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PSYCHOLOGICAL FACTORS IN IMPROVING NUMERACY

Forth Valley and West Lothian Regional Improvement Collaborative

Educational Psychology Services

AUTHORS

Nick Balchin, Falkirk Council (Editor)

Whitney Barret, Clackmannanshire Council (Editor)

Sarah Booth, West Lothian Council

Alison Boyd, Stirling Council

Lesley Craig, Clackmannanshire Council

Rachel Donaldson, Clackmannanshire Council

Katherine Fraser, West Lothian Council

Muriel McKenzie, Stirling Council

Lyn McLafferty, Falkirk Council

Susan Murray, Clackmannanshire Council

Kathryn O'Hare, Stirling Council

Tracey Ross, West Lothian Council

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INTRODUCTION

Having a basic understanding of numeracy is a necessity in modern-day society (Beilock & Willigham, 2014; Maloney, Ramirez, Gunderson, Levine & Beilock, 2015). Not only is it a core educational requirement but each of us engage with it daily, from seemingly simple tasks such as choosing the best mobile phone contract to working out how to fairly split a restaurant bill (Chernoff & Stone, 2014). It is an important factor that leads to better job prospects and evidence suggests it leads to a better quality of life (Cragg, Keeble, Richardson, Roome & Gilmore, 2017). Yet despite its importance, mathematical attainment continues to be referred to as a 'crisis' in our education system and in many other developed countries around the world.

This report collates four distinct projects aimed at improving numeracy run by each of the four Educational Psychology Services in the Forth Valley and West Lothian Regional Collaborative. The first four chapters are a report of each individual project.

1. Attachment and Numeracy, Clackmannanshire Council. This study involved a literature review of research into development of early years' numeracy and its potential links with Attachment style.
2. Bridging the Gaps, Falkirk Council. This project focused on a longitudinal analysis of pupil outcome data from an action research skills project, involving the Coach Consult method of professional learning, undertaken with teachers and managers from 12 schools, in 4 discrete projects during 2016/17.
3. Metacognitive Development, Stirling Council. This project involved a professional learning programme for 8 teachers in 3 primary schools, using an appreciative inquiry approach. The teachers then implemented interventions on metacognition in their classes.
4. Pupil Voice, West Lothian Council. This project involved asking focus groups with 56 pupils in S4 from 8 high schools about the key factors affecting their numeracy and mathematical skills development in school. All were studying for National 5 Maths.

Chapter 5 is a meta-study of psychological factors in promoting numeracy. This meta-study used a content analysis of the common psychological factors identified within each of the four projects above. Each study had considered the relationship between their key questions, the effect of poverty and the evidence base in their individual subject area. To our knowledge, this is the first study to attempt to identify key psychological factors affecting numeracy development across diverse projects in a meta-study.

CHAPTER 1 – ATTACHMENT AND NUMERACY: A LITERATURE REVIEW

Lesley Craig, Susan Murray and Rachel Donaldson, Clackmannanshire Council

INTRODUCTION

Research has shown that early aptitude in numeracy is correlated with later outcomes (Duncan et al., 2007), not only in mathematics but also in literacy (Purpura, Hume, Sims, & Lonigan, 2011). Similarly, there is strong evidence of the relationships linking early attachment style between individuals and parents with many outcomes in later life such as behaviour, mental health, and child development. There has been less research exploring links between attachment and numeracy. This is despite some commonalities in central concepts such as constancy, object permanence, risk taking and exploratory behaviours.

The aim of this chapter is to provide a literature review of impact of attachment style on numeracy development. This will be done by addressing the following three research questions:

- What are the key psychological factors affecting numeracy development?
- Is there evidence of a correlation between attachment style and numeracy outcomes?
- Is there research to indicate that lack of key developmental attachment concepts of object permanence or constancy has an impact on later numeracy development?

LITERATURE REVIEW

ATTACHMENT RESEARCH

THE INFLUENCE OF ATTACHMENT STYLE ON LEARNING

Bergin and Bergin (2009) state that attachment has at least two 'functions' which are important in the classroom: providing feelings of security so a child can 'explore freely' and to form the "basis for socialising children". This "lower exploratory competence in avoidantly and ambivalently attached toddlers" (Moss & St-Laurent, 2001) suggests repercussions in terms of numeracy problem solving and risk taking.

Insecure attachment is more likely in those with lower socio-economic status (SES; Bergin & Bergin, 2009) and for those with backgrounds that involve neglect and abuse (Maguire et al., 2015; Finzi, Ram, Har-Even, Shnit, & Weizman, 2001). Disorganised attachment is almost twice as prevalent in low SES than middle SES children (Lyons-Ruth, Connell, Grunebaum, & Botein, 1990). These associations can make the relationship between attachment and later attainment difficult to unpick and attribute to attachment alone.

A range of studies have suggested that attachment can be a predictor of:

- school dropout (Marcus, 2001);
- behavioural development (Finzi et al., 2001);
- verbal ability; maths ability; reading comprehension; overall academic achievement; and levels of curiosity (Bergin & Bergin, 2009);
- academic competency (Jacobsen & Hofmann, 1997);
- and adjustment to school transition (Granot & Mayseless, 2001).

Sroufe, (2005) argued that attachment was crucial to "*critical developmental functions—social relatedness, arousal modulation, emotional regulation, and curiosity, to name just a few.*"

Attachment influences school success through two routes: indirectly through attachment to parents, and directly through attachment to teachers and schools (Bergin & Bergin, 2009). This links to the use of nurture groups in schools. These groups provide spaces where the children can get attachment from other figures apart from parents (Reynolds, Mackay, & Kearney, 2009).

THE IMPORTANCE OF EARLY RELATIONSHIPS FOR THE DEVELOPMENT OF MATHS SKILLS

The development of attachment style may have a significant impact on numeracy development as there is evidence these skills develop from a very early age (Starkey & Cooper, 1980), including earlier than pre-school (Krajewski & Schneider, 2009).

Specifically, "preschool children typically develop early math skills informally, through exploration of their surroundings" (Dobbs, Doctoroff, Fisher, & Arnold, 2006). This makes assumptions about the type of surroundings (including the relational environments) that children find themselves in, during these formative years. It also implies that children are able to explore effectively which the attachment literature tells us that secure attachment is required in order to explore successfully.

Research shows that formal encouragement of numeracy skills does have a significant effect. Board games based around maths have been found to increase young children's understanding of number concepts (Moomaw, 2017). The improvement is often particularly noticeable when children from lower socio-economic environments are given opportunities to play math games because they may not have had this opportunity at home (e.g. Ramani & Siegler 2008; as cited in Moomaw, 2017). This shows the importance of interpersonal relationships and opportunities for supported play with a more skilled partner in the development of children's maths skills.

The pattern, that initial knowledge is positively related to future learning (Bransford, Brown, & Cocking, 2000), is unusually strong and persistent for maths skills (Dobbs et al., 2006). For example, they were considerably stronger (average of .34) than the relations between initial and subsequent reading proficiency (.16) in the same six longitudinal studies reviewed by Duncan et al. (2007; Ramani & Siegler, 2008). The researchers concluded that early maths skills were such a strong predictor of later literacy development because "maths is a combination of both conceptual and procedural competencies" (Moomaw, 2017).

INDIVIDUAL CONCEPTS AND SHARED TERMINOLOGY- OBJECT PERMANENCE AND RISK TAKING/EXPLORATORY BEHAVIOUR

OBJECT PERMANENCE AND CONSTANCY

Object Permanence (OP) is the ability to know that objects continue to exist in time and place even when they are no longer visible (Piaget, 1952). It is viewed as one of the most important early developmental milestones (Bruce & Muhammad, 2009). Piaget (1952) hypothesized that object permanence and person permanence were developed at different rates but that the two concepts were related. Therefore, differences in the development of object permanence will be affected by the development of person permanence. Piaget (1952) intended the 'object' to be an inanimate object but later revised this to examine the mother as the 'object'. This anchors the idea of a link between mother-child attachment and object permanence.

Object permanence may never be achieved, or, even if achieved, could be lost in children who suffer from repeated or prolonged periods of emotional deprivation. This loss is greatest when children are in large institutions or are exposed to multiple foster home placements (Bell, 1970). Interestingly, if the maturing capacity of object permanence is not exercised and practiced, its underdevelopment can be a hindrance to the activation and elaboration of other human, social, emotional, and intellectual capacities. For example, speech and language, the ability to engage in fantasy play, or the interest and skill in using symbol formation for problem solving or communication (both of which are important for later maths competency). These are capacities that are to some extent dependent on the individual's capacity to separate, feel separate as a self, and the ability to feel comfortably alone in the presence of others (Winnicott, 1958). Problem solving is also a large part of numeracy development which further links these ideas.

Meltzoff and Moore (1998) were able to show that OP develops in two stages – object identify first, then object permanence. Through their experiments they were able to demonstrate that very young infants (around the age of 4-5months) maintain object identity. In their experiments they were able to show that these young infants would be surprised if the wrong object reappeared from behind a screen. This means that infants were able to represent not just *an* object but *the* object which indicates that object identity is connected to recognition of numerical identify (i.e. 'that one' or the oneness of one). For these infants, because of their young age, this process of discovery through movement of objects in the environment depends on the presence of others. It makes sense that some of this object identity and searching for moving and disappearing objects would be related to the movement of caregivers, which indicates a direct link between the beginnings of the development of number sense and object representation. Since object permanence comes later and can be eroded, attachment experiences are likely to have an impact on the development of number sense.

The concept of emotional constancy develops through secure attachment and is the ability to understand that people can exist in different states (angry, tired, happy) but remain fundamentally the same (Bombier, 2007). This ability to internally represent someone (or something) as internally or materially unchanged despite external appearances would appear to map on to Piaget's concept of object conservation (e.g. of mass/volume/weight) (Piaget, 1952). Emotional constancy develops through early care giving experiences and varies depending on attachment style (Bombier, 2007). It directly forms the internal working models (or mental blueprints) formed about ourselves and others and used to assess and manage all other relationships. One part of the internal working model would be the mindset people adopt about their abilities, willingness to try and the potential consequences of making mistakes. These mindsets have been shown to relate directly to academic outcomes (Dweck, 2006). This suggests understanding the development of constancy is likely to inform understanding of the development of conservation, however, the current literature review indicates this is an area that requires further research.

RISK TAKING/EXPLORATORY BEHAVIOUR

Attachment is about how secure a child feels and a securely attached child feels able to explore knowing they have a safe base to return to (Ainsworth, 1978; Bowlby, 1969). Numeracy literature and research indicates the importance for numeracy skills development of having a willingness to take risks and try things out if they felt safe (Dobbs et al., 2006).

Exploration of environments enhances cognitive skills in young children because it enables them to interact with different people and objects (Matas et al., 1978). Previous research has shown that children with different attachment styles may explore their environments differently. Compared to their securely attached peers, avoidant children tend to investigate the environment over interacting with caregivers (O'Connor & McCartney, 2007; as cited in McCormick, O'Connor & Barnes, 2016) and ambivalent children will explore less, potentially to stay close to caregivers (e.g. Frosch, Cox, & Goldman, 2001; as cited in McCormick et al., 2016). It would be predicted that insecure children would also engage in less exploration, due to them not feeling they have a secure base (McCormick et al., 2016). These shared ideas found in both attachment theory and numeracy development, again, suggest a relationship which needs further exploration.

NUMERACY RESEARCH

ATTACHMENT AND NUMERACY

Dobbs et al. (2006) looked explicitly at the association between preschool children's maths skills and socio-emotional functioning. There was a significant correlation between attachment and maths scores (.33). They propose that of the socio-emotional factors, attachment has the weakest theoretical link to maths skills. However, the research showed a correlation and that attachment is significantly correlated with other socio-emotional factors which perhaps have a more obvious relationship to maths skills, for example, initiative (.55) and self-control (.49).

In a large-scale, longitudinal study McCormick et al. (2016) investigated mother-child attachment style and maths and reading skills. No correlation was found between controlling (disorganised-type attachment) or avoidant attachment styles and math skills. However, ambivalent (.14) and insecure/other (disorganised; .35) attachment styles were associated with lower maths skills in middle childhood (5th grade). This model controlled for early cognitive ability and maternal education level. Interestingly, ambivalent attachment was associated only with math and not reading skills. Insecure/other (disorganised) attachment on the other-hand predicted both skills across middle childhood (1st, 3rd and 5th grade). By 5th grade, this performance difference would represent being a third, and three quarters of a year behind for ambivalently and insecurely/other attached children, respectively, compared to their securely attached peers.

Dobbs et al. (2006) highlighted the importance of exploration of surroundings as a key mechanism for the development of math skills. McCormick et al. (2016) examined whether classroom exploration and task engagement would mediate the relationships found between attachment and numeracy. For ambivalent and insecure/other attachment styles, the effect on math skills was partially mediated by task engagement but not classroom exploration. While there was no link found between classroom exploration and attachment style, McCormick et al. (2016) found it notable that there was a 'robust association' between changes in exploration levels and changes in both maths and reading skills. Further investigation of this is needed to establish whether there is a relationship.

SOCIO-ECONOMIC STATUS, ATTACHMENT AND NUMERACY

Previous research has been done by North Lanarkshire Council investigating attainment levels of numeracy, whether poverty is related to the attainment gap in numeracy, and whether teacher training around numeracy led to improvements across pupil and teacher confidence and attainment (North Lanarkshire Council, 2017). Although this research did not directly relate to the relationship between attachment style and numeracy, the report provides an evidence base around child development and numeracy. Findings highlighted the attainment gap for mental arithmetic between pupils living in the most and least deprived areas, with the gap widening towards the end of primary school.

Similar to the findings on attachment, there is a significant relationship between background SES and later outcomes. Evidence suggests that variance in achievement due to social and family background emerge very early in children's lives. It was found that 'both SES and parental native language status independently predicted numeracy skills at age 3….[and] the achievement gap between higher and lower SES children widened over the preschool years' (Anders et al., 2012). It is important to consider whether attachment is playing a role in the poverty-related attainment gap. In addition, early intervention may be key in order to prevent the widening of the gap seen throughout the school years.

SUGGESTED INTERVENTIONS FOR ATTACHMENT AND NUMERACY

McCormick et al. (2016) found that an ambivalent attachment style only had an impact on numeracy development and not on reading. They hypothesised that this was because of the need for close proximity to care givers which would make reading together a motivating activity, whereas maths required more independent working. In addition to numeracy requiring more complex numeric processing skills (which may be impacted by the underlying difficulties of attachment), pupils also do need more self-regulatory skills and learning strategies to process math knowledge (McClelland & Cameron, 2012). This might explain why ambivalent pupils are reluctant to work independently during complex maths. McCormick et al. (2016) suggests that for both ambivalent and insecure/other interventions should involve helping children to attend to tasks and sustain attention, specifically in early school to help develop task engagement skills.

Dobbs et al. (2006) propose that maths interventions which improve maths skills do so in part by also improving socio-emotional functioning. Interrelating academic skills and psychological development can have positive effects which actually override effects of early negative factors: it was not possible to 'attribute most of the variation in later school achievement to our collection of school-entry factors, so the potential for productive interventions during the early school grades remains' (Duncan et al., 2007). This is a very welcome finding for those involved in working with insecurely attached children during school years.

Attachment styles have an impact on all areas of learning including numeracy. Specifically, insecurity makes it harder for pupils to work independently, feel safe to make mistakes and engage in tasks. In addition, there is some evidence that ambivalent and disorganised attachment styles have a more specific impact on numeracy development.

In order for teachers to support pupils with insecure attachment styles in their classroom, they should consider using the style-specific strategies to reduce their underlying relational anxieties which being one of many pupils engenders. They should also consider using the learning triangles (Bombier, 2007) from attachment literature when approaching support for individual pupils to help them maximise the amount of working they can do independently.

While McCormick et al. (2016) recognised that an ambivalent attachment potentially makes it harder for pupils to work independently (due to their need for close proximity to care givers) and this has an disproportionate impact on maths development over reading, the reason a pupils would require to be close to a care giver is due to insecure object and person permanence. So it may be that the poorer maths development, which has been observed in those with ambivalent attachment, is being doubly impacted by the core difficulties within this attachment style.

One intervention strategy for ambivalent pupils would be to do more of the activities which help to develop object permanence (e.g. treasure hunts, hide and seek, Kim's game); in other words, activities which make use of concrete objects which appear and disappear. This would then support later addition/subtraction skills as well as a secure development of number sense. Another intervention would be to use 'kept in mind' strategies to help them when they are required to work more independently (e.g. the use of more regular check-ins, dividing of tasks into smaller chunks to allow for regular contact with the class teacher, and more immediate feedback and interpersonal praise). In the classroom using ambivalent-specific strategies to manage the pupil's anxiety about whether the teacher is keeping them in mind will significantly increase their attention and concentration for all tasks.

For pupils with avoidant attachment, or lack of constancy the use of growth mindset (Dweck, 2006) commentaries are beneficial to help them feel more confident to try things, not to feel afraid to make mistakes and to encourage them to seek help (because not knowing the answer is OK).

CONCLUSION

There is a limited amount of dedicated research between attachment and later numeracy outcomes. However, through reviewing both the attachment and numeracy literature, links between numeracy outcomes and early attachment can be seen. The current review of literature has begun the process of 'joining the dots' to highlight links between these areas of a child's development.

Using the research questions to inform an exploration of the literature it is possible to find relationships between attachment and maths skills – see Table 1 . These connections are supported by longitudinal evidence showing the correlation between poor early attachment and negative outcomes in later life, which runs parallel to that of studies in early numeracy and the effects on outcomes in maths, literacy and overall occupational and life prospects.

