Learning and Individual Differences 109 (2024) 102402

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

How emotions are related to competence beliefs during mathematical problem solving: Differences between boys and girls

Jojanneke P.J. Van der Beek *,[1], Sanne H.G. Van der Ven [1], Evelyn H. Kroesbergen [1], Paul P. M. Leseman

Utrecht University, Department of Child, Family and Education Studies, PO Box 80140, 3508 TC Utrecht, the Netherlands

A R T I C L E I N F O

Keywords:
Mathematics
Situated competence beliefs
Emotions
Gender

A B S T R A C T

This study, grounded in Control Value Theory, aimed at increasing insight into how the emotions of enjoyment and anxiety shape students' situated math competence beliefs. Additionally, we investigated gender differences in these effects. An online survey including mathematical problems with corresponding competence belief ratings, and questionnaires regarding math-related emotions was filled out by 866 ninth-grade students. Ordinal mixed effects modelling revealed that after correcting for actual performance, emotions contributed (modestly) to students' competence beliefs: enjoyment was positively related to competence and anxiety had a negative relation. The strength of these relations was not affected by gender, but boys did report higher situated math competence beliefs than girls, despite a lack of gender difference in actual performance. Boys also showed higher math enjoyment and lower anxiety than girls. Our findings underline the need for interventions that improve girls' attitude towards mathematics and refute the math gender stereotype.

Educational relevance and implications statement: In this study we investigated factors related to ninth-grade students' situated competence beliefs in math. We found that first and foremost actual performance predicted competence beliefs, showing students' metacognitive abilities. But we also found that the emotions of math enjoyment and math anxiety affected these beliefs, and that boys held higher competence beliefs than girls, while their math performance did not differ. This suggests that a situated intervention, aimed at showing girls at the item level how often their answers are correct and stimulating them to hold positive beliefs could boost their confidence in their STEM abilities, and possibly enhance their motivation to pursue a STEM career.

1. Introduction

For a long-term successful math learning trajectory in school, possibly followed by a STEM career, it is not only important for students to perform well, but also to believe in their abilities. These competence beliefs are essential for achievement and emotions regarding math (Forsblom et al., 2022; Pekrun et al., 2023). Competence beliefs are also considered valuable in their own right, because they foster life-long learning (Lüftenegger et al., 2012). Previous research showed that math competence beliefs are related to education and career choices: low perception of mathematical competence prevents students, especially women, from pursuing STEM careers (Lazarides & Lauermann, 2019). It is therefore important to gain more insight into the development of these competence beliefs, including the role of gender.

Students' perception of competence in math is first and foremost shaped by their actual mathematical achievement. This has been well-established in the reciprocal effects model: math competence beliefs and achievement influence each other mutually (Arens et al., 2017; Marsh et al., 2022; Wu et al., 2021). If students would have a perfect understanding of their own math performance, achievement would be the only, perfect predictor of math competence beliefs. However, the predictive value of math achievement on competence beliefs varies approximately between beta coefficients of 0.40 and 0.70 (Arens & Niepel, 2023; Forsblom et al., 2022; Van der Beek et al., 2017; Weidinger et al., 2018). This means that other factors can also, in a positive or negative way, affect students' perceptions of competence.

The goal of the present study was to understand how achievement emotions and gender contribute to students' math competence beliefs,

* Corresponding author.
E-mail addresses: jojanneke.vanderbeek@ru.nl (J.P.J. Van der Beek), sanne.vanderven@ru.nl (S.H.G. Van der Ven), evelyn.kroesbergen@ru.nl (E.H. Kroesbergen), p.p.m.leseman@uu.nl (P.P.M. Leseman).
[1] Present address: Radboud University, Behavioural Science Institute, PO Box 9104, 6500 HE Nijmegen, The Netherlands.

https://doi.org/10.1016/j.lindif.2023.102402
Received 27 June 2022; Received in revised form 1 November 2023; Accepted 10 December 2023
Available online 19 December 2023

while they were working on math problems. This *situated* competence belief measure acknowledges the recent insights that competence beliefs in achievement situations are strongly context-dependent (Eccles & Wigfield, 2020; Nolen, 2020; Pekrun & Marsh, 2022). The current study can therefore yield useful, fine-grained insights in how competence beliefs are built during mathematical problem solving.

1.1. Control-value theory

Pekrun's Control-Value Theory (CVT; Pekrun, 2006) provides a theoretical framework for investigating predictors of competence beliefs in academic settings. This theory describes how control appraisals such as competence beliefs, value appraisals, positive and negative achievement emotions, and achievement are all interrelated. For example, students who feel in control and value the outcome of their achievement activities, are likely to experience positive achievement emotions, which in turn positively affect achievement outcomes. Conversely, students who experience a lack of control over achievement activities, i.e. students with low competence beliefs, experience negative achievement emotions that can hinder optimal learning and achievement.

The CVT distinguishes between proximal processes, referring to the interrelations between emotions and appraisals, and more distal determinants of these emotions and appraisals (Pekrun et al., 2023). In the present study we studied the distal effects of gender and a disposition for math anxiety and for math enjoyment on situated math competence beliefs.

1.2. Achievement emotions in mathematics

Achievement emotions, defined as "emotions that occur in response to events and actions that are judged according to competence-based standards of quality", are of crucial importance to students' academic performance and wellbeing (Pekrun et al., 2023, pp. 146). Achievement emotions can be positive or negative, activating or deactivating, and focused on either an achievement activity or an achievement outcome (Pekrun et al., 2023). Students can experience trait, habitual achievement emotions reflecting their recurring feelings in relation to achievement activities and outcomes in a subject domain, and state, momentary emotions in specific achievement situations (Pekrun, 2006). It is suggested that, on the one hand, dispositional achievement emotions and control/value appraisals contribute to situational emotions and appraisals, while on the other hand situational experiences shape more general feelings and appraisals over time (Dietrich et al., 2019; Roos et al., 2015). Within the mathematical domain, general enjoyment and anxiety are the most widely studied achievement emotions.

Enjoyment is a pleasant emotion, positively related to math achievement, while anxiety is an unpleasant emotion, negatively related to math achievement (Barroso et al., 2021; Camacho-Morles et al., 2021; Gunderson et al., 2018; Namkung et al., 2019; Pekrun et al., 2017; Raccanello et al., 2019). Both emotions are typically activating, as they arouse physiological systems such as heart rate and respiration rate. Enjoyment is best understood in relation to an ongoing activity, while anxiety is mostly related to negative achievement outcomes (Pekrun et al., 2023).

Earlier studies have shown that enjoyment in mathematics is positively related to math competence beliefs (Goetz et al., 2010; Peixoto et al., 2017; Van der Beek et al., 2017; Wen & Dubé, 2022; Živković et al., 2023), indicating that students who experience control over mathematical achievement activities also tend to enjoy these activities (Pekrun, 2006). Some longitudinal studies only found predictive effects of earlier competence beliefs on later enjoyment in mathematics but not vice versa (Du et al., 2021; Forsblom et al., 2022), while others did find prior enjoyment to be a predictor of later math competence beliefs (Clem et al., 2021; Lehikoinen et al., 2023; Pinxten et al., 2014).

Mathematics anxiety has been shown to be negatively related to competence beliefs in mathematics (Cipora et al., 2022; Goetz et al., 2010; Li et al., 2021; Peixoto et al., 2017; Van der Beek et al., 2017; Wen & Dubé, 2022; Živković et al., 2023). Longitudinal studies showed that this relation is reciprocal: students with higher global mathematics anxiety were likely to develop lower competence beliefs regarding their mathematical functioning, which in turn increased their math anxiety (Ahmed et al., 2012; Clem et al., 2021; Du et al., 2021; Putwain & Wood, 2023; Wang et al., 2020).

The studies described above were focused on students' general achievement emotions and global competence beliefs regarding mathematics as a subject domain. However, given the situational specificity of competence beliefs (Pekrun & Marsh, 2022), the question remains to what extent students' general feelings towards math can also affect their situated competence beliefs during a specific math problem solving activity. Only a few studies have been conducted on the relation between general achievement emotions and situated competence beliefs in mathematics, and they found positive concurrent correlations between situated competence beliefs and enjoyment in mathematics, and negative correlations with math anxiety (Morony et al., 2013; Stankov et al., 2014). Further research is needed in order to gain a better insight in how situated math competence beliefs are affected by general emotions regarding mathematics.

1.3. Situated competence beliefs

The CVT states that competence beliefs can be situation-specific (Pekrun, 2006; Pekrun & Perry, 2014). However, in most educational studies thus far, competence beliefs were operationalized as self-concept: students' global competence beliefs regarding their overall ability in a subject domain such as mathematics (Goetz et al., 2010; Huang, 2011). The self-concept develops over a longer period of time, and strongly depends on contextual factors such as teacher feedback and students' ability relative to their peers (Marsh, 1990; Möller & Marsh, 2013). While self-concept as a global measure of competence beliefs is recall-based and relatively stable, a situated measure assesses beliefs as they are experienced from moment to moment (Roos et al., 2015). The few studies that have addressed situated competence beliefs from a CVT (related) perspective, showed that these beliefs were strongly situation-specific (e.g., Dietrich et al., 2017; Moeller et al., 2022; Pekrun & Marsh, 2022).

