Title: Predicting Effort Regulation in Mathematics in Adolescents

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Abstract

Objectives: The primary objective of this study was to examine the role of self-efficacy in mathematics and mathematical mindset in effort regulation in mathematics. Effort regulation was defined as “management of effort in learning activities in the face of difficulties”.

Design: A large-scale survey (*N* = 1448) with four cohorts of students in years 7, 8, 9 and 11 (*M* age = 14.0 years, *SD* = 0.46) was conducted.

Methods: 1448 participants, from two comprehensive schools in the UK, completed a pen and paper survey. Demographic characteristics, measures of prior attainment and cognitive ability were provided by the schools.

Results: Findings from this study showed that mathematical mindset and self-efficacy in mathematics both positively predicted effort regulation in mathematics. Furthermore, it appears that the effect of mathematical mindset on effort regulation in mathematics was mediated through self-efficacy in mathematics.

Conclusions: This study provides initial support for the relationship between mathematical mindset and effort regulation in mathematics as a key process, mediated by self-efficacy in mathematics. These results contribute to the current understanding of effort regulation in adolescents and are indicative of possible ways to enhance effort regulation in mathematics. Implications of the findings for future research are discussed.

1 Background and Rationale

The importance of effort regulation for academic achievement is supported by prior research (Komarraju & Nadler, 2013). However, limited research to date has attempted to identify the underlying mechanisms of effort regulation. Despite theorising about the effects of self-efficacy (Bandura, 1997; Schunk & DiBenedetto, 2016) and implicit theories of intelligence (commonly referred to as mindsets; Dweck, Walton, & Cohen, 2014), research has rarely addressed their role as possible predictors of effort regulation, in particular in mathematics. Yet, raising adolescents' effort in mathematics has been a key area of focus for policymakers in the UK since 2005 (Kyriacou & Goulding, 2005; Nunes, Bryant, & Watson; 2009; Education Endowment Foundation, 2017). In this study, the role of self-efficacy in mathematics and mathematical mindset, as predictors of effort regulation in adolescents, were examined using a large-scale survey with four cohorts of students in years 7, 8, 9 and 11. A deeper understanding of these predictors can be the first step in enhancing effort regulation amongst adolescents.

2 Aims and Objectives

The aim of this study was to determine the relative contribution of two possible predictors of effort regulation in mathematics: self-efficacy in mathematics and mathematical mindset.

The key research question addressed in this study is:

RQ: To what extent do self-efficacy in mathematics and mathematical mindset predict effort regulation in mathematics amongst adolescents?

3 Extending the Theory: Proposing a Model of Effort Regulation

Effort regulation in academic settings can be defined as the management of effort in learning activities in the face of difficulties (Kim, Park, Cozart, & Lee, 2015). Effort regulation is positively correlated with adolescents' academic self- efficacy, strategy use and academic achievement (Muenks, Yang, & Wigfield, 2017; Pintrich, 1999). It is suggested that students with high effort regulation achieve better results academically by maintaining effort and persevering, when faced with setbacks, challenges, distractions or boredom, (Kim et al., 2015; Muenks et al., 2017; Pintrich, 1999).

From a social cognitive theory perspective, Pintrich (1999) views effort regulation as a facet of self-regulation that signifies the students' ability to sustain effort and attention on academic tasks, even after they feel bored or in presence of environmental distractions. This is attributed to the fact that learners with high self-efficacy are likely to anticipate success, opt for challenging tasks, and maintain and regulate their effort for learning through strategy use, resulting in positive academic outcomes (Schunk & Zimmerman, 2012). In fact, it has been shown that self-efficacy is critical for facilitating academic effort regulation and enabling learners to maintain their focus on academic tasks (Komarraju & Nadler, 2013).

Similarly, there is a great deal of evidence highlighting the importance of implicit theories of intelligence (commonly referred to as mindsets) for effort regulation and expenditure in adolescents (Dweck et al., 2014; Yeager et al., 2016; Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 2000). Yet, the role of mindsets in affecting effort regulation has not been addressed by research. Endorsing a growth mindset means believing that intelligence can be developed; while holding a fixed mindset means believing that intelligence is static and unchangeable (Dweck et al., 2014). Learners' fixed or growth mindsets can influence effort regulation since these conceptions reflect the learners' beliefs about the relationship between effort expenditure and ability in specific academic contexts or subjects (Dweck & Sorich, 1999).

