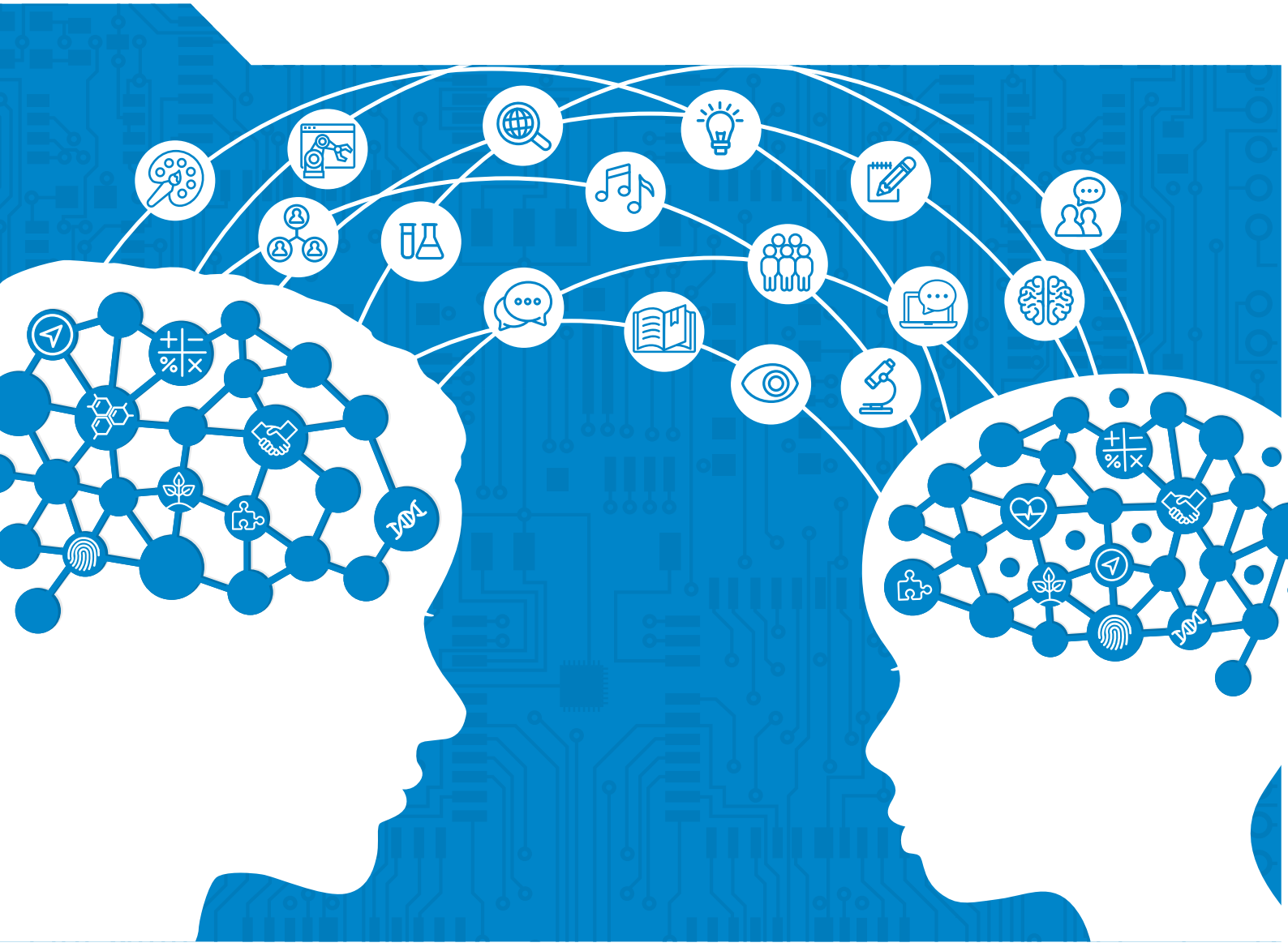
Educational Research and Innovation

Developing Minds in the Digital Age

TOWARDS A SCIENCE OF LEARNING FOR 21ST CENTURY EDUCATION

Patricia K. Kuhl, Soo-Siang Lim, Sonia Guerriero and Dirk van Damme



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Chapter 3. How stereotypes shape children's STEM identity and learning

By

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The scarcity of women who pursue careers in science, technology, engineering and mathematics (STEM) is of global concern. What are the origins of this gender gap and what can we do about it? To make progress, we need to recognise that the problem starts early in development. In early elementary school, children are already sensitive to cultural stereotypes about "who does mathematics". This begins to influence their own emerging self-concepts about mathematics. We show that children's stereotypes and self-concepts have a far-reaching impact on children's achievement in school. Science-based interventions can be designed to strengthen children's resistance to STEM stereotypes and to enhance their self-concepts. We discuss the promise of these interventions for sparking children's engagement, enjoyment and success in STEM.

