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The Role of Teacher Constructive Support for Gender Differences in Motivational Outcomes in Secondary School Mathematics

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ABSTRACT

In secondary school mathematics, females often display lower levels of motivational outcomes than males, which can lead to gender gaps in future study or career choice. To reduce these gaps, it is crucial to evaluate which aspects of classroom teaching quality might be involved. Teacher constructive support is one especially promising aspect, as it strongly relates to student motivational outcomes. The present pre-registered study investigates how student gender is related to self-concept, self-efficacy, and interest in secondary school mathematics lessons on the quadratic equation and examines the moderating role of teacher constructive support for this relationship. Using questionnaire data from the Teaching and Learning International Survey Video Study Germany (*n* = 1,116 secondary school students), we applied latent moderated structural equation models to examine the direct effects as well as the interaction of student gender and constructive support on student motivational outcomes in mathematics lessons. Female gender was negatively associated with self-concept and self-efficacy, but not with interest. Various facets of constructive support were positively associated with motivational outcomes, but no interaction effects with gender were found. These findings are discussed with regard to constructive support and the persisting gender gap in mathematics. Directions for future research are suggested.

KEYWORDS

Teacher support; gender; motivation; mathematics; secondary school

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INTRODUCTION

Male and female students tend to differ in mathematics in regards to their motivational outcomes, with female students often displaying lower levels of these outcomes, especially in secondary school (Else-Quest et al., 2010). Research shows that these outcomes can in turn affect students' achievement, as well as future academic and career choices (Pintrich, 2003; Wigfield & Eccles, 2000). In order to understand and reduce these gender gaps, it is important to investigate what aspects of students' daily experiences in school might alleviate the effects of gender on their motivational outcomes. Students spend a large portion of their lives in the classroom, and various aspects of the classroom environment have strong effects on a plethora of student outcomes, including motivational outcomes such as self-concept, self-efficacy, and interest (Scherer & Nilsen, 2016). Teacher constructive support, which is defined as positive teacher-student relationships regarding both instructional and emotional matters, is one such aspect of the classroom environment that is linked to these motivational factors (Fauth et al., 2014; Ryan & Patrick, 2001). Students who perceive teachers as more supportive and caring tend to have higher self-concept, self-efficacy, and interest in subjects such as mathematics (Yu & Singh, 2018). However, what is still unclear is whether there are differential effects of perceived constructive support on these student outcomes in regards to student gender. The goal of this study is to investigate whether perceived teacher constructive support plays a moderating role between gender and student motivational outcomes in the specific learning context of quadratic equations in secondary school mathematics classrooms. By doing so, this study aims to contribute to research which identifies classroom factors that could help to reduce gender differences in motivational outcomes in mathematics, which to date remains relatively underinvestigated.

Theoretical background

Gender differences in mathematics self-concept, self-efficacy, and interest

Gender differences in mathematics are traditionally discussed in terms of achievement outcomes such as grades or exam scores. However, research has shown that, on average, male and female students barely differ in these outcomes, if at all (Else-Quest et al., 2010; Hyde et al., 2008; OECD, 2013; Wang et al., 2013). Where research does find substantial gender differences is in regards to student motivational outcomes (Kollmayer et al., 2018; Wigfield et al., 2002). When discussing motivational outcomes in educational contexts, many different constructs are often classified under this term. Generally, motivational outcomes can be defined as student self-beliefs, values, and goals that relate to their choices, persistence, and achievement in academic settings (Wigfield et al., 2012). Gender differences in these motivational outcomes are concerning, as they have been shown to be strongly connected to further academic choices such as postsecondary study track and career choices. These differences can often be seen in mathematics classrooms (Köller et al., 2001; Möller et al., 2020; Parker et al., 2014).