TABLE 1

Research Question	Answer from literature review
What are the key psychological factors affecting numeracy development? (Collaborative Question).	Object Permanence (OP_, security to explore and take risks (i.e. secure attachment status), problem solving skills, opportunities for informal skills development. Significant correlation to SES.
Is there evidence of a correlation between attachment style and numeracy outcomes?	Some evidence, particularly around the impact of ambivalence/insecure other attachment category and maths outcomes. Further research required: • Need to unpick SES and attachment (correlation/causation) • Look at attachment relationship with CT as having an influence on attainment
Is there research to indicate that lack of key developmental attachment concepts of object permanence (OP) or constancy has an impact on later numeracy development?	Some evidence for OP. Further exploration of the concept of constancy required. Need to identify reliable measures for OP and constancy across the age range.

It can be asserted that the key psychological factors involved in attachment theory (Bowlby 1969; Ainsworth 1978) do affect numeracy development, just as they affect many other areas of development. For example, object permanence is developed through early attachment experiences and is related to object identify (including numerical identify) and both Piaget (1952) and Meltzoff and Moore (1998) identified that the concepts of object and person permanence were inextricably linked, suggesting that there is a strong connection between the foundations of attachment style and numeracy concept development. Secure attachment leads to good problem solving skills and more freedom to explore properties within the environment, which the numeracy literature has shown to be important for later numeracy development.

Likewise, there is evidence of a correlation between insecure and avoidant attachment styles and poor numeracy outcomes found in a small number of studies and this relationship would benefit from additional investigation. There would also appear to be a connection between the concept of internal working models (from attachment literature) and mindsets, which have been shown to have an impact on academic attainment. Constancy potentially equates to conservation, although this needs further exploration. Next steps would be to research or review these links further with reference to specific numeracy concepts.

An interesting finding to emerge from the third research question is the shared concepts and terminology between attachment theory and numeracy. These include object permanency/ constancy and risk taking/ exploratory behaviours – see Table 2

TABLE 2.

Secure attachment impacts on:	Numeracy development requires:
Object permanence development	Object permanence development
Attention/focus	Attention/focus
Exploratory behaviours & willingness to take risks	Exploratory behaviours & willingness to take risks
Problem solving skills development	Problem solving skills
Teacher's perceptions of student competence	Good teaching where students feel secure enough to take risks and teachers feel free to let students explore

NEXT STEPS

From this review of the literature of the impact of attachment style on numeracy development, some areas for further investigation have emerged including:

- More dedicated research needs to be done which allows an unpicking of attachment (using recognised measurement tools) from SES to determine a more reliable and scientific relationship between attachment theory and numeracy development.
- There needs to be awareness raised around how early babies begin to pick up on numeracy concepts and ideas around quantity even long before they develop the concept of number.
- Using the questions arising from the literature review to interrogate existing local data sets measuring attachment status and attainment.
- Reviewing existing assessment tools and interventions in order to identify appropriate interventions for pupils whose attachment style impacts on numeracy.
- Exploring the potential impact of attachment and constancy on the development of numeracy skills.

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CHAPTER 2 - BRIDGING THE GAPS: LONG TERM OUTCOMES OF AN ACTION RESEARCH PROGRAMME TO IMPROVE NUMERACY

Nick Balchin, Lyn McLafferty, Falkirk Council

INTRODUCTION

This project was conducted in two phases. Phase one of this project aimed to:

- enhance teachers' research skills focused on the identification of attainment gaps in mathematics and numeracy, and then to successfully plan and implement interventions that addressed these gaps. This was extending the use of the Coach Consult Method (Balchin, Randall and Turner, 2006) aiming to transfer the success of this approach for the purpose of bridging attainment gaps in mathematics and numeracy
- provide teachers with wider knowledge of evidence-based approaches to intervention in mathematics/numeracy and psychology.
- evaluate an approach to educational psychology service delivery (Coach Consult Method) in the area of attainment in mathematics and numeracy.

The outcomes of phase one are provided in Morrison & McLafferty (2018). The conclusion was that this approach to service delivery using the Coach Consult Method can assist educational psychology services to build capacity and enhance teacher practice in using research methods to target interventions that are required to lead to improved attainment.

Phase two of the project is outlined in this report. The aim of phase two of this project was to:

- demonstrate the impact on learners of the interventions implemented in school by the teacher participants in the project to bridge attainment gaps in mathematics and numeracy
- consider evidence of teachers implementing the research skills and knowledge taught in the programme
- identify factors that supported or hindered school implementation of the research skills or pedagogical knowledge and skills covered in the programme.

This work was based on a number of key principles:

- the concept of an attainment 'gap' is unhelpful, and the term attainment 'gaps' should be encouraged
- the term 'bridging' attainment gaps rather than 'closing' attainment gaps is preferred to reflect the incremental and long-term investment required
- methodical and systematic approaches are required to enhance data use and understanding to address attainment gaps
- skill development and close collaborations between managers and classroom practitioners in schools is required to address attainment gaps.

The key research questions are:

1. Was there evidence of teachers implementing the research skills and knowledge taught in the programme?
2. Did pupil skills and knowledge in mathematics and numeracy, or other targeted area for intervention improve as a result of this programme?

While acknowledging that there are multiple gaps, where the data has been examined in relation to a poverty related attainment gap this paper has identified children as belonging to a poverty group based on the postcode of where they live and using the Scottish Index of Multiple Deprivation (SIMD) (Scottish Government 2016c). This is similar to the approach used in Sosu and Ellis (2014).

LITERATURE REVIEW

Research evidence of the interventions found to have a success in narrowing the poverty associated attainment gap is continuing to grow. (e.g. see Hattie *et al*., 2017, Education Endowment Foundation and the Scottish Government Improvement Hub). However, research also strongly indicates the success of these interventions is dependent on a wider set of cultural and system circumstances. Marcus (2016) noted the need to put the child at the centre; address individual needs; encourage schools to use creativity; and allow them to develop their own strategies for learners. Multiple research sources highlight the importance of contextual circumstances in closing attainment gaps, including high quality teachers and teaching, strong school leadership, reflective practice and research, a network of support and collaboration, effective assessment and evaluation through using data and rigorous monitoring and early intervention (e.g. Baker, Gersten & Lee, 2002; Boaler, 2016; Knowles, 2017; Kunsch, Jitendra & Sood, 2007; Onu *et al*., 2012; Slavin & Lake, 2008). Therefore, *how* approaches are implemented as well as *what* approaches are implemented is central to success.

It can also be argued that the very paradigm of intervening in poverty related attainment gaps reinforces and reproduces educational and social inequity. What is required is a paradigm that cultivates strengths of individual learners, rather than "fixing their deficits" (Zhao, 2016). Identifying gaps that exist across all stages within a school due to poverty and other factors is critical as is the endeavor to close gaps in tandem with raising the quality of teaching and learning overall for learners.

RESEARCH ON THE IMPORTANCE AND EFFECTIVENESS OF THE TEACHER AS ACTION RESEARCHER

There is limited research available on the effectiveness of teachers as action researchers in improving pupil outcomes, or the poverty related attainment gap. This is an identified improvement priority of the Scottish Government (Scottish Government, 2017). The Coach Consult Method has been found to be effective in improving teacher skills, knowledge and confidence in research and in intervention or pedagogy, (Balchin, Randall and Turner, 2006; Randall, Turner and McLafferty, 2015; Morrison & McLafferty 2018). It is widely recognised that research skills in the form of practitioner enquiry is valuable for teachers, to the extent that it is incorporated in the expectations for teachers' ongoing professional learning (GTCS 2019).

Dimmock (2014) stresses three main factors or responses involved in addressing school-based problems that can be applied to addressing attainment gaps:

- research engagement on the part of all teachers and leaders;
- creating schools and school networks as professional learning communities;
- and adopting a workable methodology (namely, research–design–development) for teachers and leaders to put research into practice and tailor innovations to specific school contexts.

Prendergast and Rickinson (2018), identified that school practitioners access research in indirect and informal ways, although the teachers value it, they are discerning and selective about what research they engage with.

Teachers are the single most important influence on children's learning (Hattie, 2003). Hattie (2015) states there should be a shift in focus from between-school differences to within school difference. He highlights the variability in the effectiveness of teachers within school to be the most important contributors to this variance and rectifying this is key to positive impacts on children's learning. Achieving this "collaborative expertise" requires a system that values and develops teacher and school leader expertise. He outlines this involves: ensuring that teachers and school leaders work together on common understandings about progress and high expectations for the impact of their teaching, school leaders who focus on developing collective expertise among their teachers and that the systems in place result in robust decisions on the purpose and desired outcomes of their schools.

Engaging teachers in developing practitioner research skills is one approach to foster qualities supportive of collaborative expertise. When teachers are provided with challenge and feedback, coaching, modelling, scaffolding and mentoring, there is strong evidence of teacher capacity to become practitioner-researchers (de Vries & Manfred, 2005; Fixsen *et al*., 2009; Joyce & Showers, 1980; Lofthouse, Leat & Towler, 2010; McCarthy, 1992; Schoenwald, Sheidow & Letourneau, 2004; Sholomskas *et al*., 2005). Furthermore, teacher engagement in research, as part of evidence-based education (Davies, 1999), can improve classroom practice and professional development (Donaldson, 2011). Despite persistent sound evidence of the contribution 'teachers as action researchers' can make in their progression in professional learning and approaches to teaching and school improvement this has not been fully realised.

METHOD

Thirteen schools participated in the professional learning programme (phase 1 of this project). In the programme a small number of practitioners from each school were trained in action research methods that would identify where there were gaps in attainment and thereafter devise an intervention plan to improve these gaps and measure the change or progress.

Resultant from the programme were 4 action research projects. One of the action research projects was based in a single school. The further three action research projects involved multiple schools. One of the multi-school projects involved a cluster of associated primary schools and a secondary school. The further two multi-school projects involved two schools with a shared management team see Table 1.

Thirteen months after the programme ended, the participating schools presented their data to the Educational Psychology Service on individual children's progress in attainment and any additional data collected as part of the project in their school at the follow-up point. The authors devised a consultation approach to gather and discuss the data. This involved:

1. An invitation to a structured consultation and a request to bring their data
2. A consultation conversation using
    a. the Intervention Plan devised within the coach consult programme by the practitioners
    b. Intervention population
    c. Baseline data
    d. Tracking data
    e. Additional data
3. An opportunity to provide additional data to the EPS or second consultation meeting

The data was all anonymised at project level, such that no individual child was identifiable.

TABLE 1 – PARTICIPANTS AT FOLLOW UP BY PROJECT.

Project	Participants in programme	Intervention areas identified in 2016/17	Data in 2018	Participants by 2018.
A	8 staff from associated primary schools and a secondary school	To improve learners' attitudes & learning skills in relation to fractions. To reduce the 'age' related widening of the attainment gap. (P6 and 7 into secondary)	YES	6 staff remained 1 left school 1 changed jobs
B	3 staff from a primary school	To enhance confidence in mathematical vocabulary & word problem solving skills. To address literacy barriers to mathematical word problems. (whole school and targeted intervention for specific children)	YES	3 staff remained
C	4 staff from a shared headship across two primary schools and a nursery school	To enhance parent & child engagement and attitudes towards numeracy and mathematics. To maintain parental engagement as pupils progress through school.	NO	0 staff remained/in work
D	3 staff from a shared headship across two primary schools	To address poor engagement and motivation for learning. New classroom management approach to improve concentration and engagement. Activities planned around children's interests. (P2 target pupils)	NO	1 staff moved to the other school 1 returned after break 1 left school

See also Morrison and McLafferty (2018, p.100)

The programme had 18 participants in 2016/17. Of these participants, 10 were in post and in work for the duration of the programme and at follow up (56%). Of the 13 schools across the four projects, 10 schools (77%) had changed their headteacher, depute headteacher or principal teacher linked to the project during the period between the start of the programme and follow up. A further 2 schools (15%) had an acting manager confirmed as permanent during the period between the start of the programme and follow up. Therefore, in 12 of the 13 (92%) participating schools, management changes occurred in the twenty months between the start of the programme and follow up.

PUPIL LEVEL IMPACT AND OUTCOMES

For the purposes of this study there are 2 projects with follow up data. The factors involved in reducing participation at follow up are considered in the Implementation Factors section. As each project had a different focus of intervention a brief overview of the literature is provided for each project.

PROJECT A - USING ACTIVE LEARNING PEDAGOGY TO SUPPORT LEARNER'S' ATTITUDES AND SKILLS IN FRACTIONS

LITERATURE REVIEW

The Scottish Survey of Literacy and Numeracy (Scottish Government, 2012; 2014; 2016a) has consistently shown the questions pupils found most challenging were those on fractions, decimal fractions and percentages (P4 and P7). Fractions, decimal fractions and percentages are continually reported as the areas where fewest pupils thought they were good and pupil judgment of their skill matched their actual performance in the assessment (Scottish Government, 2012; 2014; 2016a). The contribution of affective factors alongside cognitive factors needs to be continually considered in interventions to address attainment gaps. Bandura's social cognitive theory (Bandura, 1977) defines self-efficacy as one's own belief about his or her ability to accomplish skills. Increasing a learner's self-efficacy has been shown to positively impact their cognitive processes, motivation and attainment (Goodman & Gregg, 2010; Unlu & Ertekin, 2013). Further, teacher self-efficacy (the extent to which the teacher believes he or she has the capacity to affect learners' performance) has been associated with positive teaching behaviours and student outcomes (Bates *et al*., 2011; Henson, 2001 & Siegle, 2003 cited in Unlu & Ertekin, 2013). This suggests a need for interventions that combine both skill development and raise learner and teacher aspirations.

Given the importance of numerical skills for future academic attainment, employment across many disciplines (including biology, physics, chemistry, engineering, economics, sociology, psychology, nursing, pharmacology) and daily living skills (for example, cooking and financial), weak understanding of fraction and decimals requires to be addressed. Psychologists (Piaget, 1958; Piaget & Inhelder, 1975 cited in Liu, R. Ding, Y. Zong, M. & Zhang, D. 2014) have noted the importance of leaners' advancement in their cognitive development between two stages called *concrete operations* (expected between the ages of 7 and 11 years) and *formal operations* (expected between the age 11 into adulthood). The mathematical abilities a learner has will be dependent on their successful acquisition of the cognitive skills expected in the concrete operations stage and transition into formal operations. The overall thinking of a child in the formal operations stage is much more complex than a child in the concrete operations stage and a learner to progresses into the formal operations stage, they require the foundations of knowledge and thinking from the concrete operations stage. Acquiring understanding of ratios and proportions is crucial in the transition between these two stages. Problems arising in the acquisition of fractions and decimals could derive from the earlier conceptual understanding the learner requires or the methods used to assist the learner.

Lortie-Forgues *et al*., (2015) analysed why learning fraction and decimals is so difficult and concluded that the difficulties arise from two main factors (1) inherent difficulties of fraction and decimals and (2) culturally contingent difficulties that could be reduced by improved instruction and prior knowledge of learners. The instructional factors included limited understanding of arithmetic operations by teachers, emphasis on memorisation rather than understanding, minimal instruction in fraction division, and textbook explanations of arithmetic operations that are difficult to apply beyond whole numbers. Sources of difficulties involving learners' prior knowledge included limited knowledge of whole number arithmetic and of the magnitudes of individual fractions, as well as limited general processing abilities. These sources of difficulty, of course, are not independent. Teachers' focus on memorisation may reflect reluctance to reveal their own weak conceptual understanding, learners' weak understanding of fraction magnitudes may reflect inadequate prior teaching; and so on. Moreover, there is a suggestion through research that acquiring literacy skills is seen as of greater cultural value than the acquiring of numeracy skills (Hatano, 1990 cited in Lortie-Forgues *et al*., 2015).

Schools are encouraged to use a wide range of effective learning and teaching approaches to promote positive attitudes and develop high expectations, confidence and resilience in maths (Scottish Government, 2016b:4). There are particular key skills, knowledge and understanding which provide a strong foundation for later learning in mathematics and numeracy. Without these key *pressure points* for real understanding, many learners will find it difficult to apply their skills in problem solving contexts and struggle to use mental agility to solve calculations in the most efficient and effective ways. This is pertinent in the learning of fractions, decimal fractions and percentages. Gaps are very often linked to the lack of visualisation and the ability to make connections in making sense of number.

Manipulatives and representations can be powerful tools for supporting pupils to engage with mathematical ideas. Psychologist Bruner (1966) first advocated the use of the concrete, pictorial and abstract as an effective teaching approach and this has been subsequently endorsed by further researchers (see Leong, Ho & Cheng, 2015), particularly for pupils having difficulties with mathematics (Jordan, Miller & Mercer, 1998; Sousa, 2008). The use of concrete instructional materials was also found to have been an effective in the teaching of fractions (Butler *et al*., 2003) and have a positive impact on learners' attitudes to their learning (Sowell, 1989). However, manipulatives and representations are just tools: *how* they are used is important. They need to be used purposefully and appropriately in order to have an impact (Carbonneau, Marley & Selig, 2013). There should be a clear rationale for using the manipulatives and this may be due to increasingly sophisticated mathematical concepts, such as fractions. Manipulatives can be used to support learners of all ages, yet these are predominantly used for younger children. Decisions about when to use manipulatives and when to withdraw them should be based on the learners' skills without the manipulatives and their improved knowledge and understanding. It is important that learners do not become dependent on manipulatives and this is achieved by ensuring they understand the links between the manipulatives and the mathematical ideas they represent and have other methods for representing their understanding of the concepts (Carbonneau, Marley & Selig, 2013; Nunes *et al.*, 2009).

SCHOOL CONTEXT – PROJECT A

This cluster of seven primary schools focused on improving pedagogy in the teaching of fractions by developing a coherent and practical programme for the learning and teaching of fractions in primary six and seven. They worked in partnership with their linked secondary school. Their identified needs were to:

- improve learners' attitudes and learning skills in relation to fractions
- reduce the 'age' related widening of the attainment gap.

