



The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievement: A multilevel analysis of the Programme for International Student Assessment data



Vasiliki Pitsia ^{*,1}, Andy Biggart, Anastasios Karakolidis

School of Social Sciences, Education and Social Work, Queen's University Belfast, United Kingdom

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ABSTRACT

Non-cognitive factors have been considered as particularly important aspects in shaping students' academic achievement. The current study aimed to examine a number of these factors in relation to the prediction of mathematics achievement among a representative sample of students in Greece. The sample consisted of 5125 15-year-old students who participated in the Programme for International Student Assessment (PISA) 2012. The study considered the extent to which students' mathematics self-beliefs, motivation to learn mathematics and attitudes towards school contributed to the prediction of their mathematics achievement. Multilevel modelling assessed both individual and school level variation, revealing that students' mathematics self-efficacy, anxiety, self-concept, instrumental motivation and attitudes towards school were statistically significant predictors of their mathematics achievement, even after controlling for their gender and school socio-economic status (SES). Policy implications are discussed based on the findings of the current research study.

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1. Introduction

The investigation of the factors that can have meaningful relationships with learning and academic achievement has frequently been the focus of educational research. As a result, theorists, researchers, educators and policy makers are provided with valuable information (Kupari & Nissinen, 2013). In particular, factors stemming from students' background, such as gender and socioeconomic status (SES) have been the focus of many studies and appear to be particularly salient for students' academic achievement (Areepattamannil, 2014; Hattie, 2009). Apart from the background characteristics though, non-cognitive factors have also been examined in the existing research literature as individuals who are otherwise similar tend to construe themselves differently based on the attributes they feel they possess, their confidence to employ them and others' judgements (Bandura, 1997; Bong & Skaalvik, 2003). Once these perceptions are established, they act as determinants of action and further development at the cognitive, social and emotional levels and consequently of academic achievement (Bandura, 1997; Bong & Skaalvik, 2003; Guay, Ratelle, Roy, & Litalien,

2010; Lee & Stankov, 2013; Stankov, 2013). However, studies that simultaneously examine the relationships between non-cognitive variables and academic achievement through multilevel analyses are scarce, highlighting a weakness of the existing research literature.

1.1. Mathematics literacy and the case of Greece

Mathematics constitutes one of the key competences for personal fulfillment and participation in school, society and the labor market of the 21st century (European Commission, 2011). It also appears to be a critical academic filter for students' educational pathways (Chiu & Klassen, 2010; Crombie et al., 2005; Wang, 2006). PISA, which is one of the largest international assessment studies in education, has revealed that a large proportion of students internationally are low achievers in mathematics, with this proportion being particularly high in Greece (OECD, 2014a).

Moreover, the education system in Greece is characterised by an outdated and ineffective structure, and policy initiatives by successive governments have been haphazardly applied (OECD, 2011a). Greece is also one of the few countries in Europe that lacks any form of external audit and assessment of teaching and school organisation (OECD, 2011a, 2015). PISA is the only indicator that provides information on the efficiency of the Greek educational system (OECD, 2011b, 2015).

* Corresponding author.

E-mail addresses: vpitsia01@qub.ac.uk (V. Pitsia), a.biggart@qub.ac.uk (A. Biggart), anastasios.karakolidis@dcu.ie (A. Karakolidis).

¹ Dublin, Ireland.

1.2. Rationale and aim

Given the above and the ongoing economic crisis in Greece, which can have a great influence on adults' and students' self-beliefs, motivation and attitudes and does not permit further monetary stimulus, the urgency of investing in the acquisition of citizens' skills through tackling educational deficiencies has increased (OECD, 2013b).

However, there is a paucity of research studies internationally as well as in the Greek context, that focus on a range of non-cognitive factors simultaneously, while also taking into account students' background to provide a comprehensive picture of the factors that are associated with domain-specific academic achievement. Furthermore, the lack of robust evidence regarding non-cognitive factors is attributed to the fact that most studies employ bivariate or multivariate analyses without considering that students belong to different groups of people (i.e. school, district etc.) when analysing clustered data (Chiu & Xihua, 2008).

Despite the importance of non-cognitive factors, studies undertaking a thorough investigation of this topic including a range of significant non-cognitive factors are scarce. Although a multilevel analysis conducted by Karakolidis, Pitsia, and Emvalotis (2016a) in the Greek context provided meaningful evidence regarding the importance of only some non-cognitive factors (i.e. mathematics self-concept, self-efficacy and anxiety), an in-depth, simultaneous investigation of a range of different non-cognitive factors is missing, not only from the Greek, but from the global research literature as well.

Moreover, due to the overlapping of these factors that research literature has pointed out, their simultaneous investigation through rigorous analysis and the investigation of their interaction effects will detect the actual influence they have on students' academic achievement. Through the application of multilevel modelling and exploring possible interactions between the variables, the present study filled the gap in the existing research literature, and provided valuable research evidence that could be used for policy making not only in Greece but in other countries with similar educational systems as well (European Commission, 2011; Mullis, Martin, Foy, & Arora, 2012; OECD, 2011b).