Eccles' expectancy-value motivation model proposes a widely supported explanation for how these motivational outcomes might affect student choices and behaviors. This theory posits that achievement motivation is determined by a combination of expectancy components and values for tasks in particular domains (Eccles & Wigfield, 2020; Wigfield, 1994). Expectancies for success, also commonly referred to as competency beliefs, are closely related to constructs such as self-concept and self-efficacy. These constructs pertain to how well students expect to perform in certain domains, and their perceptions of their own competence. Meanwhile, task value constructs generally refer to how useful, important, or interesting students perceive certain domains to be (Wigfield & Eccles, 2000). Following this expectancy-value model, we chose to focus our study on the motivational outcomes of self-concept, self-efficacy, and interest in order to encompass both expectancy-related (self-concept and self-efficacy) as well as value-related (interest) constructs.

Self-efficacy and self-concept both involve self-beliefs and therefore are strongly related. Self-efficacy refers to an individual's belief in their own abilities to perform certain tasks and produce desired outcomes, and the degree of confidence in one's capabilities to utilize their skills, knowledge, and resources to accomplish goals (Schunk & Pajares, 2002). Self-concept, on the other hand, is a much broader belief or perception one holds about themselves, including self-perceptions about their own abilities, characteristics, values, and affect (Bong & Clark, 1999). Both self-efficacy and self-concept are often used as indicators for the expectancy component, but slightly differ from expectancies for success, which are defined as beliefs regarding the consequences that a specific behavior will produce with respect to a task outcome (Eccles & Wigfield, 2020). Interest can be defined as the long-term orientation of a person toward an object, activity, or field of knowledge, which involves both positive emotions and positive value attributions (Schiefele, 1991). Interest is strongly related to the intrinsic value that an individual holds for a specific task or activity (Eccles, 2005).

All of these motivational outcomes are domain-specific, meaning that they are linked to the academic subject in question and can vary across different subjects (Brunner, 2008; Hornstra et al., 2016). For example, a student may have high self-efficacy in reading, but low self-efficacy in mathematics. Studies have attempted to understand how gender differences arise between students in these motivational outcomes. Differences seem to stem from multiple social, environmental, and systemic factors that influence an individuals' behaviors, interests, and self-beliefs, especially when it comes to gender-stereotyped activities (Wang & Degol, 2013). As children develop and interact with their social environment, gender stereotypes are acquired from significant people in their lives, such as parents, teachers, and peers (Smith & Farkas, 2022; Tiedemann, 2000), as well as from society and culture (Kollmayer et al., 2018). These learned gender stereotypes can have an impact on children's identity, choices, behaviors, and beliefs (Martin & Halverson, 1981).

Numerous theoretical paradigms have been proposed to explain the underlying mechanisms behind these observed effects. One prominent explanation pertains to the concept of stereotype threat. Stereotype threat theory posits that when students are aware of negative stereotypes concerning their social or demographic group (e.g., gender) in certain domains, they may feel concerned about fulfilling that stereotype, leading to decreased motivation, more negative self-beliefs, and increased anxiety in that domain (Fogliati & Bussey, 2013; Thoman et al., 2013). Certain themes and subjects may be more affected by gender stereotypes than others, and gender differences in motivational outcomes can usually be seen more often in subjects that are stereotypically favored towards one gender or the other.

Mathematics is one such subject that is consistently seen as a stereotypically "male" subject (Makarova et al., 2019). In mathematics, female students tend to display lower levels of motivational outcomes when compared to male students (Pajares, 2005). These differences have been shown to increase and become more pronounced as students get older (Bharadwaj et al., 2016; Contini et al., 2017), which can be attributed to an increasing endorsement of traditional gender stereotypes (Rowley et al., 2007) as well as an overall decrease in students' motivational outcomes after the transition to secondary school (Frenzel et al., 2010; Plenty & Heubeck, 2013). Results from the Program for International Student Assessment (PISA) 2012 showed that, on average, across 15-year old students in 72 countries, female students reported lower levels of math self-efficacy and self-concept, and more negative math attitudes as compared to male students (OECD, 2013). More recent results from PISA 2018 also demonstrated that, on average, only one percent of female students reported that they aspired to pursue a mathematics- or science-related career, compared to eight percent of male students (Schleicher, 2019). This is especially interesting in light of PISA 2018 mathematics performance results, which showed that male and female students barely differed in regards to math achievement and ability. Although there is currently no research explicitly exploring gender differences in specific sub-disciplines of math such as algebra or calculus, gender differences in self-concept, self-efficacy, and interest have been found in numerous studies spanning a range of mathematical content (Barth & Masters, 2020; Frenzel et al., 2010; Goldman & Penner, 2016; Preckel et al., 2008; Wang, 2012). It can therefore be inferred that these gender differences are likely to be present in various mathematical sub-disciplines.

