging what difference the Pupil Premium has made to school intakes and outcomes in England. *Research papers in education*, 1-25. https://doi.org/10.1080/02671522.2019.1677759

Graven, M. H. (2014). Poverty, inequality and mathematics performance: the case of South Africa’s post-apartheid context. *ZDM Mathematics Education*, *46*(7), 1039-1049. https://doi.org/10.1007/s11858-013-0566-7

Greene, J. A. (2022). What Can Educational Psychology Learn From, and Contribute to, Theory Development Scholarship? *Educ Psychol Rev*, *34*(4), 3011-3035. https://doi.org/10.1007/s10648-022-09682-5

Gumus, S. (2014). The effects of community factors on school participation in Turkey: A multilevel analysis [Article]. *International Review of Education / Internationale Zeitschrift für Erziehungswissenschaft*, *60*(1), 79-98. https://doi.org/10.1007/s11159-014-9411-7

Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S., & Yeung, A. S. (2015). Expectancy-value in mathematics, gender and socioeconomic background as predictors of achievement and aspirations: A multi-cohort study. *LEARN INDIVID DIFFER*, *37*, 161-168. https://doi.org/10.1016/j.lindif.2015.01.008

Gülşah, G. C. (2021). Thematic Analysis of Studies on Mathematics Teaching Anxiety. *International journal of psychology and educational studies*, *8*(1), 135-147.

Hamilton, L., & Brown, J. (2005). 'Judgement day is coming!': young people and the examination process in Scotland. *Improving Schools*, *8*(1), 47-57. https://doi.org/10.1177/1365480205049339

Hann, T. (2020). Investigating the impact of teacher practices and noncognitive factors on mathematics achievement. *Research in education (Manchester)*, *108*(1), 22-45. https://doi.org/10.1177/0034523719842601

Harpe, S. E. (2015). How to analyze Likert and other rating scale data. *Currents in Pharmacy Teaching and Learning*, *7*(6), 836-850. https://doi.org/10.1016/j.cptl.2015.08.001

Hart, S. A., Petrill, S. A., Thompson, L. A., & Plomin, R. (2009). The ABCs of Math: A Genetic Analysis of Mathematics and Its Links With Reading Ability and General Cognitive Ability. *J Educ Psychol*, *101*(2), 388-402. https://doi.org/10.1037/a0015115

Hartley, M. S. (2008). The application of a CAL strategy in science and mathematics for disadvantaged Grade 12 learners in South Africa. *International journal of educational development.*, *28*(5), 596.

Harvey, H. A., & Miller, G. E. (2017). Executive Function Skills, Early Mathematics, and Vocabulary in Head Start Preschool Children. *EARLY EDUC DEV*, *28*(3), 290-307. https://doi.org/10.1080/10409289.2016.1218728

Hassinger-Das, B., Toub, T. S., Zosh, J. M., Michnick, J., Golinkoff, R., & Hirsh-Pasek, K. (2017). More than just fun: a place for games in playful learning / Más que diversión: el lugar de los juegos reglados en el aprendizaje lúdico. *Infancia y Aprendizaje*, *40*(2), 191-218. https://doi.org/10.1080/02103702.2017.1292684

Hedges, H. (2021). Contemporary principles to lead understandings of children's learning: synthesizing Vygotsky, Rogoff, Wells and Lindfors. *EARLY CHILD DEV CARE*, *191*(7-8), 1056-1065. https://doi.org/10.1080/03004430.2020.1849169

Helms, J. E. (1992). Why Is There No Study of Cultural Equivalence in Standardized Cognitive Ability Testing? *AM PSYCHOL*, *47*(9), 1083-1101. https://doi.org/10.1037/0003-066X.47.9.1083

Hentges, R. F., Galla, B. M., & Wang, M.-T. (2019). Economic disadvantage and math achievement: The significance of perceived cost from an evolutionary perspective [https://doi.org/10.1111/bjep.12242]. *British Journal of Educational Psychology*, *89*(2), 343-358. https://doi.org/https://doi.org/10.1111/bjep.12242

Herringa, R. J. (2017). Trauma, PTSD, and the Developing Brain. *Current Psychiatry Reports*, *19*(10). https://doi.org/10.1007/s11920-017-0825-3

Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: an introductory analysis. In J. Hiebert (Ed.), *Conceptual and Procedural Knowledge: The Case of Mathematics* (pp. 309). Lawrence Erlbaum Associates.

Holm, J., & Kajander, A. (2012). Interconnections of Knowledge and Beliefs in Teaching Mathematics. *Can J Sci Math Techn*, *12*(1), 7-21. https://doi.org/10.1080/14926156.2012.649055

Holm, J., & Kajander, A. (2020). Seeking Intersections: Math Degrees, Beliefs, and Elementary Teacher Knowledge. *Canadian Journal of Science, Mathematics and Technology Education*, *20*(1), 27-41. https://doi.org/10.1007/s42330-019-00069-3

Häfner, I., Flunger, B., Dicke, A.-L., Gaspard, H., Brisson, B. M., Nagengast, B., & Trautwein, U. (2017). Robin Hood effects on motivation in math: Family interest moderates the effects of relevance interventions. *Developmental Psychology*, *53*(8), 1522-1539. https://doi.org/10.1037/dev0000337

IEA (2023). *International Association for the Evaluation of Educational Achievement*. Retrieved 08.01.2023 from https://www.iea.nl/

Jaciw, A. P., Hegseth, W. M., Lin, L., Toby, M., Newman, D., Ma, B., & Zacamy, J. (2016). Assessing Impacts of Math in Focus, a "Singapore Math" Program. *J RES EDUC EFF*, *9*(4), 473-502. https://doi.org/10.1080/19345747.2016.1164777

Kachwalla, B. (2021). Making math accessible to all students: Effective pedagogy? *Journal of higher education theory and practice*, *21*(3), 89-95. https://doi.org/10.33423/JHETP.V21I3.4145

Kajander, A. (2010a). Elementary Mathematics Teacher Preparation in an Era of Reform: The Development and Assessment of Mathematics for Teaching. *Canadian journal of education, 33*(1), 228-255.

Kajander, A. (2010b). Teachers Constructing Concepts of Mathematics for Teaching and Learning: “It’s like the roots beneath the surface, not a bigger garden”. *Can J Sci Math Techn*, *10*(2), 87-102. https://doi.org/10.1080/14926151003778274

Kajander, A., & Holm, J. (2013). Pre-service teachers' mathematical understanding: Searching for differences based on school curriculum background. *Fields Mathematics Education Journal*, *1*, 3-20.

Kajander, A., & Mason, R. (2007). Examining Teacher Growth in Professional Learning Groups for In-service Teachers of Mathematics. *Can J Sci Math Techn*, *7*(4), 417-438. https://doi.org/10.1080/14926150709556743

Kajander, A., Zuke, C., & Walton, G. (2008). Teaching Unheard Voices: Students At-Risk in Mathematics [Article]. *Canadian Journal of Education*, *31*(4), 1039-1063.

Kelly, B., Woolfson, L. M., & Boyle, J. (2017). *Frameworks for Practice in Educational Psychology. A Textbook for Trainees and Practitioners* (2nd ed.). Jessica Kingsley.

Kiamanesh, A. R., & Ali Reza, K. (2005). The role of students' characteristics and family background in Iranian students' mathematics achievement. In (Vol. 35, pp. 161-174). France.

Kirschner, P. A., & Hendrick, C. (2020). *How Learning Happens. Seminal Works in Educational Psychology and What They Mean in Practice*. Routledge.

Komatsu, H., & Rappleye, J. (2017). A new global policy regime founded on invalid statistics? Hanushek, Woessmann, PISA, and economic growth. *COMP EDUC*, *53*(2), 166-191. https://doi.org/10.1080/03050068.2017.1300008

Krinzinger, H., Kaufmann, L., & Willmes, K. (2009). Math Anxiety and Math Ability in Early Primary School Years. *J Psychoeduc Assess*, *27*(3), 206-225. https://doi.org/10.1177/0734282908330583

Kruse, A. J. (2016). Cultural Bias in Testing: A Review of Literature and Implications for Music Education. *Update : applications of research in music education*, *35*(1), 23-31. https://doi.org/10.1177/8755123315576212

Kuhl, U., Friederici, A. D., Emmrich, F., Brauer, J., Wilcke, A., Neef, N., . . . Skeide, M. A. (2020). Early cortical surface plasticity relates to basic mathematical learning. *Neuroimage*, *204*, 116235-116235. https://doi.org/10.1016/j.neuroimage.2019.116235

König, J., Blömeke, S., Jentsch, A., Schlesinger, L., Née Nehls, C. F., Musekamp, F., & Kaiser, G. (2021). The links between pedagogical competence, instructional quality, and mathematics achievement in the lower secondary classroom. *Educational Studies in Mathematics*, *107*(1), 189-212. https://doi.org/10.1007/s10649-020-10021-0

Langenkamp, A. G., & Carbonaro, W. (2018). How School Socioeconomic Status Affects Achievement Growth across School Transitions in Early Educational Careers. *Sociol Educ*, *91*(4), 358-378. https://doi.org/10.1177/0038040718802257

Lawson, G. M., & Farah, M. J. (2015). Executive function as a mediator between SES and academic achievement throughout childhood. *International Journal of Behavioral Development*, *41*(1), 94-104. https://doi.org/10.1177/0165025415603489

Lazarides, R., Dicke, A.-L., Rubach, C., & Eccles, J. S. (2020). Profiles of motivational beliefs in math: Exploring their development, relations to student-perceived classroom characteristics, and impact on future career aspirations and choices. *Journal of Educational Psychology*, *112*(1), 70-92. https://doi.org/10.1037/edu0000368

Lenz, K., Dreher, A., Holzäpfel, L., & Wittmann, G. (2020). Are conceptual knowledge and procedural knowledge empirically separable? The case of fractions. *Br J Educ Psychol*, *90*(3), 809-829. https://doi.org/10.1111/bjep.12333

Leung, K. C. (2019). An updated meta-analysis on the effect of peer tutoring on tutors' achievement. *SCHOOL PSYCHOL INT*, *40*(2), 200-214. https://doi.org/10.1177/0143034318808832

Levitt, H. M., Bamberg, M., Creswell, J. W., Frost, D. M., Josselson, R., & Suárez-Orozco, C. (2018). Journal Article Reporting Standards for Qualitative Primary, Qualitative Meta-Analytic, and Mixed Methods Research in Psychology: The APA Publications and Communications Board Task Force Report. *Am Psychol*, *73*(1), 26-46. https://doi.org/10.1037/amp0000151

Lidón, M., & Francisco, A. (2020). Peer Tutoring Effects on Students' Mathematics Anxiety: A Middle School Experience. *Frontiers in psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.01610

Ma, X., & Kishor, N. (1997). Assessing the Relationship between Attitude toward Mathematics and Achievement in Mathematics: A Meta-Analysis. *Journal for research in mathematics education*, *28*(1), 26-47. https://doi.org/10.2307/749662

Maccallum, R. C., Widaman, K. F., Shaobo, Z., & Sehee, H. (1999). Sample size in factor analysis. *Psychological methods*, *4*(1), 84-99.

MacKay, T. (2018). Psychological Services and Their Impact. In T. G. K. Bryce, W. M. Humes, D. Gillies, & A. Kennedy (Eds.), *Scottish Education* (5th ed., pp. 717-727). Edinburgh University Press.

MacKay, T., Boyle, J., & Cole, R. (2016). Methods for research in professional educational psychology, *Educational and child psychology*, 33(3). pp.6-10. ISSN 0267-1611.

Mammarella, I. C., Toffalini, E., Caviola, S., Colling, L., & Szűcs, D. (2021). No evidence for a core deficit in developmental dyscalculia or mathematical learning disabilities. *J CHILD PSYCHOL PSYC*, *62*(6), 704-714. https://doi.org/10.1111/jcpp.13397

Marsh, H. W., Pekrun, R., Parker, P. D., Murayama, K., Guo, J., Dicke, T., & Arens, A. K. (2019). The Murky Distinction Between Self-Concept and Self-Efficacy: Beware of Lurking Jingle-Jangle Fallacies. *J EDUC PSYCHOL*, *111*(2), 331-353. https://doi.org/10.1037/edu0000281

Martí Arnándiz, O., Moliner, L., & Alegre, F. (2022). When CLIL is for all: Improving learner motivation through peer-tutoring in Mathematics. *System (Linköping)*, *106*. https://doi.org/10.1016/j.system.2022.102773

Martínez Garrido, C. A., Gorard, S., & Siddiqui, N. (2020). Longitudinal Study of Socioeconomic Segregation Between Schools in the UK. *Revista electrónica iberoamericana sobre calidad, eficacia y cambio en educación*, *18*(4), 123-141.

McCaskey, U., von Aster, M., O'Gorman, R., & Kucian, K. (2020). Persistent Differences in Brain Structure in Developmental Dyscalculia: A Longitudinal Morphometry Study. *FRONT HUM NEUROSCI*, *14*, 272-272. https://doi.org/10.3389/fnhum.2020.00272

McGonigal, J., Doherty, R., Allan, J., Mills, S., Catts, R., Redford, M., Buckley, C. (2007). Social capital, social inclusion and changing school contexts: a Scottish perspective. *BRIT J EDUC STUD*, *55*(1), 77-94. https://doi.org/10.1111/j.1467-8527.2007.00362.x

McKinney, S., & Frazier, W. (2010). Embracing the Principles and Standards for School Mathematics: An Inquiry into the Pedagogical and Instructional Practices of Mathematics Teachers in High-Poverty Middle Schools. *The Clearing house*, *81*(5), 201-210. https://doi.org/10.3200/tchs.81.5.201-210

McNab, S. (2015, August 19). Nicola Sturgeon: Judge me on education record. *The Scotsman*. https://www.scotsman.com/news/politics/nicola-sturgeon-judge-me-on-education-record-1497298

Meaney, T. (2014). Back to the future? Children living in poverty, early childhood centres and mathematics education. *ZDM Mathematics Education*, *46*(7), 999-1011. https://doi.org/10.1007/s11858-014-0578-y

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of educational psychology*, *82*(1), 60-70. https://doi.org/10.1037//0022-0663.82.1.60

Menon, V. (2010). Developmental cognitive neuroscience of arithmetic: implications for learning and education. *ZDM*, *42*(6), 515-525. https://doi.org/10.1007/s11858-010-0242-0

Merrell, C., & Tymms, P. (2007). Identifying reading problems with computer-adaptive assessments. *Journal of Computer Assisted Learning*, *23*(1), 27-35. https://doi.org/10.1111/j.1365-2729.2007.00196.x

Michels, L., Buechler, R., & Kucian, K. (2022). Increased structural covariance in brain regions for number processing and memory in children with developmental dyscalculia. *J Neurosci Res*, *100*(2), 522-536. https://doi.org/10.1002/jnr.24998

Mikus, K., Tieben, N., & Schober, P. S. (2020). Children's conversion of cultural capital into educational success: the symbolic and skill-generating functions of cultural capital. *British journal of sociology of education*, *41*(2), 197-217. https://doi.org/10.1080/01425692.2019.1677454

Mikus, K., Tieben, N., & Schober, P. S. (2021). Concerted cultivation in early childhood and social inequalities in cognitive skills: Evidence from a German panel study. *RES SOC STRAT MOBIL*, *72*, 100547. https://doi.org/10.1016/j.rssm.2020.100547

Miles, J. & Shevlin, M. (2001). *Applying regression & correlation : a guide for students and researchers*. London ; Thousand Oaks, Calif. : Sage Publications.

Mirzaei Rafe, M. (2021). An examination of Roy Bhaskar's critical realism as a basis for educational practice. *Journal of Critical Realism*, *20*(1), 56-72. https://doi.org/10.1080/14767430.2020.1807799

Mirzaei Rafe, M., Bagheri Noaparast, K., Sadat Hosseini, A., & Sajadieh, N. (2019). The application of critical realism as a basis for agency in environmental education: The case of Roy Bhaskar. *Australian journal of environmental education*, *35*(3), 230-238. https://doi.org/10.1017/aee.2019.21

Moliner, L., & Alegre, F. (2020). Effects of peer tutoring on middle school students' mathematics self-concepts. *PloS one*, *15*(4), e0231410-e0231410. https://doi.org/10.1371/journal.pone.0231410

Mowat, J. G. (2020). Interrogating the relationship between poverty, attainment and mental health and wellbeing: the importance of social networks and support – a Scottish case study. *Cambridge Journal of Education*, *50*(3), 345-370. https://doi.org/10.1080/0305764X.2019.1702624

Muijs, D., & Dunne, M. (2010). Setting by ability - or is it? A quantitative study of determinants of set placement in English secondary schools. *EDUC RES-UK*, *52*(4), 391-407. https://doi.org/10.1080/00131881.2010.524750

Mundelsee, L., & Jurkowski, S. (2021). Think and pair before share: Effects of collaboration on students' in-class participation. *Learning and Individual Differences*, *88*, 102015. https://doi.org/10.1016/j.lindif.2021.102015

Nesbitt, K. T., Baker-Ward, L., & Willoughby, M. T. (2013). Executive function mediates socio-economic and racial differences in early academic achievement. *EARLY CHILD RES Q*, *28*(4), 774-783. https://doi.org/10.1016/j.ecresq.2013.07.005

Nonoyama-Tarumi, Y., Hughes, K., & Willms, J. (2015). The role of family background and school resources on elementary school students' mathematics achievement [Article]. *Prospects (00331538)*, *45*(3), 305-324. https://doi.org/10.1007/s11125-015-9362-1

Norman, G. (2010). Likert scales, levels of measurement and the “laws” of statistics. *Adv in Health Sci Educ*, *15*(5), 625-632. https://doi.org/10.1007/s10459-010-9222-y

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International journal of qualitative methods*, *16*(1), 1-13. https://doi.org/10.1177/1609406917733847

OECD (2007). *Reviews of National Policies for Education. Quality and Equity of Schooling in Scotland*. OECD. https://doi.org/https://doi.org/10.1787/9789264041004-en

OECD (2016). *Equations and Inequalities. Making Mathematics Accessible to All*. OECD. https://doi.org/http://dx.doi.org/10.1787/9789264258494-en

OECD (2020). *Education at a Glance 2019: OECD Indicators*. O. Publishing. https://doi.org/10.1787/f8d7880d-en

Ohlsson, A., Eckerdal, N., Lindahl, B., Hanning, M., & Westerling, R. (2021). Non-employment and low educational level as risk factors for inequitable treatment and mortality in heart failure: a population-based cohort study of register data. *BMC PUBLIC HEALTH*, *21*(1), 1-1040. https://doi.org/10.1186/s12889-021-10919-1

Oikarinen, R. M., Oikarinen, J. K., Havu-Nuutinen, S., & Pöntinen, S. (2022). Students’ collaboration in technology-enhanced reciprocal peer tutoring as an approach towards learning mathematics. *Education and information technologies*. https://doi.org/10.1007/s10639-021-10799-3

Osborne, J., Costello, A., & Kellow, T. (2008). Best Practices in Exploratory Factor Analysis. In J. Osborne (Ed.), *Best Practices in Quantitative Methods* (pp. 86). Thousand Oaks: SAGE Publications, Inc. https://doi.org/10.4135/9781412995627.d8

Pajares, F., & Miller, M. D. (1994). Role of Self-Efficacy and Self-Concept Beliefs in Mathematical Problem Solving: A Path Analysis. *Journal of educational psychology*, *86*(2), 193-203. https://doi.org/10.1037/0022-0663.86.2.193

Pallant, J. (2020). *SPSS Survival Manual. A Step by Step Guide to Data Analysis Using IBM SPSS* (7th ed.). Routledge.