A series of fractions lessons co-designed by primary and secondary (mathematics) teachers were delivered to all P6 and P7 pupils. The lessons incorporated a high level of real-world applicability and active learning approaches including the use of manipulatives and visual representations. A key aim was to implement new pedagogical approaches and increase consistency in the teaching of fractions within individual schools and across the cluster. In addition to supporting learners in acquiring understanding of fractions this also endeavored to support learners' transition to secondary school by ensuring the teaching approaches were consistent and progressive.

METHOD OF MEASURING IMPROVED OUTCOMES – PROJECT A

Pre-test data was collected in October 2017 and post-test data in June 2018. The participants devised a 32 question fractions test and attitudes questions for the children (N=159) to complete at the pre and post stage. The pupil data was compared in a table according to each learner's decile in the Scottish

Index of Multiple Deprivation (Scottish Government, 2016c). The poverty group are those in decile band 1.

OUTCOMES FOR PROJECT A

In terms of pupil attitudes, a range of questions were asked (see Table 2).

TABLE 2 – PUPIL ATTITUDES TO MATHEMATICS & FRACTIONS BEFORE & FOLLOWING INTERVENTION

	Before intervention			**After intervention**	
		No difference			No difference
Enjoy maths more than fractions	76%	24%		50%	37%
Enjoy fractions more than maths	0%			13%	
Better at maths than fractions	88%	6%		54%	37%
Better at fractions than maths	6%			9%	
Enjoy numeracy more than I feel I am good at it	11.5%	65%		25%	33%
Better at numeracy than I enjoy it	23.5%			42%	
Enjoy fractions more than I feel I am good at it	24%	47%		17%	33%
I am better at fractions more than I enjoy learning about them	29%			50%	

Prior to the intervention, no children reported to enjoy fractions more than other areas of mathematics. Following the intervention, a greater number of the children reported enjoying fractions more than other areas of mathematics or expressing their enjoyment was equal across all mathematics areas. An increased number of children rated their skills to be better in fractions following the intervention. 73% of children considered that they were better at fractions following the intervention (see Table 3). 68% of pupils showed an increase in their skills as demonstrated in the fractions test and 19% showed a decrease in skills post intervention (see Table 4).

TABLE 3 – CHANGE TO PUPIL SELF-EVALUATION

How good are you at fractions?		
Increase in rating	**Decrease in rating**	**No change**
73%	0%	27%

TABLE 4 – CHANGE TO PUPIL SKILLS AS MEASURED BY FRACTIONS TEST

Actual change pre-post in fractions skill		
Improvement	**Decrease**	**No change**
68%	19%	13%

In terms of attainment, across the whole sample there was a reduction in the average number of errors made by pupils at post intervention. There was an improvement demonstrated in 8 of the ten decile groups and the largest gains were made in the lowest and highest deciles (5.75 and 4.1 respectively). See Table 5.

TABLE 5 – COMPARISON OF PUPIL ERROR BY DECILE IN SIMD AND NUMBER OF PUPIL

SIMD decile	pre/errors (average)	post/errors (average)	CHANGE	Percentage of learners with reduced errors
1 (n=8)	19.5	13.75	-5.75	88%
2 (n=8)	9.75	10.5	+.75	63%
3 (n=30)	11.18	8.33	-2.85	80%
4 (n=15)	10.33	8.27	-2.06	87%
5 (n=25)	9.72	7.12	-2.6	80%
6 (n=7)	8	4.29	-3.71	100%
7 (n=6)	4.83	5	+0.17	67%
8 (n=18)	9.28	6.33	-2.95	89%
9 (n=32)	6.03	4.56	-1.47	81%
10 (n=10)	5.9	1.8	-4.1	80%
WHOLE SAMPLE (n=159)	*9.25*	*6.82*	*-2.43*	*82%*

At the post-test point it is clear from Table 5 that the majority of pupils had made gains in their fractions ability (reduced errors) which was six months after the teaching/intervention. An additional data gathering point with pupils once they are in secondary school could potentially be helpful to confirm whether the gains were sustained through transition. This equally may be captured though the teachers' awareness of gaps in fractions ability for the pupils in their class (i.e. being given the pre and post-measure raw data for their pupils).

REFLECTIONS AND RECOMMENDATIONS ARISING FROM PROJECT A

This project identified a gain in fractions skills and the pupils' views on competence in fractions. This indicates that they have an increased level of confidence in fractions, particularly in comparison to their wider maths skills. While it is possible that there was a recency effect in this distinction between maths and fractions, as the post measures were administered in May 2018, which was six months after the intervention, this seems unlikely.

The schools had used the data from teacher judgment and there is a role, not just for this school but all schools to continue to strengthen the methods and reliability of teacher judgment. This is highly relevant as there continue to be limitations within formal test or assessment approaches due to the high association of negative attitudes with mathematics (eg. Scottish Government, 2016b). This highlights that within the research there is a debate on the impact of 'test anxiety'. This means it is recommended practice that the formal test approach should not be relied on as the only or best indicator to measure changes in child attainment or specific skills development, and that this should be triangulated with other methods such as ongoing teaching and learning assessment and a robust teacher judgment approach.

These findings provide further evidence of the important contribution that teacher research skills can play in promoting attainment. It is suggested by the authors that that the training programme promoted:

- pedagogical change in the teaching of fractions
- positive teacher attitudes and collective teacher efficacy
- implementation of multi-stranded interventions that would increase the likelihood of known factors improving such as positive pupil attitudes and pupil's self-efficacy
- development of knowledge gain tools
- use of data and comparison approaches.

This assertion suggests that further research possibilities include:

- measures of teacher self-efficacy and collective efficacy
- measures on the degree of pedagogical change
- measures that more explicitly include other factors such as pupil self-efficacy and attitude.
- specific measures that capture discrete changes in the gain of maths knowledge that can be used to track gains over time.

The practitioner-researchers have shown their use of skills developed. The course did not include statistical analysis methods which may be something to consider in the future either within the programme design or as a next level of course for participants to extend their learning. One school who participated in the project have subsequently received training on the Improvement Model (Langley *et al*., 1996) to assist in capturing discrete changes in attainment gains over time.

It is not possible at this stage to report whether improved performance in the learners' skills in fractions have been sustained beyond the post measure. Further longitudinal analysis would be of benefit.

This project consisted of teachers from 8 schools collaborating and combining their resources to create new curricular materials as well discuss pedagogy and how they measure change. This discussion and collaboration was reported as beneficial at the end of the programme "promoted professional dialogue with colleagues" (Morrison and McLafferty, 2018, p101) and is likely to have had benefits that go beyond the immediate concerns of this project, such as the "general effect" (Balchin *et al.,* 2006, p241) and promoting networking and relationship building, which could be considered as measures in future research.

PROJECT B - THE ROLE OF LITERACY IN MATHEMATICS AND NUMERACY ATTAINMENT

LITERATURE REVIEW

A gap in vocabulary development between children from low income and high income families exists prior to entry to school and is considered one of the main contributors to attainment gaps (Bradshaw, 2011). Numbers are rarely found in isolation from text and therefore, vocabulary and reading difficulties may conceal an individual's mathematical ability and hinder their skill progression. Furthermore, mathematical discourse has a number of distinctive features, including some aspects which are particular or specialist to mathematics:

- technical terms specific to mathematics (e.g. equilateral, quotient, probability);
- specialist use of more general terms (e.g. line, factor, frequency);
- mathematical terms that use everyday words for specific mathematical concepts (e.g. function, expression, difference, area).

Mathematical discourse includes specialist syntax, particularly in relation to the expression of logical relationships. Thus the use of *and, of, or, a, if* and *then* to define mathematical relationships are all significant. Mathematical discourse includes specialised ways of talking, including written and spoken forms of mathematical explanation, proof or definition, as well as text types like word problems. These broader ways of using language are important in expressing mathematical ideas and reasoning. Strategies for supporting to the development of mathematical ways of talking have to involve creating rich opportunities for students to explain their thinking. Thus, structured pair or group work is likely to be supportive. In classrooms, mathematical discourse also includes a social dimension: the particular ways that students and teachers talk in mathematics classes that are not specifically mathematical, but that are associated with mathematics. Instructions, for example, might include expressions like 'simplify' or 'complete the following'. Teachers often use 'we' to refer to 'people who do mathematics' (e.g. we use x to represent an unknown). And word problems, like the example above, are to be interpreted in a way that is specific to mathematics lessons (Barwell, 2008).

Prior research exploring poverty-associated attainment gaps has focused more extensively on literacy than numeracy (e.g. Higgins *et al.,* 2013; Kellett & Dar, 2007; Marcus, 2016). Some of the successful or promising pedagogical approaches for bridging attainment gaps in literacy, for example comprehension (see Kamil *et al*., 2008 cited in Sosu & Ellis, 2014) can be transferred to the teaching of mathematics and numeracy to determine if these are supportive to other curricular areas.

A consistent whole school approach to the progression of mathematics and numeracy across learning is seen to improve attainment (Hodgen, Foster, Marks & Brown, 2018). The Programme for International Student Assessment (PISA) surveys frequently finds that there is a large variation in the extent to which students attending the same school report exposure to different teaching strategies and teacher behaviors, namely 'within-school variation'. This within school variation includes students' reports of exposure to formal and applied

mathematics tasks. Addressing the 'within-school variance' that exists is seen as key to school improvement and effectiveness. In addition to the use of data, effective management and listening and responding to pupil voice, addressing within school variance is dependent on improving learning and teaching through multiple means including removing variations in key aspects of practice (National College, 2011). This does not include removing all autonomy within individual classrooms, practitioners and curricular areas. Identifying where stronger standardisation of approaches is required should be data led and monitored to ensure this standardisation provides the desired outcome.

Collaborative planning for progression in mathematics and numeracy within the context of the totality of the curriculum will support better understanding of the importance of mathematics and numeracy across learning. This is also consistent with the collective teacher efficacy, which has the largest effect size in improving attainment (Hattie *et al*., 2017).

INTERVENTION – PROJECT B

This primary school developed a shared approach across all classes and all Curriculum for Excellence levels for raising attainment in mathematics and numeracy through improving whole school mathematical vocabulary and targeted intervention for children with low literacy skills.

Their identified needs were to:

- To enhance confidence in mathematical vocabulary and word problem solving skills.
- To address literacy barriers to mathematical word problems.

The school practitioners replicated approaches they had developed to improve literacy that they assessed as having a positive impact on pupil understanding and engagement in literacy. The school practitioners identified key vocabulary (single words and short phrases) from the Early, First and Second levels of Curriculum for Excellence, experiences and outcomes. The approaches adopted in all classrooms included introducing 'key vocabulary' each week; daily rehearsal and discussion about key vocabulary; developing activities and visual wall displays to enable children to make connections between vocabulary with the same, similar or opposite meanings; encouraging children to use a methodical approach to extract and interpret any vocabulary within mathematics work before attempting to answer the question; additional mathematical vocabulary activities created to target support for children with additional barriers to literacy; and incorporating homework and family learning approaches to enhance use and awareness of the maths vocabulary.

The primary school is considered to have 22% of its population with an Additional Support Need and 50% of the population live in SIMD 8 and 9 and the majority of the rest of the school, population living in SIMD deciles 2 and 3.

METHOD OF MEASURING IMPROVED OUTCOMES – PROJECT B

The school used the school tracking measure of mathematics tests within the suite from the Centre for Evaluation and Monitoring (CEM) and then the Scottish National Standardised Assessment (SNSA). These were authority and school level tools. A decision was made, beyond the school level, to change the measure and evaluation tool mid-way through this project. The SNSA is not used to assess progress for all year groups but only in P1, P4 and P7. This was administered in May 2018 for the three cohorts of P1, P4 and P7, of which one group of target pupils was in P4.

Table 6 illustrates the data that was available through the school testing programme for the target pupils It is noticeable that the CEM mathematics tests were not repeated for any year group and it is difficult to make comparisons across these different test methods. The CEM results were used as part of the information gathering process to identify the target pupils.

The participants devised a school assessment which they used for pre and post measures for the 10 target pupils. This consisted of 12 questions using numbers and numerical notation only and 12 questions using words. Some of the 'word' problems used number names (eg. 'two') and others used numerals. All 10 target pupils were administered the school devised assessment at pre-intervention and post intervention.

The SNSA assessment provides some data that allows for a consideration of whether the intervention was effective at whole school level.

TABLE 6 - ASSESSMENTS UNDERTAKEN BY TARGET PUPILS.

6 children (A-F)	P4 during programme (2016-17) P6 now (2018-19)	Pre-intervention data • CEM (May 2017) • School assessment April 2017	Post-intervention data • School assessment June 2018
4 children (G-J)	P3 during programme (2016-17) P5 now (2018-19)	Pre-intervention data • CEM (May 2017) • School assessment April 2017	Post-intervention data • School assessment June 2018 • SNSA (P4, 2017-18)

OUTCOMES FOR PROJECT B

The SNSA results for the school can be compared with the Falkirk average and 'neighborhood schools'. This is a comparison with the 7 mostly closely matched schools in the local authority in terms of the percentages of children in each decile according to the Scottish Index of Multiple Deprivation. This school is in neighbourhood group 2, with each school having a high proportion of children from deciles 1 and 2. The initial year of administration of SNSA provided children with a range of questions considered to be of low, medium and high difficulty for their expected stage in the curriculum.

Table 7 illustrates that there are more children in P1 and P4 preforming at the high level than compared to both the Falkirk average and the neighborhood schools and fewer children at medium and low level. In primary 7 there are more children performing at the medium and low levels than the comparators and fewer children preforming at the high level. This is suggestive of closing the poverty related attainment gap in comparison to schools with similar proportions of children in SMID decile 1 (~20%).

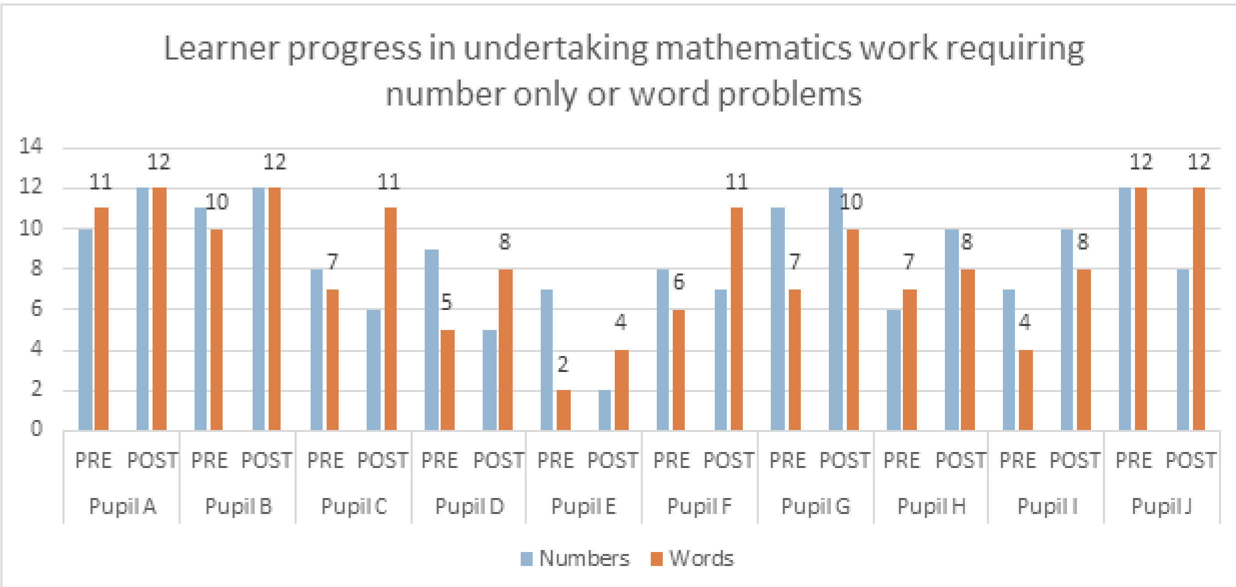
TABLE 7 - SNSA 2017/18 NUMERACY (P1, 4, 7) FOR PROJECT B SCHOOL (MAY 2018)

		% low	**% med**	**% high**
School		**0%**	**13%**	**87%**
Neighbourhood	**P1**	1%	23%	76%
Falkirk		1%	26%	73%
School		**10%**	**46%**	**44%**
Neighbourhood	**P4**	12%	54%	34%
Falkirk		11%	51%	38%
School		13%	65%	23%
Neighbourhood	P7	6%	45%	49%
Falkirk		5%	39%	56%

TARGETED INTERVENTION

Ten children had targeted support to develop their mathematical literacy. Chart 1 illustrates that 9 children's scores increased at post testing using the school assessment on word only problems and one child (J) maintained their score. When undertaking problems involving numbers, 5 children's scores increased and 5 children's scores decreased.

CHART 1 - PROJECT B - SCHOOL, INDIVIDUAL PRE AND POST COMPARISONS



From (pre) assessment in May 2017, it was identified that four of the ten children (B, E, H, I) had reading ages below their chronological age (ranging from 4 months to 1 year 9 months) whereas the other children had reading ages in line with their chronological ages or significantly greater than their chronological age (2 children; ranging from 2 years, 2 months to 2 years 10 months). The intervention was effective regardless of the children's reading age at the outset of the intervention. Four of the ten children (G-J) undertook SNSA assessment in May 2018. 3 children performed at the 'medium' level and 1 child performed at the 'high' level.

PROJECT TEAM REFLECTIONS

The school staff reported confidence was built in their skills, particularly in more discrete tracking and monitoring of individual pupils with significant gaps in their attainment.