In light of the clear evidence that female students consistently display lower levels of motivational outcomes than male students in mathematics, and the established importance of these outcomes for future academic and career choices, it is crucial to identify factors that can positively promote motivational outcomes for female students in math. While various aspects of one's environment such as family, peers, and culture do have a large impact on academic outcomes, the school environment and students' experience in the classroom play arguably one of the largest roles in shaping motivation and educational beliefs (Tiedemann, 2000; Wigfield & Harold, 1992). As teachers and their lessons are the main focus of most time spent in the classroom, teaching quality has a considerable impact on both achievement-related and motivational outcomes of students (Burić & Kim, 2020; Yang & Kaiser, 2022). Therefore, an important step in reducing gender differences is identifying what aspects of teaching quality could serve to positively promote motivational outcomes, especially for female students who are typically at risk of having lower levels of these outcomes in mathematics.

In considering the measurement of motivational outcomes, it is important to differentiate between these outcomes as traits and states. While motivational outcomes as traits reflect long-term tendencies in perceptions of abilities across various academic situations, motivational outcomes can also be measured as states, which capture perceptions specific to particular learning experiences or domains (Wasserman & Wasserman, 2020). Indeed, various motivational outcomes have been treated as both trait and state in the literature (Hausen et al., 2022; Soland et al., 2019). Evidence has also shown that these motivational outcomes, when measured as states, can be influenced by situation-specific factors and contextual interactions, especially in the context of classroom instruction (Gaspard & Lauermann, 2021). This study therefore focuses on assessing students' motivational outcomes as states in relation to two focal lessons on quadratic equations. By examining these motivational outcomes as states, we aimed to explore how perceived constructive support might influence students' immediate motivational outcomes within the targeted domain of quadratic equations, providing insights into the potential impact of support factors in a specific academic context.

Teacher constructive support and student self-concept, self-efficacy, and interest
Teacher constructive support is one such aspect of teaching quality that has been proven to be extremely important for student motivational factors (Cornelius-White, 2007). Constructive support is a rather broad construct in the literature and has also been referred to as supportive climate (Klieme et al., 2009) or positive climate (Burić & Kim, 2020). Constructive support can be defined as the quality of social interactions between teachers and students in the classroom, and to what degree they are characterized by interest, respect, support, and productive feedback (Fauth et al., 2014; Praetorius et al., 2014). Teachers who provide constructive support treat students with courtesy and warmth when correcting errors and giving feedback, allow for differentiation and adapt to individual needs, and strive to foster positive student relationships (Praetorius et al., 2018). Given its broad nature, constructive support can be further separated into two facets, namely instructional support and social-emotional support. Whereas instructional support refers to teachers who care about student learning and want to help them learn, social-emotional support refers to teachers who care about students on a personal level and provide emotional support (Patrick et al., 2007). Some examples of instructional support are aiding students with content or instruction-related problems, or providing individualized support and consistent feedback. Examples of social-emotional support include empathizing with student struggles and establishing safe emotional dynamics in the classroom (Hamre & Pianta, 2005). While empirically distinguishable, both facets are strongly correlated and can be grouped under the overarching measure of constructive support (Decristan et al., 2022; Wentzel, 1997).

