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Affect and mathematics in young children: an introduction

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Abstract
Mathematics-related affect comprises an individual's attitudes, beliefs, emotions and motivations towards mathematics. These affective constructs have been widely studied in mathematics education and cognitive psychology and have been shown to be related to cognitive outcomes such as performance on a range of mathematical tasks. However, it is not yet clear how these constructs develop, or how they relate to cognitive factors in young children who are in the early stages of learning mathematics. As such, the current special issue focuses on mathematics-related affect in primary school children aged 4 to 10 years. It brings together five recent empirical studies and two discussant articles looking at the development of attitudes, beliefs, emotions and motivations towards mathematics, and the relations between affective and cognitive factors in these young age groups. In this introductory paper, we provide some brief historical context, followed by a rationale for the special issue, and an overview of its structure and scope.

It is widely acknowledged that the development of expertise in a particular field depends not only on cognitive skills, but also on the attitudes, beliefs, emotions and motivations of the learner. These dispositions or affective factors may to some extent be pre-disposed, but also influenced by the learning environment, and thus they have been a topic of growing interest in education (Linnenbrink, 2006). This is noticeably the case in the domain of mathematics (e.g., Zan, Brown, Evans, & Hannula, 2006), likely because mathematics is a subject which is typically perceived to evoke strong and often negative reactions (Dowker, Sarkar, & Looi, 2016).

A wealth of studies from mathematics education and cognitive psychology have advanced our theoretical frameworks and methodological tools for studying affect in mathematics (see, for example, Hannula et al., 2016, for a recent overview of the field). However, studies have tended to focus on older children and adults. It is not yet clear how attitudes, beliefs, emotions

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and motivations towards mathematics develop, and how they might interact with cognitive factors in the preschool and early primary school years. This special issue brings together five recent empirical studies and two discussant articles that focus on the development of, and interactions between, affective and cognitive factors in these young age groups. Together, the contributions cover a range of affective components, giving us complementary insights into children's emerging dispositions towards mathematics and the relations between affective and cognitive factors.

In this introduction, we first provide some brief historical perspectives with an overview of the theories and methods developed for studying affect in mathematics. Next, we consider the importance of studying affect in young children who are in the early stages of acquiring formal mathematical skills. We discuss the challenges associated with studying such young age groups and the current state of research. Finally, we outline the scope and structure of the special issue.

1 Affect and mathematics: historical context

Research into the affective aspects of learning mathematics can be seen to date back to studies on mathematics anxiety and attitudes to mathematics in the early 1960s, and it has evolved considerably in the last 60 years (Dowker et al., 2016; Goldin, 2009; Goldin, Röskin, & Törner, 2009; McLeod, 1994; Zan et al., 2006). At present, the field of affect is perhaps best characterised by the richness and diversity of its theories and concepts. The term "affect" has been defined in many ways, both within mathematics education and more generally within education and psychology (see, for example, Malmivuori, 2001, for a review of definitions in the affective domain). In its narrowest sense, it is used to refer to a person's feelings and emotions (e.g., Anderson, 1981; Mandler, 1989), while in its broadest sense it is used as an umbrella term to describe a whole host of variables that are not purely cognitive, encompassing also attitudes, beliefs and motivations (e.g., Zan et al., 2006).

With a growing number of studies on a wide array of affective constructs, there have been increasing concerns over poorly defined variables and "fuzzy" definitions. The need to clarify and consolidate concepts and theoretical frameworks has dominated much of the literature since the late 1980s (Fennema, 1989; Hart, 1989; McLeod, 1989; McLeod & Adams, 1989). Several publications including a special issue on affect in mathematics education published in *Educational Studies in Mathematics* in 2006 (Zan et al., 2006) demonstrate that conceptual clarification has been (and remains) a primary focus. Here we will not attempt an in-depth review of the debates around conceptual clarification, but we will give an overview of the key developments and main constructs in the field in order to put the contributions to the current special issue in context.

