Abstract

This paper reports on a survey of students (n=11,465) carried out in Scotland in 2018 regarding attitudes to maths learning. Maths anxiety is a phenomena increasingly identified among students, and a variety of theories and practices are emerging to tackle it. Growth mindset is one such approach, in which attention is paid to the way maths is presented and the way mistakes are dealt with. Professor of maths education, Jo Boaler, champions this approach and visited Scotland to provide instruction in mathematical mindset, in association with Winning Scotland Foundation. The survey was carried out in preparation for her visit, and findings concur with Scotland's Making Maths Count's appraisal of Scotland as a maths-anxious nation.

1 Introduction

Maths anxiety is a term used to describe the specific anxiety, stress and lack of self-belief that some people feel when faced with a maths problem or lesson. It is seen to be prevalent, in contrast with other subject matter, and may be because maths is not taught in the same way as other subjects. Commentators have observed that maths, compared to other subjects, is:

- more likely to be taught as having 'right/wrong' answers,
- more likely to be taught in ability groups,
- more likely to be perceived to have a genetic component

These cultural norms are now challenged in maths education. Making Maths Count (The Scottish Government, 2016) is a group established to make Scotland a maths positive nation. The Institute of Education, London, is looking into ability grouping and helping more learners "not hate maths" (IOE London 2018). Jo Boaler's work (e.g. Boaler 2016) claims that maths anxiety can be overcome by teaching that:

- maths is a creative an open subject
- there is no such thing as a 'maths brain'
- mistake-making is a significant part of learning
- growth mindset work aids maths learning

This paper is a report on maths mindset, including maths anxiety and beliefs about maths learning, in Scotland. It presents a synthesis of literature on maths anxiety and growth mindset, with the results of a large scale survey of maths students and teachers in Scotland.

2 Maths Anxiety: Literature

This literature review focuses on maths anxiety as this is an identified problem in Scottish schools, with complex roots and a variety of suggested solutions. The concept of mathematical anxiety can have multiple origins and, as noted by Shields (2005), can be perpetuated in the home, society, and the classroom.

2.1 In the Home

Else-Quest, Hyde, & Hejmadi, (2008) highlighted that parents who themselves suffer maths anxiety can unintentionally transfer such anxiety to their children, finding that as a result this shapes parent-child interactions and relationships.

As detailed by Whyte & Anthony (2012) children who are reproached for their errors may develop a fear of taking risks and exploring new possibilities, and may start hating mathematics. Further findings from Dossel (1993) specifically into mathematical anxiety stated that parental disappointment and despair had a significantly negative effect on the child due to the role model status many parents have before their children.

The unintentional cultivation of maths anxiety by parents was identified by Stolpa (2004) who found that parental responses to challenge and frustration such as 'Don't worry, I've never understood fractions' or 'Never mind, maths was always tricky for me at school too', plants a seed that may grow into a strong belief for children that they are incapable of learning mathematics.

2.2 Societal Influence

Whilst there are numerous social factors that may impact mathematical anxiety, the often prevalent belief that people have, or do not have a maths brain may have cultivated a social acceptance to maths that is not accepted or indeed tolerated in any other subject. Latterell (2005) found that failure in maths was regarded as socially acceptable and that students were less embarrassed in relation to a lack of maths skills compared with language skills.

2.3 In the Classroom

The classroom is a place where mathematical anxiety can develop and indeed flourish (Shields 2005). Experiences of learning maths in structured, rigid classrooms where there is little opportunity for discussion, a focus on finding one correct answer, limited time to reflect and an emphasis that speed is good often encourage the development of maths anxiety.

Maths anxiety often stems from students being taught by maths anxious teachers, those teachers (Vinson 2001, The Guardian 2019) that have an over-reliance on traditional instructional activities (work sheets; assigning the same work for everyone; teaching to the textbook), insisting on only one correct way to complete a problem and concentrating more on basic skills rather than concepts.