Given that both facets of constructive support are mostly interpersonal and emotional by nature, it is not surprising that perceived constructive support has been shown to be the aspect of teaching quality most strongly related to students' motivation and enjoyment of a subject, as well as most influential for their self-beliefs (Allen et al., 2006; Cornelius-White, 2007). According to the self-determination theory of motivation, individuals have three basic psychological needs that relate to their motivation: relatedness, competence, and autonomy (Reeve et al., 2004). When students perceive teachers as involved, encouraging, and interested in both their learning and emotional well-being, this helps to fulfill their need for relatedness, competence, and autonomy (Martin & Dowson, 2009). Students' sense of relatedness is fostered when they feel an atmosphere of connection, acceptance, and belonging within the classroom environment (Ryan & Powelson, 1991). When teachers provide feedback, guidance, and support for students' progress and well-being, it also enhances students' beliefs in their own abilities and can increase their feelings of competence (Niemiec & Ryan, 2009). Finally, by showing interest in students' learning progress, individual perspectives, and ideas, teachers encourage students to exercise greater self-direction and be active in their own learning processes, addressing their need for autonomy (Ruzek et al., 2016). These mechanisms can then lead students to experience higher levels of motivational outcomes and increased engagement (Reeve, 2012; Skinner & Belmont, 1993). Indeed, multiple studies have shown positive effects of perceived constructive support on a plethora of student academic outcomes. Students who perceive their teachers as more supportive have been shown to display more interest in the subject in question (Fauth et al., 2014; Lazarides & Ittel, 2013). Perceived constructive support has also been shown to positively relate to student self-efficacy (Fast et al., 2010; Sakiz et al., 2012) and self-concept (Demaray et al., 2009; McFarland et al., 2016). How supported students feel by their teachers, both instructionally and emotionally, has also been shown to affect their engagement, self-esteem, and intrinsic motivation (Patrick et al., 2007; Ryan et al., 1994; Wang & Eccles, 2012).

When measuring constructive support, or any other aspects of teaching quality, researchers tend to rely on either external observers, teacher perceptions, or student perceptions. While each method has both advantages and disadvantages, when aiming to investigate the effects of constructive support on student outcomes, student perceptions may be considered the more appropriate method, as whether or not instruction is perceived as supportive is something students are best able to judge for themselves (Göllner et al., 2021). Therefore, in this study, we focus on student perceptions of constructive support.

While it is quite established in the literature that constructive support is important for student motivational-affective outcomes (Sabol & Pianta, 2012), it remains unclear whether these effects are the same for both genders, or whether they differ for male and female students. Researchers in this field have called for more investigation into gender differences in the relationship between student outcomes and constructive support (Rueger et al., 2008).

Teacher constructive support as a moderator between gender and student motivational outcomes

When discussing the effects of constructive support on student motivational outcomes, it is important to consider that students have individual differences and pre-existing characteristics. This perspective is in line with a central paradigm of psychology research, known as the aptitude-treatment-interaction, which states that aspects of a treatment will influence individuals differently depending on their pre-existing cognitive and motivational-affective characteristics (Snow & Swanson, 1992). This paradigm has also been applied to educational research, with aspects of teaching quality considered "treatments" and student characteristics considered "aptitudes" (Kieft et al., 2008). As gender differences have been shown to exist in student motivational outcomes from an early age, this implies that males and females have different preconditions in terms of motivation, which could in turn lead to differential effects of teaching quality.

These differing effects are especially important to investigate when considering certain groups that are in jeopardy of low motivation in mathematics. Specifically in regards to constructive support, there is some evidence to suggest that it may be more important for some students than for others (Curby et al., 2009; Decristan et al., 2016). For example, Malecki and Demaray (2006) found that perceived teacher support had a stronger relation to student academic outcomes for students from lower socio-economic backgrounds than for those from higher socio-economic backgrounds. Hamre and Piante (2005) explained this effect as the academic risk perspective, which posits that relational assets in the environment may have a greater influence on student outcomes for students who are already at risk of having lower levels of those outcomes. Applied to the mathematics classroom, research shows that female students are typically at risk of displaying lower levels of motivational outcomes such as self-concept, self-efficacy, and interest. Due to these lower levels of motivational outcomes, female students should be especially supported in mathematics classrooms.