The scarcity of women who pursue careers in science, technology, engineering and mathematics (STEM) is a concern for educators and policymakers worldwide (OECD, 2014[1]). In the United States, the White House is consulting scientists for advice about how to increase the number of females in the STEM workforce (Rodriguez and Garg, 2016[2]). What are the origins of this societal issue? We believe that the roots of the gender disparity in STEM start early in development.

Our hypothesis is that pervasive societal stereotypes about academic subjects are registered by children at surprisingly early ages. Children come to believe the cultural message that "mathematics is for boys" and this, in turn, influences children's emerging beliefs about themselves. We found a developmental trajectory progresses from: "I am a girl", (gender identity), to "girls don't do mathematics" (stereotype adoption), to "I don't do mathematics" (self-concept). More succinctly: *me = girl, girl ≠ mathematics*, therefore *me ≠ mathematics* (Cvencek, Meltzoff and Greenwald, 2011[3]).

This developmental trajectory has implications for society and helps build a bridge between experimental psychology and education, often called "convergence research". Children's identity – what they believe about themselves and their futures – influences their interests, choices and motivation to learn in formal and informal learning environments. One goal of this chapter is to document when psychological factors, such as stereotypes, begin to take hold in the mind of the child and how these eventually influence children's actual academic achievement. We will show that stereotypes and self-concepts play a powerful and measurable role in academic learning. A related goal is to speculate about what we can do to help children resist stereotypes and increase children's engagement, enjoyment and interest in mathematics. The design and implementation of practical intervention programmes, and their adoption by educators and policymakers, will be enhanced by using the evidence from the science of learning (Master, Cheryan and Meltzoff, 2017[4]; Meltzoff et al., 2009[5]; Newcombe and Frick, 2010[6]).

Establishing a conceptual framework

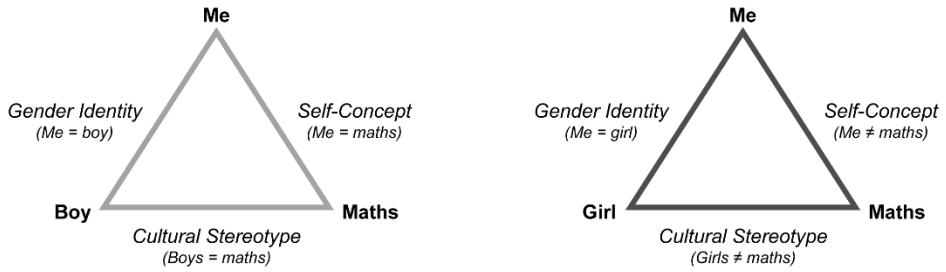
In order to make progress in understanding and ameliorating the gender gaps in STEM, it is helpful to distinguish interrelated concepts that are sometimes confused with each other. We differentiate between children's developing stereotypes and self-concepts; and also draw distinctions between children's explicit (slow, deliberate, conscious) and implicit (fast, automatic, unconscious) cognitive processes. These distinctions are useful for establishing a common interdisciplinary language and for designing more precise measurement tools. Common language and new tools, in turn, lay the groundwork for a convergence between scientific research, educational applications, and policy.

Stereotypes and self-concepts

Studies in social psychology in adults (Greenwald et al., 2002[7]) distinguish stereotypes from self-concepts, but these constructs are often confused in child development and education literature. In this chapter we distinguish these aspects of children's developing social cognition. The stereotype that we focus on pertains to a social group and what academic activities are believed to go with this social category, for example "mathematics is for boys". We refer to this as a maths–gender stereotype. The self-concept does not apply to a social group but to the self, such as "I am a maths person", which we refer to as a maths self-concept. A third related construct pertains to the child's identification with being a boy or girl, their gender identity.