Collective findings from mindset studies demonstrate that some learners choose to avoid challenges and failure when faced with setbacks, while others seek challenges and sustain efforts and strategy use under difficult conditions (Dweck et al., 2014; Dweck, 2000). Interestingly, what separates the two groups of learners is not their ability but their mindsets about intelligence (Dweck et al., 2014; Farrington, Levenstein, & Nagaoka, 2013). Learners with growth mindsets focus on learning and improving, while those with fixed mindsets focus on demonstrating competence compared with others and being seen in favourable terms (Elliot & Dweck, 2013). In particular, the greatest difference in the behaviours of learners with different mindsets relates to effort regulation and expenditure for learning *new* things, with those with a fixed mindset more likely to give up (Dweck et al., 2014). Learners with growth mindsets also tend to opt for more challenging academic tasks, attribute success and failure to effort (rather than to ability). This, in turn, has great implications future performance, self-efficacy and perseverance in academic settings (VanderStoep & Pintrich, 2007; Bandura, 1997).

Moreover, it has been found that learners with a growth mindset are more likely to demonstrate high academic self-efficacy (Ommundsen, Haugen, & Lund, 2005). Conversely, learners who espouse a fixed mindset about intelligence are more likely to have low self-efficacy (Komarraju & Nadler, 2013). Dweck and Leggett (1988) suggest that implicit theories of intelligence affect self-efficacy beliefs. When the students' mindsets and academic progress over the transition from middle school to junior high were measured, the students with a growth mindset saw improvements in their mathematics grades over a two-year period (Dweck & Sorich, 1999). In contrast, those with a fixed mindset saw their grades deteriorate over the same period, despite similar initial mathematics achievement scores. Most significantly, this grade advantage was mediated through their self-efficacy (Dweck & Sorich, 1999).

In essence, it appears that mindsets can influence whether learners view and interpret the relationship between effort and ability as positively or inversely correlated (Dweck, 2000), while directly impacting self-efficacy and perseverance. Moreover, it is believed that a growth mindset improves learners' self-efficacy through its impact on interpretation of setbacks and failure (Dweck et al., 2014). Thus, Dweck (2000) suggests that individuals' implicit mindsets influence self-efficacy beliefs. Figure 1 shows the synthesis of the research literature on the underlying mechanisms for effort regulation. Specifically, this hypothesised model of effort regulation incorporates the relationship between mathematical mindset and self-efficacy in mathematics, reflecting the findings from the research literature.

By drawing on self-efficacy theory and implicit theories of intelligence (mindsets) as the theoretical bases for explaining effort regulation, this model aims to capture this complex phenomenon in adolescents, offering a multidimensional approach to understanding effort regulation in academic settings.

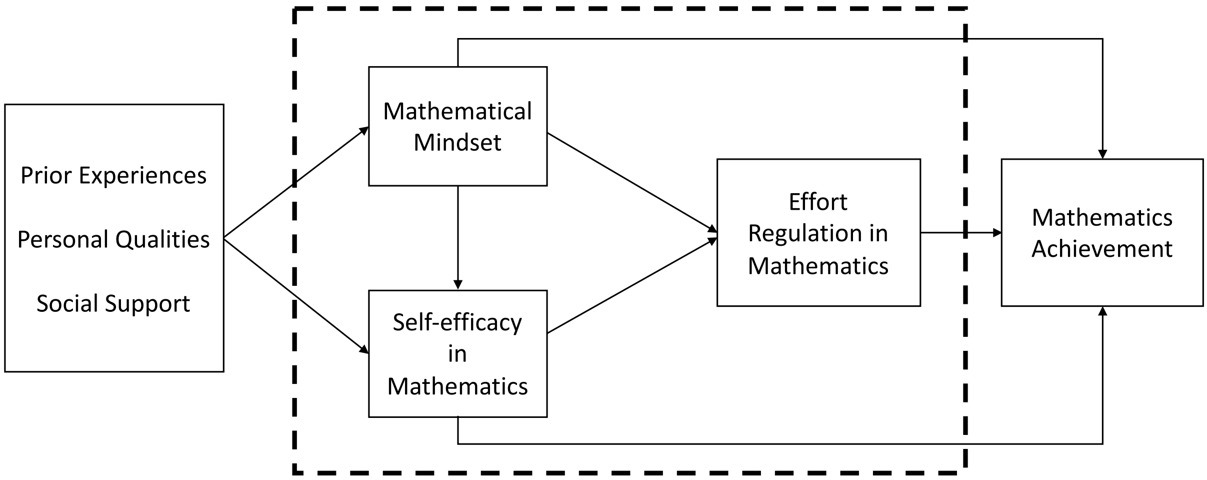

Figure 1 Hypothesised model of effort regulation in mathematics

In this study, the survey data was used to empirically test the possible mediation model (as shown by the dashed outline).