Papadakis, N., Drakaki, M., Saridaki, S., Amanaki, E., & Dimari, G. (2022). Educational capital/ level and its association with precarious work and social vulnerability among youth, in EU and Greece. *INT J EDUC RES*, *112*, 101921. https://doi.org/10.1016/j.ijer.2021.101921

Passig, D., Tzuriel, D., & Eshel-Kedmi, G. (2016). Improving children's cognitive modifiability by dynamic assessment in 3D Immersive Virtual Reality environments. *COMPUT EDUC*, *95*, 296-308. https://doi.org/10.1016/j.compedu.2016.01.009

Paterson, L., Blackburn, L. H., & Weedon, E. (2019). The use of the Scottish Index of Multiple Deprivation as an indicator to evaluate the impact of policy on widening access to higher education. *Scottish affairs*, *28*(4), 414-433. https://doi.org/10.3366/scot.2019.0296

Patkin, D., & Greenstein, Y. (2020). Mathematics anxiety and mathematics teaching anxiety of in-service and pre-service primary school teachers. *Teacher development*, *24*(4), 502-519. https://doi.org/10.1080/13664530.2020.1785541

Pearman, F. A. (2019). The Effect of Neighborhood Poverty on Math Achievement: Evidence From a Value-Added Design. *Education and Urban Society*, *51*(2), 289-307. https://doi.org/10.1177/0013124517715066

Pitchford, N. J., Papini, C., Outhwaite, L. A., & Gulliford, A. (2016). Fine motor skills predict maths ability better than they predict reading ability in the early primary school years. *FRONT PSYCHOL*, *7*(MAY), 783-783. https://doi.org/10.3389/fpsyg.2016.00783

Pizzie, R. G., McDermott, C. L., Salem, T. G., & Kraemer, D. J. M. (2020). Neural evidence for cognitive reappraisal as a strategy to alleviate the effects of math anxiety. *Social Cognitive and Affective Neuroscience*, *15*(12), 1271-1287. https://doi.org/10.1093/scan/nsaa161

Plucker, J. A., & Makel, M. C. (2021). Replication is important for educational psychology: Recent developments and key issues. *EDUC PSYCHOL-US*, *56*(2), 90-100. https://doi.org/10.1080/00461520.2021.1895796

Putwain, D. W., Schmitz, E. A., Wood, P., & Pekrun, R. (2021). The role of achievement emotions in primary school mathematics: Control–value antecedents and achievement outcomes. *Br J Educ Psychol*, *91*(1), 347-367. https://doi.org/10.1111/bjep.12367

Rachmatullah, A., Reichsman, F., Lord, T., Dorsey, C., Mott, B., Lester, J., & Wiebe, E. (2021). Modeling Secondary Students' Genetics Learning in a Game-Based Environment: Integrating the Expectancy-Value Theory of Achievement Motivation and Flow Theory. *J Sci Educ Technol*, *30*(4), 511-528. https://doi.org/10.1007/s10956-020-09896-8

Ramani, G. B., Siegler, R. S., & Hitti, A. (2012). Taking it to the classroom: Number board games as a small group learning activity. *Journal of educational psychology*, *104*(3), 661-672. https://doi.org/10.1037/a0028995

Ramirez, G., McDonough, I. M., & Jin, L. (2017). Classroom stress promotes motivated forgetting of mathematics knowledge. *Journal of educational psychology*, *109*(6), 812-825. https://doi.org/10.1037/edu0000170

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math Anxiety: Past Research, Promising Interventions, and a New Interpretation Framework. *Educational psychologist*, *53*(3), 145-164. https://doi.org/10.1080/00461520.2018.1447384

Rawolle, S., & Lingard, B. (2008). The sociology of Pierre Bourdieu and researching education policy. *Journal of education policy*, *23*(6), 729-741. https://doi.org/10.1080/02680930802262700

Reddy, L. A., Lekwa, A., Dudek, C., Kettler, R., & Hua, A. (2020). Evaluation of Teacher Practices and Student Achievement in High-Poverty Schools. *Journal of Psychoeducational Assessment*, *38*(7), 816-830. https://doi.org/10.1177/0734282920913394

Reeves, L. S., Parsell, C., & Liu, S. (2020). Towards a phenomenology of poverty: Defining poverty through the lived experiences of the 'poor'. *J SOCIOL*, *56*(3), 439-454. https://doi.org/10.1177/1440783319851204

Reise, S. P., Ainsworth, A. T., & Haviland, M. G. (2005). Item Response Theory: Fundamentals, Applications, and Promise in Psychological Research. *CURR DIR PSYCHOL SCI*, *14*(2), 95-101. https://doi.org/10.1111/j.0963-7214.2005.00342.x

Reynolds, D., Sammons, P., De Fraine, B., Van Damme, J., Townsend, T., Teddlie, C., & Stringfield, S. (2014). Educational effectiveness research (EER): a state-of-the-art review. *School Effectiveness and School Improvement*, *25*(2), 197-230. https://doi.org/10.1080/09243453.2014.885450

Ribner, A. D., Willoughby, M. T., & Blair, C. B. (2017). Executive function buffers the association between early math and later academic skills. *FRONT PSYCHOL*, *8*(MAY), 869-869. https://doi.org/10.3389/fpsyg.2017.00869

Rich, S. E. H., Duhon, G. J., & Reynolds, J. (2017). Improving the generalization of computer-based math fluency building through the use of sufficient stimulus exemplars. *Journal of Behavioral Education*, *26*(2), 123-136. https://doi.org/10.1007/s10864-016-9262-3

Rincón-Gallardo, S. (2020). Educational Change as Social Movement: An Emerging Paradigm from the Global South. *Journal of educational change*, *21*(3), 467-477. https://doi.org/10.1007/s10833-020-09374-3

Ritchie, S., & Bates, T. (2013). Enduring Links From Childhood Mathematics and Reading Achievement to Adult Socioeconomic Status. *Psychol Sci*, *24*(7), 1301-1308. https://doi.org/10.1177/0956797612466268

Rittle-Johnson, B., Siegler, R. S., & Wagner Alibali, M. (2001). Developing Conceptual Understanding and Procedural Skill in Mathematics: An Iterative Process. *J EDUC PSYCHOL*, *93*(2), 346-362. https://doi.org/10.1037/0022-0663.93.2.346

Robson, C. (2002). *Real world research : a resource for social scientists and practitioner-researchers* (2nd ed). Oxford, UK ; Madden, Mass. : Blackwell Publishers.

Romano, E., Babchishin, L., Pagani, L. S., & Kohen, D. (2010). School Readiness and Later Achievement: Replication and Extension Using a Nationwide Canadian Survey. *Dev Psychol*, *46*(5), 995-1007. https://doi.org/10.1037/a0018880

Rosa, E. M., & Tudge, J. (2013). Urie Bronfenbrenner's Theory of Human Development: Its Evolution From Ecology to Bioecology. *J Fam Theory Rev*, *5*(4), 243-258. https://doi.org/10.1111/jftr.12022

Rosenzweig, E. Q., Wigfield, A., & Eccles, J. S. (2022). Beyond utility value interventions: The why, when, and how for next steps in expectancy-value intervention research. *Educational psychologist*, *57*(1), 11-30. https://doi.org/10.1080/00461520.2021.1984242

Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2018). Narrowing the early mathematics gap: A play-based intervention to promote low-income preschoolers' number skills. *Journal of Numerical Cognition*, *3*(3), 559-581. https://doi.org/10.5964/jnc.v3i3.72

Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2020). Benefits of Playing Numerical Card Games on Head Start Children's Mathematical Skills. *J Exp Educ*, *88*(2), 200-220. https://doi.org/10.1080/00220973.2019.1581721

Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2021). When one size does not fit all: A latent profile analysis of low-income preschoolers' math skills. *Journal of experimental child psychology*, *209*, 105156-105156. https://doi.org/10.1016/j.jecp.2021.105156

Scalise, N. R., DePascale, M., Tavassolie, N., McCown, C., & Ramani, G. B. (2022). Deal Me in: Playing Cards in the Home to Learn Math. *Education sciences*, *12*(3), 190. https://doi.org/10.3390/educsci12030190

Scollon, R. (2003). The Dialogist in a Positivist World: Theory in the Social Sciences and the Humanities at the End of the Twentieth Century. *Social semiotics*, *13*(1), 71-88. https://doi.org/10.1080/1035033032000133517

Scottish Executive (2002). *Review of Provision of Educational Psychology Services in Scotland*. Retrieved 16.04.2022 from http://www.aspep.org.uk/wp-content/uploads/2014/05/Currie-Report-2002.pdf

Scottish Government (2008). *Curriculum for Excellence: Building the Curriculum 3*. Crown Publishers. Retrieved 15.04.2022 from https://education.gov.scot/documents/btc3.pdf

Scottish Government (2022a). *Achievement of Curriculum for Excellence (CfE) Levels 2021-2022*. Scottish Government. Retrieved 02.01.2023 from Achievement of Curriculum for Excellence (CfE) Levels, 2021/22 - gov.scot (www.gov.scot)

Scottish Government (2022b). *Summary Information on How the Scottish Government Measures Poverty*. Scottish Government. Retrieved 02.01.2023 from Poverty measurement methodology: summary - gov.scot (www.gov.scot)

Scottish Government (2022). *Scottish Attainment Challenge 2022/2023 - 2025/2026 Fairer Scotland Duty Summary*. Edinburgh: Scottish Government Retrieved from https://www.gov.scot/publications/fairer-scotland-duty-assessment-scottish-attainment-challenge-2022-2023-2025-2026/documents/

Scottish Government (2011). *Explanatory Notes on Statutory Supervision Order*. Scottish Government. Retrieved 28.01.2023 from Children's Hearings (Scotland) Act 2011 - Explanatory Notes (legislation.gov.uk)

Scottish Government (2012). *Scotland's Census 2011*. Scottish Government. Retrieved 17.01.2023 from Scotland's Census - Area Overview - Results for 2011 (scotlandscensus.gov.uk)

Scottish Government (2016). *Scottish Survey of Literacy and Numeracy 2016*. Crown. Retrieved 15.04.2022 from https://www.gov.scot/collections/scottish-survey-of-literacy-and-numeracy/

Scottish Government (2020). Scottish Index of Multiple Deprivation. Retrieved 8 August 2021 from https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/

Scottish Government. (2021). Achievement of Curriculum for Excellence Levels (ACEL) 2020-21. Retrieved 28.01.2023 from https://www.gov.scot/publications/achievement-curriculum-excellence-cfe-levels-2020-21/

Scottish Government. (2022c). *Pupil Equity Funding: School Allocations 2022-23.* Scottish Government. Retrieved 02.01.2023 from Pupil Equity Funding: school allocations 2022 to 2023 - gov.scot (www.gov.scot)

Scottish Government. (2022d). *Scottish National Standardised Assessments*. Crown. Retrieved 15.04.2022 from https://standardisedassessment.gov.scot/

Scottish Government. (2022e). *Summary Information on How the Scottish Government Measures Poverty*. Scottish Government. Retrieved 02.01.2023 from Poverty measurement methodology: summary - gov.scot (www.gov.scot)

Scottish Parliament Official Report (2022). *Statement by Cabinet Secretary for Education and Skills*. Retrieved 19.02.2023 from https://www.parliament.scot/chamber-and-committees/official-report/search-what-was-said-in-parliament/meeting-of-parliament-08-12-2022?meeting=14038&iob=127199#orscontributions_M3750E441P777C2449056

Seale, E. (2020). Strategies for Conducting Post-Culture-of-Poverty Research on Poverty, Meaning, and Behavior. *Am Soc*, *51*(4), 402-424. https://doi.org/10.1007/s12108-020-09460-2

Siddiqui, N. (2019). Using secondary data in education research. *Social Research Update*(68), 1-5.

Siegler, R. S., & Ramani, G. B. (2008). Playing linear numerical board games promotes low-income children's numerical development (Developmental Science (2008) 11, (655-661)). *Developmental science*, *11*(6), 895. https://doi.org/10.1111/j.1467-7687.2008.00777.x

Simmons, R., Connelly, D., & Thompson, R. (2020). 'Education ain't for us': using Bourdieu to understand the lives of young White working-class men classified as not in education, employment or training. *Research in post-compulsory education*, *25*(2), 193-213. https://doi.org/10.1080/13596748.2020.1742992

Skeide, M. A., Wehrmann, K., Emami, Z., Kirsten, H., Hartmann, A. M., & Rujescu, D. (2020). Neurobiological origins of individual differences in mathematical ability. *PLoS Biol*, *18*(10), e3000871-e3000871. https://doi.org/10.1371/journal.pbio.3000871

Smith, M. (1998). *Social Science in Question*. Sage.

Smith, R. L., Ager, J. W., & Williams, D. L. (1992). Suppressor Variables in Multiple Regression/Correlation. *EDUC PSYCHOL MEAS*, *52*(1), 17-29. https://doi.org/10.1177/001316449205200102

Sosu, E. (2018). Poverty, Class and Intergenerational Disadvantage. In T. G. K. Bryce, W. M. Humes, D. Gillies, & A. Kennedy (Eds.), *Scottish Education* (5th ed.). Edinburgh University Press.

Sperandei, S., Page, A., Spittal, M. J., & Pirkis, J. (2021). Low education and mental health among older adults: the mediating role of employment and income. *SOC PSYCH PSYCH EPID*. https://doi.org/10.1007/s00127-021-02149-y

SPICE. (2016). *Education and Skills Committee Briefing on Attainment*. S. P. I. C. (SPICe). https://archive2021.parliament.scot/Inquiries/SPICeBriefingAttainment.pdf

Standards and Testing Agency. (2016). *National Curriculum Assessments: Information for Parents*. Crown Publisher. Retrieved 15.04.2022 from https://www.gov.uk/government/collections/national-curriculum-assessments-information-for-parents

Straehler-Pohl, H., Fernández, S., Gellert, U., & Figueiras, L. (2014). School mathematics registers in a context of low academic expectations [Article]. *Educational Studies in Mathematics*, *85*(2), 175-199. https://doi.org/10.1007/s10649-013-9503-5

Stratton, S. J. (2018). Likert Data. *Prehosp. Disaster med*, *33*(2), 117-118. https://doi.org/10.1017/S1049023X18000237

Stringer, P. (2018). Dynamic assessment in educational settings: is potential ever realised? *Educational Review*, *70*(1), 18-30. https://doi.org/10.1080/00131911.2018.1397900

Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, A. (2013). Mathematical anxiety effects on simple arithmetic processing efficiency: An event-related potential study. *Biological Psychology*, *94*(3), 517-526. https://doi.org/10.1016/j.biopsycho.2013.09.012

Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, & Behavioral Neuroscience*, *16*(1), 3-22. https://doi.org/10.3758/s13415-015-0370-7

Tabachnick, B. G., & Fidell, L. S. (2014). *Using Multivariate Statistics* (6th ed.). Pearson.

Tokac, U., Novak, E., & Thompson, C. G. (2019). Effects of game-based learning on students' mathematics achievement: A meta-analysis. *Journal of Computer Assisted Learning*, *35*(3), 407-420. https://doi.org/10.1111/jcal.12347

Topping, K., Campbell, J., Douglas, W., & Smith, A. (2003). Cross-age peer tutoring in mathematics with seven- and 11-year-olds: influence on mathematical vocabulary, strategic dialogue and self-concept. *Educational Research*, *45*(3), 287-308. https://doi.org/10.1080/0013188032000137274

Topping, K., Miller, D., Murray, P., & Conlin, N. (2011). Implementation integrity in peer tutoring of mathematics. *Educational Psychology*, *31*(5), 575-593. https://doi.org/10.1080/01443410.2011.585949

Topping, K. J. (1996). The effectiveness of peer tutoring in further and higher education: A typology and review of the literature. *Higher Education*, *32*(3), 321-345. https://doi.org/10.1007/BF00138870

Topping, K. J. (1998). *The paired maths handbook : parental involvement and peer tutoring in mathematics*. London : D. Fulton.