The interrelation among these three constructs is illustrated in a triangle diagram shown as Figure 3.1. The base of the triangle shows the pervasive cultural stereotype that mathematics is associated more strongly with boys than with girls. This stereotype is widely held in the United States and other OECD countries (Leslie et al., 2015[8]; Nosek et al., 2009[9]). Because this is a generalised belief about a social group (based on gender), it is termed a stereotype. The right leg of the triangle shows the link between the self and mathematics, how much an individual identifies with maths. If the individual child thinks "I am a maths person", or "*me = maths*", he or she has a positive maths self-concept. The remaining leg of the triangle captures the idea that many individuals identify with their own gender, which is termed their gender identity. Social psychologists have made these distinctions, and the new aspect added by the work with children has been to empirically determine the developmental order of emergence of these three aspects of social cognition and how they related to actual maths achievement in school.

Figure 3.1. Children's mental network about mathematics, self and gender



Note: The interrelation between self, gender and an academic subject (in this case, mathematics) yields three constructs. The developmental ordering of these constructs and their relation to school achievement is of interest to theory and practice. The left panel depicts the triangle for boys; the right panel depicts the corresponding triangle for girls. (It incorporates the cultural stereotype that maths ≠ girls.)

Explicit and implicit cognition

In examining children's maths stereotypes and self-concepts and the role they play in maths outcomes, it is useful to assess both explicit and implicit cognition in the same children. Explicit processes are typically measured in children by asking them verbal self-report questions (or having them fill out a checklist, scale or bubble sheet). These are traditional measures used with children and adults, and are characterised as being accessible to introspection. By contrast, there has been recent attention to measuring implicit processes, which are usually characterised as being unconscious, non-deliberate responses (Greenwald and Banaji, 1995[10]). During the administration of explicit measures, the participant is aware of what is being tested; but implicit measures do not involve the participant being informed about what is being assessed. Young children may hold stereotypes but may not be able to introspect and articulate them. Even adults sometimes hold unconscious stereotypes that they cannot – or are not willing to – express. Studies show that implicit stereotypes and beliefs exert a powerful influence on people's behaviour, and we have capitalised on new tools to measure children's implicit beliefs in the maths domain.

Each type of measure, implicit and explicit, has advantages and disadvantages (Olson and Dunham, 2010[11]). There are two reasons why we put special weight on developmental studies using both types of measures in the same children. First, children may not be able to fully describe or reflect upon their beliefs about society and themselves, in which case,

using both implicit and explicit measures will provide us with a more comprehensive evaluation of the child's mind. Second, new empirical research shows implicit measures are linked to children's actual maths achievement and account for additional variance over and above explicit self-report measures. We obtain a less complete picture of the children if we restrict ourselves to one type of measurement alone. We want to know both what children verbally express and also what they implicitly believe.

Beliefs and attitudes

Here we focus on maths–gender stereotypes and maths self-concepts but in so doing we do not mean to discount the role of other factors related to maths outcomes (e.g. maths anxiety, see (Beilock et al., 2010[12])). We believe, however, that it is useful to distinguish between children's cognitive orientations towards maths (e.g. stereotypes and self-concepts) and their attitudes about maths. Children's emotions and attitudes about maths, for example their "maths anxiety", are certainly important, but we focus on maths stereotypes and self-concepts for two reasons. First, a study using the Programme for International Student Assessment (PISA) database found that the best non-academic predictors of these standardised test results were maths self-concept and maths self-efficacy (Lee, 2009[13]). Second, maths attitudes and anxiety may form relatively quickly, whereas maths–gender stereotypes and self-concepts form more gradually and maybe more malleable to targeted interventions (Gonzalez, Dunlop and Baron, 2017[14]). We take up the issue of how to design effective interventions about maths stereotypes and self-concepts in the last section of this chapter.

Development of maths stereotypes and self-concepts in elementary school children

Rationale

Research with adults shows that there are pervasive societal stereotypes about STEM. There is a stereotype that males, more than females, are linked to maths (and other STEM disciplines) which is held in varying degrees by adults in most OECD countries, including the United States (Leslie et al., 2015[8]; Nosek et al., 2009[9]). When do children acquire this societal stereotype?