They have identified as future actions that they will

- increase data gathering points
- enable children to record their own progress using simple run charts as promoted in the Model for Improvement
- further develop the approaches they use, including adding visual prompts assigned to key vocabulary to further enhance children's understanding and recall of meaning.

REFLECTIONS AND RECOMMENDATIONS ARISING FROM PROJECT B

This project identified gains in 90% of the children at post-test in word only problems. While 50% of the sample made gains in number problems, 50% regressed. The project team also considered other data sources such as reading age, SNSA and teacher judgement, breaking this down across SIMD. They used comparison approaches. The SNSA and teacher judgement approach have limitation in this project similar to those described in Project A. The difference in this case is that there is a smaller group of staff collaborating.

The Project team used research skills as evidenced by:

- considering wider areas of need as part of the needs analysis and intervention plan,
- gathering data at pre and post
- development of knowledge gain tools
- use of data and comparison approaches.

This indicates that further research in this type of project/intervention could include:

- use of control samples
- process measures such as regular recording or children recording their own scores
- explicit measures for vocabulary gain
- balancing measures to capture whether there were unintended consequences
- longer term measures to consider with the gains in number problem solving have been sustained.

The analysis by the authors would also have been assisted by the project team being clear what quantity of vocabulary was taught in the word of the week approach and what percentage of the unique or specific vocabulary this consisted of. This systematic approach could assist in determining the level or value of investment in vocabulary focus on attainment gains in mathematics, specifically word-based problems. This may be the subject of future research or projects of a similar nature.

EVALUATION OF THE EFFECTIVENESS OF THE PROGRAMME, BRIDGING THE GAPS

11 of the teacher participants (61%) contributed to the 2 projects that were able to provide evidence of research being used to target interventions and then measure and provide data on whether these were effective or not.

Both projects evidenced use of increased action research skills. Participants used multiple methods for identifying gaps and identifying whether the interventions had made a difference, see Table 8. In both projects the teachers evidenced research skills such as:

- questionnaire design
- designing knowledge gain tests
- pre and post-test comparisons
- analysis and comparison using SIMD band
- comparison using existing data, such as CEM, teacher judgment survey and SNSA
- assessment to consider wider needs in at least one project (Project2)
- use of multiple sources of evidence to consider impact and outcomes.

The projects did not use statistical methods for comparison to consider whether the observed effects reached the threshold of statistical significance.

TABLE 8 – RESEARCH METHODS USED WITHIN PROJECTS

Project	Method	Key finding
Project A	*Attitude survey*	More enjoyment of fractions
	Pupil self-evaluation on fractions	73% of children increased rating
	Fractions ability measure	Reduced errors in fractions overall, largest gain for those in decile 1. See Table 5
Project B	Tracking measures (CEM, teacher judgment and SNSA)	More children perform at high level SNSA in P1 and P4 compared to neighborhood schools. See Table 7.
	Word and number problems assessment	90% of Target pupils improved on word problems
	Reading age (target pupils)	Used in needs analysis. Identified target pupils for additional support.
	Children using Run Charts	Used in class

Italics indicates participant designed methods

Two projects were not able to be completed though to follow-up stage, which reflects 50% of the projects and consisted of 7 of the original participants (39%). Only 1 of these original 7 staff members was still in their original post and had had a significant break from this post during the period between commencement of the project and follow up.

PROJECTS C AND D – COMMENTARY

Each of these projects consisted of pairs of schools. They are paired due their organisational arrangements within the local authority. They have a shared head teacher and management team and geographical proximity. These two sets of schools participated in the programme due to different identified needs and participated in the sessions. On completion of the programme they did not progress in implementation of the interventions, or only part implemented the interventions. There were explanatory reasons for their lack of participation through to the follow up point that are unique to each school and to each participant. Additionally, some common factors were extracted following the consultation process undertaken for project D and from the pre-consultation discussion with the head teacher for project C which concluded that the consultation process would not be completed. These factors have therefore limited validity and reliability but are worth drawing attention to for consideration of future projects of this nature.

1. **Stable staff group** – both projects were affected by changes in personnel. Both schools had at least one change of head teacher in this timespan. Of the other participants only one was remaining in their original post and establishment and that individual has had a significant break from work in the timespan between initiation and follow up of the project. The original design of the programme had attempted to mitigate the likelihood of participants withdrawing affecting project completion by requesting that a project team from each school attended the programme. While in the two projects that were completed though to follow-up point had some participants change or leave their respective schools, the project had sufficient continuity to see the project through to completion. This suggests that there may be a *critical mass*

needed for programmes and projects of this nature where teachers and managers embark on programmes of learning and are confident that they can see them through to completion. There may be other methods that may be helpful in ensuring the completion of the project that are consistent with effective continuity and succession planning.

2. **Changes to local authority and school attainment tracking**. The local authority made a decision to stop purchasing an attainment tracking scheme that was universally used in P1, P4 and P7 and many schools purchased the scheme for use in the intervening year groups. This purchase decision affected schools who ceased their purchase of the scheme. In these projects case there was no longer the same attainment measures available in school. The Scottish Government was scheduled to implement a national attainment tracking scheme, Scottish National Standardised Assessment (SNSA). While this was in place by the time of follow-up, it was in its first year of use and the type of data this assessment provided in year one is different from the intended nature of data it will provide from year two onwards. There was also one year group in Project D where there was no school or national tracking data available due to the gap between the purchasing decisions and the availability of the SNSA. It is suggested by the authors that this was a unique set of circumstances which we would hope would be unlikely to be repeated. If this was to be mitigated against it would require a second standalone attainment tracking tool to be used in the timespan of this project which both seems unfeasible and potentially repetitious for pupils. In the projects that were able to complete at follow-up they had designed their own bespoke knowledge and skills tests that focused on specific intervention areas. This method is recommended for the future to support diversity of teacher judgement approaches.
3. **Implementation of Improvement**. The participants at the end of Phase 1 had highlighted factors that would support and potentially be barriers to their implementation of an intervention (i.e. carrying out their project). These included time constraints, comparability of the standardised data (the attainment tracking data) and managing the range of individual needs of children who may be subjects in their project (Morrison and McLafferty, 2018, Table 6 page 101). It would appear that those challenges that were identified became insurmountable when faced with the barrier associated with not having a stable staff group. While it seems prescient that the attainment tracking data may be problematic, at that stage they did not foresee the particular barriers that would come to pass.
4. **Benefits without completion**. Both Project C and Project D reported that there were benefits to participating in the programme for their practitioners and schools. Many of these benefits have been captured and reported within Phase 1, (Morrison and McLafferty 2018). At the follow-up point the benefits could not be evidenced in Project C due to the participants not working in the school. Project D had two of the original participants available and participated in the consultation discussion. The benefits they reported were increasing knowledge of assessment and intervention and increasing knowledge of the wider literature associated with closing attainment gaps and numeracy/mathematics pedagogy.

SUMMARY

Our findings indicate that:

1. participants used action research to identify gaps and design interventions and measures in numeracy
2. children made gains in the targeted area of numeracy;
3. children affected by poverty made gains in numeracy;
4. the Coach Consult Method was an effective method in promoting teacher research;

5. continuity of staff and leaders within schools, a critical mass of staff, is vital for improvement to be implemented, evidenced and sustained

CONCLUSION

This study is complex and multi-layered. The authors have been writers and contributors to the field of engaging teachers in practitioner research for a several years. This is the first time it has been attempted to gather outcome data at pupils and project level and analyse it in relation to the effectiveness of the programme using the Coach Consult Method. Our finding includes that it is complex to identify and present robust findings from multiple projects.

1. The programme had a positive effect on teachers use of research skills

There is evidence in this study of the effectiveness of a programme teaching participants research skills as there is evidence that the intervention was implemented and participants conducted needs analysis, intervention planning and implementation, created research questions and attempted to answer them through pre and post measures that they developed themselves. The participants were explicitly taught ethics which the authors of this report rely on in reporting this multi-project analysis.

2. The programme had a positive effect on improving numeracy attainment for all and on the poverty related attainment gap. There is a positive effect of these numeracy interventions on numeracy attainment in both project A and project B. In both projects they found a positive effect on both raising attainment and some indicators of closing the poverty related attainment gap with their chosen interventions. Project A identified the biggest effect (largest decrease in errors) for the children in decile 1, which is the 'poorest' group, while also finding positive effects overall. Project B identified that more children were performing at a high curricular level than the 'neighborhood schools' i.e. those matched against poverty indicators.

There is evidence that the children in the two projects (A and B) made gains in the areas of numeracy intervention, as evidenced by the participant designed measures. The robustness of this statement though has caveats in that the study is multi-layered and there are limitations. Examples of limitations include the extent to which we can be confident the measures are valid and reliable. The participants were at an early stage of using and applying their research skills and it is unreasonable to expect that they used research development methods such as piloting questionnaires and sampling approaches to ensure basic validity and reliability measures could be gathered.

The Education Endowment Foundation (2018) has produced guidance based on research already undertaken with eight practical, evidence-based recommendations relevant to all learners including those requiring additional assistance with mathematics. They note it is a starting point and will continue to develop their guidance as further evidence emerges about the most effective intervention approaches. Additional consideration about the impact of improving mathematical literacy on mathematical attainment is recommended.

The advantages of the Bridging the Gaps programme is that the data analysis and intervention is based on the needs of the children and the context of their education. Practitioner research when based on a short programme is always going to have limitations when compared to a standard for research such as that in peer reviewed journals where the researchers have usually undertaken postgraduate level training on research methods and in a model with close supervision of the research. The benefits of promoting practitioner research include that the endeavor is pursued. It is worth considering an adoption of a supervision or coaching model for participants in pursuing action research in schools.

The focus of this study was on the participants' use of research and the pupil outcomes in relation to numeracy. A different methodology for analysis would have been required to clarify the effectiveness of the other components of the programme; the evidence-based approaches for specific mathematics pedagogy and general teaching and learning approaches. This may be the subject of future research if it was to remain included in the programme. Equally it may lead to a re-design of the programme to have more of a focus on the practitioner research skills. The Morrison and McLafferty 2018 paper did capture the two elements, and participants at the end of the programme indicated a significant improvement in knowledge of the research skills (table 4) and reported usefulness of the curriculum pedagogy and pathways progression materials (table 7).

The Scottish Government (2017) have outlined a research strategy for Scottish Education with the overriding purpose to help deliver the priorities of improving attainment and closing the poverty related attainment gap through developing the research infrastructure, a knowledge base of 'what works' and the capacity of the system to use evidence. This study supports the assertion that this is a positive direction. It has indicated that it is possible to implement research in schools and that this can demonstrate improved outcomes or attainment for children. That two projects were not able to complete the process, while disheartening from the perspective of completing this research study, should not dampen the enthusiasm for the endeavor. There is learning that can be extracted from those projects, which have an implication beyond this immediate research and into the political and cultural domain of education. The main implication is that the system for employing teachers needs to ensure it offers sustained long-term employment within schools of the individual staff members. This may be increasingly important in the context where governance arrangements for schools and local authorities evolves or changes.

We have also concluded that in order that improvement is effective and sustainable it is vital that there is a culture that promotes continuity of staff and leaders within schools. This is consistent with the finding of a large effect size for **collective teacher efficacy** (Hattie et al 2017 and Crompton 2015). This is the collective belief of teachers that they can make a difference in student outcomes by working together. It is suggested that there may be a critical mass of teacher continuity for change to be identified, implemented and sustained.

The approach Coach Consult Method, used in Bridging the Gaps has shown a positive way forward in the context of evolving Governance as it, by design, offers a model of working with schools for educational psychology services that is responsive to the needs or gaps within a school context by providing a structure for how schools can effectively identify and intervene in what is needed. It also provides a structure for evaluation and monitoring when the intervention is commissioned from a third party as it increases the knowledge base of school practitioners in the use of data for clarifying effectiveness.

The approach described in this study may also have future implications for the models of service delivery of an educational psychology service. It increases the reach of a service through a chain of impact that ultimately demonstrates improved outcomes for children. There is a relative efficiency of time in implementing an approach of this nature, which if it can be brought to scale could have far reaching implications for how educational psychology services provide their services.

NEXT STEPS

There are school and project specific recommendations based on the individual project analysis. Each school leadership team and project team has considered how to sustain improvements evidenced in this project and incorporated them within their school and cluster improvement plans.

The Educational Psychology Service plans to implement this methodology regularly within appropriate projects as part of service delivery. Two key changes will be incorporated which involve gathering data on **effectiveness** of the planned intervention and promoting **consistency** of personnel with contingency planning for personnel change.

We plan to highlight forcefully the need for the education culture, which includes funding, employment and training, to promote the long term relationship with staff and pupils in schools. The improved outcomes evidenced in Project A and B were only possible to be identified as they had maintained the critical mass of teacher continuity.

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CHAPTER 3 – METACOGNITION AND NUMERACY: A 'THINKING ALOUD' INTERVENTION IN P3/4

Muriel MacKenzie, Alison Boyd & Kathryn O'Hare, Stirling Council

LITERATURE REVIEW

WHY METACOGNITION?

There is increasing evidence that children's metacognitive skills play an important role in ensuring effective learning, especially in the case of disadvantaged learners. This may be linked to disadvantaged children being less liable to describe their thinking and explaining their ideas than more advantaged learners, which may impact on their ability to learn Mathematics or affect teacher perceptions of their ability (Pappas et al, 2003). The Sutton Trust Education Endowment Foundation Teaching and Learning Toolkit rated metacognition and self-regulated learning as 'a high impact, low cost approach to improving the attainment of disadvantaged learners' (Education Endowment Foundation (EEF) (a), 2018).

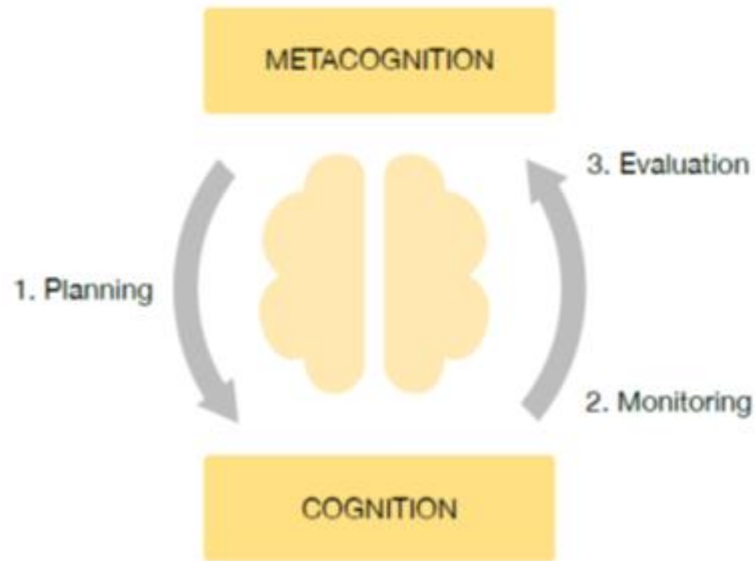
WHAT IS METACOGNITION?

The term metacognition was first coined by Flavell in 1979 and referred to knowledge about and regulation of one's cognitive abilities during the process of learning (1979). Over the years, however, conceptualisation of metacognition has developed and changed, with the Education Endowment Foundation (EEF) (b) (2018) defining self-regulated learning as comprising three essential components: cognition, metacognition and motivation. The EEF describe *metacognition* as the ways in which 'learners monitor and purposefully direct their learning' (p 9) and *metacognitive strategies* as 'the strategies we use to monitor or control our cognition, such as checking that our memorisation technique was accurate or selecting the most appropriate cognitive strategy for the task we are undertaking' (p 9). All three of the components of self -regulated learning are seen to interact in complex ways during the process of learning.

Put simply, metacognition can be seen as a term used to describe how we think about and manage our thinking and learning (Branigan and Donaldson, 2018), although in reality it is a complex multi-layered concept. Branigan and Kanevski (2018) suggested that 'within the classroom, a useful way to think about metacognition is in relation to a learning activity or task, and the things people do before, during and after tasks'. They suggested that this might entail the child considering what prior knowledge they have that may help them think about the task ahead, e.g. what strategies might be helpful to aid planning? During a task the child might then consider how they are progressing with the task, e.g. are they having difficulty or making good headway? Do they need to adapt how they are approaching the task? If so, what else they could try? Finally, on completion of a task, the child might reflect on how they tackled the task and consider what worked well or less well. This final step will serve to develop their understanding of the whole process and may inform their thinking when approaching a future task.

A helpful framework for thinking about metacognition in the classroom is a metacognitive regulation cycle of planning, monitoring and evaluation as illustrated below (EEF (b), 2018, p 10). This diagram highlights how a child's knowledge of themselves as a learner interacts with their knowledge of available and effective strategies as well as with the task in question in order to influence planning, monitoring and evaluation of progress.

DAIGRAM 1 - METACOGNITIVE REGULATION CYCLE



EEF (b), 2018, p 10

DEVELOPMENTAL PROGRESSION OF METACOGNITION

Much of the research on metacognitive skills in children has focussed on children aged nine years or above and has relied on children having the necessary language skills to talk about their use of metacognitive strategies. In a review of the field, Veenman et al (2006) noted that much of the work in metacognition suggested that metacognitive skills did not emerge until around the age of 8 – 10 years. The work of Whitebread and his colleagues at Cambridge University, however, is notable for their exploration of metacognition in 3-5 year olds (Whitebread et al, 2009) and 5-7 year olds (Bryce and Whitebread, 2012) where they devised observation tools to try and assess metacognition in younger children. This latter work explored how use of metacognitive skills changed with age and investigated if older children used the same skills as younger children or developed more sophisticated skills. Whitebread et al (2009) found evidence of both verbal and non-verbal indicators of children as young as 3 years old being able to use metacognitive processes. Bryce and Whitebread (2012) noted that children aged 5 – 7 years were able to demonstrate quantitative increases in monitoring behaviours and qualitative increases in checking and planning behaviours. They concluded that for younger children it is important to not rely on self-report as they may not yet be able to verbalise their internal mental processing but instead to use observational techniques to identify children's emergent metacognitive skills. It has been proposed by Marulis et al. (2016) that the previous lack of knowledge around the presence and development of metacognition in younger children is most likely due to the lack of a developmentally and contextually suitable assessment tool.