For example, the study by Dietrich et al. (2017) revealed the presence of substantial variation of university students' situational expectancies (e.g., 'I will be good at these contents at the exam') between and within lessons, even within relatively short time lags of half an hour. Moeller et al. (2022) accordingly demonstrated that university students' situational expectancies varied significantly between the beginning, middle and end of a single lecture. A cross-lagged panel model showed that expectancies and negative situational emotions correlated with each other at each time point during the lecture, but they were not related across time lags (Moeller et al., 2022). In line with these findings, Malmberg and Martin (2019) showed that competence beliefs (e.g., 'How well were you doing at this task?') and situational autonomous motivation (e.g., "I enjoyed the task', similar to the emotion of enjoyment) in primary school students were interrelated concurrently, but unrelated from one time point to the following within schooldays. Their findings also indicated relative stability of daily measures of competence beliefs themselves within school subjects in the course of one school week (Malmberg & Martin, 2019).

Overall, these findings underline the importance of investigating competence beliefs at a situated level in order to understand how they are built-up over time to constitute more stable beliefs. However, differences between the studies in the concepts used to describe students' sense of control, the age of the participants and the definition of 'situation' make it hard to draw further conclusions. Moreover, the role of global achievement emotions as a potential source of individual differences in situated math competence beliefs still remains unclear.

1.4. Gender differences

Gender differences in math attitudes are well-established. In general, from elementary school into adulthood, females report a higher level of mathematics anxiety, less enjoyment in mathematics and lower mathematical competence beliefs than males (Cipora et al., 2022; Dowker et al., 2016; Morony et al., 2013). These findings are often attributed to gender stereotypes: math aptitude is both explicitly and implicitly associated with the male gender. Stereotype endorsement leads to higher mathematics competence beliefs, lower math anxiety and higher interest in the STEM field in boys, and lower competence beliefs, higher anxiety and lower interest in girls (Casad et al., 2015; Master, 2021; Moè, 2018; Passolunghi et al., 2014; Rossi et al., 2022; Wen & Dubé, 2022). Men are far more likely than women to pursue a math-related study and career, even though actual gender differences in academic performance are small or even non-existent (Bench et al., 2015; Cipora et al., 2022; Dowker et al., 2016; OECD, 2014).

From the perspective of self-regulated learning, several studies have investigated gender differences in situated competence beliefs in math. These studies typically focused on the metacognitive ability to accurately estimate one's performance on a math problem or test. For example, some studies found that boys tended to overestimate their mathematical performance, whereas girls estimated their performance more accurately (Bench et al., 2015; Boekaerts & Rozendaal, 2010; Gonida & Leondari, 2011; McMurran et al., 2023; Morony et al., 2013; Sheldrake et al., 2014). Boys also generally report higher situated competence beliefs in mathematics than girls, in the absence of gender differences in performance (Morony et al., 2013; Roderer & Roebers, 2013).

The studies described above thus show that boys hold more favorable competence beliefs and achievement emotions towards mathematics. Less is known about gender differences in the relation between those concepts. That is, we are not aware of studies on gender differences in the strength of the relation between emotions and (situated) competence beliefs. Knowledge about gender differences in the predictive value of math enjoyment and anxiety on situated competence beliefs can inform the design of tailored motivational interventions in STEM education, especially for talented girls.

1.5. The present study

The goal of the present study was to gain more insight into the formation of students' competence beliefs in mathematics. We investigated the predictive value of mathematics enjoyment, mathematics anxiety and gender on students' competence beliefs during mathematical problem solving. We also investigated gender differences in mathematical performance, math enjoyment and anxiety, and in the predictive value of these emotions on situated math competence beliefs.

In the present study, we focused on situated competence beliefs, measured at the item level: after each math problem we asked high school students to rate how certain they were of their just-provided solution. In other studies, this measure has been referred to as ‘confidence’ (e.g., McMurran et al., 2023; Stankov et al., 2014). Some studies registered dichotomous responses (i.e., correct or incorrect; Bellon et al., 2021; Fernández et al., 2015), while other studies used rating scales (McMurran et al., 2023; Morony et al., 2013). Fig. 1 provides an example of a mathematical problem with a competence belief rating as used in the present study.

The actual accuracy of the provided solution is one of the most important predictors of post-item competence judgements (Boekaerts & Rozendaal, 2010; Stankov et al., 2012): whether your solution to a test item is correct or incorrect largely defines your perception of competence on that test item. However, as described before, these judgements are never perfect. In order to gain a better understanding of the factors affecting these situated competence beliefs, an item-level approach to the data is needed, which takes the actual performance on each individual test item into account (Boekaerts & Rozendaal, 2010; McMurran et al., 2023). The findings of the previous studies on the relation between general math emotions and situated competence beliefs in math (i.e., Morony et al., 2013; Stankov et al., 2014) were based on an aggregated, mean measure of the post-item competence beliefs ratings, without taking the correctness of each individual solution on the math problems into account. The item-level approach that we have used in the present study fully captures the situatedness of post-item competence judgements, and is further described in Section 2.4.

Our research was guided by the following research questions and hypotheses, which are also summarized in Fig. 2:

1. *Do the emotions of math enjoyment and math anxiety predict situated math competence beliefs, when controlling for the actual performance?* We expected that math enjoyment would positively predict situated math competence beliefs, and that math anxiety would negatively predict situated math competence beliefs.

2. Are there gender differences? We divided this question into three subquestions:

(a) Does gender predict situated math competence beliefs, when controlling for actual performance? We expected boys to have higher situated math competence beliefs.

(b) Are there gender differences in the predictive value of math enjoyment and math anxiety on situated math competence beliefs, when controlling for actual performance? We have no hypothesis on gender differences in the predictive value of emotions on situated math competence beliefs; this is an exploratory research question.

(c) Are there gender differences in the distal predictors of math enjoyment, math anxiety, and math performance? We expected boys to show higher levels of enjoyment and lower levels of math anxiety than girls. We expected no gender differences in math performance.

2. Materials and methods

This study was part of a larger cross-cultural study on a variety of non-cognitive factors related to mathematics achievement (Morony et al., 2013). The international research project was coordinated by the National Institute of Education (NIE) in Singapore. The present study was a re-analysis of the data from the Dutch sample and focused exclusively on situated math competence beliefs, math performance, emotions, and gender.

2.1. Participants

Participants were 1014 students (55 % girls; $M_{age} = 15.1$ years; SD = 0.6) in the third year of secondary education, comparable to ninth grade, from eight urban secondary schools in The Netherlands.[2] The schools were recruited based on convenience sampling. Due to missing values (see Section 2.4), the analyses were conducted on 866 participants (85.4 %) with complete data. The Netherlands has a tracked secondary education system, with broadly three tracks. The sample represented these three tracks, including 233 students (53 % girls) from VMBO-TL (i.e., lower vocational education at ISCED level 2, European Commission, 2014), 335 students (56 % girls) from HAVO (i.e., higher general secondary education at ISCED level 3) and 298 students (54 % girls) from VWO (i.e., pre-university education at ISCED level 3). The study was approved by the Singapore Ministry of Health at the time it was conducted. Re-use of these data after removing identifiers was approved of by the ethics review board of the Faculty of Social and Behavioral Sciences of Utrecht University (file number 22-0216).

[2] Gender options were either ‘boy’ or ‘girl’, there was no ‘other’ category. This was not yet common practice at the time of data collection for this study.

In a pizza restaurant you can get a basic pizza with two toppings: cheese and tomato. You can also make up your own pizza with extra toppings. You can choose from four different extra toppings: olives, ham, mushrooms and salami. Ryan wants to order a pizza with two different extra toppings.

- *How many different combinations can Ryan choose from?*
- *How confident are you that your answer is correct?*

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Just guessing										Absolutely certain

Fig. 1. Example of a mathematical problem with a competence belief rating.

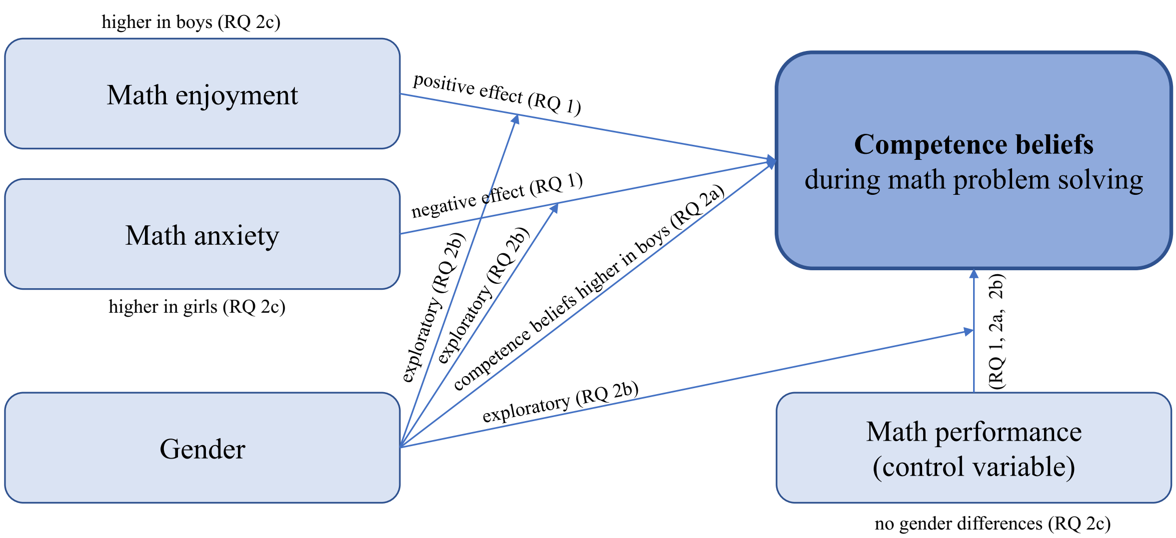

Fig. 2. Conceptual model of the research questions and hypotheses of the study.