A further influence on maths anxiety and a contribution to fixed mindsets is the subject of ability grouping. Ability grouping, streaming, or setting are a commonly used teaching practice in mathematics learning. They have received some attention in recent years as researchers try to assess their impact on the mindsets of students (Boaler et al. (2000), Education Endowment Foundation Toolkit (2018), Ireson et al. (1999)). The research has been illuminative in raising awareness of

- The high likelihood that students from lower income backgrounds are placed in lower sets
- The low possibility of changing from low sets to higher sets during school career
- Students in low and high ability groups gaining fixed beliefs about their intelligence

Ability grouping gives students implicit messages about their potential. Those in higher sets believe they should not struggle as that may jeopardise their position. Students in low sets believe there is

'no point' as they will never catch up with their peers. Teachers adopt different styles according to the set they are teaching, and lower sets are given less opportunity to learn, simply due to the nature of what is presented to them.

3 GROWTH MINDSET AND MATHEMATICS

Underpinning the survey and mathematical mindset work is the concept of 'growth mindset'. Growth mindset is a concept already in use in many of Scotland's schools, a term coined by psychologist Carol Dweck.

In her research Dweck (1999) shows that someone with a fixed mindset (entity theory of intelligence) have a belief that qualities such as intelligence, creativity, and talent are predetermined and finite, fixed traits. In accordance with fixed mindset beliefs, these qualities are set from birth and are static in a particular person.

Conversely however, people with a growth mindset (incremental theory of intelligence) have a strong belief that their qualities can continue to be developed through sustained effort, resilience and dedication. Those with a growth mindset believe that these innate qualities are the building blocks to success, understanding that challenges, failure and setbacks will come their way however accepting that these are learning opportunities.

The basis of fixed and growth mindset is in motivational theory of 'learned helplessness' (Seligman, 1974) where individuals recognise that efforts to improve their situation have failed, so they give up trying. This concept is often seen in an educational setting with teachers frequently encountering students with learned helplessness who are discouraged, turned off, or have given up trying to learn (Yates, 2009).

Blackwell, Trzesniewski, and Dweck (2007a) explored this further and shifted attribution theory from an emphasis of attributional errors and biases to the consequences to why it matters what attributions people make. When related to attainment the same research monitored student's mindsets and monitored their attainment in order to establish how the students deal with challenge. The research highlighted that despite similar levels of math's ability, there was a significant difference in levels of attainment. Blackwell *et al* (2007a) found that those students identified as having a growth mindset focused on their learning, effort, and were resilient to challenges. Conversely, those students identified as having fixed mindsets were more concerned about being perceived as smart. As a result those students avoided challenges, gave up easily, were resistant to or ignored feedback, and often felt threatened by the success of others. Over a period of two years, the research found that the attainment gap had widened and became evident that those students identified as having a growth mindset significantly outperformed those that held fixed mindsets.

In a further study, also with adolescents, Blackwell *et al* (2007b) divided students identified as having declining levels of maths attainment into two groups. Half of them, the control group, were taught about the study skills along with the stages of memory; the other half were taught about growth mindset concepts and to understand that the brain grows. This, they were told, would cause their brain to form new connections and, eventually, with sustained effort, increase their intelligence. The research findings show three times as many students in the growth mindset group showed an increase in effort and engagement compared with the control group. After the training, the control group continued to show declining grades, but the growth mindset group showed a clear

improvement in their levels of attainment. Significantly, even without knowing, the teachers noted an increased motivation to learn from the students had received the growth mindset training.

3.1 Teaching a Growth Mindset

It is however important to note that it is not only the pupil's mindset that can have an impact on learning. Rheinberg & Engeser (2010) identified that those students taught by a teacher with a fixed mindset had little or no improvement to their intellectual skills over the course of a year, highlighting that if they entered as low achievers, they remained low achievers. In contrast however when those students identified as being low achievers where taught by a teacher with a growth mindset, the students' attainment was shown to improve, leading to the students becoming moderate or even high achievers.

It is in this context that the learning environment becomes crucial to the development of young people and few other subjects polarize students as much as maths does, with the often prevalent belief that people are or are not 'maths people'.

In her book Mathematical Mindsets, Jo Boaler aims to communicate the importance of the adoption of growth mindsets for mathematical achievement. Boaler specifically applies the growth mindset approach to mathematics education and suggests that maths should be seen as an open, creative subject, one that is engaging and underpins higher levels of attainment across the curriculum.