ASSESSMENT OF METACOGNITIVE SKILLS

Assessment of metacognition is not straightforward and as knowledge and understanding of the processes involved have developed, it is clearer that metacognition is subject and task specific (EEF, (b) 2018). This means that assessment has required to move away from more generic instruments such as self-report questionnaires where children are asked to retrospectively report on their own metacognition e.g. the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich and de Groot, 1990). There are of course other disadvantages of such questionnaires as they do not measure actual behaviour during a task and rely heavily on a child's memory and self-report about which metacognitive processes they have used (McNamara, 2011).

Desoete (2008) investigated the use of multi-method assessment of metacognitive skills in one class of 3rd grade elementary children during mathematical reasoning and numerical tasks, to consider whether a 20 item teacher rating scale was a reliable method of assessing metacognitive skills. She found that the Teacher Rating Scale, which included questions about planning, monitoring and evaluation, was a valuable and reliable assessment of children's metacognitive skills.

Think-aloud protocols have also been viewed as an effective way to measure metacognitive processes (Veenman et al, 2005). During this method, children are asked to put their thoughts into words whilst working on a task. Their verbalisations are then transcribed and considered by means of a systematic observation. Gathering data by this means, however, can be time consuming and challenging to manage in a classroom and in addition can also be affected by how able a child is to articulate their thoughts verbally.

Assessment of children's use of metacognition *during* a task appears to be more accurate than assessment before or after the task (Veenman et al, 2006). Bryce and Whitebread (2012) developed an observational tool to assess metacognition in children aged 5 to 7 years. This method involved observing children during a problem solving task (building a train track to match a predefined shape from a plan) and then coding their verbal and non-verbal behaviours against a metacognitive skills coding scheme– looking for positive examples of metacognitive skills and failures to use such skills. This appeared to be a promising approach to assessing metacognition, although the authors wondered if also asking structured questions of the children after task completion would be helpful in enabling children to explain their behaviours or reasoning process.

Whitebread et al (2009) developed a study involving young children's metacognitive skills and an observational checklist for teachers to use as assessment (the Children's Independent Learning Development (CHILD) Questionnaire). They found that this questionnaire reliably distinguished between children with high and low levels of metacognitive skills. This questionnaire was also successfully used by Bryce et al (2015) to measure 5 and 7 year old children's metacognitive skills. Whitebread et al (2009) also developed an observational coding framework (C.Ind.Le. Coding Scheme) for research purposes. Again, they concluded that this was a promising observational tool to assess verbal and non-verbal indicators of metacognition in young children during a problem solving task. In addition, Marulis et al (2016) developed and tested a metacognitive knowledge interview schedule – a measure of declarative metacognitive knowledge - for use with 3 to 5 year olds. They concluded that the measure was both developmentally sensitive and reliable enough to be used with young children to assess metacognitive knowledge.

In addition to thinking about how to assess metacognition in children it may well be important to understand teachers own metacognitive understanding. Wilson and Bai (2010) explored teachers' own awareness of their metacognition and ability to reflect on their own thought processes. They suggested that having such knowledge would successfully enable the development of appropriate training programmes for teachers to support their pedagogical understanding of what is required to teach children to use metacognition. Wilson and Bai (2010) developed a bespoke questionnaire, *Teacher Metacognition Survey,* to assess teachers' perceptions of their metacognitive knowledge, i.e. declarative, procedural and conditional knowledge (Schraw, 2001) and pedagogical approach for metacognitive strategies (Baylor, 2002). They concluded that this was a useful tool to measure teachers' perceptions of their own metacognition. Similarly, the Metacognitive Awareness Inventory (Schraw and Dennison, 1994) was found to be a reliable test of metacognitive awareness in university students.

METACOGNITION AND THE TEACHING OF NUMERACY

There are a number of instructional approaches to teaching metacognition to children that have been recommended by researchers. Generally speaking, a number of researchers have noted the importance of providing explicit instruction in metacognitive strategies, as although children will develop some metacognition as they mature and develop, most will not spontaneously develop all the strategies they will need. (Schraw et al, 2006, Schraw, 1998). Schraw emphasised that direct training such as this needs to include teaching around *how* to use strategies as well as *when* to use them, and *why* they are beneficial. In addition, Schraw (1998) endorses the use of explicit prompts to support students in improving their regulating abilities. He recommends the use of a checklist with entries for planning, monitoring, and evaluation, with sub-questions included under each entry that need to be addressed. His view was that such a checklist supports the ability of students to be more systematic and strategic in their problem solving.

The Education Endowment Foundation (EEF) (b) (2018) recommends using a seven-step model for explicitly teaching metacognitive strategies that can be applied to different ages and stages as well as across teaching contexts. The seven steps are: activating prior knowledge; explicit strategy instruction; modelling of learned strategy; memorisation of strategy; guided practice; independent practice and structured reflection. This model is very closely linked to the assertion that without cognition, there is no metacognition and that without solid subject knowledge, it is very difficult to develop knowledge about how one can learn in that subject. Broadly speaking, this approach enables teachers to move from modelling towards scaffolding and eventual independent pupil practice.

Collaborative or cooperative learning structures have also been recommended for encouraging development of metacognitive skills (Kramarski & Mevarech, 2003; Kuhn & Dean, 2004). This recommendation is related to Piagetian and Vygotskyian theories that emphasise the value of social interactions for promoting cognitive development (Dillenbourg et al., 1996). These approaches highlight the potential for cognitive development when students interact with one another and are particularly effective when a child is interacting with another child of a slightly higher developmental stage. Supporters of collaborative learning approaches include Cross and Paris (1988), who report that group discussions, e.g., around the use of reading strategies, are a highly effective strategy in improving metacognitive skills. Techniques such as these are thought to encourage metacognitive discourse among students which then leads to conceptual conflict. This conflict is helpful as it often eventually leads to deeper clarity for students' in relation to their beliefs and ideas (Hennessey, 1999). Kramarski and Mevarech (2003) have also noted the superior performance of students working in collaborative groups and again have attributed this to higher quality of discourse detected among students working together. They noted that students participating in cooperative learning expressed their mathematical ideas in writing more ably than did those who worked alone.

This collaborative approach can also be seen in a study by Larkin in 2006. Larkin observed children throughout their first year in an English primary school to explore the development of metacognition in the classroom as well as the potential impact of group work on metacognitive development. The children included in this study were part of a year long 'cognitive acceleration through science programme' which involved working in a collaborative group to solve science and Maths based problems designed to enable children to practice and develop metacognitive strategies. Larkin selected two of the children in the group and examined transcripts of their participation in problem solving using a coding system based on Flavell's (1979) model of cognitive monitoring. She observed that over the course of the year, their metacognitive processing became better developed. The group context also prompted the children to further reflect on and clarify their ideas which required them to monitor and control their own thinking. Larkin concluded that through working as part of a collaborative group, the children were observed to become more aware of their own thinking and the thinking of others.

Kramarski and Mevarech (2003) reported the results of a study investigating the effects of metacognitive training on the mathematical reasoning and metacognitive skills of 384 eighth-grade students. Kramarski and Mevarech (2003) provided students with sets of metacognitive questions, including comprehension questions, strategic questions, and connection questions, to be completed during a task. Comprehension questions were designed to encourage students to reflect on a problem before solving it. Strategic questions were designed to encourage students to think about what strategy might be appropriate for a given task and to provide a reason or rationale for that strategy choice. Finally, connection questions were designed to encourage students to identify and recognise deep-structure task attributes so that they could activate relevant strategy and background knowledge. They found that students who had been exposed to metacognitive instruction, either individually or as part of a cooperative learning group, outperformed students who had not received this instruction, in a number of areas including the ability to interpret graphs, use of logical arguments to support Maths reasoning and specific Mathematical strategies for interpreting graphs.

Other recommendations around the teaching of metacognitive skills include making student reasoning, concepts, and beliefs visible (Hennessey, 1999). This can be achieved by students constructing conceptual or mental models of the topic or concept in question. Again, these models support the process of cognitive disequilibrium or conflict, leading to eventual clarity (Schraw et al., 2006). Teachers are also advised to promote general awareness of metacognition by modelling metacognitive skills during teaching, using strategies such as "thinking aloud" (Kramarski & Mevarech, 2003).

METHODOLOGY

PARTICIPANTS

Three schools were identified to participate in the project, two of which were situated in areas of deprivation (Schools B and C) and one (School A) who expressed an interest in participating. In the context of the Pupil Equity Fund, schools B and C received significant funding with 45.5% and 24.5% of their school roll respectively being in receipt of PEF funding. Less than 1% of School A's school role received PEF funding. Eight primary two and three class teachers were recruited from the selected establishments based on an observed dip in numeracy attainment in Stirling Local Authority between primaries three and four. The class teachers were asked to select a small group of approximately five pupils from their class who had additional support needs in relation to numeracy, to monitor throughout the project.

MEASURES

The Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994) (Appendix 1) was used to assess teacher knowledge about metacognition as well as their regulation of cognition across eight distinct domains; declarative, procedural and conditional knowledge, planning, information management strategies, comprehension monitoring, debugging strategies and evaluation.

Teachers used a metacognition observation schedule (Appendix 2) adapted from Bryce & Whitbread (2012) to assess the frequency of planning, monitoring and evaluation behaviours in the cohort of pupils they had selected to participate in the study. The schedule included descriptions and examples of these behaviours as well as a rating scale of the frequency with which the behaviours were observed ranging from 1(never) to 5 (always). There was also a comment section where the teachers could note any observations.

Pupils chosen to participate by their teacher were provided with a metacognition prompt sheet (Appendix 3) designed by Stirling Educational Psychology service. The measure prompted pupils to rate how difficult or easy they found each metacognitive task using a traffic light system. The measure also included the metacognitive prompts which required children to plan, monitor and evaluate their working during an observed task.

PROCEDURE

Once the three schools identified had agreed to participate, primary two and three teachers from these schools were invited to a twilight session delivered by Stirling Educational Psychology service. The session provided an introduction to metacognition and numeracy making specific reference to the recently published Educational Endowment Foundation guidance report on metacognition and self-regulated learning (EEF, 2018) as well as outlining the present study and what they would be required to do. Teachers also completed the MAI at this session and were provided with the observation schedule and metacognition prompt sheet. Teachers were offered a follow-up twilight session where they could bring any issues or updates but only one was able to attend.

Over a period of six to eight weeks the teachers participating were asked to model 'think aloud' strategies to their class during Maths problems. This involved the teacher talking the class through his/her thinking as he/she tackled a task such as a new Maths concept. The class teachers modelled these strategies in a variety of activities chosen at their discretion, such as addition or problem solving. Teachers then selected a small group of approximately 5 pupils whose numeracy attainment they felt would benefit from this additional input. Using the observation schedule, they were provided with, teachers observed the planning, monitoring and evaluation behaviors of the pupils in the group individually at the beginning and end of the project period. They noted the frequency with which they observed these behaviors and included comments on the behaviors they had observed. The pupils included were also supported by their class teacher to complete the metacognition prompt sheet and rate the tasks using the traffic light system.

At the end of the metacognition input period teachers were required to return the observation schedules to the Educational Psychology service and provide some qualitative feedback.

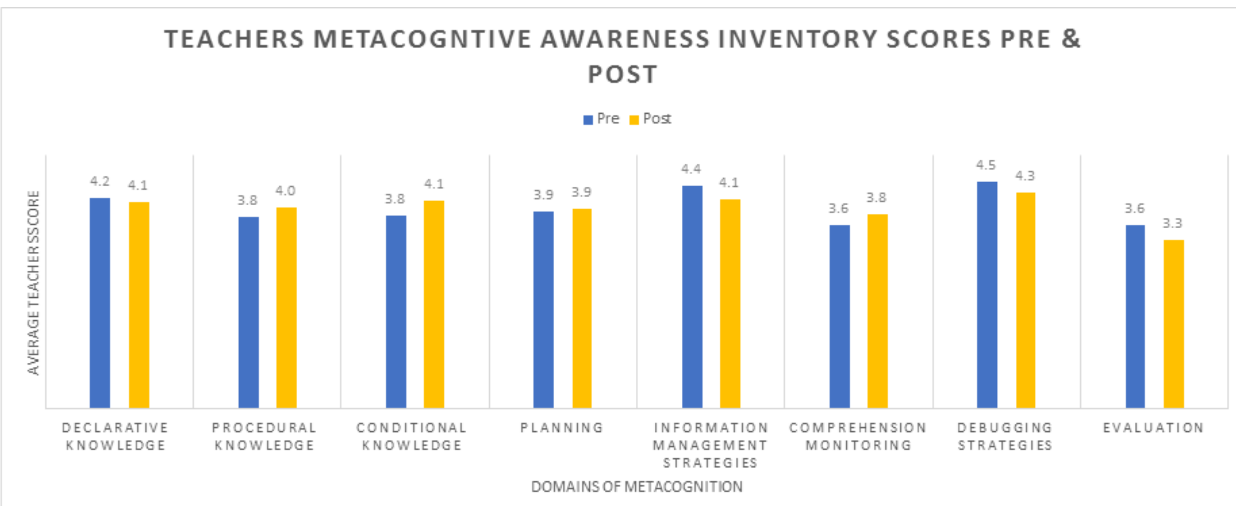
RESULTS

Of the three schools participating in the study, two completed the project with school B (comprising 3 teachers) dropping out due to factors unrelated to the project. As such, of the eight class teachers initially recruited in the study only 3 returned any data. MAI pre and post scores and qualitative feedback was collected from the three teachers, who also submitted metacognition observation schedules for sixteen pupils collectively. Feedback from the training delivered at the beginning of the project was collected from the full cohort of participating teachers.

METACOGNITIVE AWARENESS INVENTORY SCORES

Teachers completed the Metacognitive Awareness Inventory (MAI) at the training session and then again at a catch up session, when they had come to the end of the metacognitive input period in their class. The MAI is a self-report questionnaire which assesses metacognitive awareness across eight domains, including for example, declarative knowledge and procedural knowledge. The scale was adapted so that teachers could rate themselves on a 5 point scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), thus higher scores suggest perceptions of higher levels of metacognitive awareness. As can be seen from the table below there was little difference observed in the teachers mean MAI scores between the beginning and end of the intervention period. This may be due to the fact teachers initially rated themselves highly across all eight domains of metacognition assessed by the MAI, leaving little room for improvement.

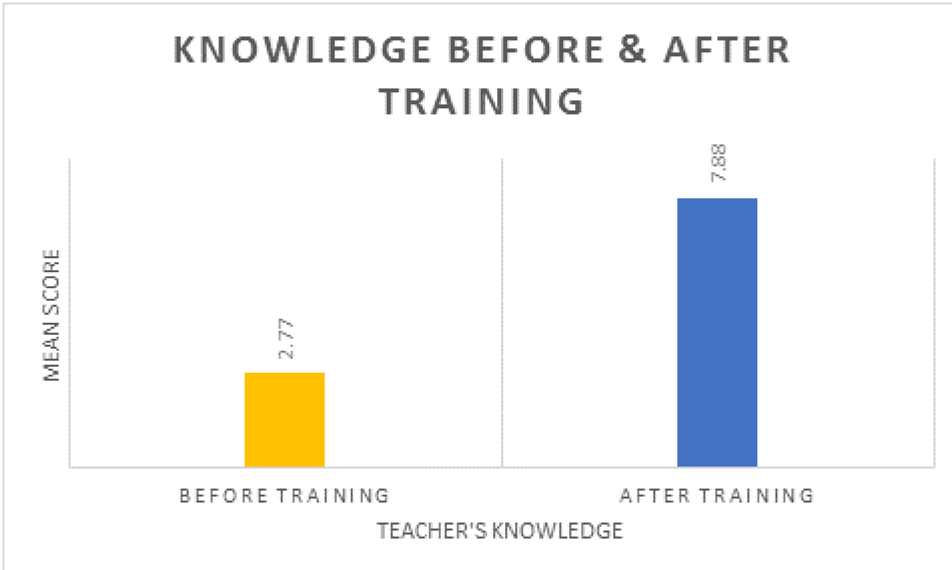
CHART 1 – TEACHERS MEAN METACOGNITIVE SCORES PRE AND POST INTERVENTION



TRAINING FEEDBACK

Teachers who received training input from the Educational Psychology Service on metacognition and numeracy at the start of the project were asked to give feedback on the training session. The teachers rated the delivery of the training and its relevance to their work highly at an 8 or above on a scale ranging from 1 (Strongly Disagree) to 10 (Strongly Agree). Furthermore, teachers rated their confidence in applying what they had learned in training to their practice highly at either 7 (33.3%), 8 (44.4%) or 9 (22.2%) on the same ten point scale. Finally, teachers were asked to rate their knowledge of metacognition before and after training, displayed in the chart below. There was an observable increase in teachers' mean self-reported knowledge of metacognition in numeracy post training. Prior to the session no teacher had rated their knowledge of the topic at 8 or above, however, following the input over half of the group (55.5%) rated their knowledge at 8 or above, with the remaining teachers rating their knowledge at either 6 (11.1%) or 7 (33.3%). Teachers commented that the training was interesting, informative and well presented, and that they looked forward to starting the project.