When viewed through the lens of mathematics classrooms, there are various positive mechanisms of constructive support that may be particularly relevant for female students. Female students tend to experience feelings of lower competence and confidence in mathematics, and may thus benefit more from perceived constructive support. Both instructional and social-emotional support from teachers can help create an atmosphere where students feel more inclined to explore and engage (Birch & Ladd, 1997; Furrer & Skinner, 2003). As studies have shown that for girls, warm and caring climates are more important to their motivation and engagement in mathematics than for boys (Fredricks et al., 2018; Rueger et al., 2008), the positive effects of supportive classroom environments may be especially pronounced for female students. Research has also shown that in mathematics, female students tend to feel less of a sense of belonging, which is another important aspect related to their competency beliefs and interest (Dasgupta & Stout, 2014; Good et al., 2012). As supportive teachers who provide feedback and make students feel respected can also lead to a deeper sense of belonging in the classroom (Liu et al., 2018), this may also be a mechanism which is especially important for female students in mathematics. Lastly, students who feel supported by their teachers report feeling more self-assured and less afraid of making mistakes or asking for help (Hughes & Chen, 2011). By providing constructive support, teachers create a safe space for students to experience failure, and students are also less likely to attribute mistakes to their lack of ability (Ryan &

Patrick, 2001). Given that female students are more likely to attribute their failures in math to their own ability and display lower competency beliefs in mathematics (Dickhäuser & Meyer, 2006; Herbert & Stipek, 2005), this is also a relationship that could be exceptionally relevant for female students' motivational outcomes. Despite theoretical explanations for why constructive support may be particularly relevant for female students, there remains a sparse number of studies that have empirically investigated this relationship. A small number of studies have provided some preliminary evidence that support from teachers in general may have differential effects on male and female students' motivational outcomes. For example, McFarland and colleagues (2016) found that perceived closeness in student-teacher relationships significantly predicted general self-concept for girls, but not for boys, in primary school. There is also evidence that these differential effects may be seen in stereotypically "gendered" subjects. Vekiri (2010), for example, found a stronger association for girls than for boys between perceived teacher support and competence beliefs in middle school information technology classrooms, which is a stereotypically "male" subject. Additionally, Hochweber and Vieluf (2018) found that higher levels of teacher support were related to smaller gender differences in reading enjoyment (a stereotypically female subject) for ninth grade students. In one of the few studies that has examined these relationships in mathematics, Fredericks and colleagues (2018) found that teacher social-emotional support was more strongly related to girls' behavioral engagement in mathematics, and teacher instructional support was more strongly related to girls' emotional engagement than boys.

The present study

Research consistently points to gender differences in students' motivation in mathematics. Although several approaches have been implemented to positively affect particularly female students' mathematical motivation, there has been little research related to regular classroom instruction. This study thus aims to examine the role of student perceptions of constructive support for motivation in mathematics in general, and the connection between students' gender and motivational outcomes in particular in order to understand whether constructive support reduces gender differences.

The research goal of this study is to investigate the effects of gender and both facets of perceived constructive support (i.e., instructional and social-emotional) on student motivational outcomes, as well as whether the two facets of constructive support moderate the relationship between gender and student motivational outcomes. Therefore, we evaluated the following research questions (RQ) and hypotheses (H):

RQ1: Do female students have significantly lower levels of self-concept, self-efficacy, and interest than male students in secondary school mathematics lessons on quadratic equations?

> H1: We hypothesize that male and female students significantly differ in their self-concept, self-efficacy, and interest in mathematics lessons on quadratic equations. We specifically hypothesize that female students will display lower

levels of self-concept, self-efficacy, and interest on average than male students.

RQ2: Are student perceptions of constructive support related to secondary school students' self-concept, self-efficacy, and interest in secondary school mathematics lessons on quadratic equations?