1.1 The traditional approach to measuring mathematics-related affect

Early studies on mathematics-related affect drew on psychological theories and methods that used a quantitative approach to measure attitudes and anxiety. The 1960s and 1970s saw the development of a number of Likert scale questionnaires, most notably the Mathematics Anxiety Rating Scale (MARS; Richardson & Suinn, 1972) and the Mathematics Attitude Scales (Fennema & Sherman, 1976). These were used widely to look at the relations between affect and performance and to explore gender differences in mathematical outcomes (see

Hembree, 1990; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; and Ma & Kishor, 1997, for reviews). As the research grew and the array of measurement tools expanded, there was a shift towards seeing attitudes and anxiety as multidimensional affective constructs (Aiken, 1974), rather than unidimensional variables that could be assessed with a single measurement scale. For example, the Mathematics Attitude Scales (Fennema & Sherman, 1976) comprised nine separate subscales measuring: attitudes towards success in mathematics; beliefs about mathematics as a male domain; perceptions of mother, father and teacher interest, encouragement and confidence in one's mathematics ability; confidence in mathematics; mathematics anxiety; motivation; and beliefs about the usefulness of mathematics.

1.2 A reconceptualization of mathematics-related affect

In the 1980s, the traditional measurement approach to attitude research became increasingly criticised for its lack of a strong theoretical basis (e.g., McCleod & Adams 1989). There were concerns that researchers were defining affective constructs merely by the questionnaires used in their research (e.g., Leder, 1985), and that neither the relationships among affective constructs, nor the mechanisms through which they play a role in the mathematics classroom were clear (e.g., McLeod, 1988). There was a move towards using more qualitative research methods such as observations and interviews to gain a richer understanding of the interplay of affective factors in real life mathematical learning situations. This research largely came from socio-cultural and socio-constructivist perspectives and centred on mathematical problem-solving activities. It opened several new avenues of research in mathematics-related affect with questions around metacognition, beliefs about mathematics and motivational aspects such as students' self-efficacy (e.g., Garofalo, 1989; Garofalo & Lester, 1985; Lester, Garofalo, & Kroll, 1989; McLeod, 1988; Schoenfeld, 1989; Silver, 1985).

The publication of the book *Affect and Mathematical Problem Solving: A New Perspective* (McLeod & Adams, 1989) marked a turning point in the field of mathematics-related affect, and this was shortly followed by a new theoretical framework for research in the affective domain (McLeod, 1992). As described by Di Martino (this issue), McLeod categorised affect into three main constructs: beliefs, attitudes and emotions, which vary in their stability and intensity. All three aspects of affect are considered in the current special issue, with the addition of motivations, a lesser studied construct in mathematics education, but one which has been widely investigated within education and psychology more generally.

According to McLeod's (1992) conceptualisation, beliefs are the most stable, least intense of the affective constructs. Research into beliefs has included beliefs about mathematics as a subject, beliefs about oneself in relation to mathematics, beliefs about mathematics teaching and beliefs about the social context (see, for example, Leder, Pehkonen, & Törner, 2006). In contrast to beliefs, emotions are considered the least stable, most intense aspect of affect, and they are harder to study given their changeable nature. Closely tied to beliefs and emotions are attitudes which McLeod (1992) defines as "positive or negative feelings of moderate intensity and reasonable stability" (p. 581). Attitudes are a somewhat controversial aspect of McLeod's framework as they are often defined as consisting of beliefs and emotions (Hannula et al., 2016). Finally, motivational aspects have been shown to be related to emotional experiences and include constructs such as interest, persistence and self-efficacy (e.g., Berhenke, Miller, Brown, Seifer, & Dickstein, 2011; Pekrun, Goetz, Titz, & Perry, 2002).

Beliefs, attitudes and motivations have largely been measured through traditional methods such as self-reports and questionnaires, although there are exceptions that have used qualitative

interviews and narrative methods, particularly for the measurement of beliefs (see, for example, Di Martino, this issue). The measurement of emotions can be seen to have involved a wider variety of methods. Emotions have often been investigated in the context of problem-solving (e.g., the "Aha!" experience (Liljedahl, 2004)), and they have been measured both qualitatively through interviews (e.g., Hannula, 2002; Op't Eynde, De Corte, & Verschaffel, 2006) and quantitatively through questionnaires and physiological measures such as heart rate, skin conductance and cortisol secretion (Dew, Galassi, & Galassi, 1984; Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011). In the next section, we consider these affective variables in relation to young children's mathematics-related affect.