2.2. Measures

The survey instruments were translated from English into Dutch by the authors. The Dutch translation was reviewed for accuracy and fluency by the collaborating Dutch-speaking Belgium research team. Clear instructions regarding the translation and review were provided by the coordinating team of the NIE in Singapore. After piloting the survey with students from a school that was not involved in the study, some adaptations were made, as some students indicated that they did not understand certain words. The survey was conducted online using Qualtrics survey software. It consisted of various non-cognitive scales, interspersed with mathematical problems. In the present study the following variables were used: situated math competence beliefs, math performance, enjoyment and anxiety in mathematics, and gender. The order of the scales and the items within the scales was randomized, except for the mathematics enjoyment item. This question was always at the end of the questionnaire, because it was added by the authors, specifically for the Dutch sample.

2.2.1. Situated math competence beliefs

Directly following each mathematical problem in the survey, students were asked to answer the question: ‘How confident are you that your answer is correct?’. In steps of 10 %, students rated their competence belief between 0 % (“just guessing”) and 100 % (“absolutely certain”). In the original study, some of the items were multiple choice questions, meaning that a pure guess still had a chance of 1/number of choice options of being correct. To prevent our competence belief rating from being confounded with the way students handle this probability calculation, only the five open-ended mathematical problems were analysed in this study. No further scaling procedure of the five math competence beliefs ratings was applied, because these competence beliefs were analysed at the item level (see Section 2.4). Hence, reliability measures are not provided. See Fig. 1 for an example of an open-ended mathematical problem with a competence belief rating.

2.2.2. Math performance

Math performance was based on the students' solution to each of the five mathematical open-ended problems that were used for investigating situated competence belief ratings. A correct solution was scored ‘1’ and an incorrect solution was scored ‘0’. The open ended mathematical problems were derived from the PISA 2003 assessment (Salz & Figueroa, 2009) and spanned several mathematical subdomains. Fig. 1 provides an example of an open-ended mathematical problem that was used in the current study. Since math performance was also investigated at the item level, no further scaling procedure was applied.

2.2.3. Mathematics emotions: enjoyment and anxiety

Mathematics anxiety was assessed with fifteen items that were used in a previous study with Dutch students (Van der Beek et al., 2017) and partly derived from PISA 2003. An example of an item is: ‘I get very nervous doing Mathematics problems’. Students responded on a four-point scale (‘strongly disagree’, ‘disagree’, ‘agree’, ‘strongly agree’, scored 1 to 4 respectively). An exploratory factor analysis was conducted to evaluate the structure of the math anxiety scale. Five items were excluded from further analyses because of small factor loadings (<0.3). The resulting factor with the remaining ten items was used for the analyses. The internal consistency was checked by computing Cronbach's alpha, which was good (α = 0.916).

Mathematics enjoyment was measured with a single item at the end of the survey: 'How much do you like mathematics?'. Students were asked to indicate their answer on a five-point Likert scale (with scale points 1 ='not at all', 2 = 'a little', 3 = 'somewhat', 4 = 'quite a bit', 5 = 'very much'). This question was specifically added to the Dutch version of the international questionnaire and it was not possible to add multiple questions. While the use of a single item is not ideal, it was still considered adequate because the concept measured was very straightforward. No further scaling procedure was applied.

2.3. Procedure

Data collection was conducted by four graduate students, who were trained and supervised by the first two authors. Participants completed the survey in groups during a mathematics class of approximately 45 min. The survey took place in the computer labs in their schools. The consent of the participants was asked on the first page of the survey, after explanation of the goal of the study and the confidentiality of the data. The students were informed that participation in the survey was voluntary and that they could withdraw at any time. Students who did not give their consent or withdrew during the survey, and students who finished the survey before the end of the lesson were asked to work on an alternative task without disturbing the other students.

2.4. Statistical analyses

Inspection of the data showed that the data on situated competence beliefs were not normally distributed, with both extremes of the scale (0 % and 100 %) being chosen relatively often. Therefore, we fitted an ordinal mixed effects model to the data with the R package lme4 (cumulative link mixed model; Bates et al., 2014), with items and students as levels and situated competence beliefs as the dependent variable. In an ordinal model, the ordinal dependent variable is transformed into a continuous latent variable by means of a link function. This continuous variable reflects probabilities for each different choice option of the ordinal scale. That is, if scores on this latent variable are low, probabilities are relatively high for options reflecting low situated competence beliefs. With increasing values on this scale, options reflecting higher situated competence beliefs gradually become more probable. For our analyses, we used a logit link function to create this variable.

The model was run in four steps. In Model 0, we used only the control variable of performance on each mathematical problem to predict situated competence beliefs. In Model 1, we added the emotions of mathematical enjoyment and anxiety. This model addresses research question 1: the effects of emotions on situated competence beliefs. With the next two models we investigated the role of gender. In Model 2, the main effect of gender was added to the model. This model addresses research question 2a regarding the effect of gender on situated competence beliefs. In Model 3, the interaction terms between gender and performance, anxiety and enjoyment were added. These interaction terms address research question 2b and test if the effects of performance and emotions on situated competence beliefs differ between boys and girls.

Sum-to-zero contrasts were used and all numerical variables were mean-centered to create interaction terms. Statistical significance of the predictors was determined with (type III) Likelihood Ratio tests using the anova function in R (R Core Team, 2023), using an alpha of 0.05. Models were also evaluated with Nagelkerke pseudo R^2, a measure that is comparable to R^2 in a regression analysis, although its values tend to be lower (Smith & McKenna, 2012).

The models are all so-called maximal models (Barr et al., 2013), meaning that each theoretically possible random intercept and random slope was included. The model thus contained random intercepts for both items and students, by-student random slopes for math performance, and by-item random slopes for gender, math performance, enjoyment and anxiety. Students and items were thus allowed to vary in their overall competence belief ratings; effects of math performance on situated competence beliefs were allowed to vary across students, and effects of gender, enjoyment and anxiety on situated competence beliefs were allowed to vary across items.

Finally, research question 2c regarding gender differences in the mean level of both emotions and math performance was investigated by conducting a *t*-test for mathematics anxiety and Mann–Whitney *U* tests for math performance and enjoyment, since these variables were not normally distributed.

The analyses were conducted on 866 of the 1014 students that participated in the study. The missing cases were 148 students that did not fill out the mathematics enjoyment item, likely because this item was one of the final questions. No further correction or control was applied because inspection of the data indicated missingness at random.

3. Results

3.1. Descriptive statistics

Table 1 provides the means and standard deviations of the variables of the study for the total sample and for boys and girls separately.

Table 2 shows the correlations between the variables of the study for the total sample and for boys and girls separately. Note that, for both boys and girls, situated competence beliefs were positively related to math enjoyment and performance, and negatively related to math anxiety.

3.2. Ordinal mixed effects models

Four consecutive ordinal mixed effects models were run to investigate predictors of situated math competence beliefs. The results are presented in Table 3. Model 0, the control model, showed that performance was a significant predictor of situated competence beliefs in mathematics: correct solutions were associated with higher competence ratings than incorrect solutions. Model 1, in which the predictors of enjoyment and anxiety were added to the model, showed that the addition of these emotions improved the prediction of these competence ratings. Mathematics enjoyment positively predicted situated math competence beliefs, and mathematics anxiety negatively predicted situated math competence beliefs.

In Model 2, gender was added to the model. The results show that this addition increased the explained variance, and gender significantly predicted situated math competence beliefs. The negative estimate indicates that boys reported higher situated math competence beliefs than girls – when correcting for emotions and performance on the math items (i.e. correctness of the solutions). As in Model 1, performance on the mathematical problems and enjoyment in mathematics were significant predictors of situated competence beliefs. However, after adding gender,

Table 1
Means and standard deviations for situated competence beliefs, math enjoyment, math anxiety, and math performance.

	Total sample (*N* = 866)	Boys (*N* = 392)	Girls (*N* = 474)
	M (SD)	*M (SD)*	*M (SD)*
Competence beliefs[a]	66.7 (23.1)	74.9 (20.8)	60.0 (22.7)
Math enjoyment	3.0 (1.3)	3.14 (1.2)	3.0 (1.3)
Math anxiety	1.9 (0.6)	1.8 (0.6)	1.9 (0.6)
Math performance[b]	2.8 (1.4)	2.9 (1.4)	2.7 (1.4)

[a] Mean of the five competence ratings (min = 0, max = 100).
[b] Mean number of correct solutions (min = 0, max = 5).