4 Methods

4.1 Participants

The participants in this study were selected from two mixed comprehensive schools in the UK. 1,448 students took part in this research. The table below summarises sample characteristics:

Table 1 Sample characteristics

Sample Characteristics	School 1	School 2	Overall Sample
Mean Age	13.8	14.3	14.0
Female	47.4%	46.2%	47.0%
Free School Meals Ever Status	12.7%	20.7%	15.9%
English as an Additional Language Status	2.2%	19.6%	8.8%
Special Educational Needs Status	15.4%	13.5%	13.6%
Year 7 Cognitive Ability Test Mean Score	106.0	103.0	105.3
Key Stage 2 Reading, Writing & Mathematics Mean Score	29.8	29.7	29.8

4.2 Procedure

The participants were recruited though their schools, with a parent information and consent letter sent home prior to the study being carried out. On the first day of data collection, the students' written consent was also obtained. After a brief introduction to the study, the students were asked to complete a pen and paper survey in their mathematics lessons.

4.3 Measures

4.3.1 Demographics, Academic Attainment and Cognitive Ability

Participants were asked to report their date of birth and gender. As a measure of prior attainment, the students' Key Stage 2 mathematics results were provided by the schools. Furthermore, the students' Cognitive Ability Test scores administered in year 7, Special Educational Needs (SEN), English as an Additional Language (EAL) and Free School Meals Ever (FSM Ever) statuses were also supplied by the school. Year 7 CAT scores and KS2 results were not available for every student.

4.3.2 Self-report Measures

Effort-regulation in Mathematics

The effort regulation scale from the MSLQ (Pintrich & De Groot, 1990) was used to measure effort regulation in mathematics. The scale consists of four items (e.g., "I work hard to do well in maths even if I don't like what we are doing"). Students responded on a scale from 1 = not at all true of me to 7 = very true of me. When responding to the items, participants were asked to think about their current mathematics lessons. A high score indicates high effort regulation (α = .72).

Mathematical Self-efficacy

Mathematical self-efficacy was assessed using the average score of two items written in accordance with recommendations by Bandura (2006; e.g., "I am confident that I can figure out even the hardest concepts in my maths lessons" and "I am confident that I can understand the material in my maths lesson") on a 6-point scale from strongly disagree to strongly agree with a high score indicating high self-efficacy in mathematics (α = .80).

Mathematical Mindset

The 2-item mindset self-report scale (Farrington, Levenstein, & Nagaoka, 2013) was used to determine a learner's implicit mindset in mathematics (mathematical mindset) with participants rating their mindset on a 5-point scale (1 = not at all true to 5 = completely true). A high score indicated a growth mindset, whereas a low score indicated a fixed mindset in mathematics (α = .68).

5 Analytic Plan

The survey data was analysed using hierarchical multiple linear regression analyses to determine the relative contribution of mathematical mindset and self-efficacy in mathematics for explaining the variance in effort regulation in mathematics. In addition, the impact of mathematical mindset on effort regulation in mathematics was examined using mediation analyses by focusing on the mediating role of self-efficacy in mathematics. To test for moderation, interaction terms were created by multiplying the standardised variables together and possible moderators, as highlighted by the research literature, were examined.

It was hypothesised that self-efficacy in mathematics would make the greatest contribution to the prediction of effort regulation in mathematics amongst adolescents, while mathematical mindset would make smaller contribution to this prediction. Moreover, it was hypothesised that the impact of mathematical mindsets on effort regulation in mathematics would likely be mediated through self-efficacy in mathematics.

5.1 Predicting Perseverance in Mathematics

Prior to conducting hierarchical multiple linear regression, preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity.

5.1.1 Predicting Effort Regulation in Mathematics

To control for the potential influence of school, age at data collection, gender, Special Educational Needs, English as an Additional Language and Free School Meals Ever status, these demographic characteristics were entered in block 1, accounting for only 2.6% of all variance in effort regulation in mathematics. In block 2, the students' Key Stage 2 Maths Fine Level, as a measure of prior mathematics attainment, and Year 7 Quantitative CAT Score as a measure of cognitive ability were entered. They only added 1.8% to the prediction of mathematical effort regulation. Mathematical self-efficacy and mathematical mindset were entered in block 3, adding 30.2% to the prediction. This model accounted for a total of 34.6% of all variance in effort regulation in mathematics (see Table 2). Consistent with the research literature, age at data collection showed a negative association with mathematical effort regulation (Dweck et al., 2014; Dweck, 2000).