2 Affect and mathematics in young children

Research on affect in mathematics has mainly focused on older children and adults, with several studies showing that affective factors are related to mathematics achievement, and that attitudes towards mathematics decline throughout the late primary and secondary school years (Hernandez-Martinez & Pampaka, 2017; Ma & Kishor, 1997; Wigfield & Meece, 1988). It is only in the last decade or so that the importance of early mathematical outcomes has become increasingly recognised and researchers have started to develop tools for measuring affective constructs in young children. The literature on attitudes to mathematics and mathematics anxiety has been particularly rife with new questionnaire-based measures (see, for example, Table 1 in Ganley & McGraw, 2016, for a summary of mathematics anxiety measures for primary school aged children). Petronzi, Staples, Sheffield, Hunt, and Fitton-Wilde (this issue) add to these new measures with a pictorial mathematics anxiety scale for children as young as 4 years.

Although there are now many self-reports for measuring young children's attitudes to mathematics and mathematics anxiety, it is not yet clear how these attitudes and emotions develop, and how they relate to concurrent and future mathematical skills. Some studies have found an association between young children's mathematics anxiety and their mathematics performance (Ramirez, Gunderson, Levine, & Beilock, 2013; Vukovic, Keiffer, Bailey, & Harari, 2013; Wu, Barth, Amin, Malcarne, & Menon, 2012), whilst others have not (Dowker, Bennett, & Smith, 2012; Haase et al., 2012; Hill et al., 2016; Krinzinger, Kaufmann, & Willmes, 2009). As such, researchers are continuing to explore the interplay between attitudes, emotions and performance in young children (e.g., Dowker, Cheriton, Horton, & Mark, this issue; Passolunghi, Cargnelutti, & Pellizzoni, this issue; Petronzi et al., this issue). There are efforts to uncover the relations between different attitudinal components (e.g., Dowker et al., this issue; Jameson, 2014) as well as the links with domain general and domain specific cognitive skills (Cargnelutti, Tomasetto, & Passolunghi, 2017; Passolunghi et al., this issue; Wu et al., 2017). Within this literature, some researchers conceptualise mathematics anxiety as an attitude (e.g., Dowker et al. this issue) focusing largely on the cognitive aspects of anxiety such as the worrisome thoughts. Others conceptualise mathematics anxiety as an emotional factor, focusing more on the behavioural reactions (e.g., mathematics avoidance) and physiological responses (e.g., increased heart rate) (e.g., Passolunghi et al., this issue). The different foci within measures of mathematics anxiety may help to explain the currently mixed findings in the field (Dowker et al., 2016).

There are of course some challenges associated with measuring affective constructs in young children. Questionnaire-based measures have to be carefully constructed to ensure they are age-appropriate, and even then, very young children may struggle to provide reliable self-reports. Moreover, questionnaires do not provide in-depth information about how attitudes, beliefs, emotions and motivations manifest in a mathematical learning or performance situation. They tend to be trait-based measures rather than state-based measures. Some researchers have preferred to use indirect measures such as teacher ratings of children's motivations (e.g., Lepola & Hannula-Sormunen, this issue). Other researchers have used creative interviewing techniques and narratives to gain insights into primary school children's beliefs about mathematics (e.g., McDonough & Sullivan, 2014). This special issue presents a variety of methods which can be taken forward and further developed to advance our methodological tools for studying affect in young children. Given the varied and complex nature of the affective domain, it is likely that a combination of methods is needed to help us understand how different affective constructs interact, and how they relate to mathematical development in this age group.

3 Overview of the special issue

Several studies have shown significant and long-lasting effects of early mathematical outcomes on later mathematical success (e.g., Duncan et al., 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Reeve, Reynolds, Humberstone, & Butterworth, 2012). As such, there has been a growing body of research into the cognitive foundations of mathematics (e.g., Rittle-Johnson & Jordan, 2016). Research with older children and adults has demonstrated that affective factors are associated with cognitive outcomes, thus a better understanding of the development of young children's attitudes, beliefs, emotions and motivations towards mathematics may help us to foster early mathematical skills.