Table 2
Pearson correlation coefficients between situated competence beliefs, math enjoyment, math anxiety, and math performance.

	1.	2.	3.
1. Competence beliefs[a]			
Total sample	–		
Boys	–		
Girls	–		
2. Math enjoyment			
Total sample	0.37*	–	
Boys	0.32*	–	
Girls	0.39*	–	
3. Math anxiety			
Total sample	−0.26*	−0.46*	–
Boys	−0.18*	−0.35*	–
Girls	−0.28*	−0.54*	–
4. Math performance[b]			
Total sample	0.57*	0.28*	−0.21*
Boys	0.65*	0.31*	−0.19*
Girls	0.53*	0.24*	−0.22*

* $p < .01$
[a] Mean of the five competence ratings (min = 0, max = 100).
[b] Mean number of correct solutions (min = 0, max = 5).

the effect of mathematics anxiety was no longer significant.

In Model 3, interaction terms between gender and math performance, math enjoyment and math anxiety were added to the model. This increased the proportion of explained variance, but only slightly. The results show that only one of the three interaction terms was significant: the interaction between Gender x Math Performance. The direction of this interaction effect is illustrated in Fig. 3. Both genders show higher situated math competence beliefs for correct solutions than for incorrect solutions, but this difference is significantly, though slightly, larger for boys than for girls. The line is also higher overall for boys than for girls, reflecting the main effect of gender. The other two interaction effects were not significant, indicating no evidence for a difference between boys and girls in the predictive value of emotions on situated math competence beliefs.

Fig. 4 illustrates how the regression coefficients presented in Model 3 relate to the original choice options on the situated competence beliefs scale (from 0 % to 100 % in increments of 10 %). Panel A shows the latent situated competence beliefs scale on the X-axis, and probability for each response option on the Y-axis. Each of the 11 response options is displayed as a curve. The panel shows how at low situated competence belief levels, lower percentage options have higher probabilities of being chosen, and as situated competence beliefs increase, higher options increase in probability. The regression coefficients presented in Table 3 represent movement along this axis. For example, the coefficient of 0.34 for enjoyment means that for every 1SD increase in enjoyment, one moves 0.34 steps to the right on this axis.

The values that were presented in Fig. 3 are also depicted in Fig. 4 as vertical lines. For example, the predicted latent situated competence value for a boy with average anxiety and enjoyment levels who had provided a correct solution is 1.49 (see also Fig. 3). Fig. 4 displays that at this value, the probability of a 100 % score on the situated competence belief scale is around 0.40, and for 90 % this is around 0.20. For a girl with otherwise similar values, the probability of a 100 % choice is only around 0.15. Inspection of the raw data confirmed that boys were far more likely than girls to choose the 100 % score. Boys chose this option for about 50 % of their correct solutions, against 20 % in girls. Boys were still 100 % certain about 23 % of their incorrect solutions, against 11 % in girls.

Since the curves in Panel A are not very easy to discern, Panel B shows a cumulative probability plot of the same curves: here the curves are stacked on top of each other so each is clearly visible. The probability for each option at a certain Situated Competence Beliefs value is reflected as the vertical distance between two consecutive curves.

3.3. Gender differences in the mean level of emotions and math performance

Table 4 shows the test results for gender differences on math enjoyment and anxiety and math performance. The independent samples *t*-test showed a significant difference between boys and girls in math anxiety. Girls reported slightly higher math anxiety levels than boys (see Table 1 for the means and standard deviations). The Mann–Whitney *U* tests showed a significant but small gender difference on enjoyment in mathematics, with boys (mean rank 454.40) enjoying math more than girls (mean rank 416.22). There was no significant difference between boys and girls in math performance.

4. Discussion

The goal of the present study was to gain more insight into how achievement emotions and gender contribute to students' competence beliefs during mathematical problem solving. Using the framework of

Table 3
Results of the ordinal mixed effects model, including gender, predicting situated math competence beliefs.

	Model 0				Model 1			
	B	*SE*	*LR*	*p*	*B*	*SE*	*LR*	*p*
Perform[a]	1.65	0.24	12.08	<0.001	1.65	0.24	12.08	<0.001
Enjoy					0.38	0.15	21.04	<0.001
Anxiety					−0.46	0.06	7.14	0.008
Nagelkerke pseudo-R^2				0.187				0.208

	Model 2				Model 3			
	B	*SE*	*LR*	*p*	*B*	*SE*	*LR*	*p*
Perform[a]	1.68	0.22	13.30	<0.001	1.72	0.24	18.81	<0.001
Enjoy	0.34	0.05	16.93	<0.001	0.34	0.05	20.00	<0.001
Anxiety	−0.26	0.13	3.47	0.062	−0.26	0.14	3.52	0.061
Gender[b]	−0.65	0.07	20.06	<0.001	−0.62	0.07	24.58	<0.001
Gender × Perform					−0.19	0.09	3.98	0.046
Gender × Enjoy					0.05	0.05	1.66	0.198
Gender × Anxiety					−0.03	0.14	0.45	0.503
Nagelkerke pseudo-R^2				0.235				0.237

Note. Perform = Math performance; Enjoy = Math enjoyment; Anxiety = Math anxiety.
[a] Mean centered: incorrect = −0.55, correct = 0.45
[b] Boys = −1; girls = 1

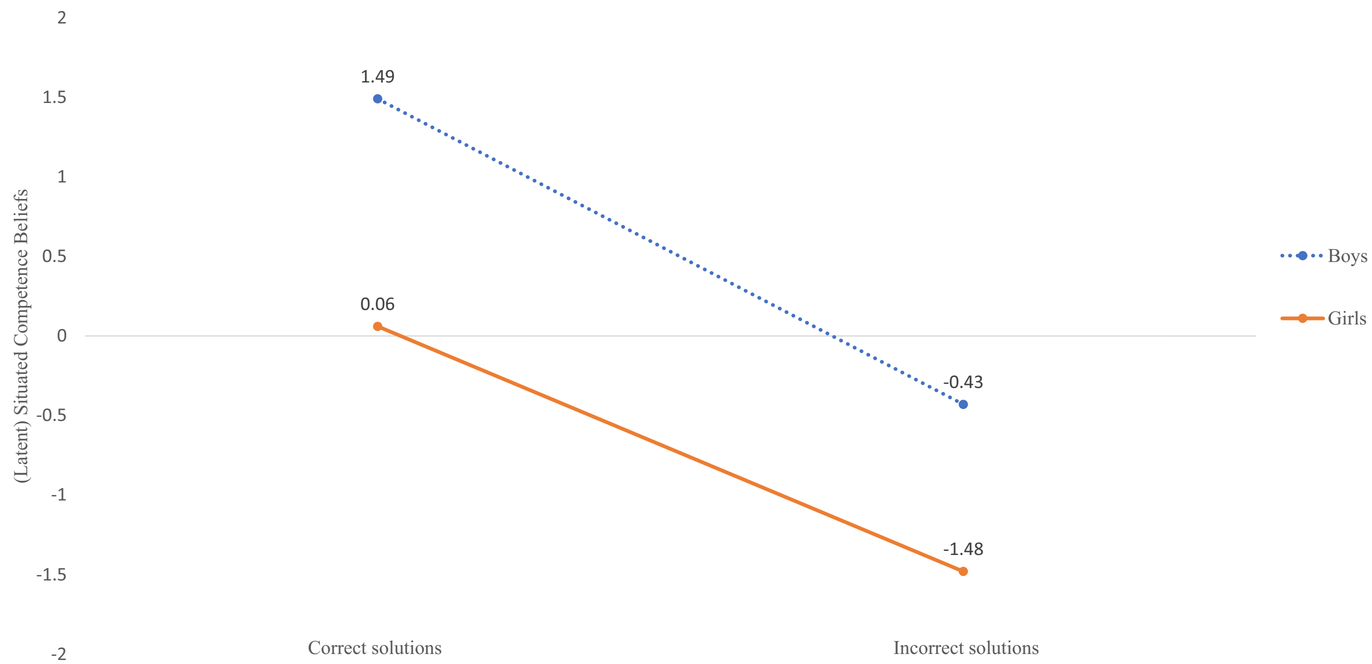

Fig. 3. Illustration of the interaction effect between Gender x Math performance on (latent) situated math competence beliefs.