Topping, K. J. (2020). Implementation fidelity and attainment in computerized practice of mathematics. *Research papers in education*, *35*(5), 529-547. https://doi.org/10.1080/02671522.2019.1601759

Tosto, M. G., Asbury, K., Mazzocco, M. M. M., Petrill, S. A., & Kovas, Y. (2016). From classroom environment to mathematics achievement: The mediating role of self-perceived ability and subject interest. *Learn Individ Differ*, *50*, 260-269. https://doi.org/10.1016/j.lindif.2016.07.009

Tryon, W. W. (1981). A methodological critique of Bandura's self-efficacy theory of behavior change. *J Behav Ther Exp Psychiatry*, *12*(2), 113-114. https://doi.org/10.1016/0005-7916(81)90003-3

Tymms, P., Merrell, C., Thurston, A., Andor, J., Topping, K., & Miller, D. (2011). Improving attainment across a whole district: school reform through peer tutoring in a randomized controlled trial. *School effectiveness and school improvement*, *22*(3), 265-289. https://doi.org/10.1080/09243453.2011.589859

Tzuriel, D. (2013). Mediated Learning Experience and Cognitive Modifiability. *J Cogn Educ Psychol*, *12*(1), 59-80. https://doi.org/10.1891/1945-8959.12.1.59

Tzuriel, D. (2021). Mediated learning and cognitive modifiability / [internet resource]. https://doi.org/10.1007/978-3-030-75692-5

UNICEF Office of Research. (2016). Fairness for Children: A league table of inequality in child well-being in rich countries', Innocenti Report Card 13. UNICEF. Retrieved 15.04.2022 from https://www.unicef-irc.org/publications/pdf/RC13_eng.pdf

United Nations (2015). *Sustainable Development Goals*. United Nations. Retrieved 15.04.2022 from https://www.un.org/sustainabledevelopment/education/

Usher, E. L., & Pajares, F. (2008). Sources of Self-Efficacy in School: Critical Review of the Literature and Future Directions. *Review of educational research*, *78*(4), 751-796. https://doi.org/10.3102/0034654308321456

Von Aster, M. G., & Shalev, R. S. (2007). Number development and developmental dyscalculia. *DEV MED CHILD NEUROL*, *49*(11), 868-873. https://doi.org/10.1111/j.1469-8749.2007.00868.x

Voutsina, C. (2012). Procedural and conceptual changes in young children's problem solving. *Educ Stud Math*, *79*(2), 193-214. https://doi.org/10.1007/s10649-011-9334-1

Walshaw, M. (2017). Understanding mathematical development through Vygotsky. *Research in mathematics education*, *19*(3), 293-309. https://doi.org/10.1080/14794802.2017.1379728

Watson, K. H., Coiro, M. J., Ciriegio, A. E., Dakkak, A., Jones, M. T., Reisman, J., Compas, B. E. (2023). COVID-19 stressors and symptoms of anxiety and depression in a community sample of children and adolescents. *CHILD ADOL MENT H-UK*, *28*(1), 172-179. https://doi.org/10.1111/camh.12598

Weiss, M. J., & Headlam, C. (2019). A Randomized Controlled Trial of a Modularized, Computer-Assisted, Self-Paced Approach to Developmental Math. *Journal of Research on Educational Effectiveness*, *12*(3), 484-513. https://doi.org/10.1080/19345747.2019.1631419

White, I. R., Horton, N. J., Carpenter, J., & Pocock, S. J. (2011). Strategy for intention to treat analysis in randomised trials with missing outcome data. *BMJ*, *342*(7803), 910-912. https://doi.org/10.1136/bmj.d40

Wigfield, A., & Eccles, J. S. (2000). Expectancy–Value Theory of Achievement Motivation. *Contemp Educ Psychol*, *25*(1), 68-81. https://doi.org/10.1006/ceps.1999.1015

Wigfield, A., Eccles, J. S., & Möller, J. (2020). How Dimensional Comparisons Help to Understand Linkages Between Expectancies, Values, Performance, and Choice. *Educational psychology review*, *32*(3), 657-680. https://doi.org/10.1007/s10648-020-09524-2

Wilkey, E. D., Pollack, C., & Price, G. R. (2020). Dyscalculia and Typical Math Achievement Are Associated With Individual Differences in Number-Specific Executive Function. *CHILD DEV*, *91*(2), 596-619. https://doi.org/10.1111/cdev.13194

Wilkins, J. L. M., Woodward, D., & Norton, A. (2021). Children’s number sequences as predictors of later mathematical development. *Mathematics*

Education Research Journal, *33*(3), 513-540. https://doi.org/10.1007/s13394-020-00317-y

Willoughby, M., Hudson, K., Hong, Y., & Wylie, A. (2021). Improvements in Motor Competence Skills Are Associated With Improvements in Executive Function and Math Problem-Solving Skills in Early Childhood. *DEV PSYCHOL*, *57*(9), 1463-1470. https://doi.org/10.1037/dev0001223

Woessmann, L. (2016). The economic case for education. *Education Economics*, *24*(1), 3-32. https://doi.org/10.1080/09645292.2015.1059801

Wolf, S., Magnuson, K. A., & Kimbro, R. T. (2017). Family poverty and neighborhood poverty: Links with children's school readiness before and after the Great Recession. *Children and Youth Services Review*, *79*, 368.

Woolfson, L. M. (2017). The Woolfson *et al* Integrated Framework: An Executive Framework for Service Wide Delivery. In B. Kelly, L. M. Woolfson, & J. Boyle (Eds.), *Frameworks for Practice in Educational Psychology: A Textbook for Trainees and Practitioners* (pp. 151-166). Jessica Kingsley.

Yamaguchi, Y., Misumi, T., & Maruo, K. (2018). A comparison of multiple imputation methods for incomplete longitudinal binary data. *J Biopharm Stat*, *28*(4), 645-667. https://doi.org/10.1080/10543406.2017.1372772

Zhang, F., Jiang, Y., Ming, H., Ren, Y., Wang, L., & Huang, S. (2020). Family socio-economic status and children’s academic achievement: The different roles of parental academic involvement and subjective social mobility. *British Journal of Educational Psychology*, *90*(3), 561-579. https://doi.org/10.1111/bjep.12374

Zhang, Y., Tolmie, A., & Gordon, R. (2023). The relationship between working memory and arithmetic in primary school children: a meta-analysis. *Brain Science*, *13*(22), 18. https://doi.org/doi.org/10.3390/brainsci13010022

Zigo, D. (2001). Rethinking reciprocity: Collaboration in labor as a path toward equalizing power in classroom research. *International journal of qualitative studies in education*, *14*(3), 351-365. https://doi.org/10.1080/09518390110029094

Appendix A: Ethics Submission for Study 1

Douglas Hutchison: additional information for ethical approval

4th January 2021

1. **Project title**: Characterising the link between deprivation and attainment in mathematics in Local Authority A primary schools.

2. **Purpose of the project and its academic rationale**: The purpose of the study is to explore in detail the link between relative deprivation and lower outcomes in mathematics attainment at primary school level. Educational outcomes for children who live in areas with relatively high levels of deprivation are below those of children who live in areas of relatively low deprivation. In order to address the poverty related attainment gaps it is necessary to understand the mechanisms that result in these attainment gaps. The study will focus principally on attainment in mathematics in Scottish Attainment Challenge primary schools, but will also explore maths attainment in the wider group of children across the local authority who are entitled to free school meals compared to their peers who do not meet the criteria for free school meals. Entitlement to free school meals is considered a proxy measure for relative deprivation. Teachers' attitudes to mathematics can influence learners' outcomes which is why a Perceptions of Mathematics survey is included for teachers to determine if there are differences in attitudes between schools, which may influence outcomes for learners.

3. **Number of participants (age, gender, exclusion/inclusion criteria) and how they will be recruited**:
   a. **The schools involved** have been identified in consultation with the local authority Principal Educational Psychologist as an independent third party and then through discussion with the head teachers who sought agreement from their staff to be involved in the study. The two schools involved in this part of the study are B Primary School which is situated within the area that has the highest levels of deprivation in the local authority and is one of only three schools that meet the criteria for Scottish Government Scottish Attainment Challenge schools programme funding, i.e more than 70% of pupils entitled to free school meals. B Primary School is the main focus for the first study and later intervention. The second school selected for the teacher survey is A Primary School which is selected as the school with the lowest levels of deprivation in the local authority and because it is within the same secondary school cluster as B Primary. The research is an applied enquiry which is embedded in the local authority in which the researcher works as an educational psychologist. In addition to carrying out the research, the researcher will be carrying out the routine work of an educational psychologist in B Primary School.
   b. **Approximately 40 primary school teachers** between the two primary schools will be invited to complete an online perceptions of maths survey. The staff involved are the teaching staff in B Primary and A Primary. All

teaching staff will be invited to take part by a survey e-mailed to all staff in both schools from a generic mailbox used by the LA Numeracy Strategy Group.

c. **Project start and end dates**: February 2021 until June 2022.

d. **Brief description of methods and measurements**

Design

The first part of the project involves analysis of existing historical local education authority data, i.e. secondary data. The data are principally standardised test results generated between 2010 and 2017 as part of the local authority's standardised testing regime. The data are anonymised and used in line with GDPR. At the start of each school session, parents / carers agree to their child's attainment data being stored and used for research and self-evaluation.

The first study will also involve administration of an online survey to class teachers at the study primary school, B Primary, and one other primary school in the same cluster but in an area where there are lower rates of relative deprivation, A Primary. The survey is the *Perceptions of Mathematics* survey (POM) developed by Prof. Ann Kajander in 2007 and used with permission of the author. Staff will be invited to take part by e-mail containing a link to the survey using MS Forms. The survey will be anonymous with the only information gathered, apart from the responses, being the respondent's school in order to compare responses.

The second part of the study will involve a mathematics intervention and a further ethics proposal will be submitted for the intervention stage of the study.

a. **How and where materials will be administered**: The Perceptions of Mathematics (POM) survey will be administered online using a link to MS Forms. An e-mail will be sent to all teaching staff in the two primary schools inviting them to take part, explaining the nature of the survey and including the participant information sheet. The consent form will be contained in the survey. In order to reduce any sense of coercion the e-mail will come from a generic mailbox rather than the researcher's e-mail address.

b. **Measures to be collected (Please list all the measures to be used and append all non-standard questionnaires and questionnaires that are diagnostic)**
Perceptions of Mathematics Survey – POM (teachers)

c. **Length of time each participant will be involved in the study**
POM takes around 5-10 minutes to complete.

Procedure for the study

Data analysis: Existing historical attainment data are gathered with consent of users on the basis that it may be used for research purposes. All data are anonymised so that no individual learners can be identified. Data will be analysed in order to characterise the nature and extent of the connection between lower attainment and relative levels of deprivation using free school meals and the Scottish Index of Multiple Deprivation as proxies for relative deprivation. The outcome of the analysis will inform the second part of the overall research which will be a maths intervention aimed at improving maths outcomes.

Perceptions of Maths Survey: Teachers' perceptions of mathematics influence the way they teach which in turn has an impact on learners' outcomes. The survey will be administered to determine if there are differences in perception between teachers in different contexts. Depending on the outcome, this may influence the intervention stage of the research. The survey will be administered online and anonymously. A generic e-mail address used by the local authority Numeracy Strategy Group will be used to issue the surveys in order to reduce any perceived coercion.

e. **Data storage arrangements**: Data will be stored on the University of Strathclyde Onedrive and will be stored only for the duration of the study.
f. **A clear but concise statement of ethical considerations raised by the project and how you intend to deal with them.**

A central ethical concern is the possibility of coercion since the researcher is the head teacher's line manager and occupies a senior position in the local authority. The nature of the Doctorate in Educational Psychology is that it involves embedded action research which means it is very difficult to select schools from a local authority other than the schools in the local authority where the researcher works as an educational psychologist. The researcher is the Director with responsibility for education in the local authority. The researcher previously worked as an educational psychologist in the local authority and has continued to work a part of each month as an educational psychologist since taking on the role of Director. The school he is currently allocated to (B Primary School) is the project school and main focus of the project. The researcher is working in the school as an educational psychologist independently of the research. From the outset it has been made very clear to the head teacher and his staff that they are entirely free not to take part in any aspect of the research. E-mail interaction sets this out where this was stated explicitly following initial discussions with the head teacher. While it is very difficult to say with complete certainty there is no element of coercion, the embedded nature of the work and the researcher working alongside staff as an educational psychologist reduces the power imbalance between research and participants (Zigo, 2001)[12]. Zigo

[12] Zigo, D. (2001). Rethinking reciprocity: Collaboration in labor as a path toward equalizing power in classroom research. International journal of qualitative studies in education, 14(3), 351-365. https://doi.org/10.1080/09518390110029094

goes on to say that ‘a researcher’s contribution to the labor [sic] needs found within a research site might therefore contribute towards equalizing the traditional power differential between researcher and participant’ (op. cit., p.354). Both schools have pupils who benefit from free school meals who should also benefit from the outcome of the research. Therefore there is a degree of reciprocity in the research (Flinders, 1992)[13] with the benefits not all going in the direction of the researcher, especially at the second stage of the project, the intervention. The researcher will also maintain ongoing dialogue with the head teachers to keep the situation under review in line with the BERA (2018)[14] guidance which recognises ethical decision making as an ‘ongoing and iterative process’ (op. cit., p.2). The Principal Educational Psychologist will also check with both head teachers as an independent third party that neither they nor their staff feel any degree of coercion.

Staff in the project school and one other school will be invited to participate in a brief *Perceptions of Maths* survey involving 20 statements rated using a Likert type scale. In order to minimise the possibility of coercion or the perception of coercion the survey will be issued using the generic mailbox used by the Numeracy Strategy Group. As indicated earlier, staff are familiar with surveys and information on professional learning coming from the generic central mailbox used by the Numeracy Strategy Group. A participant information sheet will be issued with the survey link and consent sought at the start of the survey itself. Use of the generic mailbox for the staff survey reduces the potential for coercion as the survey is not coming directly from the researcher. The researcher is identified in the Participant Information Sheet. Not naming the researcher would amount to deception without sufficient justification, however, using a generic mailbox reduces the impact of receiving an e-mail directly from the Director. Approval for surveys being administered in the local authority is normally granted following approval by the Principal Educational Psychologist. An e-mail approving the administration of the survey contingent upon ethical approval by the Psychological Sciences and Health Ethics Committee is included.

The project involves analysis of secondary data on attainment in mathematics which is available from the local authority for whom the researcher works. This secondary data does not present any specific ethical issues as it will be entirely anonymised. At the point where the data was originally gathered, parents / carers consented to the data being used for research purposes. Use of the data is consistent with the Council’s Information Governance procedures and consistent with GDPR. The secondary data are all routinely available to the researcher in the course of his normal work for self-evaluation, research and planning purposes. The researcher is line managed by the Chief Executive of the local authority who has given her support for

[13] Flinders, D. J. (1992). In search of ethical guidance: constructing a basis for dialogue. International journal of qualitative studies in education, 5(2), 101-115. https://doi.org/10.1080/0951839920050202
[14] https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018

the research to take place as part of the application process to engage in the Doctoral programme.

One further ethical consideration is the possibility that the schools in question or their communities may be characterised or depicted in ways that are embarrassing or insensitive. Research relating to the impact of deprivation risks characterising participants in ways they don't recognise or identify with. The need to address the ongoing and entrenched differences in educational outcomes however means the research remains necessary. In any publications, the names of schools and the local authority will be anonymised to ensure no embarrassment or characterisation that results in any participants feeling uncomfortable.

Participant Information Sheet for Perceptions of Maths Survey

Name of department: Psychological Sciences and Health
Title of the study: Characterising the link between deprivation and attainment in mathematics in LA primary schools.

Introduction
Thank you for considering participation in this research. The research is being carried out as part of a Doctorate in Educational Psychology at the University of Strathclyde by Douglas Hutchison who is also working part time with educational psychology service.

What is the purpose of this investigation?
The investigation is exploring the links between deprivation and maths attainment for children at primary schools in LA. Attitudes towards maths can influence how well pupils achieve. This survey explores teachers' attitudes towards maths.

Do you have to take part?
You do not have to take part. Taking part is entirely voluntary and there is no detriment to you or the school if you choose not to take part. If during the process of completing the study you decide you no longer wish to take part, you can withdraw simply by closing the browser window.

What will you do in the project?
You are being asked to complete a questionnaire anonymously. The questionnaire will take about 5-10 minutes and involves rating 20 statements about your views on maths using a scale from 1 to 4. The only other information gathered is the name of your school.

Why have you been invited to take part?
All teachers in your school and in one other school are being invited to complete the questionnaire. The aim is to investigate whether attitudes towards maths among teachers influence outcomes in maths for children.

What are the potential risks to you in taking part?
There are no risks involved in completing the survey and no detriment if you choose not to complete the survey.

What happens to the information in the project?
If you choose to complete the survey, since it is completed anonymously, it will not be

possible to withdraw your responses after completion. No individual respondent can be identified, only the name of the school. If you choose to withdraw after you have started and before submitting your responses you can simply close the browser. The responses are collated on MS Forms and stored securely in the University of Strathclyde Onedrive. The data will be stored for the duration of the project which will be no later than the end of 2022. Data will be stored and processed in line with GDPR. The collated data will be used as part a doctoral thesis and may be used in publications or presentations at conferences. No schools will be identified in any publications or conferences. The data will also be accessed by Dr Clare Daly at the University of Strathclyde.

Thank you for reading this information – please e-mail any questions if you are unsure about what is written here using the following e-mail address: douglas.hutchison@strath.ac.uk

What happens next?
If you are happy to take part you will be asked to indicate your consent at the start of the online survey which will be on the next page.
If you do not want to be involved in the project thank you for your time in reading this information sheet.
If you want any feedback on the survey, please contact Douglas Hutchison douglas.hutchison@strath.ac.uk

Chief Investigator details:
The Chief Investigator for this research is Dr Clare Daly who can be contacted at clare.daly@strath.ac.uk

This investigation was granted ethical approval by the School of Psychological Sciences and Health Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

School of Psychological Sciences and Health Ethics Committee
University of Strathclyde
Room GH 6.76, Graham Hills Building
40 George Street
Glasgow
G1 1QE

Telephone: 0141 548 2700
Email: hass-psh-ethics@strath.ac.uk

Wording for consent form

(The following information will be stated at the start of the online form with a yes / no option agreeing to consent. A no will result in the participant being unable to proceed due to branching restrictions set up in the form. The PIS will be attached to the e-mail invitation.)

Consent Form for Perceptions of Maths Survey

Name of department: School of Psychological Sciences and Health
Title of the study: Characterising the link between deprivation and attainment in mathematics in LA primary schools.

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.
- I understand that anonymised data (i.e. data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I consent to being a participant in the project

Appendix B: Perceptions of Mathematics Survey

(Used with permission from Prof Ann Kajander, Lakehead University, Ontario, Canada.)

Please answer these questions by circling the response, where 0 is low or poor or disagree, and 3 is high or positive or agree. Please do not add other responses such as "not sure" – choose the closest response to your feeling.

1. It is important to me to be able to get the correct answer to maths questions
2. It is important to me to really understand how and why maths procedures work
3. It is important for everyone to accurately do basic math calculations such as addition or multiplication, without a calculator
4. Everyone needs to deeply understand how and why maths procedures work if they are going to make effective use of them
5. It is important to be able to recall maths facts such as addition facts or times tables quickly and accurately
6. It is important to have to think through and understand a variety of different approaches to problems
7. It is the teacher's job to teach steps in each new maths method to the pupils before they have to use it
8. There are often several correct ways to get a right answer
9. Accurate and efficient calculation skills are highly important in mathematics
10. It enriches pupil understanding to have to think about different ways to solve the same problem
11. It is important to practice on many familiar shorter maths questions in school
12. It is important to develop connections between related ideas and models in mathematics
13. Most people learn maths best if they are taught the methods step by step
14. When I'm learning maths I really want to know 'how' and 'why' the methods and ideas work
15. Calculators shouldn't be used too much in school because they can lessen opportunities to practise computational skills
16. Children learn deeply by investigating new types of problems different from ones they've seen before
17. There is usually one best way to write the steps in a solution to a maths question
18. Most people learn maths best if they explore problems in small groups to discuss and compare different approaches
19. Learning to follow 'the steps' to generate correct answers is very important
20. It is important to develop connections between ideas by working on multi-step problems

Appendix C: Maths Attitude and Anxiety Questionnaire

Mathematics Attitude and Anxiety Questionnaire (MAAQ) Answer Sheet

Name:____

Interview date: 12.01.22

Class: P5 P4/5

School: B Primary A Primary

How good are you at:

1. Maths in general

✔	✓	?	✗	✘

2. Written maths

✔	✓	?	✗	✘

3. Mental maths

✔	✓	?	✗	✘

4. Easy maths

✔	✓	?	✗	✘

5. Difficult maths

✓	✓	?	✗	✗

6. Maths tests

✓	✓	?	✗	✗

7. Understanding the teacher

✓	✓	?	✗	✗

How much do you like…

8. Maths in general

		0		●

9. Written maths

		0		●

10. Mental maths

		0		●

11. Easy maths

		0		●

12. Difficult maths

		0		●

13. Maths tests

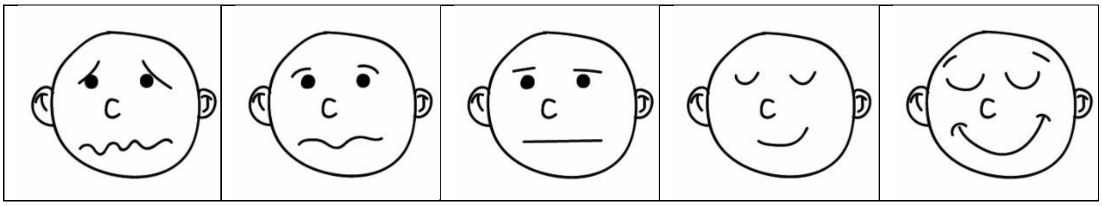
		0		●

14. Understanding the teacher

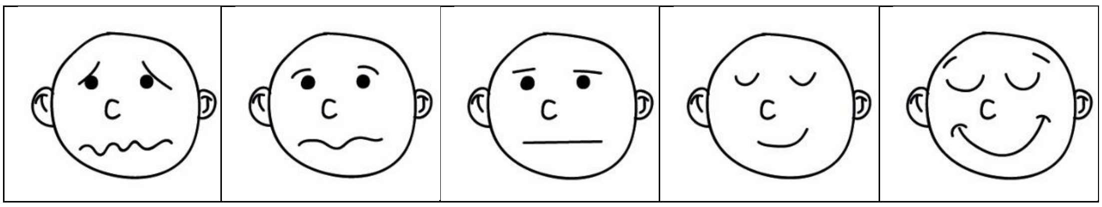
		0		●

How worried are you with….