Boaler (2016) discusses evidence-based practice such as emphasising the exploration of students' errors and the use of concrete manipulatives. Further emphasising the need for educators to explore misunderstanding of concepts and procedures as a positive learning and teaching strategy (Hansen *et al* 2014). In addition, there are a plethora of studies that suggest adaptive and flexible strategies are a key component to successful learning in arithmetic including Geary & Brown (1991); Vanbinst, Ghesquiere & De Smedt, (2012) who suggest that a classroom environment should be one where educators encourage the use of different learning strategies, allowing students the freedom to develop adaptive learning skills when faced with a challenge. Boaler (2016) suggests that the growth mindsets literature has proven this type of intervention to be effective: "Research has shown definitively the importance of growth mindsets" (p34), a finding also evidenced by Paunesku *et al* (2015) who observed that growth mindset interventions increased attainment in children who were at risk of dropping out of school, and by Hembree *et al*, (1990) who found that teaching with a growth mindset approach led to increased confidence, decreased anxiety about learning and thus led to increased achievement in mathematics.

4 Maths Performance in Scotland

The Children and Young People (Scotland) Act (Legislation.gov.uk, 2014) is about improving the wellbeing of children and young people in Scotland. The Act is wide ranging and includes key parts of the Getting it right for every child approach, commonly known as GIRFEC.

Wellbeing sits at the heart of the GIRFEC approach and reflects the need to tailor the support and help that children, young people and their parents are offered to support their wellbeing.

In 2016, 'Transforming Scotland into a maths positive nation' (The Scottish Government, 2016) was published, following research by The Making Maths Count Group.

The report focusses on three key areas:

- Transforming public attitudes to maths.
- Improving confidence and fluency in maths for children, young people, parents and all those who deliver maths education to raise attainment and achievement across learning.
- Promoting the value of maths as an essential skill for every career.

The 'Transforming Scotland into a maths positive nation' report highlights some of the key issues with young people learning maths in Scotland and specifically states that one of the challenges is *'the belief that some people are "naturally" or "innately" good at maths and others are not'*.

The paper then goes on to recommend a *"greater enthusiasm for maths as a vital life skill amongst children and young people, parents and carers and the wider public"*.

The report found that 30% of Scottish learners feel very tense and nervous when doing maths work and more than 50% worry that maths will be difficult, qualifying the OECD recommendation that "the issue of maths anxiety in Scotland warrants close attention", further stating that the promotion of "a growth mind-set approach, and other methods of improving learner confidence such as positive learning dispositions, are essential to addressing maths anxiety and raising attainment."

This also follows publication of Programme for International Student Assessment (PISA) scores in 2018 (OECD, 2018) showing a trend in a negative direction. Scotland's scores for maths, reading and science all declined noting that it was the first time since the tests began in 2000 that all three subject areas were classed as "average", with none "above average".

5 Survey Instrument

Students in Scotland were asked to complete online questionnaire surveys in June 2018. Requests were sent by Winning Scotland Foundation, using their existing established networks. The surveys were collaboratively written by Winning Scotland Foundation and YouCubed's team of researchers, who collected the responses and carried out various statistical analyses. Statistics were shared with Winning Scotland Foundation and form the basis of the analysis in this paper.

The survey comprised of two instruments:

- A questionnaire for primary school children
- A questionnaire for secondary school children

The student questionnaires differed only in language used, for example the primary students were offered 'really agree' and 'really disagree' on their Likert scale responses where the secondary students had 'strongly agree' or 'strongly disagree'. Similarly in posed questions language was made audience appropriate, such as 'I believe that I can be really good at maths' for primary was expressed 'I believe that I can take maths to any level' for secondary. Student questionnaires probed beliefs about their ability to succeed, their feelings when working on maths, beliefs about mistakes, speed, and effort. All questions had 5 point Likert scale responses, i.e. included a neutral position of 'not sure'

6 RESULTS

The online survey was completed by 4870 Secondary school students and 6233 Primary school pupils.

6.1 ATTITUDES REGARDING MATHS 'INTELLIGENCE'

Students were posed a number of questions which related to their beliefs about maths intelligence. These questions were designed to discover whether students believe they can achieve, or if their ability is predetermined. Five questions assessed this belief, shown in Table 6.1 below.

When I don't do well in maths, I think that I am not very good at it.
I believe that I can be really good at maths
People can't change how good they are at maths.
Some people are just born good at maths.
If I work really hard I can become very good at maths.