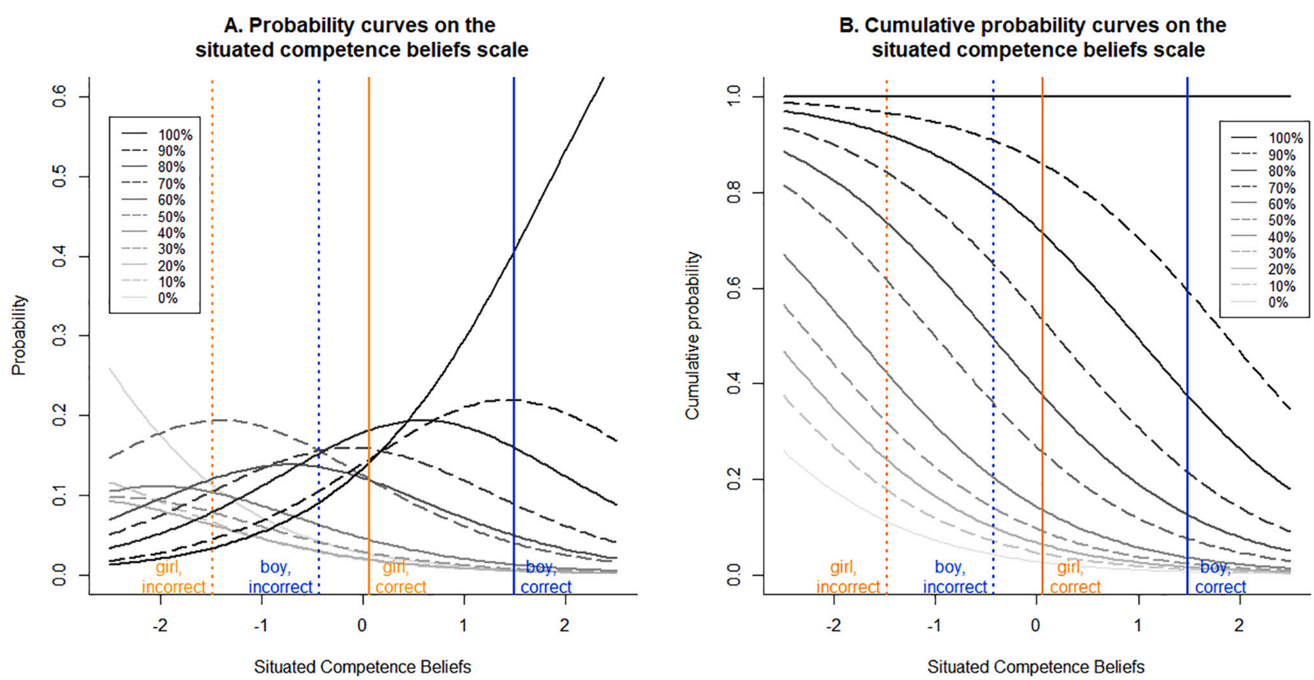

Fig. 4. (Cumulative) Probability curves on the latent situated competence beliefs scale.

Pekrun's Control-Value Theory (CVT; 2006), and recent insights into the context-dependent nature of competence beliefs (Eccles & Wigfield, 2020; Nolen, 2020; Pekrun & Marsh, 2022), we investigated the predictive value of math enjoyment, math anxiety and gender on students' situated math competence beliefs. The results were controlled for actual math performance, as this is regarded as an important predictor of situated competence judgements. Our item-level analyses of these competence ratings provided the opportunity to control for the actual accuracy of the provided solutions. This enabled us to investigate the unique predictive value of gender and emotions on situated math competence beliefs.

First, our findings corroborated previous studies on the predictive value of actual math performance on situated math competence beliefs (Boekaerts & Rozendaal, 2010; McMurran et al., 2023; Stankov et al., 2012): students rated their competence beliefs higher after a correct solution than after an incorrect solution. Although the relative contributions were modest, our findings also showed that situated math competence beliefs were additionally explained by emotions and gender. As expected based on propositions of the CVT and corresponding empirical evidence (e.g., Clem et al., 2021; Forsblom et al., 2022; Morony et al., 2013), math enjoyment was positively related to situated math competence beliefs and math anxiety was negatively related to

Table 4
Test results for gender differences in situated math competence beliefs, math enjoyment, math anxiety and math performance.

	t	*df*	*p*	*Cohen's d*
Math anxiety	4.0	864	<0.001	0.27

	U	*z*	*p*	*r*[b]
Math enjoyment	101,095.00	2.31	0.021	0.08
Math performance[a]	99,598.50	1.87	0.062	0.06

[a] Mean number of correct solutions (min = 0, max = 5).
[b] $r = z/\sqrt{866}$.

situated math competence beliefs, although the latter effect disappeared in models that also included gender as a predictor. Gender differences were in the expected direction (e.g., Cipora et al., 2022; Dowker et al., 2016; Morony et al., 2013): boys reported higher situated math competence beliefs and higher math enjoyment than girls, whereas girls reported higher math anxiety. We found no further gender differences, neither in math performance nor in the predictive value of both emotions on situated math competence beliefs. This shows that while the degree to which the emotions of anxiety and enjoyment are experienced differs between boys and girls, their effect on competence beliefs is the same.

4.1. Emotions and situated math competence beliefs

Research question 1 addressed the predictive value of math enjoyment and anxiety on situated math competence beliefs, controlled for actual math performance. As hypothesized, math enjoyment positively predicted situated competence beliefs in mathematics: after correcting for actual performance, students who generally tend to enjoy mathematical activities reported higher situated competence beliefs, while students with higher general math anxiety tend to report lower competence beliefs. These findings expand earlier studies showing strong interrelations between general math enjoyment and anxiety and global math competence beliefs such as mathematical self-concept (e.g., Goetz et al., 2010; Peixoto et al., 2017; Van der Beek et al., 2017; Wen & Dubé, 2022; Živković et al., 2023).

The positive effect of enjoyment turned out to be robust: the predictive value on situated math competence beliefs remained significant even when controlling for the predictive value of math performance, math anxiety, gender and interaction effects between gender and the other predictors. The negative predictive value of math anxiety, on the other hand, was only significant in the presence of math performance and math enjoyment. It is possible that the level of math anxiety as reported by the ninth-grade students in our sample was too low to significantly affect competence belief ratings in the presence of the stronger predictor of gender. As reported in the international study by Morony et al. (2013, pp. 86), Dutch students showed the lowest mathematics anxiety of all participating countries. Similar studies in different contexts (i.e. different ages, cross-cultural studies) could shed more light on this issue.

In sum, it can be concluded that, taking actual mathematical performance into account, students' habitual, recurring feelings regarding mathematics are a small but additional source of individual differences in situated math competence beliefs. Although it is not possible to draw causal conclusions from our concurrent data, it is suggested that students' general feelings towards math can to a limited extent affect their situated competence beliefs in a positive or negative way.

4.2. Gender differences

Research question 2 concerned gender differences in situated math competence beliefs, math performance, emotions and in the predictive value of emotions on situated math competence beliefs. Our results showed that gender indeed had a modest but unique predictive value. Even when correcting for emotions and math performance, boys rated their competence higher than girls. Furthermore, we found that the difference in competence ratings between correct and incorrect solutions was larger for boys than for girls. Phrased differently, the gender difference in situated competence beliefs was stronger for correct than for incorrect solutions.

Inspection of the raw competence belief data showed that boys were often absolutely certain (100 %) about their solutions, even after a mistake but especially when they had given a correct answer, while girls did not show such a pronounced peak. Corroborating previous research, our study did not find gender differences in math performance (Morony et al., 2013; Roderer & Roebers, 2013). This suggests that our findings are in line with the gender bias in math competence beliefs as reported in previous studies (e.g., Bench et al., 2015; Sterling et al., 2020). Boys do not only show higher global mathematics competence beliefs: the gender bias also manifests at single items.

In addition to the gender difference in math competence beliefs, girls also reported higher math anxiety and less math enjoyment than boys – factors that we also found to contribute to competence beliefs, especially enjoyment. In line with previous studies on gender differences (e.g., Cipora et al., 2022; Samuelsson & Samuelsson, 2016), these findings seem to reflect girls' general negative attitude towards math (Frenzel et al., 2007). This is rather worrying in the light of girls avoiding education and careers that require mathematical skills and knowledge (Ahmed, 2018; Bench et al., 2015; Dowker et al., 2016). Girls' negative attitude towards math has been related to gender stereotyping by parents and teachers: they believe that boys are better at math and more appropriate for STEM professions than girls (Gunderson et al., 2012; Rossi et al., 2022; Samuelsson & Samuelsson, 2016; Starr et al., 2022; Wang et al., 2021). Furthermore, higher confidence and overconfidence in one's mathematical performance has been directly associated with a higher testosterone level in men (Eisenegger et al., 2017).

In sum, our findings showed that being a boy or a girl contributes to situated math competence beliefs, even when gender differences in emotions are controlled for. That is, the gender difference in situated math competence beliefs, without taking emotions into account, would actually be larger: the fact that boys like math more and have lower math anxiety will positively contribute to their situated math competence beliefs, while girls' lower enjoyment and higher anxiety will negatively affect their situated math competence beliefs even more.

4.3. Implications for educational research and practices

An important topic for future research is to further unravel the contribution of global and situational factors in the development of students' competence beliefs in mathematics, as research on this topic is in its early stages (Eccles & Wigfield, 2020; Pekrun & Marsh, 2022). Our study showed that situated math competence beliefs are partially explained by variations in students' dispositional, trait achievement emotions. This aligns with the idea that dispositional emotions and control/value appraisals contribute to situational emotions and appraisals (Dietrich et al., 2019; Orbach et al., 2019).