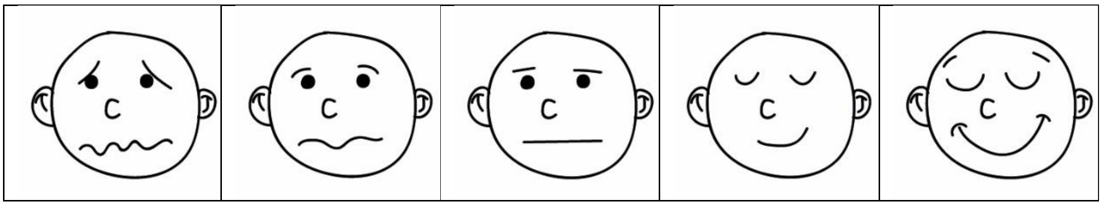
15. Maths in general



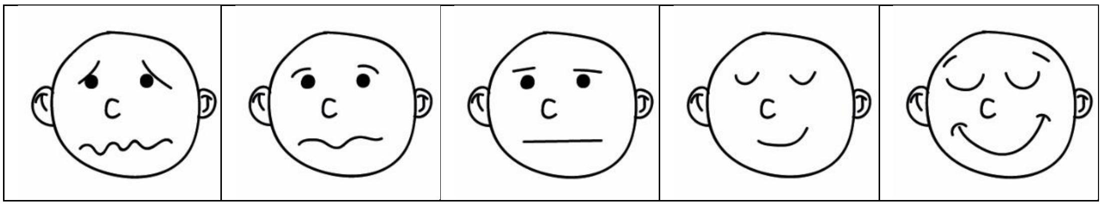
16. Written maths



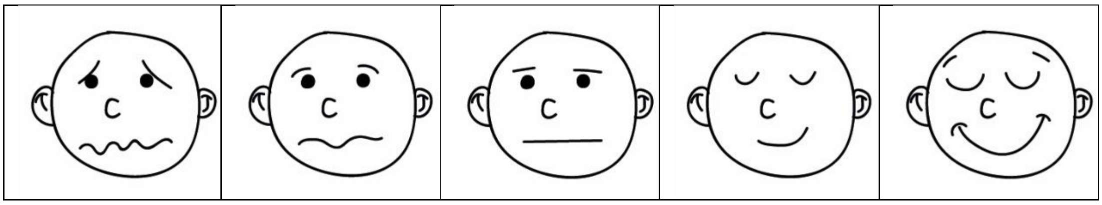
17. Mental maths



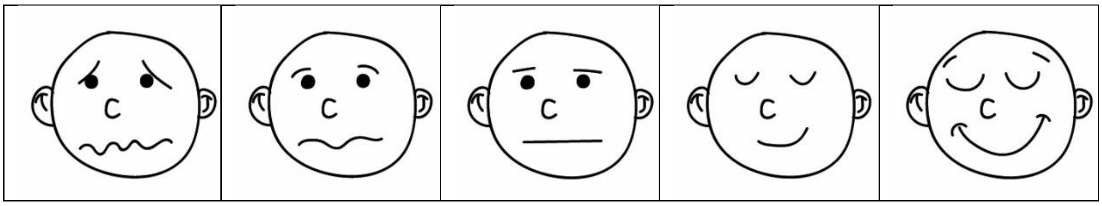
18. Easy maths



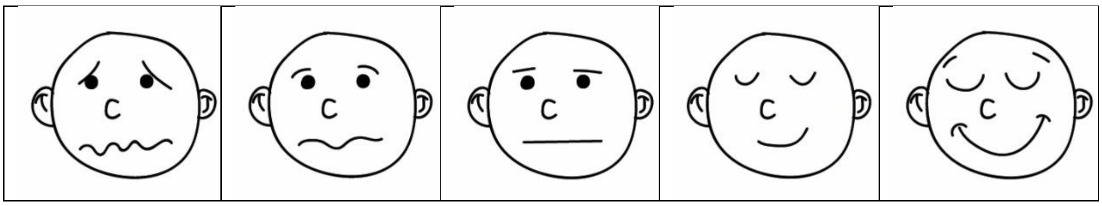
19. Difficult maths



20. Maths tests

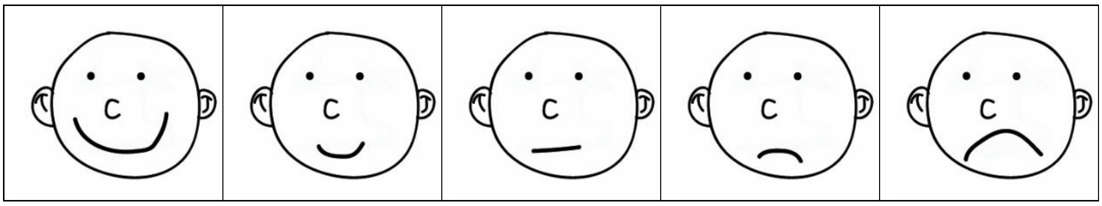


21. Understanding the teacher

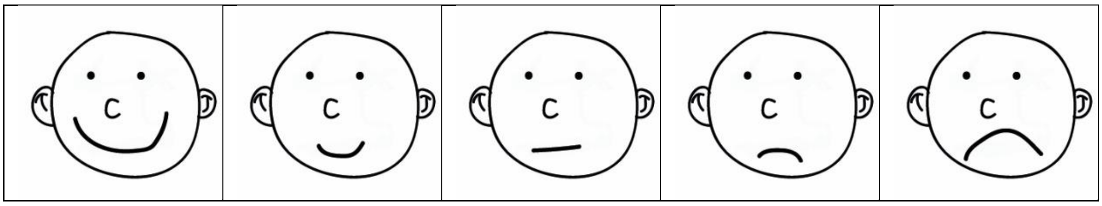


How happy are you with…

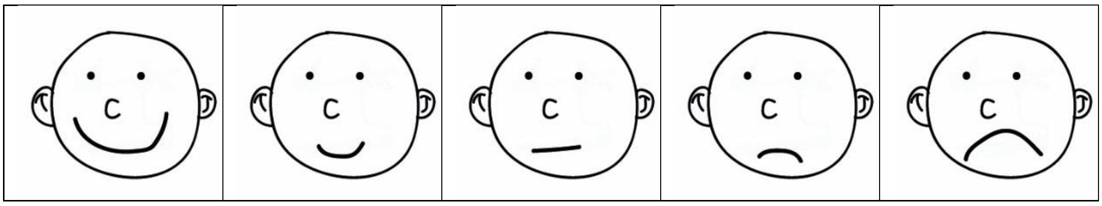
22. Maths in general



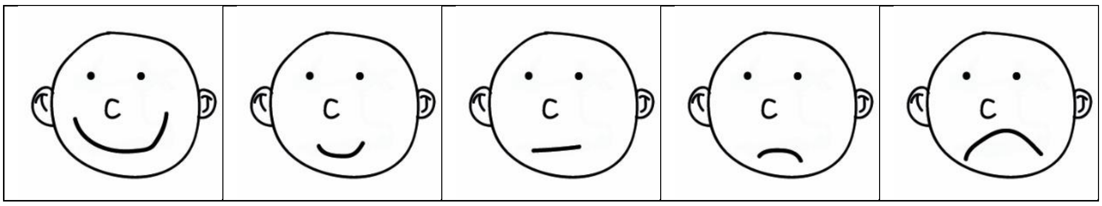
23. Written maths



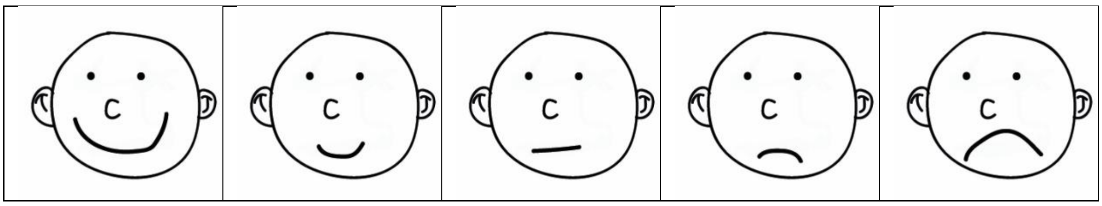
24. Mental maths



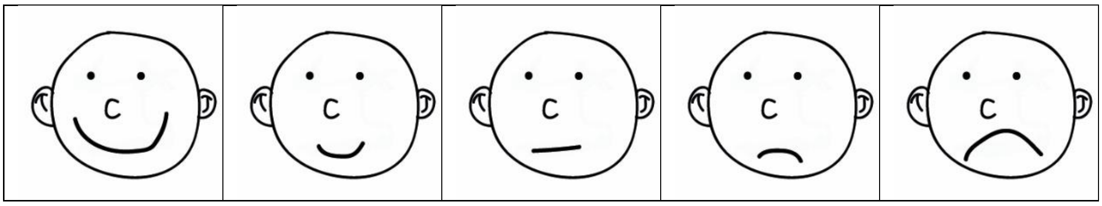
25. Easy maths



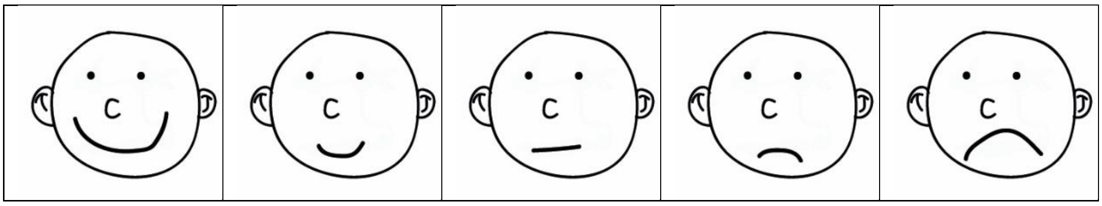
26. Difficult maths



27. Maths tests



28. Understanding the teacher



Appendix D: Myself As A Learner Scale

Myself As Learner Scale (MALS)

Below you have 20 sentences about you as a learner. They are about how you see yourself when it comes to learning and school work. There are no right or wrong answers and nobody else will see your answers. The most important thing is that you answer for you alone and as truthfully as you can.

Name:______________________________________

Your age in years:______________________

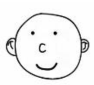
Circle your school: A Primary B Primary

Circle your class: P5 P4/5

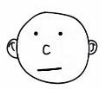
For each sentence there are 5 faces you can circle.

The first is definitely agree

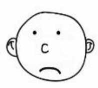
The second is agree a bit



The third means it is true about half the time

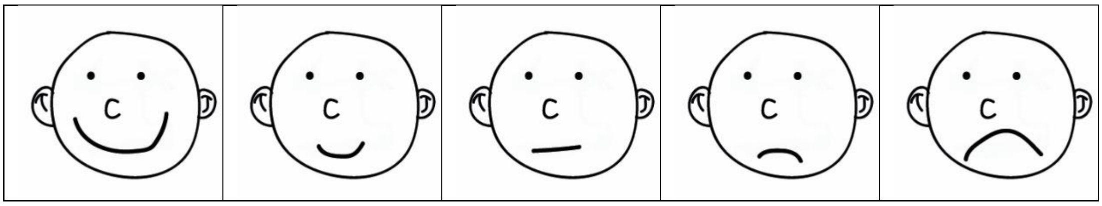


The fourth means you don't agree

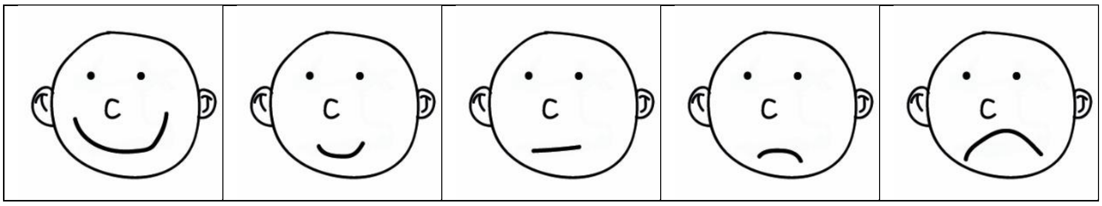


The fifth means you strongly disagree

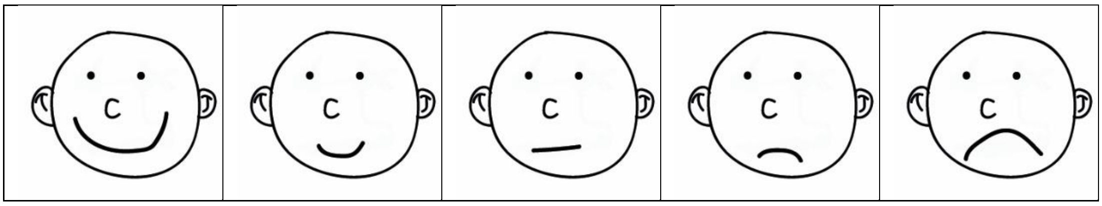
1. I'm good at doing tests



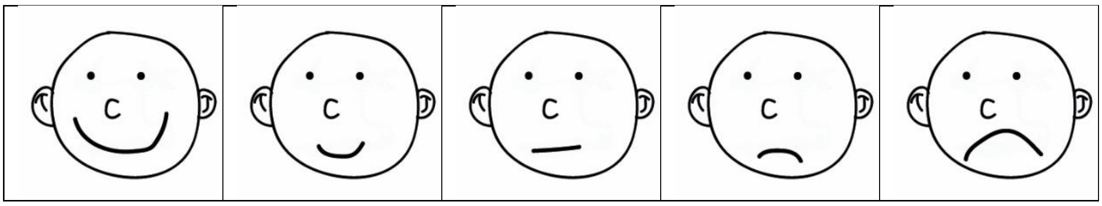
2. I like having problems to solve



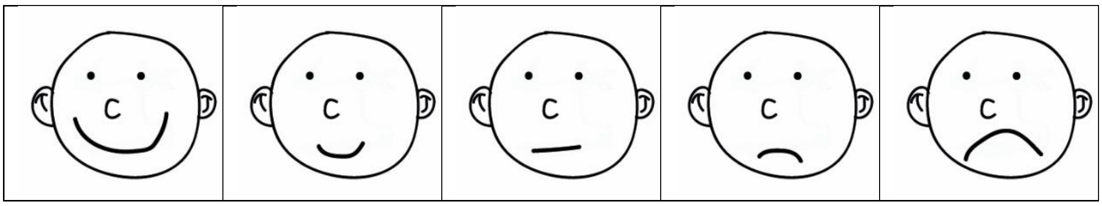
3. When I'm given new work to do, I usually feel confident I can do it.



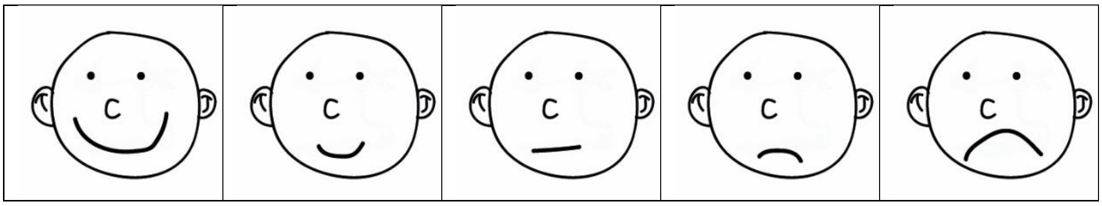
4. Thinking carefully about your work helps you to do it better.



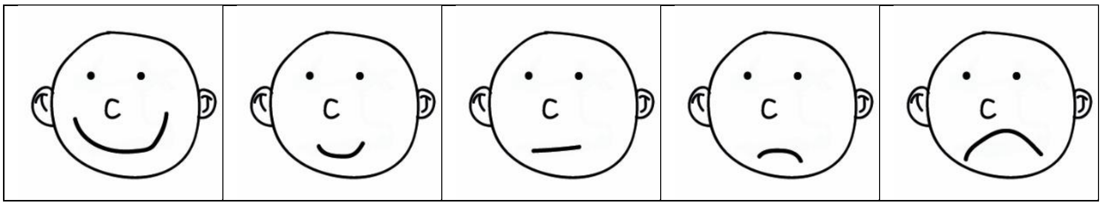
5. I'm good at discussing things.



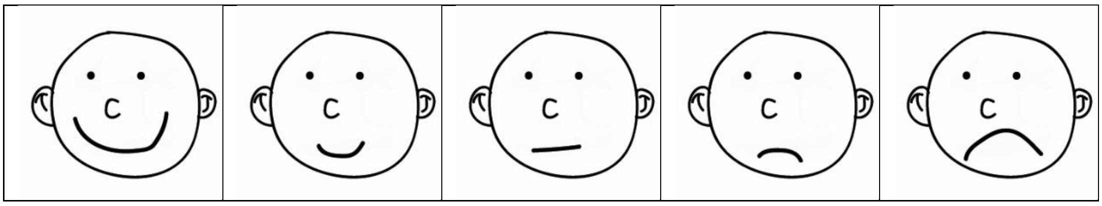
6. I need a lot of help with my work.