CHART 2 – TEACHERS MEAN KNOWLEDGE PRE AND POST TRAINING OF METACOGNITION



PRE & POST METACOGNITION OBSERVATION SCHEDULES

Class teachers participating in the project submitted their completed Metacognition Observation Schedules to the Educational Psychology Service for analysis. Observation schedules were submitted for N=16 pupils. Increases in the frequency of all metacognitive behaviours: planning; monitoring; and evaluating were observed for N=7 of the pupils who were observed. A further N=2 observed increases in frequency of only their evaluating behaviours, with a further N=2 demonstrating decreases in their monitoring behaviours, with the frequency of their other behaviours remaining stable. For N=3 pupils either a pre or post observations schedule had not been completed and as such no inference can be made about the frequency of metacognitive behaviours. Teachers recorded observations of pupils using concrete resources more frequently, checking their work with increased frequency and looking to peers for help and support more often also. Many pupils were recorded as having increased the frequency and detail with which they vocalised their metacognition in numeracy and several also felt their ability in Maths had improved as well as enjoying the tasks more.

QUALITATIVE FEEDBACK

All teachers reported a positive impact on their teaching practice and said they would continue to incorporate metacognitive strategies in their teaching practice. They also stated they would pause more frequently during times when the class were working to revisit the metacognitive prompts with the whole class e.g. ‘had they seen a problem like this before?’ as they had found these prompts to be especially beneficial. One teacher said she would continue in the routine of problem solving at the same time each week as she observed the routine was something her class enjoyed. All teachers reported an increase in observations of the children using resources e.g. number lines during Maths to solve problems. Two of the teachers reported an initial increase in the vocalisation of her groups’ problem solving which decreased towards the end of the 8 weeks. It was hypothesized that the decrease in vocalisation of their thought process could be due to an increase in pupils' confidence (and internalisation of) using metacognitive strategies to solve Maths problems. There was also an increase in frequency in planning and monitoring behaviours observed across all groups.

CONCLUSIONS

This was a small scale, exploratory study involving relatively small numbers of teaching staff and pupils, with the intervention taking place over a short time frame – 6 weeks. Therefore, any conclusions need to be considered as tentative. Teachers reported that they found the use of metacognitive strategies helpful and reported that the project led to them adapting their teaching behaviour to support use of metacognition.

The children involved showed an increase in planning and monitoring behaviours and an increase in using resources such as number lines, during the timeframe of the project. There was also some evidence that the children from a school in an area of relative deprivation demonstrated less use of metacognitive strategies at the outset, and during the course of the project increased the frequency with which they used these strategies. As such, this may suggest that modelling aloud of metacognitive strategies could be a promising intervention in closing the poverty relation attainment gap, although further research is needed.

Much of the work done on metacognition tends to be with older children and in relation to literacy so this project provides some support for metacognition as a helpful intervention with younger children and in relation to numeracy.

A limitation of the study is its reliance on teacher observations and teacher self report. If the project was to be repeated or similar studies undertaken it would be helpful for researchers to conduct independent observations of teaching practice and children's use of metacognitive strategies to triangulate the evidence gained. Similarly, further work to clarify whether metacognition positively supports children from lower SIMD deciles would be useful.

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CHAPTER 4 – PUPIL VOICE: VIEWS OF NATIONAL 5 PUPILS IN RELATION TO THEIR EXPERIENCES OF NUMERACY SKILL DEVELOPMENT

Tracey Ross, Sarah Booth and Katherine Fraser, West Lothian Council

INTRODUCTION

Having a basic understanding of numeracy is a necessity in modern-day society (Beilock & Willigham, 2014; Maloney, Ramirez, Gunderson, Levine & Beilock, 2015). Not only is it a core educational requirement but each of us engage with it daily, from seemingly simple tasks such as choosing the best mobile phone contract to working out how to fairly split a restaurant bill (Chernoff & Stone, 2014). It is an important factor that leads to better job prospects and evidence suggests it leads to a better quality of life (Cragg, Keeble, Richardson, Roome & Gilmore, 2017). Yet despite its importance, mathematical attainment continues to be referred to as a 'crisis' in our education system and in many other developed countries around the world.

One of the daily challenges for school teachers is how to help pupils become better learners. Research shows that students who are more confident about their learning ability will learn faster, be more motivated, embrace challenges and generally find learning more enjoyable (Claxton, 2002).

Raising attainment levels in maths continues to be a key challenge across Scotland. This chapter explores the views and experiences of National 5 maths pupils across West Lothian in relation to their experiences of numeracy skill development to help inform improving standards of numeracy and mathematics within secondary schools. This was done by addressing the following research question:

- According to National 5 Maths pupils, what are the key factors affecting their numeracy and mathematics skill development in school?

WHY IS MATHS DIFFERENT TO OTHER SUBJECTS?

As a subject matter and learning process, mathematics differs from all other subjects. Duval's (2006) "A Cognitive Analysis of problems of Comprehension in a learning of mathematics" explains the importance of semiotic representations in maths acquisition, and the requirement for one to shift between these abstract constructs. The sheer number of possible representations within mathematics and their infinite interactions adds to learner difficulty. No other subject, no other science even, requires this process of mastering interchangeable semiotic representations. Cline (2009) points out that mathematical vocabulary can be challenging and introduces language which pupils are not already familiar with. To add additional confusion, certain words which are previously known take on an alternative meaning in maths e.g. product, odd and remainder.

PSYCHOLOGICAL FACTORS UNDERPINNING NUMERACY DEVELOPMENT

There is a plethora of research universally into mathematics and the factors impacting student's learning, development and attainment. Historically, the teaching of mathematics in Scotland has been informed by Associationist theories of learning, which support the 'Direct Transmission' approach. This approach considers the principles of association and reinforcement to be central elements of learning, supporting a highly controlled learning environment which encourages the memorising of mathematic rules and routines (Resnick & Hall, 1998). However, this approach is unable to fully explain how conceptual mathematical knowledge is acquired in order to solve complex problems (Straub & Stern, 2002).

More recent work supports a shift towards a more constructivist approach to learning and teaching mathematics, which evolved from Piaget's theory of cognitive development and focuses on prior knowledge and the individuals' ability to relate learned material in a deeper way to their own experiences. Boaler (1998) demonstrated that teaching maths to pupils using open-ended activities and group work, rather than the more traditional text-book methods, enabled the students to adapt their knowledge and develop a more conceptual understanding of maths. This more flexible approach to maths meant that exams were far more manageable, and the percentage of students who passed their GCSE was higher than the national average. This has also been demonstrated by Straub & Stern (2002) who found that the way in which a maths problem was presented influenced how successful the pupils were in completing the task, and that learning based on conceptual understanding was more advantageous than teaching which adopted a direct transmission approach.

Additional work points to the merits of employing a metacognitive approach to mathematical problem solving (Ozzy & Attaman, 2009). Metacognition refers to an individual's awareness of their thinking process and their ability to control this. Metacognitive skills can be developed through instruction and can improve problem solving performance.

A number of teaching practices have been identified as having a positive impact on student's learning in general, such as formative feedback, positive praise and effective questioning (Hattie, 2015; 2011) but the most influential factor is the student themselves and what they bring to the classroom in terms of different attributes, different levels of knowledge and their motivation to learn (Hattie, 2015; 2009). Creating a learning environment that supports students to be more resourceful, imaginative, self-disciplined and self-aware provides them with the tools they need to become better learners (Claxton, 2002).

PSYCHOLOGICAL FACTORS INFLUENCING LEARNING

Bandura's Social Cognitive Theory (SCT: 1986) suggests that the behaviour of an individual is learned through direct or indirect observations of social interactions and cultural experiences, with cognitive processing representing an essential component of this social learning, with individuals functioning as a consequence of their own self-efficacy, motivation and reciprocal interactions with others**.** Bandura (1977) defines Self-efficacy as an individual's belief in their own abilities to achieve desired outcomes and incorporates personal and environmental factors. He believed that a strong sense of self-efficacy is the attitude required for improving self-confidence so that a sense of mastery can be achieved by the learner, and as such can affect people's behaviour, motivation and achievements (Bandura, 1977).

Self-efficacy in learning can be shaped by both social context and social interactions. Positive praise from peers or teachers can strengthen an individual's belief that they are capable of achieving their desired outcome, as can the direct observation of a desired action or task being modelled by others. Experiencing success can also have a positive impact on self-efficacy, as it can validate a person's self-belief by providing confirmation of an individual's skills, strengths and qualities (Bandura, 1977). This suggests that for a learner to develop self-efficacy they need time to gain a sense of mastery in a task, and that their belief in their ability is related to the final outcome.

Feedback has been highlighted as one of the most powerful influences on learning and achievement (Hattie & Timperley, 2007), however to be most effective the feedback has to be given within a learning context and provide useful information to address a specific gap relating to completing the task. The way a teacher interacts with pupils in the classroom can have a marked effect on their view of intelligence. Praising intelligence and focusing on the end result of a task promotes a fixed view of intelligence, while providing specific, process-based praise is more likely to promote a mastery approach (Dweck, 2000). Students need to try different strategies when they face challenge in order to learn and improve, and so it is important for teachers to support pupils effectively by encouraging self-reflection and alternative options.

MINDSETS AND NUMERACY DEVELOPMENT

Growth mindset, or the incremental theory of intelligence (Dweck, 2000) is a cognitive theory which has become increasingly more prominent within education, and particularly with regards to numeracy development. It has been linked to improved academic achievement as well as helping pupils become more resilient learners, and many studies have suggested that this mindset can be taught.

Dweck's research has also shown that an individual's belief about intelligence can influence how students learn (Dweck & Leggett, 1988). Individuals who believe that intelligence is innate and unchangeable (entity theorists) will choose performance goals when approaching tasks, as they see completing tasks or tests as a measure of how intelligent they are. However, this means they will regard failing a task as a criticism of themselves, as they will associate this with a lack of intelligence. On the other hand, students who believe their intelligence is changeable (incremental theorists) are more likely to set learning goals, as they welcome challenges and see failure as an opportunity to learn from, or improve on their mistakes (Elliott & Dweck, 1988). These different belief systems shape how we view our ability and are defined as being a fixed or growth mindset, respectively (Dweck, 2000).

Changing our beliefs about intelligence can have profound effects on behaviour, and by enhancing the learning environment a more incremental approach to intelligence can be facilitated (Mueller & Dweck, 1998). These findings have serious implications for education and teaching practices, as they suggest that by encouraging pupils to adopt learning goals and by giving them specific proces- based praise and feedback, teachers can have a positive impact on learning and academic achievement by helping to highlight new possibilities for learning and improvement.

Indeed, the attitudes our society holds towards mathematics is a common challenge. Turner (2016) reported that many people suffer from maths anxiety ('Terror') and many more exhibit maths avoidance. Biases exist in western populations such as 'you're either a maths person or you're not' and these views are held not just by pupils but by parents and teachers alike. The Making Maths Count Initiative (Scottish Government, 2016) was set up to establish how to best encourage an enthusiasm for maths both in children and young people and in the wider community and Turner advocates for a change to lesson format to better encourage positivity and self-confidence when it comes to mathematic ability, including making maths more relevant to real life and work and to make it more enjoyable, which correlates with the constructivist approach to learning and teaching mathematics.

RAISING ATTAINMENT IN SCOTLAND

In Scotland there is a strong focus on 'closing the attainment gap' (Scottish Government, 2014). 'Raising Attainment for All' is a Scottish Government initiative which encourages collaborative working within schools to promote effective learning communities. Raising attainment means improving the ability of all young people to learn and progress to their maximum potential, and subsequently helps to improve their life chances.

The attainment gap refers to the difference in academic attainment reported between pupils who come from houses with higher versus lower household incomes in Scotland. The Joseph Rowntree Foundation reports that almost 1 in 4 Scottish children are living in poverty (JRF, 2018). The Growing up in Scotland Survey (Bradshaw, 2011) examined differences in cognitive ability between the ages of three and five amongst children who come from different social backgrounds. The data revealed that differences in cognitive ability at age 3 persist at age 5, with those from disadvantaged circumstances testing on average 11-18 months behind in their expressive vocabulary skills and between 6-13 months behind in their problem solving ability. This gap typically widens as children grow older, ultimately having important consequences for leaver destinations.

LOCAL CONTEXT

West Lothian is committed to delivering the best possible outcomes for children and young people by ensuring that pupil's are supported to maximise their potential through effective learning. Their "Raising Attainment Strategy" (West Lothian Council, 2018/23) focuses on effective collaborative working to support teaching practices in line with key national policies such as Getting it Right for Every Child (GIRFEC; Scottish Government, 2008) and the Curriculum for Excellence (Scottish Executive, 2004), with the overarching aim of raising attainment for all.

Within West Lothian the Principal Teachers of Maths Curriculum (PTC Maths) from all eleven secondary schools within the authority, are working together to raise attainment in numeracy and mathematics through targeted research-based interventions, reviewing curriculum design and collaborative working through numeracy learning communities. The long-term goal is to improve standards of numeracy and mathematics across West Lothian primary and secondary schools. The key objectives are to improve the quality of learning and teaching in Mathematics at National 5 and Higher; to improve pupil engagement, particularly those who are 'at risk"' of failing the final exam; and to improve the standards of numeracy and mathematics in the Broad General Education P1-S3.

CURRENT RESEARCH

The current research is part of the wider initiative to raise attainment in numeracy and mathematics across West Lothian and is aimed at investigating pupils' experiences of National 5 maths, and feelings towards maths in general to help inform improving standards of numeracy and mathematics across West Lothian primary and secondary schools. The current research was carried out in 8 secondary schools within West Lothian. A qualitative approach was used to broadly explore what was working well, what pupils were struggling with and what they would change. The results of this study aim to provide a greater psychological understanding of why some pupils have struggled with National 5 maths and what can be done to address these barriers in the future.

METHODOLOGY

ETHICAL CONSIDERATIONS

This work adheres to the British Psychological Society's Code of Ethics and Conduct (2018) and the Health and Care Professionals Council Standard of Conduct, Performance and Ethics (2016). Informed, written consent was obtained from the parents/carers of all pupils prior to the start of the study, as well as from the pupils themselves. Participant information sheets were provided to the parents/carers of all pupils. All participants were notified that all data would be strictly confidential and anonymised, and that there would be no reference to individual names in the final report. The participants were advised that they were free to withdraw from the study at any time, should they wish to do so. All participants were informed that the results of this research would be incorporated into a report for the Authority as well as part of a bigger project for Education Scotland, and were assured that all data would be kept in a secure location in accordance with The Data Protection Act (2018) and General Data Protection Regulation would remain anonymous and confidential, and would be destroyed after 5 years.

PARTICIPANTS

Participants were selected through consultation with the Maths PTC of each secondary school and comprised 56 pupils from 8 secondary schools across West Lothian (see Table 1). All participants were currently studying towards their S4 National 5 Maths qualification were selected by the maths PTC in each secondary school. 40% of the pupils who participated in the focus groups were from SIMD (Scottish Index of Multiple Deprivation) Deciles 1-4. The participants were representative of a variety of abilities within National 5 level, however the majority of pupils were those who had not passed their prelim or were recorded as being within the ‘amber’ zone of their school tracking and monitoring system for maths. Written consent was given by all participants and their parents/carers. The participant names, and all mentions of schools or individual persons, have been omitted for confidentiality.

Table 1. The number of participants in each focus group from each secondary school.

Secondary School	**No. of Participants**
1	9
2	5
3	5
4	10
5	9
6	4
7	9
8	5
Total	*56*

DATA COLLECTION

FOCUS GROUPS

The experiences of a selection of National 5 maths pupils was explored using a focus group, to allow ideas and concepts to be explored in depth with a small group of participants producing rich, qualitative information (Vaughn, Schumm & Sinagub, 1996). It also provided an open, supportive environment in which the pupils could discuss their experiences and opinions, allowing for a more relaxed/ less formal process than interviews and gave pupils the opportunity to expand on and explain their answers in their own words.

A focus group was conducted in each of the 8 selected secondary schools between February and March 2018 as the pupils had all conducted their National 5maths prelim examinations but had not yet sat their SQA examination. Five focus group questions were developed by the PTC maths group and the West Lothian EPS research team in order to explore the pupils’ experiences and opinions of National 5 maths, and maths in general (see Appendix 1). The questions were designed to explore what was working well, difficulties/dislikes the pupils had, and what changes they would make. The questions used were based on those in Boaler’s (1999) study, which compared two contrasting methods of teaching maths in the UK.

The focus groups took place within school hours and were facilitated by the Research Assistant (RA). In three of the schools the link Educational Psychologist (EP) assisted with note taking. Each focus group took place in an empty classroom within the school, and participants sat around a table with the RA. The RA started by thanking the pupils for volunteering to take part and fully explained the purpose of the focus group, including how the information would be recorded and used. She explained that there were no right or wrong answers and that the purpose of the focus group was to explore their views and ideas.

Participants were all briefed with the same information and had the chance to ask any questions before the session began. Each session was recorded on an iPad and notes were taken by the RA, or when present, the EP. The focus groups lasted no longer than 50 minutes and key themes were extracted and agreed collaboratively after each question. On finishing the session participants were thanked for their time.

ANALYSIS

The focus group recordings were transcribed using the method of 'gisted transcription', using the written notes as an aid (Paulus, Lester & Dempster, 2014). Verbatim transcription was not necessary for this study; rather it was more important to extract the general gist and key points from the discussions. The qualitative data was analysed using the principles of thematic analysis for each individual school and holistically across all eight secondary schools (Braun & Clarke, 2006). The data was summarised and reported under key themes, using a psychological lens to help shape the discussion.

RESULTS

Despite some slight differences in teaching approaches across the eight secondary schools involved, common themes consistently arose, which could be separated into two distinctive categories: beneficial and detrimental factors in maths. The categorisation of these factors was largely dependent however on the pupils' attainment in maths, as those who were struggling ('the majority') had differing views to those who were succeeding ('the minority').

