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From classroom environment to mathematics achievement: The mediating role of self-perceived ability and subject interest

Maria G. Tosto [a,c], Kathryn Asbury [a,*], Michèle M.M. Mazzocco [e], Stephen A. Petrill [f], Yulia Kovas [b,c,d]

[a] Psychology in Education Research Centre, Department of Education, University of York, York YO10 5DD, United Kingdom
[b] Department of Psychology, Goldsmiths, University of London, London SE14 6NW, United Kingdom
[c] Department of Psychology, Tomsk State University, 36, Lenina Avenue, Tomsk 634050, Russia
[d] SGDP Centre (PO80), Institute of Psychiatry, King's College London, De Crespigny Park, London SE5 8AF, United Kingdom
[e] Institute of Child Development, University of Minnesota, Minneapolis, MN 55455, United States
[f] Department of Psychology, The Ohio State University, Columbus, OH 43210, United States

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ABSTRACT

Drawing on Bandura's triadic reciprocal causation model, perceived classroom environment and three intrapersonal factors (mathematics self-efficacy, maths interest and academic self-concept) were considered as predictors of test performance in two correlated mathematics assessments: a public examination (GCSE) and an online test, both taken by UK pupils at age 16 (n = 6689). Intrapersonal factors were significantly associated with both test scores, even when the alternative score was taken into account. Classroom environment did not correlate with mathematics achievement once intrapersonal factors and alternative test performance were included in the model, but was associated with subject interest and academic self-concept. Perceptions of classroom environment may exercise an indirect influence on achievement by boosting interest and self-concept. In turn, these intrapersonal factors have direct relationships with achievement and were found to mediate the relationship between perceived classroom environment and maths performance. Findings and their implications for mathematics education are discussed.

1. Introduction

1.1. The importance of mathematics

Maths matters. International surveys predict an increase of almost 1% in annual GDP growth per capita with half a standard deviation's increase in individual maths and science performance (OECD, 2010). In addition to predicting national wealth, mathematical skills are associated with socio-economic well-being. For example, longitudinal research in the UK suggests that people with poor mathematical skills are more than twice as likely as those with better skills to be represented at the lowest level of employment, and are at increased risk of poor mental and physical health (Bynner & Parsons, 2005).

In England and Wales the public examination taken at age 16 (GCSE: General Certificate of Secondary Education) really matters, having lifelong implications. GCSE maths is graded from A* (A-star) to G, and Grade C is the minimum requirement for many educational and employment opportunities. Students who do not achieve a C in maths are not eligible to study certain A Level subjects (Advanced qualifications for UK 16+ year olds); will not be accepted by some technical and vocational courses; and are unlikely to be accepted at University. The number of employment opportunities requiring a minimum of Grade C is constantly growing. Grade C, therefore, is a minimum requirement for accessing many opportunities the adult world has to offer, and achieving it is an important hurdle for young people to overcome. And yet, in summer 2014, 42.4% of candidates for GCSE maths achieved less than Grade C (Joint Council for Qualifications, 2014).

1.2. Explaining individual differences in mathematics

To some extent, people differ in mathematics achievement because they vary in abilities that are important for learning mathematics. For example, individual differences in maths performance have been found to be associated with individual differences in memory (Swanson & Sachse-Lee, 2001), processing speed (Geary, 2011; Taub, Keith, Floyd, & McGrew, 2008), intelligence (Deary, Strand, Smith, & Fernandes, 2007), attention (Dulaney, Vasilyeva, & O'Dwyer, 2015), language ability (Vukovic & Lesaux, 2013) and spatial skills (Rohde & Thompson, 2007; Tosto et al., 2014).

A robust body of research further suggests that individual differences in motivation are also associated with maths achievement (Elliot & Dweck, 2005; Robbins et al., 2004). Academic motivation includes the value that individuals place on a subject, their expectation

* Corresponding author.
E-mail address: kathryn.asbury@york.ac.uk (K. Asbury).

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of succeeding in it (Eccles & Wigfield, 2002), and whether they like and are interested in it (Marsh, 1986). In addition, the place where learning happens has been found to influence learning outcomes (Pianta, Belsky, Houts, & Morrison, 2007; Young, 2005). In summary, learning mathematics appears to be linked to factors related to both motivation (intrapersonal factors) and the wider world (learning environments) as consistently as it is with cognitive abilities. Bandura's triadic reciprocal causation model predicts dynamic relationships between intrapersonal factors, behaviour (learning) and the environment (Bandura, 1986, 2012) and this theoretical framework forms the basis for the current study's hypotheses. We evaluate the extent to which individual differences in mathematics achievement are associated with three intrapersonal factors and one learning environment.

1.3. Self-perceived abilities and interest in maths

The current study assesses self-efficacy for mathematics, academic self-concept and subject interest in relation to mathematics performance and perceptions of the classroom environment.

Maths self-efficacy refers to an individual's belief in their ability to perform a specific maths task in a specific context (Bandura, 1977; Pajares, 1996). Self-efficacy beliefs about mathematics tasks have been found to be strongly associated with mathematics achievement (e.g. Hackett & Betz, 1989; Hoffman & Schraw, 2009; Pietsch, Walker, & Chapman, 2003). The relationship is likely to be reciprocal, as predicted by social cognitive theory: achieving well in maths may foster the belief that you are good at maths which in turn may foster mathematical achievement – a two-way street (Marsh & Craven, 2006; Williams & Williams, 2010).