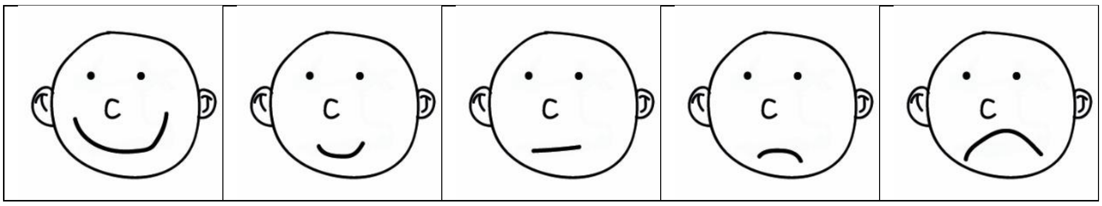
7. I like having difficult work to do.



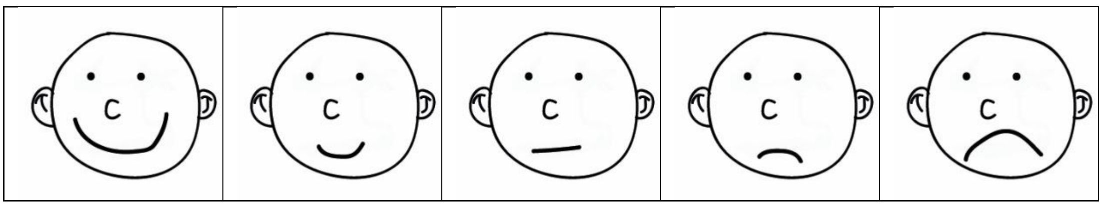
8. I get anxious when I have new work to do.



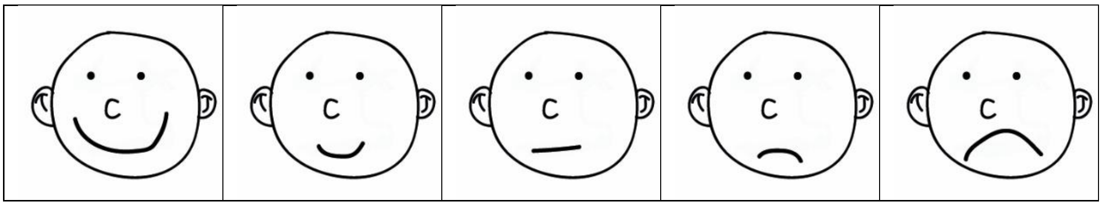
9. I think that problem-solving is fun.



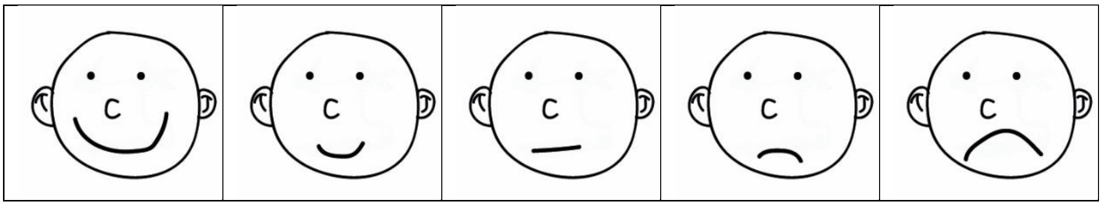
10. When I get stuck with my work I can usually work out what to do next.



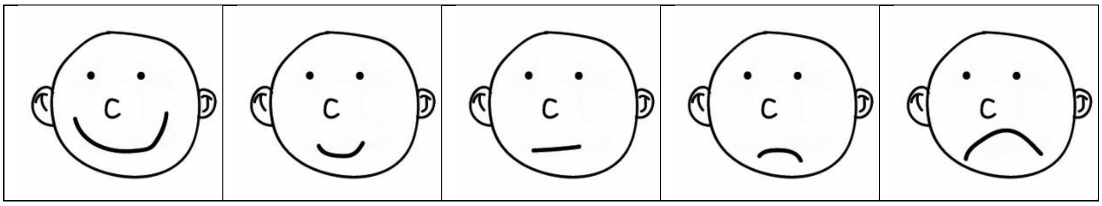
11. Learning is easy.



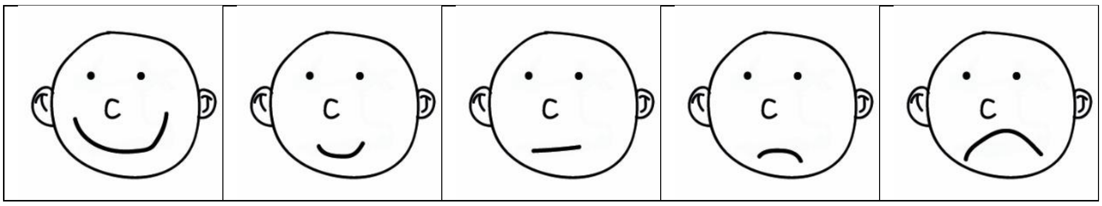
12. I’m not very good at solving problems.



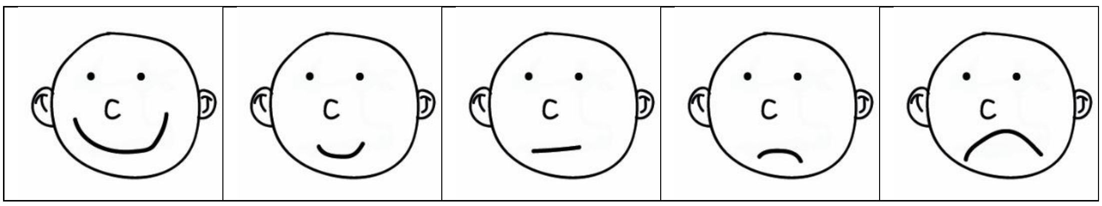
13. I know the meaning of lots of words.



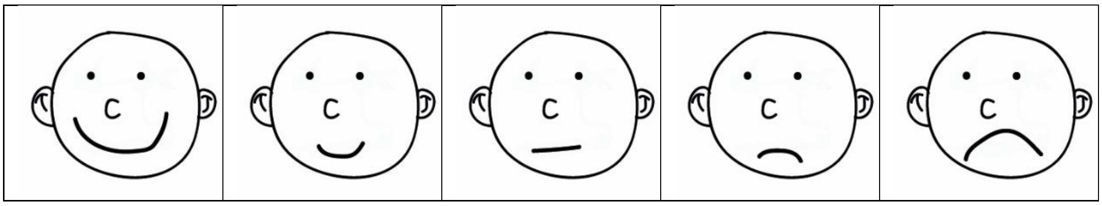
14. I usually think carefully about what I’ve got to do.



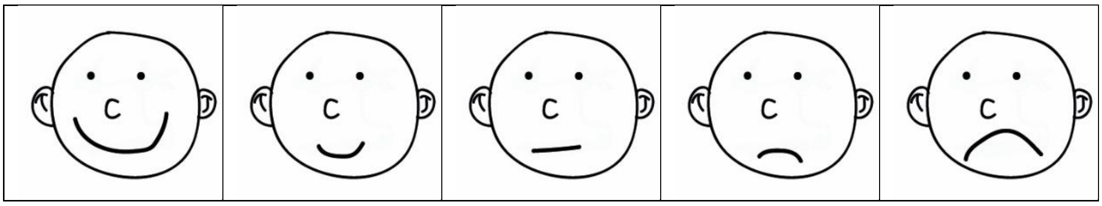
15. I know how to solve the problems that I meet.



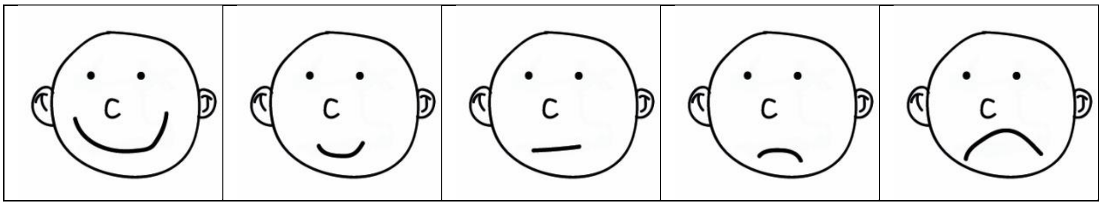
16. I find a lot of schoolwork difficult.



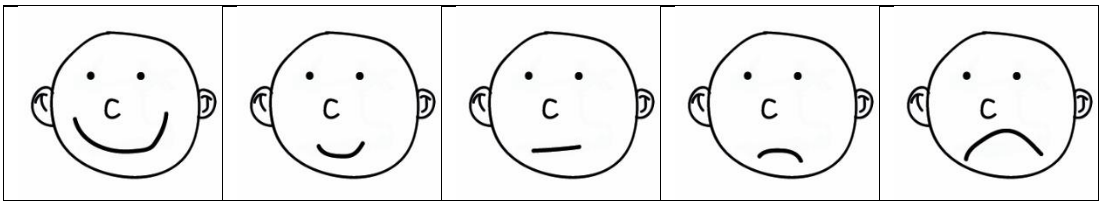
17. I'm clever.



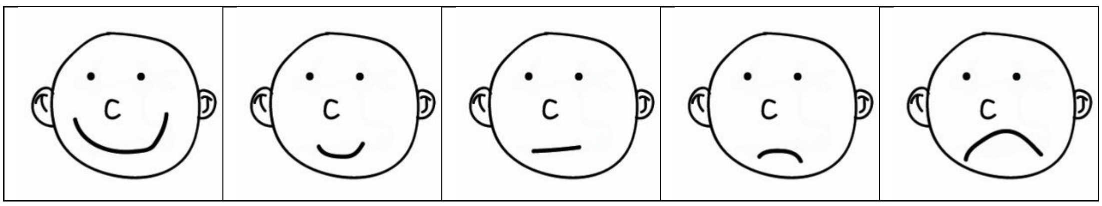
18. I know how to be a good learner.



19. I like using my brain.



20. Learning is difficult.



Appendix E: Ethical approval form for Study 3: Games-based peer-assisted learning intervention

SCHOOL OF PSYCHOLOGICAL SCIENCES AND HEALTH ETHICAL APPROVAL FORM DOUGLAS HUTCHISON	
Title of project: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances. **Date**: 31st January 2022	
Name of Supervisor: Dr Clare Daly	Name of Student: Douglas Hutchison
Supervisor E-Mail address: clare.daly@strath.ac.uk	Student Email: douglas.hutchison@strath.ac.uk

	Please tick one box		
	Yes	**No**	**N/A**
1. Have you read the remit of the University Ethics Committee and have established that your project does NOT meet any of the project or participant characteristics that would necessitate it submission to UEC?	Y		
2. Will you inform participants of all aspects of the study that might reasonably be expected to influence their willingness to participate and in particular, any negative consequences that might occur?	Y		
3. Will you tell participants that their participation is voluntary?	Y		
4. Will you tell participants that they may withdraw at any time and for any reason?	Y		
5. Will you obtain written consent for participation or the equivalent for online questionnaire studies?	Y		
6. If an experiment, will you describe the main experimental procedures to participants in advance, so that they are informed about what to expect?			N/A
7. With questionnaires, will you give participants the option of omitting any questions they do not want to answer?	Y		
8. If the research is observational or involves audio or video recording, will you ask participants for their consent to being observed or recorded?	Y		
9. If the study will use measures of a sensitive or potentially distressing nature will you provide contact details of appropriate support services on the information sheet to be retained by participants?	Y		
10. Will you offer to debrief participants at the end of their participation (i.e. give them a brief explanation, orally or in writing, of the study)?	Y		
11. Have all activities associated with this project been risk assessed?	Y		
12. Are the data anonymous? (If you tick NO to this question then please answer question 13 below)	Y		
13. If the data are not anonymous, will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	Y		
14. Have you completed OHS Risk Assessment (S20) for the research? (an S20 is required for all studies)	Y		
15. Will the sponsor of the study be the University of Strathclyde? (if the answer is No, please provide details of the study sponsor in your application)	Y		

PLEASE TICK **EITHER** BOX A OR BOX B BELOW AND **PROVIDE THE DETAILS REQUIRED** IN SUPPORT OF YOUR APPLICATION.

A. I consider that this project has **NO** specific ethical implications to be brought before the School's Ethics Committee	

Give a brief description of participants and procedure (1-4) in around 200 words.

1. Project title
2. Number of participants (age, gender, exclusion/inclusion criteria) and how they will be recruited
3. Project start and end dates
4. Brief description of methods
    a. Design
    b. How and where will materials be administered
    c. Measures to be collected (Please list all the measures to be used and append all non-standard questionnaires)
    d. Length of time each participant will be involved in the study
5. Data storage arrangements (how will the data be stored and for what period of time)
6. Debrief: how will participants be debriefed (Note: in most cases verbal debrief is acceptable). Please delete as appropriate: verbal / written

Attachments Required:

Please complete Question 24: Insurance from the UEC form and submit this with your application (UEC question 24: insurance is attached below).
SEC does not require to see the PIS, consent, debrief or S20 risk assessment forms. It is the responsibility of the project supervisor to ensure these documents conform to BPS and University ethical standards and the University's Health and Safety standards.

B. I consider that this project **may** have ethical implications that should be brought before the School's Ethics Committee, and/or it will be carried out with children or other vulnerable populations	**Yes**

Please provide the details described below on a separate sheet (normally **no more than** 2 sides of A4**). <u>Annex 1</u>**

1. Project title
2. Purpose of the project and its academic rationale
3. Number of participants (age, gender, exclusion/inclusion criteria) and how they will be recruited
4. Project start and end dates
5. Brief description of methods and measurements
    a. Design
    b. How and where materials will be administered
    c. Measures to be collected (Please list all the measures to be used and append all non-standard questionnaires and questionnaires that are diagnostic)
    d. Length of time each participant will be involved in the study
6. Procedure for the study
7. Data storage arrangements (how will the data be stored and for what period of time)
8. A clear but concise statement of ethical considerations raised by the project and how you intend to deal with them.

Attachments Required (all to use the standard PIS and consent forms (modified to study requirements as necessary) available on the UEC page of the university website but with the School brand as document headers):

9. Participant Information Sheets **<u>Annex 9, 10, 11 & 12</u>**
10. Consent Form(s) **<u>Annex 9, 10, 11 & 12</u>**
11. Copies of all letters to gatekeepers. **<u>Annex 6 & 7</u>** (Local authority consent given at Study 1)
12. Copies of non-standard questionnaires **<u>Annex 3, 4 & 5</u>**
13. Debrief information (can be delivered verbally or in written form as required)
14. E-Risk Assessment – **<u>Annex 17</u>**
15. Question 24: Insurance details from the UEC form – COMPLETED.

Annex 1: Additional information for ethical approval , 4th January 2022

1. **Project title**: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances.

2. **Purpose of the project and its academic rationale**: The overall purpose of the study is to explore in detail the link between relative deprivation and lower outcomes in mathematics attainment at primary school level. Educational outcomes for children who live in areas with relatively high levels of deprivation are below those of children who live in areas of relatively low deprivation. The study for which ethical approval is sought is the intervention phase of the overall investigation. Paired maths as an intervention involves children in the same class taking on the role of tutor with their peers while engaging in maths activities, normally in a games environment. Peer assisted learning has a robust evidence base over many years[15] and in this intervention is targeting psychological variables and cognitive influences which lead to poorer outcomes associated with socioeconomic disadvantage. The psychological variables include self-concept as a learner, attitude to maths and maths anxiety. The cognitive influences include a deeper conceptual understanding of mathematical relations in number and number processes.

3. **Number of participants (age, gender, exclusion/inclusion criteria) and how they will be recruited**:
a) The schools involved have been identified in consultation with the local authority Principal Educational Psychologist as an independent third party and then through discussion with the head teachers who sought agreement from their staff to be involved in the study. The two schools involved in this part of the study are B Primary School which is situated within the area that has the highest levels of deprivation in the local authority and is one of only three primary schools in LA that meet the criteria for Scottish Government Scottish Attainment Challenge schools programme funding, i.e more than 70% of pupils entitled to free school meals. The second school selected is A Primary School which is within half a mile of B Primary and shares most of the demographic characteristics. A Primary has two Primary 5 classes which enables one of them to act as a control group during the intervention. As a denominational primary school, A has a wider catchment area and therefore, while 75% of the children attending live in areas of relatively higher deprivation, the school includes children from across the deciles of the Scottish Index of Multiple Deprivation.
b) Approximately 75 to 80 children from the two schools will be invited to take part. The classes involved are the P5 class from B PS

[15] Alegre, F., Moliner, L., Maroto, A., & Lorenzo-Valentin, G. (2019b). Peer tutoring in mathematics in primary education: a systematic review. *Educational Review, 71*(6), 767-791. https://doi.org/10.1080/00131911.2018.1474176

and the two P5 classes from A Primary School which means the children are aged between 8 and 9 years of age. P5 has been identified as it is the start of Second level of Curriculum for Excellence, the Scottish primary school curriculum, and is also identified as a point when attainment in maths starts to decline.

4. **Project start and end dates**: If ethical approval is granted the start will be February 2022 until end April 2022.

5. **Brief description of methods and measurements**
a) Design: The main objective is to analyse the influence of peer tutoring on psychological and cognitive variables in the subject of mathematics, and specifically the benefits for relatively more deprived children. The investigation has peer tutoring as the central axis based on research which indicates that in certain circumstances students can be better mediators of learning than adults. The design therefore is an action research intervention that involves brief training for staff and children on peer tutoring; surveys to establish baseline measures involving three classes, one of which forms the control group and two forming the intervention groups; followed by a six week long peer tutoring intervention. The initial surveys will be repeated at the end of the intervention with all children taking part. In addition, class teachers will identify a criterion referenced learning goal for each child at the start and evaluate progress at the end using goal attainment scaling.
b) **How and where materials will be administered**: The baseline surveys will be administered in the classroom by the researcher. The briefing for staff will be carried out using MS Teams and the briefing for children will take place in the classrooms. The peer assisted learning will take place in the children's own classroom at a time decided by the class teacher and will abide by all of the Scottish Government and LA Council Covid mitigations in place at the time. The Peer Assisted Learning will use commercial off the shelf games designed to develop mathematical skills and abilities; games designed as part of a Paired Maths programme[16]; a small selection of online games (Annex 2).
c) Measures to be collected (Please list all the measures to be used and append all non-standard questionnaires and questionnaires that are diagnostic)

- **Mathematics Attitude and Anxiety Questionnaire (Annex 3):** The MAAQ has been designed, tested, developed and shown to be a simple to complete assessment of attitudes and anxiety related to the individual respondent's view of maths. It is age appropriate and uses a combination of Likert type responses and pictorial representations for respondents. It consists of 28 questions focused on maths in general; written sums; mental maths; easy maths; difficult maths; maths tests and understanding the teacher.