Evidence

We assessed a large sample of elementary school children (N = 247 participants, approximately 6.5-10.5 years of age) using both implicit and explicit tests. To obtain the implicit measures we used a new assessment tool, which is a child-friendly version of the adult Implicit Association Test (IAT). The Child IAT is an easy-to-administer sorting task in which stimuli are presented on a screen (Baron and Banaji, 2006[15]; Cvencek, Meltzoff and Greenwald, 2011[3]). Children are asked to rapidly sort the stimuli belonging to four categories by using two response keys. The Child IAT is based on the principle that it is easier to give the same response to items that are associated than if they are not.

Children with a strong maths–gender stereotype (*maths = boys*) should respond faster when maths words and boy names share a response key ("congruent task") than when maths words and boy names are mapped on different response keys ("incongruent task"). Details about the particular variant of the Child IAT used in this study are provided elsewhere (Cvencek, Meltzoff and Greenwald, 2011[3]).

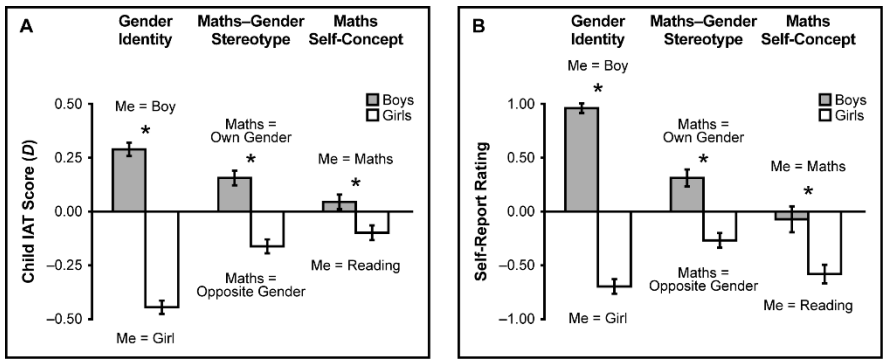
Figure 3.2 displays the results for both the implicit (Child IAT) and explicit (self-report) measures separately for boys and girls, combined over the five elementary school grades.

The left-most pair of bars show, as expected, that boys strongly associated *me* with *boy* and girls strongly associated *me* with *girl*. This is not a surprise. It is known from other tests that gender identity develops quite early – obtaining these results with the Child IAT helps to validate the child implicit measure.

The new findings pertain to maths stereotypes and self-concepts. Both boys and girls associated maths more strongly with boys than with girls (Figure 3.2). There were also differences between the maths self-concepts of boys and girls. Boys associated *me* with *maths*, and girls associated *me* with *reading*. Further probing of the data suggests that the stereotype begins to emerge by 2nd or 3rd grade in this US sample, and the maths self-concepts emerged later.

Figure 3.2. Results of (A) implicit tests and (B) explicit tests of elementary school children

* indicates statistically significant effects; error bars indicate ±1 *SE*.



Source: Cvencek, D., A. Meltzoff and A. Greenwald (2011[3]), "Math–gender stereotypes in elementary school children", http://dx.doi.org/10.1111/j.1467-8624.2010.01529.x.

Why it matters

The results suggest that the maths–gender stereotype is acquired early. Interestingly, this stereotype is acquired prior to the age that self-concepts about mathematics emerge (Del Rio et al., 2018[16]). Moreover, girls in this age range receive equal or higher school grades in maths than boys (Hyde et al., 2008[17]), and they do equally well on standardised maths tests (Mullis, Martin and Foy, 2008[18]). Thus, the adoption of the maths stereotype and the gender-related differences in maths self-concepts precede actual differences in maths achievement. This has societal and educational implications, as discussed in the final section.

Cross-cultural studies on children's maths stereotypes and self-concepts: Singapore

Rationale

Singaporean children excel in maths, consistently ranking in the top two or three top countries in the world on standardised tests, ahead of the United States and other OECD countries (Mullis, Martin and Foy, 2008[18]). We conducted cross-cultural work in Singapore to: 1) examine maths stereotypes and self-concepts in high-achieving children; and 2) assess children's actual maths achievement and its relation to our psychological factors.