Table 6.1 Survey questions relating to maths intelligence

The majority of primary aged children did not show a belief in math intelligence, disagreeing with the idea that people are born with maths skills and cannot change. They also did not agree that not doing well in caused them to believe they are not good at it. Figures 6.1 and 6.2 show these responses as bar charts, showing the consistency in responses, and the belief "I can become good at maths". Girls were significantly more likely than boys to agree with both "When I don't do well in maths, I think that I am not very good at it", and to disagree with "If I work really hard I can become very good at maths". The other three questions saw no significant difference between the responses of girls and boys.

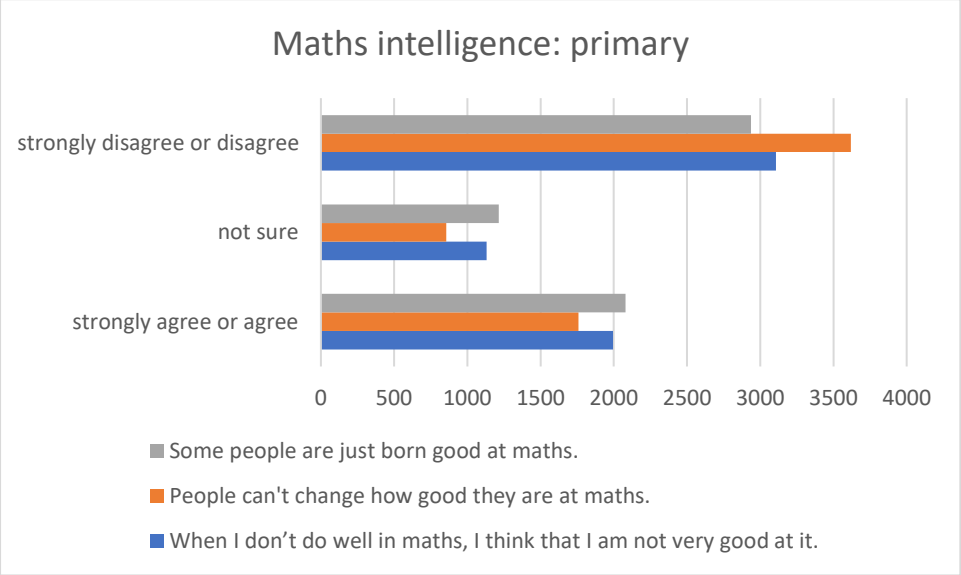

Figure 6.1. Primary students' belief in the existence of an underlying maths ability

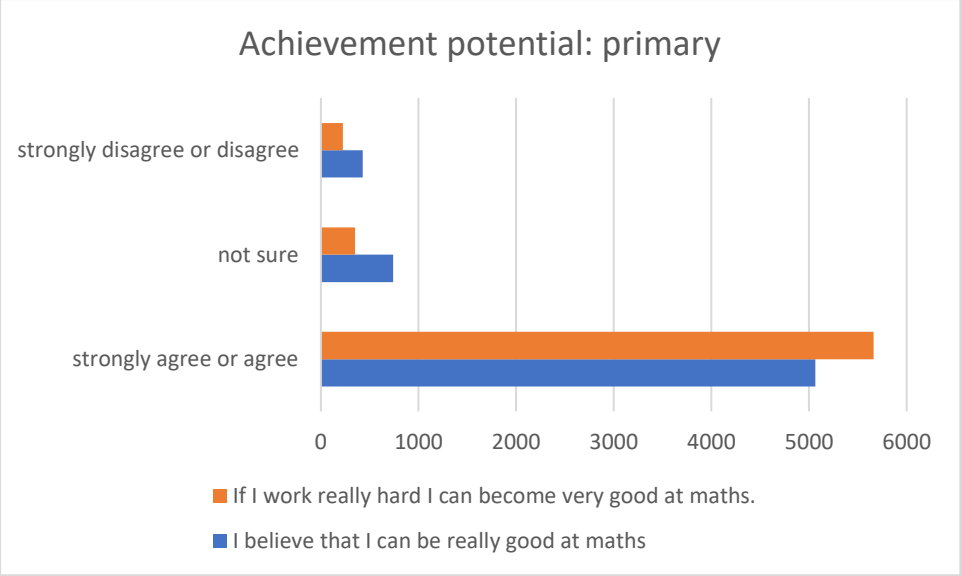

Figure 6.2. Primary students' belief in potential for maths achievement

Secondary student responses indicated some belief in an underlying intelligence, with only 37% of respondents disagreeing (including 'strongly disagree' responses) with the statement that "People can learn more maths, but they can't really change their basic maths intelligence". Half of students (49%) agreed that getting a bad mark made them think they were not good at maths. However 46% also disagreed that there might be limits on a person's ability to improve their basic ability, with 29% agreeing. Their responses to the belief in their own potential are shown in Figure 6.3, showing that while most (90%) of them agree that their effort impacts their achievement, far fewer believe that they personally can take maths to any level (47%).