[16] Topping, K. and Bamford, J. (1998) *The Paired Maths Handbook. Parental Involvement and Peer Tutoring in Maths.* London, David Fulton.

- **Myself as a Learner Scale (Burden, 2000) (Annex 4):** MALS is a 20 item scale with statements such as "I know how to be a good learner" with a Likert type response scale. It is designed to focus specifically on children's learning.
- **Goal attainment scaling (Annex 5):** The class teacher will set out a specific criterion referenced target for each individual learner in the area of number and number processes at First and Second Level of Curriculum for Excellence and assess progress over the 6 week intervention.

The above measures will be taken before the start of the intervention and at the end of the intervention.

d)Length of time each participant will be involved in the study: The survey measures at the start of the intervention take around 30 minutes per child but will be carried out as a class group. The intervention involves three 20 minute paired maths sessions per week over a 6 week period. The maximum length of time for each child will be 6 to 7 hours.

6. **Procedure for the study**:
   - The investigation involves a peer assisted mathematics intervention involving two Primary 5 classes in two different schools where the P5 children will take turns at being the tutor and the tutee. The Paired Maths intervention will involve the P5 children using educational maths games during three 20 minute sessions a week for 6 weeks, 18 sessions in total. The aim of the paired maths sessions is to develop confidence in maths and to develop targeted conceptual skills including mathematical thinking and strategy forming as well as relationships and concepts involved in number and number operations.
   - Prior to the intervention starting, baseline measures of self-concept as a learner and attitude to maths as well as maths anxiety will be taken using two validated questionnaires. The surveys will also be completed at the end of the intervention. The surveys will be carried out in class as a group with children being talked through each survey by the researcher. In addition to the two classes taking part in the intervention a third class of P5s in one of the schools will be the control group and will complete the baseline and follow up surveys but will not take part in the intervention.
   - In addition to the baseline and follow up questionnaires which focus on psychological variables, each class teacher will use Goal Attainment Scaling to define a progress goal for each child involved in the investigation. The goal will be consistent with the normal routine of the class teacher who reports termly on progress children in the class are making, especially in numeracy and literacy.
   - An initial training session for participants will be provided by the researcher who, in addition to being a charted educational psychologist is a GTCS registered teacher. The session will last no longer than 30 minutes. A briefing and training session will also be given to staff involved from both schools.

7. **Data storage arrangements**: Data will be stored on the University of Strathclyde Onedrive and will be stored only for the duration of the study. Where there is merit in retaining data for potential publication at the end of the study fully anonymised data will be registered with and stored on the Open Science Framework. Children's record forms will be scanned with names redacted and replaced with numbers. The school names will also be anonymised.

8. **A clear but concise statement of ethical considerations raised by the project and how you intend to deal with them.**

The researcher is a Chartered Educational Psychologist and a registered teacher with the General Teaching Council for Scotland (GTCS). The researcher will abide by the ethical standards required by the Health and Care Professionals Council, British Psychological Society and GTCS. The researcher is also a member of the PVG Scheme and his most recent statement of scheme membership was completed on 13 November 2021 in respect of regulated work with children.

a) **Recruitment of participants**: The major ethical consideration is to ensure that at school level, class level, parent / carer level and child level, participants are able to give informed consent without any coercion. The researcher was previously a senior manager in the local authority but is now a senior manager in a different local authority. The issue of coercion needs to be addressed at the level of the relationship between the researcher and the school represented by the head teacher; the relationship between the head teacher and the class teacher; and that of the class teacher and the children in their class. In addition, it is also important to ensure no coercion between the researcher or school and parents / carers. Generally, parents / carers and children are trusting of the school and the class teacher in particular. Steps need to be taken to ensure the researcher does not exploit the trust parents / carers have in the school, nor exploit the trusting relationship children have with their teacher. Taking each one of these relationships in turn:

- Consent will first be sought from the head teacher to take part and permission sought to approach the class teachers and seek their consent independently of the head teacher (Annex 6).
- If the headteacher agrees to take part, the researcher will approach the class teachers to seek their consent (Annex 7).
- If the class teachers agree to take part, they will consult with the children in their respective classes on whether or not they want to be involved. A draft script for the class teacher is provided at Annex 8 specifically referencing the UNCRC and the right to have their views sought and taken account of.
- A participant information sheet will be provided to parents / carers in order to request consent for children to take part in the investigation (Annex 9).

A separate PIS will be prepared for the parents / carers of the control group class (Annex 10).

- Verbal consent will also be sought and recorded from children and a more age appropriate Participant Information Sheet made available for children taking part in the full investigation (Annex 11) and for those in the control group (Annex 12). Their verbal consent will also be sought again at the point of completing pre and post intervention surveys. A record of children's verbal consent (Annex 18) will be kept securely. Written records will be scanned and stored on the university Onedrive with hard copies securely destroyed.
- A training session will be arranged for staff to explain the paired maths approach and a briefing note given to staff (Annex 13). A briefing session explaining the process will also be carried out with children and the games explained. "How to play x game" sheets will be provided as well as a leaflet reminding children of the role of the tutor (Annex 14 and 15).
- The class teacher will then decide the timing of the three 20 minute sessions each week and once started the intervention will run for 6 weeks, 18 sessions in total.
- Children taking part will be asked to complete a record of games played and once each week a very brief note of what, if anything, they have learned and what they liked or dislike (Annex 16).
- At the end of the intervention, the surveys will be repeated with the two intervention classes and the control class. The class teachers will also evaluate progress against the goals set for each child using a 5 point Goal Attainment Scale from -2 to +2.

It will be made clear to the head teacher, teachers, parents and children that they are free to withdraw their consent before, during and after the intervention. As stated already, the investigation involves a paired maths intervention which is not out of the ordinary in a classroom and school setting. From the perspective of the pupils involved, the paired maths activity will be experienced as work which is part of their daily routine. From the school perspective, the intervention is consistent with their published priorities contained in their School Improvement Plan. A Primary School's improvement plan includes the following: *Priority 1 - Improvement in attainment, particularly in Numeracy and Literacy • Continue to develop pedagogy around excellent teaching and learning opportunities through the continuation of practitioner enquiry (A. PS, SIP 2021-22).* B. PS Priority 2 in their School Improvement Plan is to raise attainment in numeracy including: *Targeted individuals and groups of children will achieve appropriate levels of attainment in numeracy through relevant and focussed early intervention strategies. Learners in our Early Years Centre and Primary 1 stage experience an embedded play-based curriculum. Improved problem solving and numeracy attainment for all learners through implementation of a clear numeracy strategy and programme. A 10-15% increase of learners achieving overall levels of numeracy through consistent learning experiences and improved breadth, pace and challenge across all stages.* There are no children in any of the classes who are currently Looked After by the local authority and who would require an additional level of consent from an officer in the LA Health and Social Care Partnership.

b) **Pre and post intervention measures**: The Mathematics Attitude and Anxiety Questionnaire asks children four questions applied to maths in general, written number calculations, mental maths, easy maths, difficult maths, maths tests and understanding the teacher. In relation to each of these children are asked *How good are you at…? How much do you like…? How happy are you with…? How worried are you with…?* In the event of any child being distressed or anxious as a result of being asked these questions the child will be offered support from a trusted adult in school. In addition, parents will be given the contact details of the school's educational psychologist should a child report any distress or anxiety as a result of taking part in the survey. If there is any distress, the child will not be re-tested at the end of the intervention but is still free to take part in the paired maths intervention should they choose to. The Myself As a Learner Scale includes 20 age appropriate statements each child rates on a Likert type scale. The same approach to MALS will be used as with the MAAQ. The Goal Attainment Scaling will not involve children directly and will be set in line with the class teachers' knowledge of the child and so will be work which is part of the routine professional practices in the teaching and learning context. The MAAQ and the MALS will be administered to the whole class at the same time with each child completing their own individual response sheet. Once the data has been collated, the response sheets will be destroyed and the data only retained until the post intervention questionnaires are completed in order to be able to match the pre and post intervention surveys. Once pre and post intervention MAAQ and MALS are matched and the Goal Attainment Scaling scores matched, each participant will be assigned a number and the data will be anonymised.

The number of participants has been set at three classes from two different schools, with one class being a control group and therefore not taking part in the paired maths intervention. Since this is a reciprocal peer assisted learning intervention, with around 25-30 pupils in each class, they will be spending half their time as peer tutors and the other half as tutees. Two class groups will amount to approximately half the time as tutors and half as tutees meaning one class would only result in approximately 13-15 tutored children and 13-15 tutors. Two class groups therefore offer around 30 tutors and 30 tutees which is an acceptable pilot group for developing a protocol which may be used more widely across the local authority. The third class group will not be part of the paired maths intervention but will act as a control group and take part in the Mathematics Attitude and Anxiety Questionnaire and the Myself as a learner scale before and after the intervention period in order to check for a difference between the intervention classes and a non-intervention group. Using G*Power 3.1.9.7 to calculate statistical power, in order to achieve an effect size of 0.5 in a t-test for matched samples, a sample of 75 is required to achieve statistical power of 0.98 while a sample size of 60 gives statistical power of 0.97.

Risk assessment: The surveys carry a very small risk of a reaction to the questions about anxiety and almost no risk in relation to the Myself as a learner questionnaires. In both cases it will be made clear to children who they can speak to if the surveys cause them any difficulties. In addition to a trusted adult in school, parents or children can speak to the school educational psychologist or the researcher if there are any concerns. The intervention itself will take place during normal class time and will follow the normal class routines and rules. There are no specific risks associated with the intervention that are not part of the normal routine of the classroom every day.

Covid mitigations: The investigation process will follow the Scottish Government, local authority and university guidance which is in operation at every stage of the investigations. LA Educational Psychology Service have a risk assessment which is required for staff in schools and will be used in addition to the standard risk assessment form. The researcher will carry out a Lateral Flow Test before visiting the school and will not be in two schools in the same day. There are no additional risks to children or school staff associated with the intervention. The children and staff are staying within their own class group and are not engaged in any activities that are different from their normal classroom activities. The activities will take place within the classroom in class time and Scottish Government guidance for schools will be followed along with all mitigations.

Record keeping and data management: Hard copies of surveys will have names redacted and assigned a number for matching before being scanned and kept electronically on the university Onedrive. All hard copies of records will be kept securely in a locked filing cabinet until scanned and then they will be securely destroyed. Similarly, pupils' hand written records during the investigation will be redacted and scanned to be retained electronically with no individuals identifiable and hard copies securely destroyed. The data will be retained for the duration of the investigation which is approximately December 2022. Any data which merits retentions will be totally anonymised and registered and stored on the Open Science Framework maintained by the Centre for Open Science.

Listening to those in the research context: The British Educational Research Association ethical guidance (BERA, 2018) recommend that at all stages of a project, from planning through conduct to reporting, educational researchers continue to engage and listen to those in the research sites. "This means that ethical decision-making becomes an actively deliberative, ongoing and iterative process of assessing and reassessing the situation and issues as they arise" (op.cit. p2). With this in mind, the research process will include a weekly check in with the teachers involved to identify any potential issues arising. If the investigation, for example, is causing any concerns of an ethical nature these can be addressed or consideration given to terminating the investigation. The issue of ethics therefore will not be considered only at the start of the investigation but will be considered actively throughout the process, especially given the power imbalance between children and adults (Brown et al., 2020).

References

British Educational Research Association [BERA] (2018) *Ethical Guidelines for Educational Research*, 4th edition. https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018 Accessed 10th January 2021.

Brown, C., Spiro, J., & Quinton, S. (2020). *The role of research ethics committees: Friend or foe in educational research? An exploratory study.* British educational research journal, 46(4), 747-769. https://doi.org/10.1002/berj.3654

Annex 2: List of games available for use during paired maths

Commercial off the shelf games

Gangsta Granny Mental Maths Games (x4)	2 or 3 pupils per game - total 8 or 12
Genius Square (x4)	2 per game - total 8 pupils
Mobi (x2)	2, 3 or 4 per game – total 4, 6 or 8 pupils
Mobi Kid (x1)	2 per game - total 2 pupils
Rolling Cubes (x1)	2 or 3 per game – total 2, or 3 pupils
Shut the Box (x4)	2, 3 or 4 per game – total 8, 12 or 16 pupils
The Brain Train (x1)	2 per game
IQ Digits (x1)	2 per game – 2 pupils

Games reproduced from Topping Paired Maths book

Need coloured pens or pencils; dice and squared paper

Navigrid - squared paper and dice	2 per game
Tri-box; square box – squared paper	2 per game
Pathway Board – 24 counters, 2 colours	2 per game
Sidewinder Board	2 per game

Computer games (Online – laptop)

Mathbrix Grade 2	2 per game
Blooket	2 per game

Annex 3: Mathematics Attitude and Anxiety Questionnaire Answer Sheet

Mathematics Attitude and Anxiety Questionnaire (MAAQ) Answer Sheet

Childs name (or unique identifier):
Date of birth:
Interview date:
Class / school year:
Gender:

		Response option 1 "How good are you at…?"	Response option 2 "How much do you like….?"	Response option 3 How Happy are you with…?"	Response option 4 "How worried are you with…?"
1	Maths in general	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4
2	Written sums	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4
3	Mental sums	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4
4	Easy maths	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4
5	Difficult maths	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4
6	Maths tests	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4
7	Understanding the teacher	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4	4 – 3 – 2 – 1 - 0	0 – 1 – 2 – 3 - 4

From: HealthOutcomes <healthoutcomes@innovation.ox.ac.uk>
Sent: 19 October 2020 09:20
To: HealthOutcomes <healthoutcomes@innovation.ox.ac.uk>; Douglas Hutchison <douglas.hutchison@strath.ac.uk>
Subject: RE: Order Confirmation

Dear Douglas,
Thanks for your licence request. I will be pleased to grant permission.
However, may I ask that you keep in touch with us when your research is complete and send us a summary of your findings. If you plan to publish on academic journals please be advised there are rules we ask you to comply with. Please do not assign rights to the journal publishers, do not

disseminate to others, do not translate, do not publish the questionnaire in its entirety on the journal, quote our copyright message and address any potential users to us for a licence.
Best of luck
Kind regards
Martina
Project Manager, Oxford University Innovation Ltd.

OXFORD UNIVERSITY INNOVATION
UNIVERSITY OF OXFORD

Annex 4: Myself As A Learner Scale

1. I'm good at doing tests
2. I like having problems to solve
3. When I'm given new work to do, I usually feel confident I can do it.
4. Thinking carefully about your work helps you to do it better
5. I'm good at discussing things
6. I need lots of help with my work
7. I like having difficult work to do
8. I get anxious when I have to do new work
9. I think that problem-solving is fun
10. When I get stuck with my work I can usually work out what to do next
11. Learning is easy
12. I'm not very good at solving problems
13. I know the meaning of lots of words
14. I usually think carefully about what I've got to do
15. I know how to solve the problems that I meet
16. I find a lot of schoolwork difficult
17. I'm clever
18. I know how to be a good learner
19. I like using my brain
20. Learning is difficult

(Responses on a 5 point Likert scale ranging from definitely agree; agree a bit; true half the time; don't agree; strongly disagree)

Annex 5: Goal Attainment Scaling Template

Pupil:	**Maths – number and number operations; problem solving;**
-2 Much less than expected	
-1 Less than expected	
0 Expected / current level	
+1 Greater than expected	
+2 Much greater than expected	

Annex 6: E-mail from the researcher to head teacher

E-mail to HT from researcher
Dear Head Teacher
I am asking your consent for the school to be involved in an intervention study using Paired Maths with a class at P5. The intervention is consistent with the local authority approach to closing the poverty related attainment gap. However, in this instance please consider it purely as a piece of research regardless of who the researcher is. I would ask you to consider if you would agree to this intervention if the researcher was someone not known to you? Only consider participation if you consider there to be benefit to the class and the school. You are free to decline the request to participate and there will be no detriment to you or the school as a result. Equally, once the intervention is underway you are free to withdraw your consent at any point. In the current context it is accepted that there may well be significant absences both among staff and pupils as a result of Covid, therefore your agreement at the outset does not mean you are committed regardless. You may withdraw or pause your consent once the intervention is underway. Please let me know once you have made your decision or if you want to discuss further.

Annex 7: E-mail to class teacher from the researcher

Dear class teacher
Thank you for listening to an explanation of what may be involved in a paired maths intervention with your class. Now that you are aware of what is

involved, you are being asked for your consent to take part in the intervention with your class. You are completely free to decline your consent and there are no consequences for you personally or for the school. Equally, once the intervention is underway, you are free to withdraw or pause your consent. Circumstances may change, for example, significant absence as a result of Covid, and you may decide that it is no longer appropriate to dedicate the time to the intervention. You are completely free to withdraw your consent once the intervention is underway. Please let me know once you have made your decision or if you want to discuss further.

Annex 8: Class teacher script for consultation with pupils

Children, you know that in the school we are doing a lot of work on Children's Rights. We want to be a Rights Respecting School. One of the big ideas in the Convention on Children's Rights is that you are involved in decision making if something affects you. Well, today, I'm going to ask your views on taking part in a project. The project is about trying to improve how well everybody is doing in maths. Some people enjoy maths and some people don't and that's okay. This project will involve playing maths games three times a week. You will get to pick the games. But in these games sometimes you will be like the teacher, helping your partner with the game, then at other times your partner will be helping you. That's why it is called paired maths. If you agree to do it, we will be doing the maths games three times a week for 20 minutes from now until near the Easter Holidays. As well as playing the games, at the start you will be asked some questions about how you feel about maths and how you feel about learning, then you'll be asked the same questions at the end when we finish the whole project. If you don't want to answer some or any of the questions, that's okay too, or if you just want to answer some of the questions that's fine. So I'm going to put the information on the board now and talk you through it to see if anybody has any questions. Your Mum or Dad or a grown up at home will also get a letter explaining this and asked if they are okay with you taking part.

- Put child PIS on board and talk through
- Any questions or concerns?

Annex 9: Participant Information Sheet and Consent form for Parents of children invited to take part in the full investigation

Participant Information Sheet for Paired Maths project

Name of department: Psychological Sciences and Health

Title of the study: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances.

Introduction

Thank you for considering participation in this research. The research is being carried out as part of a Doctorate in Educational Psychology at the University of Strathclyde by Douglas Hutchison.

What is the purpose of this investigation?

The investigation is exploring why some children perform less well than others in maths at primary schools in LA. Some children are anxious about maths or feel they are not good at maths which can affect their performance. That is why the investigation starts with children completing a survey on their attitude to maths and whether or not they feel anxious about maths. Each child will also complete a survey on how they feel about themselves as a learner. The class teacher will also set some individual goals for your child to work on during the investigation. Finally, the investigation will involve your child working with the children in his or her class three times a week for 20 minutes on a paired maths programme. The children will take turns at being the tutor during maths games which are aimed at helping their understanding of maths concepts. The programme will last for six weeks once it starts. At the end of the programme, the initial questionnaires and surveys will be repeated to see if there is any change in your child's attitude to maths, anxiety about maths or feelings about how well they work in school. In addition, the teacher will rate the progress they have made against their own targets.