Evidence

An interesting developmental picture has emerged from our research with four key points (Cvencek, Meltzoff and Kapur, 2014[19]; Cvencek, Kapur and Meltzoff, 2015[20]). First, the Singaporean children exhibited a maths–gender stereotype, but did so at a slightly weaker level than their same-age US counterparts. Second, Singaporean children's maths–gender stereotypes increased as a function of age. Although the younger Singaporean children did not show significant evidence of the stereotype (whereas US children did), the older Singaporean children began to exhibit the stereotype. Third, there was a significant relation between children's implicit maths self-concepts and their actual maths achievement. There was no such correlation between the explicit self-report measure and actual maths achievement, underscoring the value of implicit measures. Fourth, we found mathematical evidence for "cognitive consistency", that is, we found that the strength of children's maths–gender stereotypes, together with their gender identity, significantly predicted their maths self-concepts. That is, the psychological constructs were related in a consistent and balanced way. Those particular boys who strongly identified with being a boy, and thought that *maths = boys*, also tended to have strong maths self-concepts (which significantly predicted actual maths achievement).

Why it matters

Even in Singapore, where boys and girls both excel in this domain compared to their peers in other cultures, children tend to have stereotypes linking maths with boys. Based on what is known about school grades and performance on standardised tests of maths achievement, both within this study and on TIMSS (Trends in International Mathematics and Science Study) (Cvencek, Kapur and Meltzoff, 2015[20]; Mullis, Martin and Foy, 2008[18]). Singaporean boys and girls are not developing maths–gender stereotypes based on differences in actual achievement (because boys do not outperform the girls on these measures of achievement). Why would Singaporean children hold the stereotype that "maths is for boys"?

Possible sources of the stereotype include parents/family members, peers, teachers, the worldwide web, and media messages. American print media and television programmes are freely available in Singapore. Fully 98% of children aged 7 to 14 have accessed the Internet in the past 12 months, and 76% of Singapore households have regular access to the Internet. It is possible that Western cultural stereotypes reach Singaporean children through the web and other electronic and print media. Also, many Singaporean adults espouse stereotypical views about gender and academic subjects (Nosek et al., 2009[9]), and children may be likely to adopt the stereotypes of their grandparents and parents. In current studies we are investigating whether children pay particular attention to the maths stereotypes of their own father and mother and the degree to which this interacts with the child's own gender (Del Rio et al., 2018[16]). Finally, Singapore is a collectivist culture that values traditionally masculine gender roles. It also prides itself on its educational system, especially the world-famous "Singapore maths" programmes. Because children seek a consistent and balanced organisation of their beliefs, they may come to associate two highly valued categories (i.e. maths and males) with each other.

What can be done? Bridging between psychological science and education

Children are extremely social and pay special attention to others who they judge to be "like me". Meltzoff (Meltzoff, 2007[21]; Meltzoff, 2013[22]), has argued that this drive to identify with others "like me" and to form social groups begins in infancy. This is a fundamental

social drive before language and formal schooling and indeed may have neuroscience correlates (Meltzoff and Marshall, 2018[23]). There are benefits of this deep-seated sociality, but it also has costs. One cost is that it leaves our human young vulnerable to the pervasive and sometimes pernicious stereotypes about their own social group.

By preschool or earlier, children develop a sense of gender identity. Many children identify with being a boy or a girl, and feel a sense of belonging to their own gender group. Meltzoff's "like-me" social developmental theory (Meltzoff, 2007[21]; Meltzoff, 2013[22]), proposes that children have heightened attention to how society treats others of their own gender – others identified as "like me". Children's sense of belonging to a social group (based on gender) makes them vulnerable to rapidly acquiring cultural stereotypes about their gender. Children apply the cultural stereotypes about their social group to their own emerging individual identities (self-concepts). On top of this, children seek consistency or "balance" between societal expectations about how people "like me" can and should act and their own sense of self. Thus, when adults in the culture hold strong stereotypes about gender, young girls (similarly to adults) may experience: *me = girl*, *girl ≠ maths*, therefore *me ≠ maths*. Research with adults demonstrates that college age (and older) women sometimes feel conflicts between being a female and identifying with STEM disciplines that are not stereotypically associated with women in their society (Master, Cheryan and Meltzoff, 2016[24]; Nosek, Banaji and Greenwald, 2002[25]). Obviously, women may also excel in stereotypically male disciplines, but such success may be accompanied by extra psychological pressures that are not experienced by their male counterparts.