However, studies on the discrepancy between trait and state emotions in mathematics suggest that trait measures mainly reflect subjective beliefs because they are recall-based, and that state measures reflect actual emotions as they are experienced in the moment (Roos et al., 2015). Therefore, situational, state emotions may possibly be more impactful on situated math competence beliefs than dispositional emotions regarding math (Orbach et al., 2019). Future research could expand our findings by investigating achievement emotions at a situated level, for example by using experience sampling (Goetz et al., 2016; Pekrun & Marsh, 2022). Moreover, implementing these measures in real achievement test situations could foster the ecological validity of the study (Roderer & Roebers, 2013). As our study underlines girls' negative attitude towards mathematics, gender differences should be the focus of attention. Furthermore, based on the propositions of the CVT (Pekrun, 2006), other possible predictors of situated competence beliefs such as value appraisals and achievement goals, could be investigated in future research in order to gain a profound insight into how these competence beliefs are built in specific achievement situations.

It is suggested that the frequency and intensity of situational experiences in achievement situations influence the development of more stable, dispositional emotions and appraisals such as competence beliefs (Dietrich et al., 2019; Orbach et al., 2019). The embeddedness of a situated competence belief rating in the achievement situation has the potential to provide clear and detailed cues for educational professionals to implement self-enhancement interventions in their practices, such as guidance in reflective thinking and feedback strategies (Stankov & Lee, 2014). A meta-analysis on the effects of competence beliefs interventions showed that interventions targeting a specific domain such as mathematics were much more effective than global self-enhancement interventions (O'Mara et al., 2006). It can be expected that more specific and recurring competence beliefs interventions directed to specific tasks yield even better effects.

Enhancing situated competence beliefs requires feedback aimed at a specific task, such as feedback on self-regulation skills and the processes needed to understand tasks. These types of feedback are generally found to be effective for learning (Hattie & Timperley, 2007). By contrast, the frame of reference model on self-concept entails that feedback is global and primarily directed towards the student rather than the process. This type of feedback, specifically aimed at personal evaluations, has been found not to be beneficial for either cognitive or affective aspects of learning (Dweck et al., 2004; Hattie & Timperley, 2007). Research on the effects of specific feedback strategies on situated competence beliefs and achievement emotions in mathematics is worthwhile (e.g., Shaqlaih & Celik, 2017). Furthermore, longitudinal research could provide insights into the effects of this intervention on the development of more global, habitual competence beliefs and emotions regarding math.

Given the disadvantaged position of girls in the mathematical field, their affect and achievement in mathematics deserves special attention in educational practices. Interventions designed to improve girls' attitudes towards mathematics should already be administered in elementary school, as negative affect starts to build from an early age (Frenzel et al., 2007). An intervention focusing on showing especially girls how often their answers are correct, even when they doubt themselves, may strengthen their confidence and possibly also reduce anxiety and enhance motivation. Furthermore, students with negative feelings towards mathematics, especially girls, could also benefit from interventions aimed at emotion regulation strategies and structured interventions fostering the belief that emotions and math abilities are malleable (Moè, 2016; Moè et al., 2021; Raccanello et al., 2022). Finally, informing parents and teachers about the undesirable effects of stereotyping for girls, and female role-model interventions with counter-stereotypical content are important steps in tackling this persistent problem in mathematics education (González-Pérez et al., 2020). These interventions could be a focus of future research.

4.4. Limitations

There are several limitations to our study. First, our study used concurrent data. Longitudinal data is to be preferred in order to profoundly understand the development of situated competence beliefs over time, and the causal relations between dispositional and situational aspects of emotions and appraisals. A second, related limitation is that we measured all variables of the study at the same time, while our conceptual model assumes that math enjoyment and anxiety, as predictors, were measured prior to the situated competence beliefs. Possibly, the (difficulty of the) math problems and the competence beliefs ratings in the questionnaire affected students' responses to the questions on math enjoyment and anxiety. In that case, although the questions were aimed at mathematics in general, our emotion measures might have also captured situational experiences. Furthermore, for future research we recommend to measure math enjoyment with multiple items, as is usually done in other studies (e.g., Raccanello et al., 2019).

By presenting the same mathematical items to all students, effects of item difficulty relative to ability could not be disentangled. Future research could adapt item difficulty to students' individual ability in mathematics, leading to similar proportions of correct and incorrect solutions for students with different levels of ability. This circumvents the issue that confidence in one's solution is easier to determine for items that were either very easy or very difficult for a particular student. Competence belief ratings are specifically interesting for items that generally match the individual students' overall mathematical knowledge and skills. Our study made a first step to correct for the biases that this may yield by including performance on the math problems of the solution as a predictor in the analyses. However, difficulty of the item is regarded as an important determinant of post-item competence judgements (Dinsmore & Parkinson, 2013; McMurran et al., 2023).

Finally, the study was done in a convenience sample of Dutch 15-year-olds and warrants generalization in studies in different populations. On the other hand, the large sample size of our study and the representation of students from different tracks add to the credibility and trustworthiness of our findings.

4.5. Conclusion

In conclusion, in the present study we demonstrated the modest predictive value of math enjoyment and math anxiety on situated competence beliefs in mathematics. Our results furthermore showed lower situated math competence beliefs and math enjoyment, and higher math anxiety in girls, despite the absence of a gender difference in math performance. These findings underline the need for specific educational interventions that enhance competence beliefs and positive emotions and invalidate the math gender stereotype. Post-item competence judgements capture the situatedness of competence beliefs and provide sound opportunities for motivational interventions. Our study expands the literature on relations between emotions and global math competence beliefs and acknowledges the context-dependent nature of competence beliefs. We encourage the use of situated competence belief measures in future research in order to gain more insight into how competence beliefs are built during mathematical problem solving.

Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Jojanneke P.J. Van der Beek: Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Sanne H.G. Van der Ven:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Supervision. **Evelyn H. Kroesbergen:** Writing – review & editing, Supervision. **Paul P.M. Leseman:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

None.

Acknowledgements

The data are part of a cross-cultural study by the National Institute of Education (NIE), Nanyang Technological University, Singapore, under the research project OER 48 LS, and the data collection was partially funded by NIE. We would especially like to thank Suzanne Morony for pre-processing the data. We would also like to thank Bernd Figner for his advice regarding the statistical analyses.

References

Ahmed, W. (2018). Developmental trajectories of math anxiety during adolescence: Associations with STEM career choice. *Journal of Adolescence, 67*, 158–166. https://doi.org/10.1016/j.adolescence.2018.06.010

Ahmed, W., Minnaert, A., Kuyper, H., & van der Werf, G. (2012). Reciprocal relationships between math self-concept and math anxiety. *Learning and Individual Differences, 22*(3), 385–389. https://doi.org/10.1016/j.lindif.2011.12.004

Arens, A. K., Marsh, H. W., Pekrun, R., Lichtenfeld, S., Murayama, K., & Vom Hofe, R. (2017). Math self-concept, grades, and achievement test scores: Long-term reciprocal effects across five waves and three achievement tracks. *Journal of Educational Psychology, 109*(5), 621–634. https://doi.org/10.1037/edu0000163

Arens, A. K., & Niepel, C. (2023). Formation of academic self-concept and intrinsic value within and across three domains: Extending the reciprocal internal/external frame of reference model. *British Journal of Educational Psychology, 00*, 1–26. https://doi.org/10.1111/bjep.12578

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Barroso, C., Ganley, C. M., McGraw, A. L., Geer, E. A., Hart, S. A., & Daucourt, M. C. (2021). A meta-analysis of the relation between math anxiety and math achievement. *Psychological Bulletin, 147*(2), 134–168. https://doi.org/10.1037/bul0000307

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bellon, E., Fias, W., & De Smedt, B. (2021). Too anxious to be confident? A panel longitudinal study into the interplay of mathematics anxiety and metacognitive monitoring in arithmetic achievement. *Journal of Educational Psychology, 113*(8), 1550–1564. https://doi.org/10.1037/edu0000704

Bench, S. W., Lench, H. C., Liew, J., Miner, K., & Flores, S. A. (2015). Gender gaps in overestimation of math performance. *Sex Roles, 72*, 536–546. https://doi.org/10.1007/s11199-015-0486-9

Boekaerts, M., & Rozendaal, J. S. (2010). Using multiple calibration indices in order to capture the complex picture of what affects students' accuracy of feeling of confidence. *Learning and Instruction, 20*(5), 372–382. https://doi.org/10.1016/j.learninstruc.2009.03.002

Camacho-Morles, J., Slemp, G. R., Pekrun, R., Loderer, K., Hou, H., & Oades, L. G. (2021). Activity achievement emotions and academic performance: A meta-analysis. *Educational Psychology Review, 33*(3), 1051–1095. https://doi.org/10.1007/s10648-020-09585-3

Casad, B. J., Hale, P., & Wachs, F. L. (2015). Parent-child math anxiety and math-gender stereotypes predict adolescents' math education outcomes. *Frontiers in Psychology, 6*, 1597. https://doi.org/10.3389/fpsyg.2015.01597

Cipora, K., Santos, F. H., Kucian, K., & Dowker, A. (2022). Mathematics anxiety - where are we and where shall we go? *Annals of the New York Academy of Sciences, 1513*(1), 10–20. https://doi.org/10.1111/nyas.14770