Does your child have to take part?

Your child does not have to take part. Taking part is entirely voluntary and there is no detriment to you, your child or the school if you choose not to take part. If once the study has started you decide you no longer wish your child to take part, you can withdraw your child by contacting the class teacher and letting her know. Furthermore, even if you give consent, your child can still choose not to take part. If your child is not taking part, appropriate alternative maths work will be given to your child. Your child will not miss out on learning in maths as a result of not taking part.

What will your child do in the project?

Your child will:

- Be interviewed for approximately 15 minutes by the researcher who will complete a questionnaire with them on their attitude to maths and whether or not they feel anxious about maths (Mathematics Attitude and Anxiety Questionnaire). The questionnaire will be repeated at the end of the programme.
- Complete a questionnaire with the class on how they feel about themselves as a learner (Myself as a Learner scale). The questionnaire will be repeated at the end of the programme.
- Take part in a paired maths programme involving three 20 minute sessions a week for 6 weeks. The sessions are during class time, supervised by the teacher using maths games designed to build important maths skills.
- The 20 minute sessions will take place when the children would normally be doing a mental maths lesson and a personal and social education lesson. The paired maths activities aim to develop mental maths skills and social skills and so it is considered appropriate to use mental maths time and personal and social education time.
- The class teacher will set individual goals for your child and monitor their progress through the programme.

Why has your child been invited to take part?
All children in your child's class are being invited to take part along with the children in one other school in LA.

What are the potential risks to your child in taking part?
There are no risks involved in taking part in the investigation and no detriment if you choose for your child not to take part. There is no history of the questionnaires resulting in any issues for children, but If the questionnaire triggers any anxiety the school's educational psychologist is available to talk about any issues you or your child may have and can be contacted at 01292 61*****.

What happens to the information in the project?
Once the investigation is complete, the data will include questionnaire results as well as scores on progress towards the targets set by the class teacher. This information will be anonymised so that your child's name is removed and a number allocated to them. If you choose to withdraw your child during the study or at the end of the study before the data is anonymised, their data and records of work will be deleted. All data will be stored securely in the University of Strathclyde Onedrive with paper records scanned then the paper copies destroyed. The data will be stored for the duration of the project which will approximately be the end of 2022. Data which merits retention will be totally anonymised, registered and stored on the Open Science Framework maintained by the Centre for Open Science. Data will be stored and processed in line with GDPR. The collated data will be used as part a doctoral thesis and may be used in publications or presentations at conferences. No schools will be identified in any publications or conferences. The data will also be accessed by Dr Clare Daly at the University of Strathclyde.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

All personal data will be processed in accordance with data protection legislation. Please read our Privacy Notice for Research Participants for more information about your rights under the legislation.

Thank you for reading this information – please e-mail any questions if you are unsure about what is written here using the following e-mail address: douglas.hutchison@strath.ac.uk

What happens next?
If you are happy for your child to take part you will be asked to sign the consent form which is on the next page and return it to your child's class teacher.

If you do not want your child to be involved in the project thank you for your time in reading this information sheet.
If you want any feedback on the investigation, please contact Douglas Hutchison douglas.hutchison@strath.ac.uk

Chief Investigator details:
The Chief Investigator for this research is Dr Clare Daly who can be contacted at clare.daly@strath.ac.uk
This investigation was granted ethical approval by the School of Psychological Sciences and Health Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:
School of Psychological Sciences and Health Ethics Committee
University of Strathclyde
Room GH 6.76, Graham Hills Building
40 George Street
Glasgow
G1 1QE
Telephone: 0141 548 2700
Email: hass-psh-ethics@strath.ac.uk

University of Strathclyde
Humanities & Social Sciences

Consent Form for Paired Maths investigation

Name of department: School of Psychological Sciences and Health

Title of the study: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my child's personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my child's participation is voluntary and that I am free to withdraw my child from the project at any time, up to the point of completion, without having to give a reason and without any consequences.

- I understand that anonymised data (i.e. data that do not identify my child personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies my child will be made publicly available.
- I consent to my child being a participant in the project.

Child's name:___________________________

Parent / carer signature:________________________

Please return this form in the envelope provided to the school. Your child will not take part without your signed consent. Thank you.

Annex 10: Participant information sheet and consent form for parents of children in the control group.

University of Strathclyde Humanities & Social Sciences

Participant Information Sheet for Paired Maths project

Name of department: Psychological Sciences and Health

Title of the study: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances

Introduction
Thank you for considering participation in this research. The research is being carried out as part of a Doctorate in Educational Psychology at the University of Strathclyde by Douglas Hutchison.

What is the purpose of this investigation?
The investigation is exploring why some children perform less well than others in maths at primary schools in LA. Some children are anxious about maths or feel they are not good at maths which can affect their performance. That is why the children are being invited to complete a survey on their attitude to maths and whether or not they feel anxious about maths. Each child will also complete a survey on how they feel about themselves as a

learner. The results of the surveys will be compared to another group of children who are taking part in a peer maths project.

Does your child have to take part?
Your child does not have to take part. Taking part is entirely voluntary and there is no detriment to you, your child or the school if you choose not to take part. If once the investigation has started you decide you no longer wish your child to take part, you can withdraw your child by contacting the class teacher and letting her know. Furthermore, even if you give consent, your child can still choose not to take part. If your child is not taking part, appropriate alternative work will be given to your child by the class teacher while those taking part are completing the questionnaires.

What will your child do in the project?
Your child will:

- Be interviewed for approximately 15 minutes by the researcher who will complete a questionnaire with them on their attitude to maths and whether or not they feel anxious about maths (Mathematics Attitude and Anxiety Questionnaire). The questionnaire will be repeated at the end of the programme.
- Complete a questionnaire with the class on how they feel about themselves as a learner (Myself as a Learner scale). The questionnaire will be repeated at the end of the programme.
- Approximately six weeks after completing the two questionnaires, the same questionnaire will be repeated with your child and compared to the results from the first questionnaires.

Why has your child been invited to take part?
All children in your child's class are being invited to take part along with the children in one other school in LA. The two schools involved are the P5 class at B Primary and the P5 and P4/5 class at A Primary. P5 is the start of the second Level in Curriculum for Excellence and is the point where children's progress in maths sometimes slows down.

What are the potential risks to your child in taking part?
There are no risks involved in taking part in the investigation and no detriment if you choose for your child not to take part. There is no history of the questionnaires resulting in any issues for children, but If the questionnaire triggers any anxiety the school's educational psychologist is available to talk about any issues you or your child may have and can be contacted at 01292 61*****.

What happens to the information in the project?
Once the investigation is complete, the data will include questionnaire results. This information will be anonymised so that your child's name is removed and a number allocated to them. If you choose to withdraw your child during the study or at the end of the study before the data is anonymised, their data will be deleted. All data will be stored securely in the University of Strathclyde Onedrive with paper records scanned then the paper copies destroyed. The data will be stored for the duration of the project which will be approximately the end of 2022. Data which merits retention will be totally anonymised, registered and stored on the Open Science Framework maintained by the Centre for Open Science. Data will be stored and processed in line with GDPR. The collated data will be used as part a doctoral thesis and may be used in publications or presentations at conferences. No schools will be identified in any publications or conferences. The data will also be accessed by Dr Clare Daly at the University of Strathclyde.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.

All personal data will be processed in accordance with data protection legislation. Please read our Privacy Notice for Research Participants for more information about your rights under the legislation.

Thank you for reading this information – please e-mail any questions if you are unsure about what is written here using the following e-mail address: douglas.hutchison@strath.ac.uk

What happens next?
If you are happy for your child to take part you will be asked to sign the consent form which is on the next page and return it to your child's class teacher.

If you do not want your child to be involved in the project thank you for your time in reading this information sheet.
If you want any feedback on the investigation, please contact Douglas Hutchison douglas.hutchison@strath.ac.uk

Chief Investigator details:
The Chief Investigator for this research is Dr Clare Daly who can be contacted at clare.daly@strath.ac.uk
This investigation was granted ethical approval by the School of Psychological Sciences and Health Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:
School of Psychological Sciences and Health Ethics Committee
University of Strathclyde
Room GH 6.76, Graham Hills Building
40 George Street
Glasgow
G1 1QE
Telephone: 0141 548 ****
Email: hass-psh-ethics@strath.ac.uk

University of Strathclyde
Humanities & Social Sciences

Consent Form for Paired Maths investigation

Name of department: School of Psychological Sciences and Health

Title of the study: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my child's personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my child's participation is voluntary and that I am free to withdraw my child from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that anonymised data (i.e. data that do not identify my child personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies my child will be made publicly available.
- I consent to my child being a participant in the project.

Child's name:___________________________

Parent / carer signature:________________________

Please return this form in the envelope provided to the school. Your child will not take part without your signed consent. Thank you.

Annex 11: Participant Information Sheet for Children

University of Strathclyde
Humanities & Social Sciences

Participant Information Sheet for Paired Maths project

Name of department: Psychological Sciences and Health

Title of the study: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances.

What is the purpose of this project?

- You are being invited to take part in a project with your class that is about maths.

- The project involves playing maths games three times a week for 20 minutes over 6 weeks
- You will be helping others and others will be helping you. You will take turns at being like the teacher and the pupil.
- You will also be invited to answer questions that ask you how you feel about maths and how you feel about learning.
- If you don't want to answer some or all of the questions, you don't have to.

Do you have to take part?

- You do not have to take part. If you do not want to take part it is okay. You will be given a choice of other maths work to do at the same time. It might be Big Maths, Sumdog or TT Rockstar.

What will you do in the project?

You will:

- Be asked some questions about how you feel about maths.
- Do some questions with the class about how they feel about learning generally.
- Take part in a paired maths programme involving three 20 minute sessions a week for 6 weeks. The sessions are during class time, with the teacher using maths games about important maths skills.

Your teacher will also set individual goals for you and check your progress through the programme.

Why have you been invited to take part?

- All children in your class are being invited to take part along with the children in one other school in LA.

What happens to the information in the project?

- At first, your answers to the questions will be kept on a computer in Strathclyde University along with your record of games you have played. Once the project is finished your name will be taken off your answers and records so that nobody can tell whose information it is. Your name will not be kept on any records so that your information is private.

What happens next?

- You will be asked at the start of the project and during it if you want to take part. If you don't want to then you don't have to and you will be given something else to do.

Annex 12: Participant Information Sheet for Children in the Control Group

Participant Information Sheet for Paired Maths project

Name of department: Psychological Sciences and Health

Title of the study: Paired Maths Intervention in two LA Primary Schools – trying to meet the learning needs of children taking account of different needs and circumstances

What is the purpose of this project?

- You are being invited to take part in a project with your class that is about maths.
- The project involves answering questions on how you feel about maths and how you feel about learning.
- If you decide you want to answer the questions you will be asked the questions now and then again six weeks from now.
- If you don't want to answer some or all of the questions, you don't have to.

Do you have to take part?

- You do not have to take part. If you do not want to take part it is okay. The teacher will give you something to do while those taking part are answering questions on how they feel about maths.

What will you do in the project?

You will:

- Be asked some questions about how you feel about maths.
- Do some questions with the class about how they feel about learning generally.

Why have you been invited to take part?

- All children in your class are being invited to take part along with the children in one other school in LA. The two schools involved are the P5 class at B Primary and the P5 and P4/5 class at A Primary.

What happens to the information in the project?

- At first, your answers to the questions will be kept on a computer in Strathclyde University. Once the project is finished your name will be taken off your answers so that nobody can tell whose information it is. Your name will not be kept on any records so that your information is private.

What happens next?

- You will be asked at the start of the project and during it if you want to take part. At the start you will be asked by your teacher or another adult. They will take a note of what you decided (Appendix 18). If you don't want to take part then you don't have to and you will be given something else to do which will be Sumdog, Big Maths or TT Rock Star.

Annex 13: Briefing note for teachers involved in the investigation

NOTE FOR CLASS TEACHERS: PEER ASSISTED LEARNING IN MATHS

Aim: The aim of the peer assisted learning intervention in mathematics is to improve children's attitude to maths; self-concept as a learner in maths; reduce maths anxiety; improve skills in number and number processes using maths games as the context for learning. The focus is specifically on bringing about improvement for those children who experience the highest levels of social disadvantage by encouraging mathematical thinking in a non-threatening games environment and in so doing increasing their capacity for mathematical thinking and conceptual understanding of mathematics. Through the intervention the intention is to develop a protocol for improving outcomes for socially disadvantaged learners across the local authority.

School and teacher consent: As the class teacher you are entirely free not to participate in this intervention. Even if the head teacher offers consent for the class to be involved you are also asked for your consent to take part and there is no detriment to you or the school by not participating.

Parental consent and pupil consent: A signed parental consent form will be required for each child taking part. Parents will be given a participant information sheet and a child's version will also be given to children taking part. In addition, verbal consent will be sought from pupils before the start of the intervention following a verbal briefing by the class teacher.

Measuring progress: Baseline measures will be taken before the intervention as follows:

1. **Goal attainment scaling**: Criterion referenced attainment measures using goal attainment scaling. The class teacher will determine the measure of progress for each child during the period of the intervention using a 5 point GAS measure ranging from minus 2 to plus 2 with zero representing no change.
2. **Mathematics Attitude and Anxiety Scale** (MAAQ): The MAAQ will be undertaken before and after the intervention. The range of scoring

on the MAAQ is 0 to 28 giving an indication of positive or negative attitude to maths and the degree of anxiety towards maths for 6-9 year old children.

3. **Myself as a Learner Scale (MALS)**: Academic self-concept measure prior to intervention.
4. The measures will be carried out with the B PS P5 class, the A PS P5 class and the A PS P5 control group. The MAAQ and MALS will be repeated at the end of the intervention and the class teachers will evaluate progress using the GAS for each pupil

The Peer Assisted Learning Intervention

Paired learning works most effectively when it takes place three times a week for between 20-30 minutes. In the current context the peer assisted learning will be within class reciprocal pairing. That means the 'peers' will take turns at being the tutor and the tutee either on different sessions or different weeks. Paired learning also works most effectively on interventions between 5-10 weeks. The intention is for the current intervention to run for 6 weeks and have three 20 minute sessions a week. If possible and practical the researcher will arrange a weekly check-in with the teachers for 10-15 minutes.

Training for the tutors

- 'What to do' tutor leaflet will be given to all children and the role of the tutor explained. A verbal briefing will also be given by the researcher prior to the start of the intervention. The briefing will include a brief explanation of each of the games which will also help in pairs or groups selecting which games to play at the first session.
- Pairing or groupings will be at the discretion of the class teacher

Games available

Commercial off the shelf games – simplified instructions available)

Gangsta Granny Mental Maths Games (x4)	2 or 3 pupils per game - total 8 or 12
Genius Square (x4)	2 per game - total 8 pupils
Mobi (x2)	2, 3 or 4 per game – total 4, 6 or 8 pupils
Mobi Kid (x1)	2 per game - total 2 pupils
Rolling Cubes (x1)	2 or 3 per game – total 2, or 3 pupils
Shut the Box (x4)	2, 3 or 4 per game – total 8, 12 or 16 pupils
The Brain Train (x1)	2 per game
IQ Digits (x1)	2 per game – 2 pupils

Games reproduced from Topping Paired Maths book

Need coloured pens or pencils; dice and squared paper

Navigrid - squared paper and dice	2 per game
Tri-box; square box – squared paper	2 per game
Pathway Board – 24 counters, 2 colours	2 per game

Sidewinder Board 2 per game

Computer games (Online – laptop)
Mathbrix Grade 2
Blooket

Paired Maths Process

- The class teacher will set aside three 20 minute sessions each week over a 6 week period for Paired Maths.
- The teacher can decide if children will be tutor and tutee alternating each 20 minute session or at the end of a week.
- The pair or group choose the game they will play for the 20 minute period. Not everyone will get their first choice but the games will be rotated over the 18 sessions so that everyone has a chance to play all the games if they want to.
- Children record which games they played each session on the record sheet provided.
- At the end of each week the children are also asked to reflect or debrief on what they have learned at the end of the third session by writing one thing they have learned or feel they are getting better at as a result of the paired maths activities.

Annex 14 : 'What to do' tutor leaflet for tutors (children)

Thank you for agreeing to be a paired tutor and help your friends with their maths. This project will last for six weeks. This page is a reminder of some important things about being a paired tutor.

This is what you will have:

- Maths games
- A page that tells you how to play the game
- A diary record card for you and the person you are working with.

This is what you do:

- Try to help your partner to enjoy playing the games
- If your partner makes a mistake, don't make a fuss
- Just show them or explain how to do it
- Then go through it again
- Let your partner discover as much as possible without your help
- Do encourage and guide if you think it is needed

Talk with your partner and listen to your partner

- It is important that you and your partner talk about what you are doing.
- Try to answer your partner's questions and ask them questions about what they are doing

Diary Record Card

- We would like you to note down a few things for us each time you play a game. You will have a record card and so will your partner. You can fill it in at the end of the games session.

Annex 15: Example of 'How to play x game'

Contains 13 dice
4 blue dice with even numbers
4 green dice with odd numbers
4 red dice with +, -, x, ÷ operators
1 orange dice with = symbol
You also need pencil and paper.

<u>How to play Rolling Cubes</u>

Game 1:

- Each player takes a turn and rolls all 13 dice.
- Use the 13 dice rolled to make an equation, for example: 6x2=3x4
- Scoring is as follows
    - 1 point for each dice used
    - 2 points for a multiplication sign used
    - 3 points for a division sign used (not if you multiply or divide by 1, that's too easy - sorry!)
    - A double digit number scores 3 points
    - A three digit number scores 6 points
    - 1 bonus point for using 12 dice
    - 2 bonus points for using all 13 (that's really hard!)
- The winner is the first to score 47 points

Game 2:

- Each player needs a sheet of paper and a pencil
- This is like game 1 except you all use the same dice that are rolled
- The dice are all rolled at the same time and left where they are
- Each player tries to make the longest equation they can (writing it on paper this time)
- Points are awarded the same way as in game 1
- The winner is first to 41 points

Appendix E, Annex 16: Children's Record of Games Played and reflections

Pupil name:

Session	Games played	How was the session?
Week 1 Session 1		
Session 2		
Session 3		
One thing I learned this week		
Week 2: Session 1		
Session 2		
Session 3		
One thing I learned this week		
Week 3 Session 1		
Session 2		
Session 3		
One thing I learned this week		

Session	**Games played**	**How was the session?**
Week 4 Session 1		
Session 2		
Session 3		
One thing I learned this week		
Week 5 Session 1		
Session 2		
Session 3		
One thing I learned this week		
Week 6 Session 1		
Session 2		
Session 3		
One thing I learned this week		

Annex 17: Risk assessment

Two separate attachments – LA Risk assessment and University of Strathclyde risk assessment.