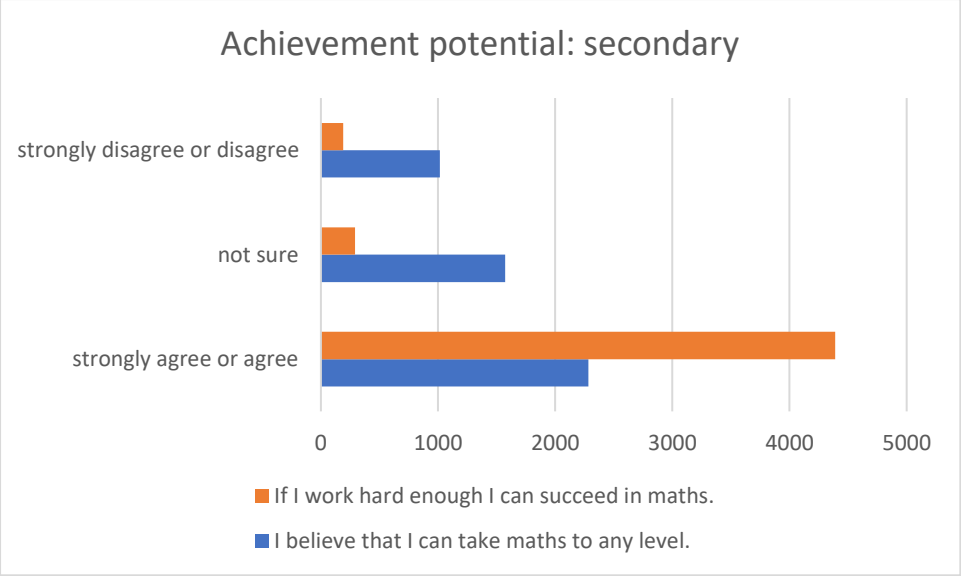

Figure 6.3. Secondary students' belief in potential for maths achievement

6.2 BELIEFS ABOUT MISTAKES, EFFORT AND SPEED

6.2.1 Mistakes

Students were asked the extent to which they agreed that it is important not to make mistakes in maths. More children disagreed than agreed with the statement (52% of Primary, 46% of Secondary), however a large proportion still express a belief that mistake-making is important to avoid. At both primary and secondary age more boys than girls responded positively to this, agreeing that they felt avoiding mistakes was important. Figure 6.4 shows the results, excluding the 'not sure' respondents (15% of all responses).