Clem, A. L., Hirvonen, R., Aunola, K., & Kiuru, N. (2021). Reciprocal relations between adolescents' self-concepts of ability and achievement emotions in mathematics and literacy. *Contemporary Educational Psychology, 65*, Article 101964. https://doi.org/10.1016/j.cedpsych.2021.101964

Dietrich, J., Moeller, J., Guo, J., Viljaranta, J., & Kracke, B. (2019). In-the-moment profiles of expectancies, task values, and costs. *Frontiers in Psychology, 10*, 1662. https://doi.org/10.3389/fpsyg.2019.01662

Dietrich, J., Viljaranta, J., Moeller, J., & Kracke, B. (2017). Situational expectancies and task values: Associations with students' effort. *Learning and Instruction, 47*, 53–64. https://doi.org/10.1016/j.learninstruc.2016.10.009

Dinsmore, D. L., & Parkinson, M. M. (2013). What are confidence judgments made of? Students' explanations for their confidence ratings and what that means for calibration. *Learning and Instruction, 24*, 4–14. https://doi.org/10.1016/j.learninstruc.2012.06.001

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology, 7*, 508. https://doi.org/10.3389/fpsyg.2016.00508

Du, C., Qin, K., Wang, Y., & Xin, T. (2021). Mathematics interest, anxiety, self-efficacy and achievement: Examining reciprocal relations. *Learning and Individual Differences, 91*, Article 102060. https://doi.org/10.1016/j.lindif.2021.102060

Dweck, C. S., Mangels, J. A., & Good, C. (2004). Motivational effects on attention, cognition, and performance. In *Motivation, emotion, and cognition* (pp. 55–70). Routledge.

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61*, Article 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

Eisenegger, C., Kumsta, R., Naef, M., Gromoll, J., & Heinrichs, M. (2017). Testosterone and androgen receptor gene polymorphism are associated with confidence and competitiveness in men. *Hormones and Behavior, 92*, 93–102. https://doi.org/10.1016/j.yhbeh.2016.09.011

European Commission. (2014, November 14). The structure of the European education systems 2014/15: Schematic diagrams. Retrieved on March 28th 2022, from https://eacea.ec.europa.eu/national-policies/eurydice/content/structure-european-education-systems-201415-schematic-diagrams_en.

Fernández, T. G., Kroesbergen, E., Pérez, C. R., González-Castro, P., & Gonzalez-Pienda, J. A. (2015). Factors involved in making post-performance judgments in mathematics problem-solving. *Psicothema, 27*(4), 374–380. https://repository.ubn.ru.nl/bitstream/handle/2066/178258/178258.pdf.

Forsblom, L., Pekrun, R., Loderer, K., & Peixoto, F. (2022). Cognitive appraisals, achievement emotions, and students' math achievement: A longitudinal analysis. *Journal of Educational Psychology, 114*(2), 346–367. https://doi.org/10.1037/edu0000671

Frenzel, A. C., Pekrun, R., & Goetz, T. (2007). Girls and mathematics - a "hopeless" issue? A control-value approach to gender differences in emotions towards mathematics. *European Journal of Psychology of Education, 22*, 497–514. https://doi.org/10.1007/BF03173468

Goetz, T., Cronjaeger, H., Frenzel, A. C., Lüdtke, O., & Hall, N. C. (2010). Academic self-concept and emotion relations: Domain specificity and age effects. *Contemporary Educational Psychology, 35*(1), 44–58. https://doi.org/10.1016/j.cedpsych.2009.10.001

Goetz, T., Sticca, F., Pekrun, R., Murayama, K., & Elliot, A. J. (2016). Intra-individual relations between achievement goals and discrete achievement emotions: An experience sampling approach. *Learning and Instruction, 41*, 115–125. https://doi.org/10.1016/j.learninstruc.2015.10.007

Gonida, E. N., & Leondari, A. (2011). Patterns of motivation among adolescents with biased and accurate self-efficacy beliefs. *International Journal of Educational Research, 50*(4), 209–220. https://doi.org/10.1016/j.ijer.2011.08.002

González-Pérez, S., Mateos de Cabo, R., & Sáinz, M. (2020). Girls in STEM: Is it a female role-model thing? *Frontiers in Psychology, 11*, 2204. https://doi.org/10.3389/fpsyg.2020.02204

Gunderson, E. A., Park, D., Maloney, E. A., Beilock, S. L., & Levine, S. C. (2018). Reciprocal relations among motivational frameworks, math anxiety, and math achievement in early elementary school. *Journal of Cognition and Development, 19*(1), 21–46. https://doi.org/10.1080/15248372.2017.1421538

Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*, 153–166. https://doi.org/10.1007/s11199-011-9996-2

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487

Huang, C. (2011). Self-concept and academic achievement: A meta-analysis of longitudinal relations. *Journal of School Psychology, 49*(5), 505–528. https://doi.org/10.1016/j.jsp.2011.07.001

Lazarides, R., & Lauermann, F. (2019). Gendered paths into STEM-related and language-related careers: Girls' and boys' motivational beliefs and career plans in math and language arts. *Frontiers in Psychology, 10*, 1243. https://doi.org/10.3389/fpsyg.2019.01243

Lehikoinen, H., Väisänen, P., Havu-Nuutinen, S., Lappalainen, K., & Niemivirta, M. (2023, March 23). *Developmental relations between mathematics self-concept, interest, and achievement: A comparison of solo-teaching and co-teaching.* https://doi.org/10.31234/osf.io/26m8e

Li, Q., Cho, H., Cosso, J., & Maeda, Y. (2021). Relations between students' mathematics anxiety and motivation to learn mathematics: A meta-analysis. *Educational Psychology Review, 33*, 1017–1049. https://doi.org/10.1007/s10648-020-09589-z

Lüftenegger, M., Schober, B., Van de Schoot, R., Wagner, P., Finsterwald, M., & Spiel, C. (2012). Lifelong learning as a goal. Do autonomy and self-regulation in school result in well prepared pupils? *Learning and Instruction, 22*(1), 27–36. https://doi.org/10.1016/j.learninstruc.2011.06.001

Malmberg, L. E., & Martin, A. J. (2019). Processes of students' effort exertion, competence beliefs and motivation: Cyclic and dynamical effects of learning experiences within school days and school subjects. *Contemporary Educational Psychology, 58*, 299–309. https://doi.org/10.1016/j.cedpsych.2019.03.013

Marsh, H. W. (1990). Influences of internal and external frames of reference on the formation of math and English self-concepts. *Journal of Educational Psychology, 82*(1), 107–116. https://doi.org/10.1037/0022-0663.82.1.107

Marsh, H. W., Pekrun, R., & Lüdtke, O. (2022). Directional ordering of self-concept, school grades, and standardized tests over five years: New tripartite models juxtaposing within-and between-person perspectives. *Educational Psychology Review, 34*, 2697–2744. https://doi.org/10.1007/s10648-022-09662-9

Master, A. (2021). Gender stereotypes influence children's STEM motivation. *Child Development Perspectives, 15*(3), 203–210. https://doi.org/10.1111/cdep.12424

McMurran, M., Weisbart, D., & Atit, K. (2023). The relationship between students' gender and their confidence in the correctness of their solutions to complex and difficult mathematics problems. *Learning and Individual Differences, 107*, Article 102349. https://doi.org/10.1016/j.lindif.2023.102349

Moè, A. (2016). Teaching motivation and strategies to improve mental rotation abilities. *Intelligence, 59*, 16–23. https://doi.org/10.1016/j.intell.2016.10.004

Moè, A. (2018). Mental rotation and mathematics: Gender-stereotyped beliefs and relationships in primary school children. *Learning and Individual Differences, 61*, 172–180. https://doi.org/10.1016/j.lindif.2017.12.002

Moè, A., Hausmann, M., & Hirnsten, M. (2021). Gender stereotypes and incremental beliefs in STEM and non-STEM students in three countries. Relationships with performance in cognitive tasks. *Psychological Research, 85*, 554–567. https://doi.org/10.1007/s00426-019-01285-0

Moeller, J., Viljaranta, J., Tolvanen, A., Kracke, B., & Dietrich, J. (2022). Introducing the DYNAMICS framework of moment-to-moment development in achievement motivation. *Learning and Instruction, 81*, Article 101653. https://doi.org/10.1016/j.learninstruc.2022.101653

Möller, J., & Marsh, H. W. (2013). Dimensional comparison theory. *Psychological Review, 120*(3), 544–560. https://doi.org/10.1037/a0032459

Morony, S., Kleitman, S., Lee, Y. P., & Stankov, L. (2013). Predicting achievement: Confidence vs self-efficacy, anxiety, and self-concept in Confucian and European countries. *International Journal of Educational Research, 58*, 79–96. https://doi.org/10.1016/j.ijer.2012.11.002

Namkung, J. M., Peng, P., & Lin, X. (2019). The relation between mathematics anxiety and mathematics performance among school-aged students: A meta-analysis. *Review of Educational Research, 89*(3), 459–496. https://doi.org/10.3102/0034654319843494

Nolen, S. B. (2020). A situative turn in the conversation on motivation theories. *Contemporary Educational Psychology, 61*, Article 101866. https://doi.org/10.1016/j.cedpsych.2020.101866

OECD. (2014). *PISA 2012 results in focus: What 15-year-olds know and what they can do with what they know*. Paris: Organisation for Economic Co-operation and Development Publications.