Annex 18: Record of children's consent

CONSENT RECORD FOR CHILDREN

School: Class: Date:

NAME OF CHILD	CONSENT Circle YES / NO		CONSENT TAKEN BY (Name of class teacher / researcher / other)
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	
	Yes	No	

Appendix F: Qualitative data – children's comments

Primary A Comments per session

(bold text is start of new respondent)

- **I really enjoyed the games**
- I really liked the game
- I found this challenging
- I was the teacher today
- I liked the game I played today
- It was a good session today
- I felt my multiplication is getting better
- I feel that I am becoming better at working with others
- I think I am getting better at multiplication and division
- I thought the games were okay
- Good session
- **I really enjoyed this game**
- I didn't enjoy the game
- I really improved my skills in maths today
- I was the pupil today
- I was a pupil today during the game
- I feel my times is getting better
- I feel I am making progress in maths
- I feel I am getting better at adding and multiplying calculations
- I thought the games were okay today
- Good session
- **I really enjoyed this game**
- I am getting quicker with maths
- I really improved my skills in maths today
- I helped others in my group
- It was really fun
- It was a good session today
- I think I am getting better at adding and subtracting
- I really enjoyed playing games today
- Good session
- **I really enjoyed this game, I had fun**
- I didn't enjoy this game
- I really enjoyed this game today it was fun
- It was really fun today
- It was a good session today, I had fun
- I feel my multiplication is getting better
- I feel that I am making progress in maths
- I feel I am getting better at adding and subtracting calculations
- I really enjoyed playing the games today
- Good session
- **I really enjoyed this game**
- I improved my skills today
- I didn't really enjoy this game
- I improved my times table but it was a little hard
- I was the pupil today
- I loved this game
- I felt I can make sums quickly
- I am becoming better at working with others
- I am getting better at times and division facts
- Good lesson
- My fav lesson was Genius Squares
- **I really liked the game**
- I really improved my skills in maths today
- I helped others in my group
- I was the pupil today
- It was a good session today
- I think my times is getting better
- I feel I am becoming better at working with others
- I think I am getting better at times and division calculations
- Excellent session
- My fav game overall is Gangsta Granny

- **I don’t really think this game is for me**
- I improved my skills today
- I helped others to play
- I really enjoyed this game
- I was the pupil today
- I helped others to play
- I think I can explain how to play the game really well
- I find this game quite difficult
- I feel that I am getting better at working with others
- I think I am getting better at adding and subtracting calculations
- I did not really like the game today
- Excellent session
- My favourite game is Shut the Box
- **I really enjoyed this game**
- I am getting better at maths
- I didn’t like it
- I really enjoyed this game
- I was the teacher today
- I was a pupil today
- I find this game fun
- I think the games are becoming boring
- **I really enjoyed this game and I loved it**
- I really enjoyed this game
- I like this game
- I enjoyed this game
- I helped others in my group
- It was really fun for me
- love maths
- I feel my multiplication is getting better (Gangsta Granny)
- I don’t think this is making a difference to my maths (Shut the Box)
- I am getting better at multiplication and division calculations
- I thought the games were okay today
- Okay session
- My favourite game was Genius Squares
- **I loved playing this game**
- I really liked the game today
- I improved my skills today
- I really improved my skills today
- I helped others
- I had lots of fun today
- I feel I can make sums quickly
- I feel that I am making progress in maths
- I think I am getting better at multiplication and division calculations
- I really enjoyed playing the games today
- Okay session
- My favourite game was genius squares
- **I really enjoyed this game**
- I am getting better with maths
- This game isn’t for me
- I really enjoyed this game it as really fun
- Other pupils helped me
- It was really fun
- I am okay with maths!
- I really like this game
- I am getting better at maths
- I am getting better at adding and calculations
- I really enjoyed this game
- Excellent session
- My favourite game was Genius Square
- **I really enjoyed this game**
- I improved my skills today
- I improved my problem solving
- I was the teacher today
- It was really fun
- I had lots of fun today
- I really enjoyed competing against others
- I feel I am becoming getter at working with others

- I think I am getting better at adding and subtracting calculations
- I really enjoyed playing the game today
- Excellent session
- My favourite game was Genius Square
- **I really enjoyed this game**
- I really liked the game today
- I didn't enjoy this game
- I helped others play
- I really enjoyed this game
- I had lots of fun today
- I feel I can make sums quickly
- I feel that I am becoming better at working with others
- I feel I am getting better at times and division calculations
- I really enjoyed playing the games today
- Very good session
- My favourite game was Genius Square
- **I thought Genius Square was awesome as I like coordinates**
- I improved my skills today
- I like this game very much
- I learned a lot using this game
- I was the teacher today
- It was really fun
- I had lots of fun today
- I really like this game
- I feel like I am getting better at maths
- I think I am getting better at multiplication and division calculations
- I enjoyed the game today
- Okay session
- Favourite game Genius square
- **I don't really like this game**
- I improved my skills today
- This game is not for me
- I really enjoyed the game
- I helped others in my group
- I helped others in my group
- I had lots of fun today
- I feel I can make sums quickly
- I don't think I'm learning when playing this game (Genius Square)
- I think I am getting better at division calculations
- I really enjoyed playing the games today
- Excellent session
- My favourite game is Genius Square
- **I really liked this game**
- I improved my skills today
- I helped others to play
- I was teaching others
- I was the teacher today
- It was really fun
- I had lots of fun today
- I feel that I can make sums faster
- I feel that I am becoming better at working with others
- I think I am getting better at multiplication and division
- I really liked playing the game today
- Great session
- Great session
- **I loved playing this game**
- I really liked the game today
- I didn't enjoy the game
- I was helping others to calculate
- Other pupils helped me
- I helped the others in my group
- I had lots of fun today
- I feel my multiplication is getting better
- I feel that I am becoming better at working with others
- I think I am getting better at adding and subtracting calculations
- I thought the games were okay today
- Very good session
- My favourite game overall is Genius Square

- **I loved playing this game**
- I improved my skills today
- I loved this game, it was so fun
- I really enjoyed this game
- I was the pupil today
- It was really fun
- I think I am getting better at adding and subtracting calculations
- I liked the game but it was hard
- Excellent session
- My fav game overall is Mobi
- **I loved playing this game**
- I really like the game today
- I improved my skills today
- I helped others to play
- I helped others in my group
- I was the pupil today
- I was a pupil today during the game
- I really enjoyed competing against others
- I feel that I am becoming better at working with others
- I think I am getting better at times and division calculations
- I thought the games were okay today
- Excellent session
- My favourite game overall was rolling cubes
- **I really enjoyed this game**
- I liked this game
- I helped others in the group
- It was amazing
- I was a pupil during the game
- I feel I makes sums quick
- I need a bit of help
- I thought the game was okay today
- **I really enjoyed this game**
- I didn't enjoy the game
- I was really proud of my score
- I was the pupil today
- I find I can make sums quickly
- I feel that I am making progress in maths
- **I really enjoyed this game**
- It wasn't my favourite but it as alright
- I enjoyed this game and loved helping others count
- I helped people at my group understand the game today
- It was really fun today
- I think I can explain how to play the game really well
- I really enjoyed competing against others
- I feel that I am making progress in maths
- I think I am getting better at times and division calculations
- I thought the game were okay today
- **I improved my skills today (Harry)**
- I liked this game great
- I love it today
- It was okay
- I find this quite hard
- I think I am getting better at adding and subtracting
- I thought the games were okay today
- I like it
- **I really enjoyed this game**
- I really liked the game
- I was really proud of my score
- I was the teacher today
- It was really fun
- It was a good session today
- I feel my times is getting better
- I think I am getting getter at adding and subtracting
- **I really liked this game**
- I didn't enjoy this game
- I found this a little hard at some parts
- Other people helped me
- It was really fun
- I had lots of fun today
- I feel my times is getting better

- I don’t think I am learning when playing this game (Shut the Box)
- I think I am getting better at times and division
- I really enjoyed playing the game today

ONE THING I LEARNED THIS WEEK

- **I am getting better at counting and adding**
- I found out that I am really good at problem solving
- I learned more times facts
- I can calculate quicker
- **My opinion of maths has got better**
- I am becoming more confident in times, divide, add, subtract.
- I am good at solving problems
- I learned more times tables facts
- I can use a variety of number talks strategies to help me
- **I am much quicker at adding numbers together**
- I found out that I am really good at problem solving
- I am able to sue my mental number talks to help me
- I learned more times facts
- I am calculating quicker
- **I am getting better at counting and adding**
- I am becoming more confident in times, divide, add, subtract.
- I am very good at solving problems
- I learned more addition facts
- I can calculate quicker
- **My opinion of maths has got better**
- I learned more multiplication facts
- I am developing problem solving facts
- **I am much quicker at adding numbers together**
- I learned how to play as a team
- I am very good at solving problems
- I learned more addition facts
- I can calculate quicker
- I really enjoyed taking part in this project
- **I found out maths can be fun**
- I am very good at solving problems
- I learned more addition facts
- I can calculate quicker
- I really enjoyed taking part
- **I don’t think I learned much this week apart from how to play the games**
- I found out I am good at problem solving
- I liked taking part
- **I learned that I’m a really good mentor as I helped people to take part**
- I think I am really good at teaching others
- I am great at solving problems
- I learned more division facts
- I can calculate quicker
- I really enjoyed taking part
- **I am getting better at counting and adding**
- I found that I am really good at problem solving
- My accuracy is improving
- I learned more addition facts
- I can calculate quicker
- I really enjoyed taking part
- **My opinion of maths got way better**
- I am becoming more confident at add, subtract, multiply and divide
- I feel I am becoming more confident with maths
- I learned more times table facts
- I can use a variety of number talk strategies to help me
- **My opinion of maths is better**
- Good at problem solving
- I am able to use mental number talks to help

- I am developing my problem solving skills
- I really enjoyed taking part
- **I don't think I learned anything apart from how to play the games**
- I feel happier during maths
- I am very good at problem solving
- I learned more times facts
- I know multiplication and division are different
- I really enjoyed taking part
- **I found out that maths can be fun**
- I am very good at problem solving
- I am able to use my mental number talks to help me
- I can calculate quicker
- I really enjoyed taking part in this project
- **My opinion of maths has got better**
- I feel happier during maths
- I am very good at solving problems
- I learned more multiplication facts
- I can calculate quicker
- I liked taking part
- **I don't think I learned much this week apart from how to play the games**
- Good at problem solving
- I feel I am becoming more confident
- Learned more adding acts
- I can calculate quicker
- Enjoyed taking part
- **Maths can be fun**
- I know that multiple and divide are inverse
- Enjoyed taking part
- **I am trying to improve my times tables**
- More confident in add, subtract, multiply and divide
- I am good at solving problems
- I learned more times tables facts
- I can calculate quicker
- I really enjoyed taking part
- **I found out I am very good at maths**
- My accuracy is improving
- **I am trying to improve my times tables**
- I am able to use my mental number talks to help me
- I learned more times facts
- **I don't think I learned much this week apart from how to play the games**
- I think I am really good at teaching others
- My accuracy is improving
- I learned more division facts
- I am developing my problem solving facts

<u>Primary B Comments per session</u>

- **Confusing and hard**
- Really fun and confusing
- Good
- Really fun
- Not good
- Annoying
- Really funny
- Annoying
- Very very annoying
- Funny and cheated – soz!
- Really good
- Really funny
- Not fun
- Really fun
- Funny – okay
- Not fun
- Really fun
- Funny
- **Really good, really fun**
- Quite good, trickier than shut the box
- Fun and hard
- Fun

- Fun and hard and good
- I love it, you win and you lose and that's okay
- Fun and good
- I love it
- Really good
- **Good fun, liked making different sums**
- Good fun, liked
- Good fun, liked.
- **Very fun**
- Kinda fun
- Very funny
- Fun
- Bad because I lost and she rubbed it in my face
- I learned how to lose and not to get angry or sad if I loose
- **Fun**
- Funny, hard
- Really exciting
- Boring
- **Fun but frustrating**
- Exciting but challenging
- Difficult
- Confusing
- Fun
- Okay
- Good, nice
- Confusing but fun, mind scrambled
- Amazing
- Exciting
- Helpful with multiplication Interesting
- Stressful
- Competitive
- Frustrating
- Extremely fun
- Good – you have to win out of luck is what I like
- **Thrilling but difficult**
- Amazing
- Honestly annoying
- Funny, good
- Funny, got along with opponent
- Fun, got to know partners
- Fun, difficult
- Nothing but fun
- Fun again
- Fun, difficult
- Fun
- It wasn't that fun, but it as alright
- Loved it
- Didn't enjoy it
- Yes
- Loved it
- Hated it
- **Really fun and difficult**
- Confusing but hard
- Challenging
- Fun
- Tempting
- Intense
- Cool
- Easy, easy
- How to make a lot of noise
- Harder than usual
- Very annoying
- It was a good game
- It was cool
- I lost all of it
- Not fun
- **Fun and confusing**
- Challenging
- Unbelievable
- Fun
- Challenging
- Stressful
- Fun
- Good team work
- Good
- Amazing
- Challenging
- Amazing
- Unbeatable
- Cool and stressful
- I lost about 10 times
- Stressful
- Amazing
- **Unbeatable**
- Frustrating

- Fun
- Funny
- Good fun to play
- A class game
- Very confusing
- Love it, very very good
- **Fun, exciting, thrilling**
- Challenging, confusing
- Unbeatable
- Tricky, challenging
- I won a lot
- I hated it
- Fun
- Okay
- Terrible
- The best
- I loved it
- I'm a master at it
- Not the best
- **Confusing / good**
- Fun, challenging
- Fun
- Fun, cool, I recommend
- One of the best
- Fun
- Epic game! I like it
- Fun, annoying
- Fun
- Annoying
- The best!
- I learned team work
- It was okay
- I didn't like it
- Fun but a bit confusing
- Frustrating
- Was very fun but still tricky
- Competitive
- **Exciting but challenging**
- Thrilling, confusing
- Unbeatable
- Competitive
- Funny
- Fun, Exciting
- Intense
- Thrilling
- Fun and funny
- Competitive and funny
- Challenging
- Exciting, thrilling
- Annoying, frustrating
- Joyful but annoying
- Tricky
- Competitive
- Boring
- **Fun**

- Fun, really fun
- Terrible, fun
- Not fun
- **Difficult**
- Unbeatable
- Brilliant
- Good
- Not good
- **Good**
- Fun
- Fun
- Good
- Fun because you had to pick two cards up
- **Confusing, exciting, fun**
- Hard, fun, confusing
- Fun, intense
- Nice, easy
- Cool
- Fun, hard, exciting
- Challenging
- **Frustrating**
- Fun
- I hate it
- I love it
- Fun (x6)
- **Challenging, exciting**
- Competitive, hard
- Fun, confusing
- Frustrating but fun
- Challenging
- Fun, courageous
- Strategic
- Powerful, easy
- Fun, challenging
- Fabulous

- Fantastic
- Intelligent
- Crazy competitive
- Strategic
- **Like it but challenging**
- I liked it a lot
- Fun
- Hard
- Very fun. Loved it
- Fun
- Not fun, annoying
- Fun, loved it
- Fun, I won
- Fun
- Exciting
- Fun, I won every time
- I liked it
- **Liked it, good fun**
- Good
- I found this fun today
- **Rubbish**

ONE THING I LEARNED THIS WEEK

- **Losing to a teacher is not fun!**
- **Don't get angry if you lost**
- You win and you lose and that's okay
- To have fun no matter what
- **Maths is more than an explanation**
- Improvising
- You win and you lose and that's okay
- Team work is important
- **I learned team work**
- Team work is so important
- It's okay to lose and to win
- **Team work is the key**
- I'm better at solving problems, don't get angry and smile and enjoy the game
- I learned to help people
- Team work is so important
- **Mobi kids is brilliant**
- Solving maths problems
- Team work
- **Nothing**
- **Friendship**
- **To have some fun and challenge yourself**
- To help by improvising
- To have fun no matter what
- That maths is always fun, you just have to dig deep
- **How to not be too competitive**
- Have more fun
- To have fun no matter what
- That maths isn't always in a boring text book
- **Think outside the box**
- Nothing
- About team mates
- I love Genius Square
- **You win and lose**
- Losing is fine
- Sometimes life can be luck
- Every piece counts and you can add any numbers
- **Genius square is unbeatable**
- Team work
- You win and you lose
- Maths is fun
- **The games are fun and B is crazy and scary**
- You win, you lose
- Sportsmanship
- How to win and lose
- Teamwork and how to improve
- **About team mates, got to become better friends with team mates**
- Mostly friendship but Mobi taught me hatred
- **That maths can be fun and you win and you lose, it doesn't matter**
- Maths is fun
- Good sportsmanship
- It does not matter if you win or lose
- Maths isn't always in text books

- **Playing with other people**
- To keep happy, put on a happy face
- To keep team work
- How to rage more
- **Teamwork and tolerance, not to get angry if you lose**
- How to have fun
- **Team work**
- I learned team work, I learned to help people. I learned that you win and you lose and that's okay.
- **Team work**
- I learned to help people
- How to play all the games
- **Division and some multiplication**
- Multiplication
- Team work and helping

Appendix G: Notes from interview with class teacher

NOTES FROM INTERVIEW WITH P5 TEACHER PRIMARY A (Intervention Group)

How did it go and how did you feel?

- Nervous at first
- Not just learning the games but teaching and explaining
- Got champions for each game from the children
- Played them all first
- Then over taught
- Hardest was the evaluation
- The kids were excited
- Visual timetable daily – they could see the maths games activity coming up and were excited every day
- Excitement didn't go away
- Same the last week as it was the first week
- Good selection of games made a difference
- Didn't do the same game twice in a row
- Grouped them based on what wanted to achieve
- Kids good at looking after the games - they had a sense of pride
- Used Mr H as a reference point
- Dialogues at reflection – all very engaged
- We're going to show the other class how it works
- Plan to use P6/7 next year with P5s for paired learning
- Group of 6 who detested maths liked the games
- Kids quite disappointed when it finished
- Kept in a tray and used for reward time.

How did you manage the time and fitting the intervention in?

- Curricular so no loss of time
- Good dialogue
- Excitement

Any games didn't work?

- Train
- IQ Digits

If doing it again what would you change – do differently?

- Initially nervous and not sure about it but enjoyed it
- Reflections – would have spent less time on it or would have found an easier way, simplify the reflection

How did the children interact?

- Good class
- Some can’t stand to lose
- H. was good during the programme

Any final thoughts and would you do it again?

- Focus on add and subtract within 30 for the lowest achieving children
- Smallest group made the biggest difference
- 8 who struggle with number sense made big strides
- Made a difference, e.g. doubles
- A. detests maths but was so excited with the games. I can understand their attitude.