In particular, the aim of the present study was to examine whether non-cognitive factors, with a particular focus on mathematics anxiety, mathematics self-efficacy, mathematics self-concept, intrinsic and instrumental motivation to learn mathematics and attitudes towards school, predict mathematics achievement of Greek 15-year-old students, while accounting for their gender and school SES.

1.3. Research questions

1. How much of the variability in 15-year-old Greek students' mathematics achievement is distributed within and between schools?
2. Are 15-year-old Greek students' non-cognitive constructs, their gender and school SES significant predictors of their mathematics achievement?
3. How much of the variability in 15-year-old Greek students' mathematics achievement is explained by the student- and school-level variables included in the multilevel model?

2. Literature review

2.1. Student background

2.1.1. Gender

One of the most often considered factors assumed to account for differences in mathematics achievement is gender. However, research findings are not consistent in relation to the role of gender in students' mathematics achievement. In the past there was a prevalent view about boys' superiority, but more recent research has either shown

that girls' performance was superior, or alternatively an absence of gender differences in mathematics performance (Antunes & Fontaine, 2007; Guo, Marsh, Parker, Morin, & Yeung, 2015; Meelissen & Luyten, 2008; Steinmayr & Spinath, 2008).

Two recent large-scale meta-analyses on gender differences in mathematics achievement among adolescents found that girls' and boys' mathematics performances did not differ, or even when they did, the differences were negligible (Else-Quest, Hyde, & Linn, 2010; Lindberg, Hyde, Petersen, & Linn, 2010). These findings are in accordance with Hyde's (2005) "gender similarities hypothesis" which suggests that males and females are similar in terms of most psychological variables as well as their actual levels of mathematics attainment.

Nevertheless, some research studies suggest that gender differences exist in mathematics achievement. Steinmayr and Spinath (2008), who investigated gender differences in adolescents' mathematics performance, supported that the gender gap existed in favor of girls. Moreover, a very recent study examining all PISA cycles from 2000 to 2009 indicated that girls outperformed boys in overall performance, including mathematics (Stoet & Geary, 2015). However, the same authors suggested that boys were more likely to be top performers, an inference also supported by other authors (Gillece, Cosgrove, & Sofroniou, 2010; Mullis et al., 2012; OECD, 2014a; Stoet & Geary, 2015). Other studies have found conflicting results highlighting a gender gap in favor of boys (Arepattamanni, 2014; Byrnes & Miller, 2007). Most authors, though, pointed out that the magnitude of the gender gap has declined in recent years (Else-Quest et al., 2010) and the synthesis of meta-analyses by Hattie (2009) confirmed this conclusion giving an overall effect size of 0.12 (Cohen's *d*), which was considered of minor practical significance. Therefore, due to the inconsistency of the findings in the literature, it is not possible to draw clear conclusions about gender differences in mathematics performance.

2.2. Non-cognitive constructs

2.2.1. Mathematics anxiety

Mathematics anxiety is a domain-specific self-belief which refers to the extent to which students feel helpless or stressed when studying mathematics. It is unlike any other types of anxiety as it appears to affect visual rather than verbal working memory (Marsh, Hau, Artelt, Baumert, & Peschar, 2006; Miller & Bichsel, 2004; Stankov, Lee, Luo, & Hogan, 2012; Stankov, Morony, & Lee, 2014). Large proportions of students admit that they are highly anxious and they report feeling tense and afraid of mathematics, therefore they tend to avoid mathematics related activities and practices which are necessary for mastering mathematics skills. This can also result in the avoidance of career paths that require these skills (Morony, Kleitman, Lee, & Stankov, 2013; OECD, 2013c).

Many research studies, including large-scale studies in different countries, have indicated a strong negative relationship between mathematics anxiety and students' achievement in mathematics, revealing correlations of $r = -0.27$ to -0.57 (Goetz, Cronjaeger, Frenzel, Lüdtke, & Hall, 2010; Lee & Stankov, 2013; Morony et al., 2013; Stankov, 2013; Stankov et al., 2014). Regarding Greek students, Lee (2009) found a correlation of $r = -0.36$ between mathematics anxiety and mathematics achievement based on the PISA 2003 data, concluding that mathematics anxiety is one of the strongest predictors of mathematics achievement among self-beliefs.

2.2.2. Mathematics self-efficacy

Academic self-efficacy consists of people's judgements about their abilities to perform academic tasks, without having to compare themselves with others (Bong & Skaalvik, 2003; Kleitman & Gibson, 2011; Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2014). In particular, mathematics self-efficacy refers to the confidence and the extent to which students believe in their own skills to handle mathematical

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