This special issue aims to shed light on the current state of research on young children's mathematics-related affect and its relation with cognitive outcomes. It seeks to complement the previous special issue on affect in mathematics education published in *Educational Studies in Mathematics* in 2006 (Zan et al., 2006), which compared different theoretical frameworks for studying affect without specific attention to measurement issues, relations with mathematics performance, or the early years of mathematics education. The five empirical contributions include samples of children ranging 4–10 years, each paper focusing on one or two of the affective constructs identified above.

In the first contribution, Dowker et al. investigate attitudes to mathematics in English and Chinese first graders, aged 6 years. They focus on four attitudinal components, namely children's mathematics anxiety, liking for mathematics, unhappiness at poor performance in mathematics and self-rating in mathematics. By examining both their interrelations and their associations with mathematical performance, they deepen our understanding of the key attitudes that may be important for early success in mathematics. Moreover, comparisons between the Chinese and English samples provide novel insights into the interplay of affective factors in young children in different educational settings.

The second contribution of Petronzi et al. focuses specifically on mathematics anxiety, one of the most prominently studied aspects of math-related attitudes and emotions. Petronzi et al. report on the development of the Children's Mathematics Anxiety Scale—UK (CMAS-UK), a new pictorial Likert scale questionnaire for children aged 4 to 7 years. In developing and

validating the CMAS-UK, they extend the available tools for measuring mathematics anxiety in the first years of school, and they further our understanding of the interplay between anxiety and performance in early years mathematics education.

In the third contribution, Lepola and Hannula-Sormunen present a longitudinal study of 6- to 8-year-old children's motivational orientations, domain-specific attention to number (i.e., spontaneous focusing on numerosity; SFON) and arithmetical skills. They shed light on the developmental relations between these variables, deepening our understanding of the direction of the associations between affect (motivations) and early mathematical outcomes. Their use of teacher ratings of affect, rather than direct child assessments or self-reports, is unique to this special issue contribution and it offers a complementary tool for researchers to consider using when working with particularly young age groups.

In the fourth contribution, Passolunghi et al. address the role of mathematics anxiety on a specific aspect of mathematics achievement that is arithmetical problem-solving skills. Their sample consists of 10-year-old children, the eldest age group considered in this special issue, and they include measures of domain-general cognitive skills (processing speed and working memory) as well as domain-specific mathematical skills. The inclusion of these domain general skills, which have been shown to be important for mathematics learning and performance, helps to build a broader picture of the interplay between affect and cognition within this special issue and opens several avenues for future research.

The fifth contribution of Di Martino provides an in-depth qualitative analysis of primary school children's views of mathematical problems. It complements the previous contributions not only in its methodology (qualitative rather than quantitative), but also in terms of its theoretical scope and the sample of children studied. Using a three-dimensional framework of attitudes, beliefs and emotions, Di Martino examines, cross-sectionally, the evolution of children's characterisation of a "problem" from kindergarten to the end of primary school. In doing so, he offers richer descriptive information on the development of math-related affect across the whole age range of children covered in this special issue.

The five empirical studies are followed by two discussion papers, the first from Markku Hannula, a specialist in mathematics-related affect, and the second from Andreas Obersteiner, a specialist in the mathematical learning of young children. In their discussion articles, Hannula and Obersteiner reflect on the critical issues and findings in the different contributions, the educational relevance and the potential directions for future research.

4 Note

The initiative for this special issue grew out of a workshop entitled "Beyond the cognitive side of expertise", October 12–14, 2016, Irish College Leuven, organised by the Scientific Research Community: WO.008.14N "Developing competencies in learners: From ascertaining to intervening", of which the University of Leuven is coordinator, and sponsored by the Fund for Scientific Research-Flanders. However, the specific themes addressed in the special issue and the authors involved coincide only partially with those involved in that workshop.

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