Academic self-concept reflects an individual's assessment of their own general academic self-worth, based on past performance as well as their performance relative to others (Williams & Williams, 2010). Academic self-concept has been associated with both general school achievement (Hattie, 1992; Valentine, DuBois, & Cooper, 2004) and maths-specific achievement (Marsh, 1986).

Maths interest relates to people's intrinsic motivation to acquire new mathematical skills. The association between subject interest and achievement is complex. Stable interest in particular academic subjects has been found to predict achievement in those subjects but, indirectly, through the mediating effects of self-regulation (Lee, Lee, & Bong, 2014). In mathematical learning, maths interest has been studied to understand pupil motivation for engaging in mathematics activities (e.g. Wigfield & Cambria, 2010). Using a longitudinal design, Marsh, Köller, Trautwein, Lüdtke, and Baumert (2005) reported a positive correlation between mathematics interest and achievement that may have been mediated by a reciprocal relationship between interest and mathematics self-concept. This study also suggested that the mathematical component assessed may affect study outcomes as both mathematics self-concept and interest were more strongly associated with school grades (average $r = 0.35$) than with standardised mathematics tests (average $r = 0.22$).

There is evidence that individual differences in aspects of motivation emerge as early as primary school and that such factors predict future learning (Masters & Santrock, 1976; Mazzocco, Hanich, & Noeder, 2012). A recent study found that motivation towards mathematics at age 11 accounted for variance in mathematics achievement at age 16 beyond that explained by cognitive ability (Murayama, Pekrun, Lichtenfeld, & vom Hofe, 2013). The researchers also found that motivation and learning strategies were associated with growth in achievement, whereas cognitive ability was associated with concurrent achievement but not growth (Murayama et al., 2013).

In addition to research reporting individual differences in motivation as early as primary school (Mazzocco et al., 2012), several studies have observed a general decline in academic motivation during early adolescence, which parallels a decline in academic achievement (Frenzel, Goetz, Pekrun, & Watt, 2010; Meece, Anderman, & Anderman, 2006). Research investigating associations between self-perceived abilities and achievement could potentially help here by building an evidence-base for developing new systems aimed at maintaining pupils' interest in maths, and their self-perceived ability, at least to the extent that they reach the required standard for good educational and occupational choices at the end of compulsory schooling. Beyond that, intrapersonal factors such as maths self-efficacy, maths interest and academic self-concept appear related to decisions about pursuing advanced levels of mathematical training, or occupations with a mathematical component (Van den Broeck, Opdenakker, & Van Damme, 2005; Wang, 2012). Promoting interest and self-belief in students with the ability to pursue mathematics to a high level may be a relevant consideration.

1.4. Perceptions of the classroom environment

It is important to seek insight into the development of individual differences in intrapersonal factors which may vary across learning environments (Bandura, 2012). Several studies have found that *Classroom Environment*, or perceptions thereof, are related to both self-efficacy beliefs and maths achievement (Danielsen, Wiium, Wilhelmsen, & Wold, 2010; Eccles & Roeser, 2011; Schunk, 1982; Schunk, 1984; Schunk & Hanson, 1985; Wentzel, Battle, Russell, & Looney, 2010; Eshel & Kohavi, 2003). One study of the relationships between perceptions of the classroom environment, intrapersonal factors and maths achievement in 10 year-old children found that pupils who perceived their maths classrooms as caring, challenging and mastery oriented reported significantly higher levels of maths self-efficacy (Fast et al., 2010). In turn, having higher levels of maths self-efficacy was positively associated with maths performance. Interestingly, in this study self-reported classroom environment did not show any direct relationship with maths achievement. Conversely, the results of another study suggested a direct association between perceptions of the classroom environment, derived through observational measures and gains in test performance (Pianta et al., 2007). A further study, using self-reported perceptions of chemistry classrooms found an indirect relationship with both achievement and intrinsic motivation via achievement goals (Church, Elliot, & Gable, 2001). Inconsistencies in the literature may reflect different measures and definitions of classroom environment as well as complex inter-relationships between learning environments, intrapersonal factors and achievement. As academic motivation tends to decline with age, academic subject, age and developmental stage may also be important to perceived classroom environment. Two of the studies mentioned above were focused on pupils in middle childhood rather than adolescence and the third involved undergraduates studying chemistry (Church et al., 2001). It is possible that relationships between intrapersonal measures, environmental measures and achievement may differ by subject, and by age, and in the current study we focus specifically on mathematics at age 16.

1.5. Aims and hypotheses

Findings about inter-relationships between learning environments, achievement and intrapersonal factors have been somewhat heterogeneous. Some of this heterogeneity may have derived from how constructs are operationalized and which mathematical components have been assessed. The current study aimed to increase understanding of the relationship between mathematics as assessed by GCSE school achievement and tests, three intrapersonal factors, and a maths learning environment. It used data from a large representative sample of UK 16-year-old students, many of whom are at the end of their mathematics education (UK students are not required to pursue mathematics beyond GCSE). The sample is spread throughout the UK and was drawn from the full range of schools in the UK therefore controlling, to some extent, for school type.

The study aimed to explore whether, at this particular age and educational stage, a process of triadic reciprocal causation will be observed,