BENEFICIAL FACTORS TO NUMERACY DEVELOPMENT

RELATIONSHIP WITH TEACHER

This appeared to be one of the most important factors in shaping pupils' experiences of maths. Pupils who had a good relationship with their teacher felt more comfortable to ask for help, felt understood and listened to, felt more relaxed in the classroom and liked that they could have a laugh with the teacher. Pupils' negative experiences of maths were often linked to having a poor relationship with the teacher.

SUPPORTIVE RESOURCES

All schools felt the study support was really positive and they appreciated it. Attending the supported groups allowed a deeper understanding of the work to be explored. Pupils felt this was a safe environment where they were able to ask questions and have them answered, and they were also able to work at a slower pace.

ENJOY THE CHALLENGE AND SATISFACTION OF GETTING THE RIGHT ANSWER

A common response across all the schools was that pupils enjoyed the satisfaction of getting the correct answer. There was a sense of achievement when this happened, and the feeling of improvement. Pupils felt that getting the answer right was confirmation that they understood it and this made them feel good about themselves. This was also closely related to the familiarity of certain topics, as pupils enjoyed maths when it was familiar and they could do it.

FLOW/STRUCTURE

This characteristic polarised the participants. For some they enjoyed the logical flow and structure of certain topics, as they found it easy to follow a procedure and easy to track mistakes. A few pupils also liked that there was only one right answer (although these pupils were in the minority). Some felt the structure of maths meant you could be prepared for anything in an exam, and that it was good that you could get marks for showing your working out. Some pupils liked that there were no assignments throughout the year as this relieved the pressure.

WORKING IN SIMILAR ABILITY CLASSES

Some schools had different ability classes, and many of the pupils reported that they preferred this as set classes, rather than mixed ability classes, allowed them to ask more questions and have more discussions. They also felt that they could spend more time with the teacher, and they felt less intimidated.

INTERACTIVE/CREATIVE LESSONS

Most of the participants found maths enjoyable when they got to work in pairs/groups, or when the when the class worked through the same question together (although this did not happen often). They found the tasks and methods of learning (e.g. show-me-boards) more enjoyable, and found it was easier to discuss what they did not understand and find solutions together. When the class worked together there was also less competition as everyone moved at the same pace. Pupils also said they enjoyed maths when it was relevant to real life and when it linked with other subjects.

DETRIMENTAL FACTORS TO NUMERACY DEVELOPMENT

BIG JUMP TO NATIONAL 5 CURRICULUM

Pupils generally found the move to National 5 a big jump, and as a result no longer liked or enjoyed maths. This 'jump' made them feel overwhelmed and stressed, particularly when they felt they did not understand what they were learning. This linked in again with the pace and content of the National 5 course, as they felt it was a drastic change to earlier years and they could no longer keep up. As a result, many commented that they felt there should be more preparation in earlier years for the National 5 course.

There was a lot of agreement that National 5 work was significantly harder than the work covered in S3. In particular, the formulas were confusing and the course did not focus on understanding maths in depth. Many pupils felt the course should start earlier or that the maths in S1-S3 should be more relevant to building up to National 5 as they felt that previous work wasn't relevant to the National 5 content. There was also a perception for some that the National 5 maths exams were harder than other subjects

PACE- TOO FAST!

A key dislike/difficulty with regards to teaching was the pace of the lessons. The fast pace meant that teachers did not go into depth when describing what to do or would only explain things once before moving on. Across the schools there was agreement that in National 5 maths there was too much content and not enough time to understand it all. There was unanimous agreement that the pace of the maths curriculum was too fast in S4. The amount of content required for the course meant that the lessons felt rushed and that the class moved onto a new topic regardless of whether everyone understood it or not.

MIXED-ABILITY CLASSES

Interestingly across all the schools there was a dislike for having mixed ability classes. Although everyone in the class was at National 5, they felt that having different abilities in the class meant that the pace moved too quickly and this made maths more difficult. Pupils who were struggling often felt they were holding the class back when they asked for help and felt stupid compared to their higher scoring and faster peers. Pupils felt they were all aware of what level they were working at and that in mixed ability classes the course was taught at the pace of the fastest and most able pupils. Therefore for those who required more time to grasp a topic, the pace of the lessons was too quick for them. Many of the pupils felt left behind in their classes and that despite being in National 5 they were not as smart as their peers. Working with the higher achieving pupils left them feeling stupid/intimidated/disheartened and put them off asking for help as they don't want to hold back the class.

PRESSURE/EXPECTATION

Compared to other subjects, it was felt that maths is more competitive and that there was more pressure/expectation. There was a negative stigma against asking for help and getting things wrong, particularly in a mixed ability classes.

In S4, a lot of the participants felt there was increased pressure and expectation from teachers and parents. The environment of National 5 classes was exam focussed which made going through the course stressful. The pressure and expectation was, for many pupils, the maths mentality that had been instilled in them since primary school, as they have always been streamed for maths. It was felt that being streamed since primary school determines the rest of your maths education and whether you are good or bad at maths. Some felt that being good at maths in primary school did not mean the National 5 course was right for them.

NOT UNDERSTANDING THE WORDING OF EXAM QUESTIONS

There was agreement that the wording of exam questions was a key difficulty. They felt they could do the maths in isolation, but in the exam context it was difficult to understand what the questions were asking them to do. Many found exams difficult because they had to remember various formulas and that the questions they had completed in class did not reflect those in the exam due to the difference in language used.

'TRADITIONAL' TEACHING STYLES

Many participants found maths difficult because the teaching style of the class teacher was not suited to their learning, and the teaching was not engaging (i.e. just textbook and board work). Sometimes pupils felt intimidated by the teacher's approach (e.g. if they roll their eyes or shouted this made the pupils feel stupid for not understanding). As a result some pupils would not ask questions or would wait to speak to a different teacher. Some pupils felt teachers were less helpful if they only offered one method to a problem rather than alternative solutions. It was felt that the way that Maths was taught had a huge impact on their experience of maths, and whilst some participants had positive teaching experiences there were many participants who felt they had not.

Many participants felt that National 5 maths was "boring". The patterns of the lessons were repetitive, the majority of work came from the textbook, some teachers remained at their desk/front of the classroom and did not interact with the class, there was not any group work and there were no creative tasks. As a result many pupils found it hard to engage with and enjoy maths.

NO RELEVANCE TO REAL LIFE

Many of the participants felt that National 5 maths was not relevant to 'real world' problems or situations. Being unable to see the relevance of the maths they were learning made it difficult to remain motivated as they could not understand why they were learning it. Most pupils who were struggling would prefer to be able to take 'life skills' maths.

FIXED MATHS-MINDSETS

Many pupils commented that they felt they weren't maths people. They reported feeling intimidated or "stupid" in their maths class at times. For some this was because of an implicit assumption that they should be good at maths due to being in top sets for other subjects, or the belief that if you are good at maths you are smart (thereby you are stupid if you are not good at it). This therefore made them scared to ask for help or ask questions in front of the class in case they are laughed at.

The majority of participants found maths difficult because there is a specific method and answer. By comparison they felt other subjects were more subjective and it was possible provide explanations or evidence for the given answer.

Many of the participants felt like giving up when maths got difficult and they continued to get answers wrong. The lack of understanding made them feel stressed and the continuous low scores made them feel de-motivated. Some said they would try to concentrate on the bigger questions to get more marks in an exam however this tended to be the harder problem-solving questions that incorporated different topics. A lot of the participants struggled when they were only taught one method (and they didn't understand it), and this made them feel that they were bad at maths.

Across the groups there were similar stereotypes about maths: you are smart if you are good at maths, there is a maths hierarchy in class and pupils are either Maths or English people. Being streamed from primary school means that you are aware from a young age of whether you are good or bad at maths. They felt that according to the teachers, being good at maths was associated with speed. Some did comment that there is satisfaction with maths however when you do get it right and when you can understand the link. Then it feels good.

NO FOCUS ON ENJOYING OR UNDERSTANDING MATHS

Not understanding the maths was a key problem. The pupils felt they are going through the motion of maths but not understanding what they are doing or why.

LACK OF FEEDBACK

Pupils across several schools reported that there was a lack of feedback with respect to homework. Pupils mentioned that homework was often not getting marked and so there was often a lack of motivation to complete the work.

Similarly, in class, many pupils felt that mistakes weren't being discussed and pupils reported just being told that they were wrong and so they felt there was no learning opportunity. As a result, many of the pupils felt that it was all too easy to just sit at the back of the class and not do the work.

WHAT WORKED WELL?

The study support: All participants agreed that the study support in their school was good and helpful. The particular features of this were the fact that there were smaller groups, more teachers and a slower pace.

Relaxed environment: Pupils felt they had a better experience in maths when a relaxed atmosphere was created. For example, being allowed to listen to music whilst working, being allowed to confer with peers, when there was a good rapport with the teacher and when everyone worked at the same pace. Some people preferred being allowed to sit with their friends as they felt more confident asking for help, but others liked having to sit in rows as it was less distracting. They liked having this choice though.

HOW WOULD PUPILS CHANGE THE WAY MATHS IS TAUGHT?

More creative/interactive lessons: Pupils wished that National 5 maths was delivered in a more creative and interactive manner. For example more group discussions, projects that made maths relevant and memorable, techniques for remembering formulae, more student involvement in the lessons, carousel method to work on problems, more group work, and alternative methods to copying work from a board/textbook.

More focus on understanding/enjoying maths: Currently the mindset and focus is on passing exams, but many pupils felt they would like the focus to be on understanding maths. They would find it more enjoyable and less stressful if there was more exploration and a longer time spent on understanding the topics. If the competition element was removed (i.e. finishing first, getting best grades), pupils report they would feel less stressed and understand maths more.

More relevant to real life: Similarly, many pupils would like to see how maths is relevant to real life- both in terms of the way the content is explained and being able to learn 'life skills' maths. They know that maths is important, but they do not understand why maths has more importance than other subjects (like Drama or French). A lot of the pupils resented that it had been mandatory to do National 5, and instead would have preferred to do life skills maths (or an equivalent).

Teacher Style: Many of the participants agreed that the teacher made all the difference to their experience of maths (and in any subject). They felt it was important for a teacher to be enthusiastic about the subject, to motivate the class, to interact with the class, to give praise, to speak to students as individuals as well as a class, to be emotionally aware and to not be so serious. They felt the best teachers were the ones who were happy to help and explain things at the appropriate pace, and did not make the pupils feel like they were being a burden for asking for help.

More consistent teaching: Throughout the focus groups there were similar comments about the communication and consistency between teachers. Some felt that the teachers were in competition with each other to finish the course first, and would continuously compare the pace of work between classes. They also felt it would be beneficial to have more consistent methods (or an awareness of different methods) between the teachers, as there were differences to the way solutions were taught and explained.

Start National 5 work earlier: To address the issue of 'too much content, not enough time', there were suggestions for starting the course earlier in S3. This would allow for more time to understand the topics and achieve deeper learning.

More recognition for personal progress: A lot of the participants felt that because they were not the best in the class, they were never praised for what improvement or achievements they had. The impetus on getting high A grades meant that anything less seemed like a failure, even if it was still a pass. Many felt they would feel more confident and better about maths if they were achieving more in a lower set class, rather than being at the bottom of a top class. They also found it unfair that their views were not considered with regards to changing classes throughout the year.

Different paced classes: Across all the schools, participants said they would prefer to be in classes that progressed at the same pace. When there are mixed abilities in the same class, those who need longer to grasp topics felt inadequate and struggled to keep up with the faster pupils. Many knew they had the capability to pass; it was just the pace of the class that was hindering their development.

Pupil Voice: A lot of the pupils felt they were not listened to with regards to what level of maths they should be in, and also felt some teachers did not believe them when they were genuinely stuck. They felt it would be better if they had some say in what class they were in (some wanted to choose their teacher)and to have the opportunity to change throughout the year.

Class Changes: There was agreement that smaller classes would be better as there would be more chance of 1-1 time with the teacher. Some also felt that having a double period of maths first thing was too draining, and that having 4 single periods was better than 2 double periods of maths (though there were others who felt the opposite). It was also suggested that there should be a longer break between the prelim and exam to work on improving and understanding mistakes.

Homework/Revision: Many pupils said they would find it useful to have more frequent unit recaps throughout the year to help consolidate each topic. Some also said that their homework rarely gets marked, or that it is easy to not do the homework you do not understand. They would like the homework to be marked and explained so that they can understand where they have gone wrong.

Revision resources: It was consistent across the groups that there were a lot of revision resources provided by the maths department that the pupils really appreciated and benefited from. In particular the supported study and twilight sessions were helpful. One school had a maths camp and the pupils found this really helpful because of the relaxed atmosphere and 1-1 time with teachers.

Wish there were two options of maths: Many pupils felt that there should be two options of maths available: 'every day' life-skills maths and 'academic' maths that is required to continue in a career with maths. They felt that because maths was mandatory it was very difficult to find the motivation to do it, especially when they could not see the relevance of learning it. There is no focus on enjoying maths, just a focus on passing it with a good grade. Some felt that they would have more confidence with maths if they were doing better at a lower level rather than doing poorly at a high level.

DISCUSSION

This research aimed to explore the views and experiences of National 5 maths pupils across West Lothian in relation to their experiences of maths and numeracy skill development to help inform improving standards of numeracy and mathematics within secondary schools. The findings from the pupil focus groups have important implications with regard to teaching practice within the National5 as well as other areas of the mathematics curriculum and fell into four key areas.

The overarching factor underpinning the success of numeracy development in the views of the National 5 maths pupils was the way in which maths and numeracy is taught. The pupils strongly felt that they enjoyed their classes more when a more constructivist approach was taken, rather than the more 'traditional' text book learning, as they felt that having more interactive lessons and discussions with staff and peers resulted in a more conceptual understanding of maths. They felt that it was easier to understand the lessons when the concepts were linked to real life experiences and examples as this made their learning relevant and purposeful. This links in with the findings of Boaler (1998) who found that teaching maths and numeracy in this more flexible way allowed pupils to learn material in a deeper way when they related it to their own experiences.

The pupils felt that supported study allowed them to deepen their level of understanding by asking questions in a more relaxed environment and at a pace that was more suited to their learning. They felt that staff should encourage more group and partner working, as they had done in primary school, as they felt that this facilitated their learning, enabling the co-construction of ideas and discussions around different approaches and strategies to learning.

The second overarching factor was the feeling that pupil's struggled to learn in maths due to a lack of self-efficacy and self-belief. Teaching environments which lacked in positive praise and process-based feedback resulted in pupils lacking in the self-belief that they would be able to develop a sense of mastery in their learning. Pupils who reported that they enjoyed their maths lessons stated that they had positive relationships with their teachers where they felt able to ask questions and were provided with constructive feedback. Pupils who did not have a positive relationship with their teacher reported feeling "stupid", de-motivated and not listened to. These results support the research which highlights the importance of providing a positive learning environment in which teachers support pupils effectively by encouraging self-reflection and alternative options (Dweck, 2000).

These findings support the research that shows the importance of providing positive learning environments to promote feelings of self-efficacy in pupils and to foster the development of self-regulatory skills, to help pupils successfully navigate their learning (Claxton, 2002). This can be accomplished by providing pupils with appropriate levels of challenge, setting realistic learning goals, providing constructive feedback and encouraging learners to see failure as a learning experience. This helps to provide pupils with the relevant tools to work towards meaningful goals, and develop a sense of mastery and control over their learning.

The final overarching psychological factor affecting numeracy development encompasses the pupils' beliefs about their abilities in maths. Most of the pupils reported feeling under pressure to be "good" at maths, both within school and outwith. They felt there was an implicit assumption that they should be good at maths due to being in top sets for other subjects, or the belief that if you are good at maths you are smart (thereby you are stupid if you are not good at it). It has been shown that changing our beliefs about intelligence can have profound effects on behaviour, and by enhancing the learning environment a more incremental approach to intelligence can be facilitated (Mueller &Dweck, 1998). These findings have significant implications for education and teaching practices, as they suggest that by encouraging pupils to adopt learning goals and by giving them specific process-based praise and feedback, teachers can have a positive impact on learning and academic achievement by helping to highlight new possibilities for learning and improvement. A key issue for many pupils was that they felt that they did not receive effective feedback. Homework was often not marked and the pace of the class meant that the pupils were not often given the opportunity to explore alternative methods/strategies or work out where they had gone wrong. Providing the opportunity to learn from mistakes is key in helping pupils to develop a growth mindset (Dweck, 2000) and also links into building a sense of self-belief and confidence in learning.

In addition to the key psychological factors that pupils felt influenced their numeracy development, the pupils also touched on a number of pedagogical factors, such as the flow and structure of the lessons, the fact that many felt the lessons were too fast paced and that they felt there were too many National 5 concepts that were only introduced in S4 and that these could have been introduced earlier. All the information gathered during this research was fed back to the maths PTCs from all the secondary schools within West Lothian and will be used in conjunction with their own practitioner enquiries to inform and improve their practice. There are certain elements that are out with the control of schools, for example the course content, the wording of exam questions, the structure of the final exam, however the Maths PTCs plan to use the information gathered from the pupils in the focus groups to challenge and change the way maths is approached, taught and learned within all the secondary schools across the authority.

It is important to remember that whilst the experiences reported here provide valuable insight, they are not fully representative of all National 5 pupils' experience of maths, or even fully representative of each school. Despite efforts to encourage everyone to talk, some participants did not and others were particularly dominant throughout the session, therefore it was not always possible to record a balance of opinions. However, this information is an important starting point for change in learning and teaching and highlights the importance of creating a positive learning environment for pupils.

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APPENDIX 1: FOCUS GROUP QUESTIONS

Question 1: How do you feel about maths?

- *Follow up question*: Do you feel maths is different to other subjects?

Question 2: What do you enjoy about maths/what do you find difficult about it?