Table 2 Results of regression analyses predicting mathematical effort regulation

	Model		
Variable	**B**	**SE**	**β**
Intercept	3.905	.567	
School 2	-.063	.064	-.026
Age at Data Collection	-.137	.034	-.098***
Male	-.094	.062	-.038
SEN Status	.058	.072	.021
EAL Status	.015	.106	.004
FSM Ever6 Status	-.129	.083	-.039
Y7 CAT Quantitative Score	.007	.003	.077
KS2 Maths Fine Grade	-.025	.010	-.097*
Self-efficacy in Mathematics	.513	.029	.488***
Mathematical Mindset	.209	.032	.178***
R^2		.346	
Adjusted R^2		.340	
F		F(10,1094)=57.958***	

*p < .05. **p < .01. ***p < .001.

5.1.2 Exploring the Possible Mediating Role of Self-efficacy in Mathematics in the Relationship Between Mathematical Mindset and Effort Regulation in Mathematics

The survey data was used to empirically test the hypothesised mediation model of perseverance (see dashed lines on Fig. 1), given the theoretical support for this model (Dweck et al., 2014; Komarraju & Nadler, 2013; Muenks et al., 2017; Pintrich, 1999). To test for mediation, PROCESS Add-on to SPSS was used (Hayes, 2013). From a simple mediation analysis conducted using ordinary least squares path analysis, mathematical mindset indirectly influenced effort regulation in mathematics through its effect on mathematical self-efficacy. Participants' mathematical mindset (*N*= 1434) influenced their self-efficacy in mathematics (a= .442, p<.001) and that in turn affected the participants' effort regulation (b= .498, p<.001). A bias-corrected bootstrap confidence interval for the indirect effect (ab= .220) based on 10,000 bootstrap samples was entirely above zero (.184 to .260). Mathematical mindset also influenced effort regulation in mathematics independent of its effect on mathematical self-efficacy (c'= .234, p<.001).

5.1.3 Testing for Moderation

In the regression model predicting effort regulation in mathematics, gender made very limited contribution to the model. Yet there is some theoretical and empirical evidence suggesting associations of gender with self-efficacy and mindset (Pajares & Urdan, 2006). It was, therefore, important to investigate possible interaction terms with these variables. To test for the moderating effect of gender, the possible interaction terms (e.g. gender x mindset, gender x mathematical self-efficacy and gender x mindset x mathematical self-efficacy) were examined using PROCESS Add-on to SPSS (Hayes, 2013). None of these terms were found to be statistically significant.

6 Discussion

The aim of this study was to examine the underlying mechanisms of effort regulation in adolescents. This was achieved by testing the hypothesised model of effort regulation in mathematics. Findings from this study showed that mathematical mindset and self-efficacy in mathematics both positively predicted effort regulation in mathematics. Hierarchical multiple linear regression analyses showed that self-efficacy in mathematics and mathematical mindset were significant predictors of effort regulation in mathematics, accounting for 30% of the variance in effort regulation in mathematics.

Furthermore, it appears that the effect of mathematical mindset on effort regulation in mathematics was mediated through self-efficacy in mathematics. Findings from the mediation analyses showed that mathematical mindset influenced mathematical effort regulation independent of its effect on mathematical self-efficacy. Furthermore, the findings highlight that self-efficacy in mathematics had a greater effect on effort regulation than mathematical mindset (total effect of self-efficacy in mathematics on effort regulation = .498 while total effect of mathematical mindset on effort regulation = .454).

The findings of this study are supported by previous research which has shown that when faced with challenge, students with high self-efficacy and a growth mindset are more likely to regulate their effort and persevere. These findings provide initial support for the relationship between mathematical mindset and effort regulation in mathematics as a key process, mediated by self-efficacy in mathematics. These results contribute to the current understanding of effort regulation in mathematics in adolescents. They are also indicative of the underlying mechanisms for effort regulation in mathematics and highlight possible ways to enhance effort regulation in mathematics amongst adolescents.

6.1 Limitations and Implications for Future research

The results of mediation analyses support the hypothesised theoretical model and are indicative of a causal relationship. However, since the data was cross-sectional, further conclusions about causality need to be proven through longitudinal mediation analyses. A randomised controlled field experiment has since been completed, addressing this shortcoming. Despite the limitations, the findings for this study have the potential to provide guidance for the development of educational interventions that enhance effort regulation amongst adolescents and to inform practice in the classroom.

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