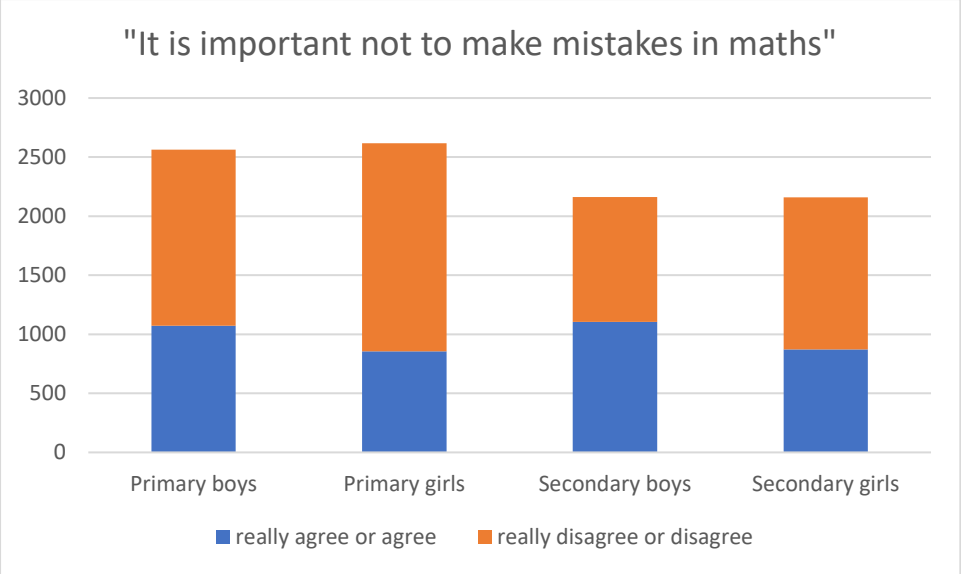

Figure 6.4. Student responses about mistake-making

6.2.2 Effort and enjoyment

Students were asked about effort from the three angles of feeling good in struggle, liking solving something hard, and giving up when something is difficult (three questions).

Students tended to disagree that they give up when faced with a challenging problem, with 10% of primary students agreeing and almost half disagreeing, equally distributed between boys and girls. Secondary students had a higher rate of responding neutrally, with a third disagreeing and 9% of boys and 14% of girls agreeing. This difference between the responses of boys and girls was statistically significant.

The trend for younger students to like the challenge with older students less likely to enjoy hard questions is corroborated in the student answers to whether they like solving a complex problem. The plots (using percentage data) in Figures 4.5 and 4.6 show the Primary students agreeing more to "I like to solve complex problems" and less to "I feel good when I struggle", compared to Secondary students.

Girls were significantly more likely than boys to state that they do not like to solve complex problems, and significantly more likely than boys to say that they 'feel good when they struggle in maths class'. This significant difference held for both primary and secondary students.

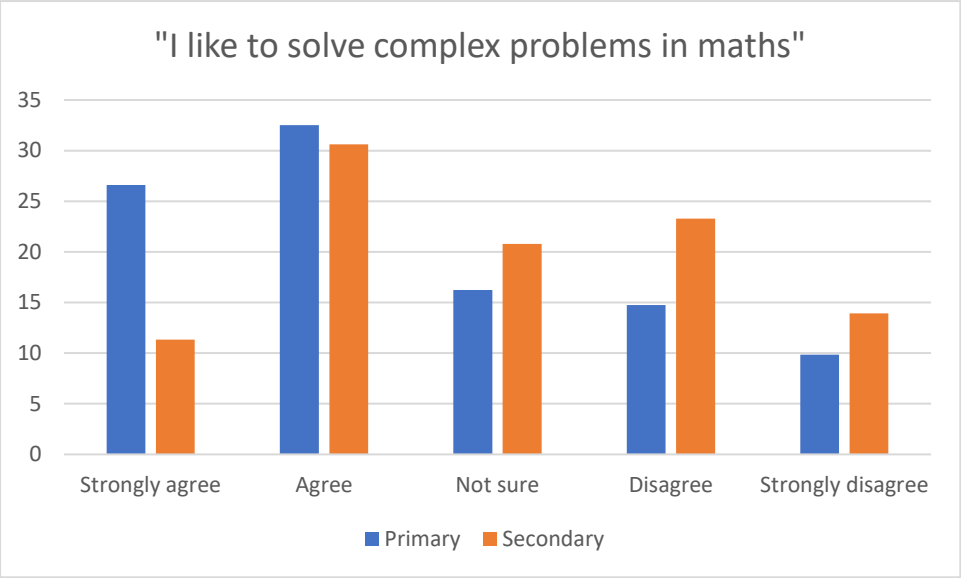

Figure 6.5. Comparing Primary and Secondary student responses relating to hard work in maths