O'Mara, A. J., Marsh, H. W., Craven, R. G., & Debus, R. L. (2006). Do self-concept interventions make a difference? A synergistic blend of construct validation and meta-analysis. *Educational Psychologist, 41*, 181–206. https://doi.org/10.1207/s15326985ep4103_4

Orbach, L., Herzog, M., & Fritz, A. (2019). Relation of state-and trait-math anxiety to intelligence, math achievement and learning motivation. *Journal of Numerical Cognition, 5*(3), 371–399. https://doi.org/10.5964/jnc.v5i3.204

Passolunghi, M. C., Ferreira, T. I. R., & Tomasetto, C. (2014). Math–gender stereotypes and math-related beliefs in childhood and early adolescence. *Learning and Individual Differences, 34*, 70–76. https://doi.org/10.1016/j.lindif.2014.05.005

Peixoto, F., Sanches, C., Mata, L., & Monteiro, V. (2017). "How do you feel about math?": Relationships between competence and value appraisals, achievement emotions and academic achievement. *European Journal of Psychology of Education, 32*, 385–405. https://doi.org/10.1007/s10212-016-0299-4

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18*, 315–341. https://doi.org/10.1007/s10648-006-9029-9

Pekrun, R., Lichtenfeld, S., Marsh, H. W., Murayama, K., & Goetz, T. (2017). Achievement emotions and academic performance: Longitudinal models of reciprocal effects. *Child Development, 88*(5), 1653–1670. https://doi.org/10.1111/cdev.12704

Pekrun, R., & Marsh, H. W. (2022). Research on situated motivation and emotion: Progress and open problems. *Learning and Instruction, 81*, Article 101664. https://doi.org/10.1016/j.learninstruc.2022.101664

Pekrun, R., Marsh, H. W., Elliot, A. J., Stockinger, K., Perry, R. P., Vogl, E., … Vispoel, W. P. (2023). A three-dimensional taxonomy of achievement emotions. *Journal of Personality and Social Psychology, 124*(1), 145–178. https://doi.org/10.1037/pspp0000448

Pekrun, R., & Perry, R. P. (2014). Control-value theory of achievement emotions. In R. Pekrun, & L. Linnenbrink-Garcia (Red.) (Eds.), *International handbook of emotions in education* (pp. 130–151). Routledge.

Pinxten, M., Marsh, H. W., De Fraine, B., Van Den Noortgate, W., & Van Damme, J. (2014). Enjoying mathematics or feeling competent in mathematics? Reciprocal effects on mathematics achievement and perceived math effort expenditure. *British Journal of Educational Psychology, 84*, 152–174. https://doi.org/10.1111/bjep.12028

Putwain, D. W., & Wood, P. (2023). Anxiety in the mathematics classroom: Reciprocal relations with control and value, and relations with subsequent achievement. *ZDM–Mathematics Education, 55*(2), 285–298. https://doi.org/10.1007/s11858-022-01390-2

R Core Team. (2023). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Raccanello, D., Brondino, M., & Moè, A. (2022). Malleability beliefs shape mathematics-related achievement emotions: The mediating role of emotion regulation in primary school children. *Learning and Individual Differences, 97*, Article 102177. https://doi.org/10.1016/j.lindif.2022.102177

Raccanello, D., Brondino, M., Moè, A., Stupnisky, R., & Lichtenfeld, S. (2019). Enjoyment, boredom, anxiety in elementary schools in two domains: Relations with achievement. *Journal of Experimental Education, 87*, 449–469. https://doi.org/10.1080/00220973.2018.1448747

Roderer, T., & Roebers, C. (2013). Children's performance estimation in mathematics and science tests over a school year: A pilot study. *Electronic Journal of Research in Educational Psychology, 11*(1), 5–24. https://doi.org/10.7892/boris.45238

Roos, A. L., Bieg, M., Götz, T., Frenzel, A. C., Taxer, J., & Zeidner, M. (2015). Experiencing more mathematics anxiety than expected? Contrasting trait and state anxiety in high achieving students. *High Ability Studies, 26*(2), 245–258. https://doi.org/10.1080/13598139.2015.1095078

Rossi, S., Xenidou-Dervou, I., Simsek, E., Artemenko, C., Daroczy, G., Nuerk, H. C., & Cipora, K. (2022). Mathematics–gender stereotype endorsement influences mathematics anxiety, self-concept, and performance differently in men and women. *Annals of the New York Academy of Sciences, 1513*(1), 121–139. https://doi.org/10.1111/nyas.14779

Salz, S., & Figueroa, D. T. (2009). *Take the test: Sample questions from OECD's PISA assessments*. OECD Publishing.

Samuelsson, M., & Samuelsson, J. (2016). Gender differences in boys' and girls' perception of teaching and learning mathematics. *Open Review of Educational Research, 3*(1), 18–34. https://doi.org/10.1080/23265507.2015.1127770

Shaqlaih, A., & Celik, M. (2017). Fostering students' preparation and achievement in upper level math courses. *International Journal for Mathematics Teaching and Learning, 18*, 383–397. https://doi.org/10.4256/ijmtl.v18i3.33

Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2014). Calibration of self-evaluations of mathematical ability for students in England aged 13 and 15, and their intentions to study non-compulsory mathematics after age 16. *International Journal of Educational Research, 76*, 49–61. https://doi.org/10.1016/j.ijer.2013.10.008

Smith, T. J., & McKenna, C. M. (2012). An examination of ordinal regression goodness-of-fit indices under varied sample conditions and link functions. *Multiple Linear Regression Viewpoints, 38*(1), 1–7.

Stankov, L., & Lee, J. (2014). Quest for the best non-cognitive predictor of academic achievement. *Educational Psychology, 34*, 1–8. https://doi.org/10.1080/01443410.2013.858908

Stankov, L., Lee, J., Luo, W., & Hogan, D. J. (2012). Confidence: A better predictor of academic achievement than self-efficacy, self-concept and anxiety? *Learning and Individual Differences, 22*(6), 747–758. https://doi.org/10.1016/j.lindif.2012.05.013

Stankov, L., Morony, S., & Lee, Y. P. (2014). Confidence: The best non-cognitive predictor of academic achievement? *Educational Psychology, 34*, 9–28. https://doi.org/10.1080/01443410.2013.814194

Starr, C. R., Gao, Y., Lee, G., Safavian, N., Rubach, C., Dicke, A. L., … Simpkins, S. D. (2022). Parents' math gender stereotypes and their correlates: An examination of the similarities and differences over the past 25 years. *Sex Roles, 87*, 603–619. https://doi.org/10.1007/s11199-022-01337-7

Sterling, A. D., Thompson, M. E., Wang, S., Kusimo, A., Gilmartin, S., & Sheppard, S. (2020). The confidence gap predicts the gender pay gap among STEM graduates. *Proceedings of the National Academy of Sciences, 117*(48), 30303–30308. https://doi.org/10.1073/pnas.2010269117

Van der Beek, J. P. J., Van der Ven, S. H. G., Kroesbergen, E. H., & Leseman, P. P. M. (2017). Self-concept mediates the relation between achievement and emotions in mathematics. *British Journal of Educational Psychology, 87*(3), 478–495. https://doi.org/10.1111/bjep.12160

Wang, Z., Borriello, G. A., Oh, W., Lukowski, S., & Malanchini, M. (2021). Co-development of math anxiety, math self-concept, and math value in adolescence: The roles of parents and math teachers. *Contemporary Educational Psychology, 67*, Article 102016. https://doi.org/10.1016/j.cedpsych.2021.102016

Wang, Z., Rimfeld, K., Shakeshaft, N., Schofield, K., & Malanchini, M. (2020). The longitudinal role of mathematics anxiety in mathematics development: Issues of gender differences and domain-specificity. *Journal of Adolescence, 80*, 220–232. https://doi.org/10.1016/j.adolescence.2020.03.003

Weidinger, A. F., Steinmayr, R., & Spinath, B. (2018). Changes in the relation between competence beliefs and achievement in math across elementary school years. *Child Development, 89*, e138–e156. https://doi.org/10.1111/cdev.12806

Wen, R., & Dubé, A. K. (2022). A systematic review of secondary students' attitudes towards mathematics and its relations with mathematics achievement. *Journal of Numerical Cognition, 8*(2), 295–325. https://doi.org/10.5964/jnc.7937

Wu, H., Guo, Y., Yang, Y., Zhao, L., & Guo, C. (2021). A meta-analysis of the longitudinal relationship between academic self-concept and academic achievement. *Educational Psychology Review, 33*, 1749–1778. https://doi.org/10.1007/s10648-021-09600-1

Živković, M., Pellizzoni, S., Doz, E., Cuder, A., Mammarella, I., & Passolunghi, M. C. (2023). Math self-efficacy or anxiety? The role of emotional and motivational contribution in math performance. *Social Psychology of Education, 26*, 579–601. https://doi.org/10.1007/s11218-023-09760-8