Our central thesis is that these psychological pressures begin to exert themselves early in development. Once stereotypes are internalised, students may begin to devalue particular school subjects, not because they have experienced difficulties with those subjects in the past, but because the stereotypes connote that they may experience difficulties in the future. A tendency to organise social knowledge in a way that is cognitively consistent or balanced implicates maths–gender stereotypes as an early developing "mental filter" that differentially influences boys' versus girls' developing maths self-concepts. This can, in turn, influence their maths achievement and aspirations for the future. Cultural stereotypes block or dissuade many young girls from engaging in certain maths and STEM-related activities, with the cost that society misses out on the potential contributions of large numbers of our youth. This also squarely raises issues about gender equity.

Translational impact

The scientific findings provide information that may be of practical use to teachers. For example, Carol Dweck (Dweck, 2006[26]) has shown that "mindsets" influence learning, and this has been extended to learning about STEM (Master, Cheryan and Meltzoff, 2016[24]). It is likely that cultural stereotypes about maths contribute to some girls' belief that they lack maths ability and perhaps nudges them towards a mindset that this is an inherent state (linked to their gender), which may prompt them to put less effort into mathematics. This immediately suggests "convergence research" in which scientists and practitioners co-operate to design valid and reliable ways to both 1) identify such beliefs early in development (when they may be malleable) and also 2) to design intervention tools to change this trajectory.

Regarding the early identification issue, our child implicit measures are easily administered, psychometrically sound and extremely sensitive to individual differences. Implicit measures have the potential to be used, alongside other already existing batteries, as diagnostic, teacher-administered tools to identify students who are at risk for lower

academic performance. Regarding the design of interventions for young students, one could seek to change their beliefs and motivation about maths (Master, Cheryan and Meltzoff, 2017[4]), their actual maths skills (Clements and Sarama, 2011[27]), or both. Interventions on maths skills are the most common approach, but we suggest that intervening to change young students' beliefs and motivation about maths might also be effective and cost-efficient. Of course, doing both in parallel would be ideal, because the two approaches probably interact with each other in positive ways. Below we offer some speculative ideas about how to use existing research to design interventions to help reduce the impact of cultural stereotypes and improve children's maths self-concepts. The ultimate goal is to have young children approach and enjoy maths and other STEM disciplines. By changing students' underlying beliefs and attitudes, we may in turn influence their behavioural choices and engagement with maths-related activities, and thereby contribute to enhancing skills and achievement.

Interventions targeting students' thoughts and feelings about school – rather than solely teaching children academic content – can have long-term effects on educational performance (Dweck, 2006[26]). Building on this work, we believe that interventions concerning children's maths stereotypes and self-concepts can be designed in an age-appropriate fashion for elementary school children. One possible way to strengthen young students' identification with maths is to have them "approach" maths. At the most basic level, approach behaviours can be conceptualised as pulling something or someone towards one's body. Work with adults found that training female college students – who initially had weak implicit maths self-concepts – to approach maths by pulling a joystick towards themselves increased their implicit maths self-concepts relative to those who were trained to avoid maths by pushing a joystick away (Kawakami et al., 2008[28]). We are working on designing a similar intervention for elementary school children.

Another possible intervention derives from providing young children with an opportunity to affirm their identity as a maths learner, along the lines that has been used with older students (Yeager and Walton, 2011[29]). It would be possible to have very young children reflect on how good they are at numbers or maths, and have them generate some reasons why it is important to be good at this activity, which could have longer-term benefits for children's motivation and learning in maths. Another promising direction is to re-design the classrooms and curricular resources to remove gender stereotyping and convey a broader diversity of people who are associated with and good at maths (and STEM more generally) (Cheryan, Master and Meltzoff, 2015[30]).

Designing early interventions can have cascading and cumulative effects as the child develops. Early interventions may be particularly effective due to the malleability of maths stereotypes and self-concepts during their embryonic stage, when first being acquired. Interventions involving the whole family – parents and siblings included – warrant special attention. The family is often the young child's first "culture;" parents/close-kin have a powerful influence of children's developing sense of identity, who they are and what they aspire to become.

Society will profit from a convergence of multiple scientific disciplines co-operating to address scientific puzzles that address societal concerns. In psychology and education, a goal is to develop and scale up interventions that help children reframe or resist the effects of stereotypes and increase their identification and joyful engagement with mathematics and other STEM disciplines. By investigating children's stereotypes, identity, and maths outcomes we can contribute evidence-based information that can help achieve this end.

This may provide a showcase example of how the science of learning can fulfil its potential for advancing practical responses to problems that matter to society.

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