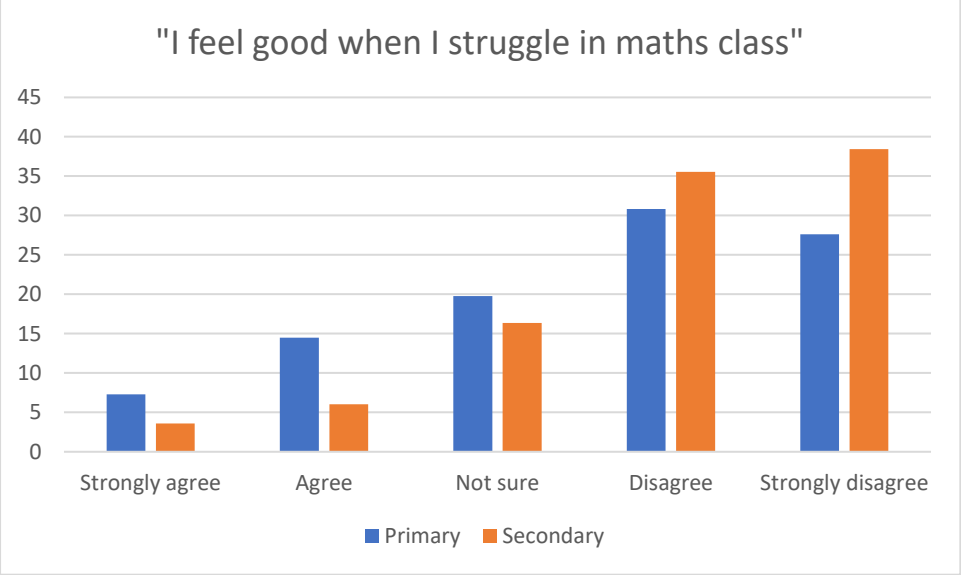

Figure 6.6. Comparing Primary and Secondary student feeling during struggle

6.2.3 Speed

Students were asked two questions related to maths and speed. The survey showed a strong agreement among students that 'really understanding maths' will mean being quick. Sixty four percent of primary students and 67% of secondary responded positively to this statement. Secondary boys were significantly more likely to agree that speed is a marker of understanding than girls. There was no significant difference between the responses of primary aged girls and boys.

This is in contrast to their responses to the sentence "It is important in maths to be fast", to which 58% of primary students and 61% of secondary students *disagreed.* Girls in both age groups were significantly more likely to disagree than boys - or viewing it differently, boys were more likely than girls to believe that speed is important in maths.

6.3 BELIEFS

ABOUT MATHS AS A CLOSED OR OPEN SUBJECT

A number of questions were designed to give insight into the beliefs among participants that maths is an open or a closed subject.

No significant difference was seen among primary students, however secondary boys were more likely to respond that maths has a right and wrong way to find the answer than girls.

All participants were asked about the use of creativity in maths (see Table 6.2).

Primary pupils	When learning maths, I feel that I can use my creativity.
Secondary pupils	I feel maths is a creative subject.

Table 6.2: Survey questions rating creativity in maths

Sixty one percent (61%) of primary students agreed with the statement that you can be creative in maths compared to only 32% of secondary pupils.

No significant difference was seen among primary students, however secondary girls were more likely than boys to disagree that maths is a creative subject.

On maths as an open or closed subject students were also asked to respond to “Maths is a subject that can connect lots of ideas together”, and “It is really helpful to talk about maths with other people”. One third of students were ‘Not sure’ about maths as a subject connecting ideas, with the non-neutral responses significantly agreeing (53% of secondary and 63% of primary responses). Similarly the majority of participants agreed that talking about maths is helpful (64% of secondary and 75% of primary).

6.4 RATES OF MATHS ANXIETY

Students were invited to respond to ‘Sometimes maths makes me feel nervous’ (Primary age) and ‘Sometimes maths makes me feel anxious’ (Secondary age). In both age groups 17% responded neutrally. Within the primary range, 46% of students agreed, increasing to 58% for secondary students, which is a significant increase.

Girls were significantly more likely than boys to agree that they feel anxious/nervous in maths sometimes. Of the non-neutral responses, 61% of girls of primary age agreed, rising to 80% of secondary girls.

7 EMERGENT OBSERVATIONS

This paper’s scope does not extend to discovering or suggesting reasons for certain attitudes or beliefs in maths learning in Scotland. However, it is worth highlighting some questions and comments emerging from the survey’s findings.

Enjoyment of maths decreases with age. More research can explore developmental and environmental aspects of this trajectory. It may be no coincidence that enjoyment decreases as assessment increases, for example.

Girls are more likely than boys to say that maths causes anxiety, and are more likely to give up in a struggle with a maths problem than boys. They are also more likely to believe that working hard will

not impact their ability to "be good at maths". More research could investigate any possible correlation between these findings.

There is a discrepancy in findings about speed. The majority agreement that understanding maths will lead to being quick contrasts with the disagreement that speed is important. Belief that real understanding means fast calculations can cause demotivation and confusion about the purpose of maths activity. Understanding the source of this apparently contradictory finding would contribute to teaching practice conversations.

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