- *Follow up questions*: What do you do when maths gets hard?

Question 3: How do you feel about the way maths is taught in S4?

- *Follow up question:* Is this different from the way it's taught in other years?
- *Follow up question:* What is different about the way it is taught compared to other subjects?

Question 4: If you could change the way schools taught maths, what would you do to make it better (or keep the same)?

- *Follow up question:* What would help you to understand maths better?
- *Follow up question:* What would help you enjoy maths more?

Question 5: Are there any other comments or experiences you would like to share?

CHAPTER 5 – PSYCHOLOGICAL FACTORS IN PROMOTING NUMERACY: A META STUDY

Nick Balchin, Falkirk Council

INTRODUCTION

Raising attainment in mathematics continues to be a key priority for the government and education authorities across Scotland. We sought to explore the identification of key psychological factors in the development of numeracy; interventions that address these factors, and how these may contribute to bridging the attainment gaps in numeracy, including the poverty related attainment gap.

This report considers four distinct studies aimed at improving numeracy run by each of the four Educational Psychology Services in the Forth Valley and West Lothian Regional Collaborative. The first four chapters are a report of each individual project.

1. Attachment and Numeracy, Clackmannanshire Council. This study involved a literature review of research into development of early years numeracy and its links with childhood development and particularly Attachment theory.
2. Bridging the Gaps, Falkirk Council. This project focused on a longitudinal analysis of pupil outcome data from an action research skills project, involving the Coach Consult method of professional learning, undertaken with teachers and managers from 12 schools, in 4 discrete projects during 2016/17.
3. Meta Cognitive Development, Stirling Council. This study involved a literature review of meta-cognitive aspects of numeracy development, which in turn is being used to contribute to a professional learning programme for teachers in early primary in Stirling Schools, using an appreciative inquiry approach.
4. Pupil Voice, West Lothian Council. This piece of research involved focus groups with 56 participants from 8 high schools. All were studying for National 5 Maths and in S4.

It could be argued that psychological factors impact on attainment in all areas, but it would appear that they may have a particularly strong influence within numeracy development for several reasons. The importance of early relationships for the development of maths skills as young children typically develop these skills informally in interaction with their surroundings and mediated by their relationship with their main caregivers as described in chapter 1. Maths differs from other subjects for learning in its requirements to shift between abstract constructs and the infinite possible interactions as described in chapter 4. The language used within mathematics is both familiar and unfamiliar as known words have new meanings, as described in chapter 2 and 4. Factors such as learners' motivation and ability to use metacognitive skills will be particularly important for a subject that is perceived as more difficult than others to learn (see chapter 3). Action research, as used by teachers, have an important contribution in how improvement in numeracy and the psychological factors can be implemented, see chapter 2.

These four studies form the basis for an analysis of the key psychological factors which contribute to the development of numeracy. The four studies were diverse in nature and scope. This meta-study therefore considered the following as in scope for identifying psychological factors:

- Four literature reviews with an emphasis on different age ranges and different aspects of psychological influence and mathematical development
- West Lothian's thematic analysis of focus groups of S4 students (aged 14-16)
- Falkirk, Project A - fractions test approach for primary 6/7 (age 10-12)
- Falkirk, Project B - math test approach for primary 4 (age 8-10) and whole school tracking

Each Study has considered the relationship between their key questions, the effect of poverty and the evidence base in their individual subject area. To our knowledge this is the first attempt at identifying key psychological factors affecting numeracy development across diverse studies in a Meta-study.

RESEARCH QUESTIONS

The research questions were:

1. What psychological factors are present in the development of mathematics?
2. Which of these factors are important for implementing improvements?

METHOD

PROCESS

The Principal Educational Psychologists of the four services identified one project each and this collaborative approach for the meta-study and applied as a collaborative to the National Enquiry Research and Development project sponsored by Education Scotland. The purpose was:

- to combine findings from the four studies to provide robust comment on key psychological issues affecting numeracy development
- Share key findings across the collaborative to support improvement planning.

The four project groups collaborated through a combination of online collaboration on an ongoing basis within Glow and four meetings, two within the Regional Collaborative and two within the National Enquiry project.

1. Setting clear research goals and questions (National Enquiry meeting)
2. Sharing practice and initial findings (Regional Meeting)
3. Sharing interim findings and report production (Regional Meeting)
4. Draft findings and completion goals (National Enquiry Meeting)

The Principal Educational Psychologists had regular overview meetings with the objective of ensuring each study completed within a similar period to allow completion of the meta-study.

ANALYSIS

The four studies were analysis using a two-stage content analysis:

1. Initial coding of psychological factors identified in the study
2. Thematic coding of the identified factors through an iterative process of two iterations

The definition of Psychological factor used in the initial coding stage was:

*The **factors** that talk about the **psychology** of an individual that drive his or her actions.*

The factors were the grouped into meaningful clusters and levels of psychological influence.

RESULTS

The initial coding identified 94 psychological factors. Thematic coding iteration 1 identified three categories of factor: individual (48), intersubjective (39) and contextual (7).

Iteration two of the thematic coding identified clusters of psychological factors within the three categories. These are outlined in Table 1 and illustrated in Diagrams 1 to 3 There were at total of 20 cluster factors identified where 9 cluster factors identified for the individual, 8 for intersubjective and 3 for contextual.

TABLE 1 – CLUSTER FACTORS

Individual	Intersubjective	Contextual
Enjoyment and motivation	Prior relationship	Poverty
Early skills and knowledge	Teacher relationship	Leadership and culture
Prior Learning	Learning Activity	Continuity and sustainability
Emotional development and self-regulation	Pedagogy fit	
Maths specific skills knowledge and learning	Teacher led culture	
Attitudes and beliefs	Quantity/resource	
Purpose and relevance	Teacher practice	
Learning approach	Peer dynamics	
Cross-cutting - developmental stage and age		

DIAGRAM 1 - INDIVIDUAL FACTORS

DIAGRAM 2 – INTERSUBJECTIVE FACTORS

DIAGRAM 3 – CONTEXTUAL FACTORS

DISCUSSION

Within this study the psychological factors were codded across individual, intersubjective and contextual. This is consistent with the Ecological Framework for Human Development, described by Bronfenbrenner in the 1960s that evolved through to the 90s (Bronfenbrenner and Morris, 1998). This is a widely accepted understanding of child development, psychology and learning, and parallels the national practice model's My World Triangle within Getting it Right for Every Child.

TABLE 2 – VALIDITY ANALYSIS

Study	Ecological system	GIRFEC My World Triangle
Individual development	microsystem	Within child factors - "how children grow and develop"
Intersubjective	mesosystem	Immediate relationship factors - "what I need from those that look after me"

Effective pedagogy and peer dynamics		
Contextual	exo, macro and chronosystems	Wider societal factors - "my wider world"

IMPORTANT PSYCHOLOGICAL FACTORS

The findings are that the psychological factors important for the development of numeracy need to be taken in the context of an ecological model of understanding child development and learning. While these categories are helpful in describing the phenomena in learning mathematics it is also important to highlight that the factors have inter-related dynamics. For example, secure attachment, which arises from an 'attuned' relationship, has the resulting impact on the individual child's development. Insecure attachment is found to be more prevalent in households affected by poverty.

The four studies explored different aspects of numeracy and explored this with different age groups of children, ranging from the literature review of attachment as it affects early numeracy development to the voice of the child in those approaching the age they are entitled to leave school, but it also includes the teachers' perspective within the Bridging the Gaps study.

MATHEMATICAL FACTORS

Effective pedagogy in mathematics, the art of teaching maths well to students, is not revealed by the nature of these studies. It is widely acknowledged that the pedagogy of maths, which has been taught for thousands of years, is intrinsically linked to encouraging the mastery of the conceptual knowledge from concrete through to more abstract forms of thought. This is highly linked to the development of thought, which follows a similar process from more concrete thinking to abstract thinking. We identified one cluster factor that highlighted specific mathematical concepts, *Maths Specific.* This included the factors: problem-solving, mathematical language, mathematical literacy, inherent problems to task, cultural problems, fractions and decimals, specific skills (pressure points) to progress in learning maths, mental agility, problem solving, wording of exam questions, reasoning. These factors are not exclusive to mathematics but are particularly required in the learning of mathematics.

Similarly, within the intersubjective category there was one cluster factor that had a specific emphasis on mathematics, which has been termed, *teacher led culture*, which included; Mathematical discourse, Metacognitive discourse, Teacher perception of student competence, Collaborative learning, Changing student beliefs about learning/intelligence, Maths avoidance/terror.

The remaining 18 cluster factors, which this study identified as important for the learning and teaching of mathematics are not specific to mathematics but reflect wider learning and development. This is also reflected in the field of improving learning research. There are two significant sources of insight into effective methodologies, the Education Endowment Fund and Visible Learning. Both of these centers employ meta-study methodologies and then publish their findings. In both cases there is an absence of mathematics specific studies in their research. The Education Endowment Fund website lists 34 interventions, none of which are specific to mathematics. The Visible Learning group, Hattie (2017) have listed 3 mathematics specific strategies on pupil attainment from over 250 influences on attainment. All are found to have a positive effect, of which only mathematics programs have the "Potential to accelerate student achievement" with the other two describes as "Likely to have positive impact on student achievement" – see Table 3.

TABLE 3 – EFFECT SIZE OF MATHEMATICAL SPECIFIC INFLUENCES

MATH AND SCIENCES	EFFECT SIZE
MANIPULATIVE MATERIALS ON MATH	0.30
MATHEMATICS PROGRAMS	0.59
SCIENCE PROGRAMS	0.48
USE OF CALCULATORS	0.27

Extracted from Hattie et al, (2017)

The most effective influences are more overarching in nature, with the largest being for teachers' collective efficacy (1.57), self-reported grades (1.33), teacher estimates of achievement (1.29), cognitive task analysis (1.29) and response to intervention (1.29). See Hattie et al. (2017).

This study would be consistent with the view that positive learning in mathematics is not exclusive to mathematics and there are other important psychological factors.

Early development of concepts and skills

There are several psychological factors crucial to the development of numeracy. These include the development of object permanence, which in turns leads to the development of understanding of quantity. These aspects of psychology development are interlinked with growth and development. There appears to be a strong link with attachment theory to suggest that a positive influence will be the promotion of positive and secure relationships with the primary care-givers in a child's life. It is worth noting that the interventions proposed by the increase in availability of early learning and child care provision could appear contradictory to the development of secure relationship development with the primary care givers unless steps are taken to ensure continuity of attachment for children in these settings. This basis of psychological development is also important for the development of key skills such as exploratory behaviour and risk taking and taking their own initiative. This cluster factor was termed ***Early skills and knowledge***. There are linked cluster factors at both the individual and intersubjective level, which include ***Prior Learning, Prior relationship,*** and ***Teacher relationship***. This includes that there is a correlation between poverty and insecure attachment styles, which, if there is a causal link, suggests we might address maths attainment through interventions that promote secure attachment. This may form the start of the cycle for the growing gap in attainment as the children affected in this way are likely have lower levels of **prior learning** and **emotional development and self-regulation**.

Psycho-educational interventions such as the Nurture Principles and relationship-based practice can go some way to ameliorate the effects of disrupted development of secure attachments but have never been suggested as a replacement for these. There are other associated developmental areas which have applicability to mathematics such as Language enrichment and particularly the language involved in mathematics; and Problem-solving skills which is applicable to both maths and to wider learning.

PERCEPTION, BELIEF AND CULTURE

There are several cluster factors which indicate the importance of the perception. This includes the individual, intersubjective and contextual factors. One of the most important of these is the ***Enjoyment and Motivation*** of the learner, which is also influenced by their ***Attitudes and Beliefs*** about intelligence, mastery and when encountering a 'jump' in challenge, and where they are in relation to their ability and peers (***Peer Dynamics***). Other significant cluster factors that influence the learner motivation and enjoyment are that

- they perceive a clear ***Purpose and Relevance*** of the learning task and maths in general;
- their ***Emotional Development and Self-regulation*** includes development of self-control, can manage anxiety, they can focus attention and are able to self-regulate;
- There is a ***Teacher Led Culture*** which positively influences the ways in which teachers influence students' beliefs and feelings about learning through discourse about mathematics and metacognition, collaborative learning and monitoring their own perceptions about student's competence.
- There is a ***Leadership and Culture*** which ensures maths is consistently taught between teachers, within a whole school approach, teacher collaboration is encouraged within a context of effective school leadership as a whole.

EFFECTIVE TEACHING AND LEARNING AND RELATIONSHIP BASED PRACTICE

There is a dynamic interaction between the individual learner and the teaching. This is well captured within the analysis of factors by the association between the cluster factors:

- ***Teacher Practice,*** which includes their assessment, reflective practice, whether they are interactive and creative in their approach and can adjust the pace, flow or structure
- ***Pedagogy Fit,*** the specific skills and competencies the teacher uses such as planning, monitoring, scaffolding and modelling, questioning, constructivist approaches, direct transmission, positive praise and formative feedback,
- ***Learning Activity,*** the specific learning activity such as board-games, family learning, homework or using specific strategies according to pupil need or type such as attachment specific strategies
- ***Learning Approach,*** the particular skills, strengths and abilities in learning, such as speed of learning, cognitive skills, metacognitive skills, ability to contract mental models, speed of learning, memory, development of abstract concepts and ability to use self-report or verbalising. This may be associated with learners' perceptions of their own learner style and may be accommodated by using active learning approaches which encourage and foster learners to use their skills and attributes as strengths.

This indicates that the intersubjective elements which to a degree are within the sphere of influence of the teacher also need to fit with the learners that are in the classroom and their strengths in learning, and the teacher having the confidence as a reflective practitioner and action researcher to modify and adapt their pedagogy, learning task or practice.

IMPLEMENTATION OF IMPROVEMENT FACTORS

A vital component of improving attainment are the factors that influence whether the planned improvement is implemented first and foremost and then actually moves in a positive direction rather than stalls or even regresses. This study identified several factors that can influence whether intervention, i.e. improvement in the individual, teacher approach or culture can be sustained. The study identified that ***Poverty***, and the linkages this factor has with experience of self, access to opportunities and its correlation with insecure forms of attachment was a cross cutting socio-political factor. A second cross-cutting factor was the Age of the child. This is cross cutting as the types of responses to children required to improve mathematics attainment, across all categories and cluster factors required differential responses from the learner, the adults and the context depending on their age and stage.

It was also identified that an important dimension was the ***Quantity/resource factor,*** i.e. to ensure that there is enough time spent on maths by students and where resources may be required such as time spent with teachers through timetabling and additional study groups.

Two cluster factors ***Leadership and culture***, and ***Teacher practice***, described above, are also vital influencers on the final cluster factor ***Continuity and Sustainability.*** This is highlighted as of crucial important of improvement and change make a genuine difference. The psychological factors which were highlighted in this study that contributed to this cluster factor being identified included the continuity of Staff which in turn leads to sustainability of improvement. It also included expectation around the curriculum, its start time and the wider construct of school. all our efforts will be in vain in improving attainment if the turnover of staff is high, if the expectations for teachers and pupils have significant mismatch or are two low and that the construct of school; the perceptions of what it means to be at school, the purpose of school and the benefit of school, becomes negative.

The Hattie et al (2017) research has clearly indicated the positive benefits of collective teacher efficacy in influencing student attainment. This research also indicates the types of interventions that schools and students should prioritize, for example any influence with a greater effect size than 0.4 and the intervention or influence that they should only prioritise once all the other important elements are in place; those listed as positive yet less than 0.4 effect size. Collective Teacher Efficacy has the largest effect size of all influences. It means that teachers need to believe they are collectively engaged in a positive common purpose and actively engage in this collaboratively. If this is utilized in promoting evidence-based interventions in practice we can be optimistic of the positive influence on the psychological factors described above in promoting attainment.

RECOMMENDATIONS

This meta-study finds that, given the complexity and multitude of factors that influence numeracy development and mathematical attainment, Councils, the Regional Collaborative and Scottish Government need to find ways of:

1. promoting long term duration of teacher pupil relationships,
2. promoting whole school consistency and beyond in the teaching of mathematics
3. consider the impact that relationships and attachment style may have on pupils' numeracy development
4. ensure that teacher led innovations occur in a culture of learning, knowledge and research and with reference to the existing evidence base on effective interventions
5. Encouraging parents to become more involved in contributing to the development of concepts skills and knowledge which are fundamental to math but not necessarily math specific such as risk-taking behaviour, metacognition, self-regulation and beliefs about intelligence and mastery.
6. Actively encourage collective teacher efficacy in a context that promotes sustainability of improvement in evidence based ways.

This highlights the need for a cultural change with regard to numeracy education to include funding, employment and training arrangements that promote the long term relationship with staff and pupils in schools, effective mathematics teaching, and recognise the impact of relationships and attachment style on pupils' numeracy development. Implementing improvement needs sustainability and implementation of improvement to be considered as important as the specific mathematic concepts and knowledge in encouraging children to learn maths.

Or final recommendation is that there is a need for debate about practice and improvement at a strategic and practice level within the Regional Collaborative and the four education authorities.

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STUDIES ANALYSED WITHIN THIS META-STUDY:

Attachment and Numeracy: A Literature Review. Lesley Craig, Susan Murray and Rachel Donaldson, Clackmannanshire Council

Bridging the Gaps: Long Term Outcomes of an Action Research Programme to Improve Numeracy. *Nick Balchin, Lyn McLafferty, Falkirk Council*

Metacognition and Numeracy: A Literature Review. Muriel Mackenzie, Alison Boyd & Kathryn O'Hare, Stirling Council

Pupil Voice: Views of National 5 Pupils in Relation to their Experiences of Numeracy Skill Development. *Tracey Ross, Sarah Booth and Katherine Fraser, West Lothian Council*

[hyperlink to publication place]