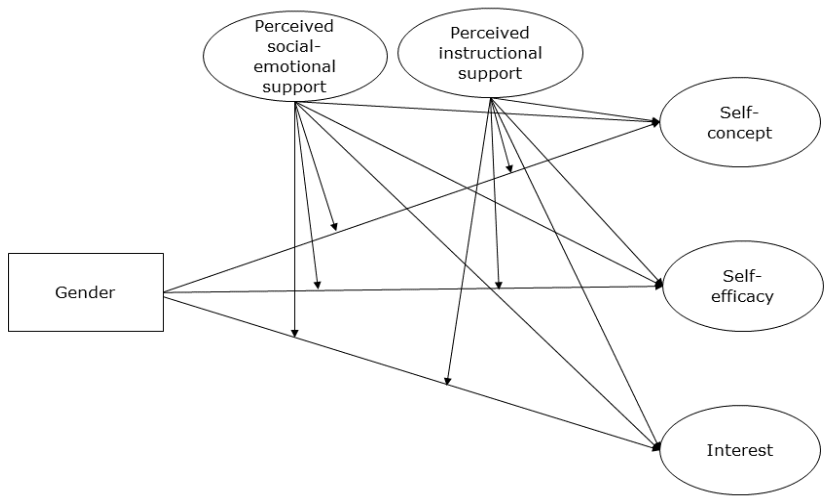
H2: We hypothesize that student perceptions of constructive support (i.e., instructional and social-emotional) are significantly and positively related to student self-concept, self-efficacy, and interest in mathematics lessons on quadratic equations.

RQ3: Do student perceptions of constructive support moderate the relationship between gender and students' self-concept, self-efficacy, and interest in secondary school mathematics lessons on quadratic equations?

H3: We hypothesize that student perceptions of constructive support (i.e., instructional and social-emotional), moderate the relationship between gender and student self-concept, self-efficacy, and interest in mathematics lessons on quadratic equations in secondary school. Specifically, we hypothesize that higher levels of perceived constructive support will have a stronger, positive effect on the relationship between gender and student self-concept, self-efficacy, and interest for female students than for male students.

Figure 1 shows the assumed relationship between gender and the two facets of perceived constructive support with students' motivational outcomes as examined in RQ3. This study is pre-registered, and all hypothesis and planned analyses were uploaded to the Open Science Framework (OSF) platform prior to conducting the data analyses. The pre-registration can be viewed via the following link: https://osf.io/q9bej/?view_only=499c86b19d964d018ed8520bee753430

Figure 1
Interplay between gender and perceived constructive support and its effects on motivational outcomes



Note. The oval shapes represent latent variables and the rectangle shapes represent manifest variables.

METHODS

Sample and procedure

This study is a secondary analysis of data from the German sample of the Teaching and Learning International Survey (TALIS) Video Study, an international field study in secondary school mathematics education (OECD, 2020a, 2020b). The full data contains coded videos of lessons, as well as student and teacher questionnaires and student achievement tests. The German sample is made up of 50 classes from grades 8 to 10 from 38 schools throughout Germany. However, for this study, one class from the overall sample was excluded, as data for motivational outcomes and perceived teacher support was missing for all students in this class. The sample included in this study therefore consisted of 49 classes with a total of 1,116 students (48.5% female, n = 554). The mean age of the students was 15.0 years (SD = 0.80), with 6 classes from grade 8 (12.25%), 37 classes from grade 9 (75.5%), and 6 classes from grade 10 (12.25%). The portion of students with a migration background (defined as mother, father, or student not born in Germany) was 15.8% (n = 165). From the 49 teachers, 22 (44.9%) were female.

Students were taught by their usual mathematics teachers. In order to ensure that student outcomes could be accurately compared across classes, all students received the same two lessons on quadratic equations. Quadratic equations are an integral concept in algebra, which is one of the main components of mathematics education across numerous countries (National Council of Teachers of Mathematics

(NCTM), 2000; OECD, 2019) and therefore an appropriate topic for comparison.

Data was collected over a timespan of about 8 weeks. Prior to starting with the focus unit on quadratic equations, the pre-test questionnaire was administered to both students and teachers. Two separate lessons were then randomly selected to be recorded throughout the unit, one from the first half of the unit and one from the second half. Once the unit was finished, students and teachers completed a post-test questionnaire.

Measures

All measures used in this study, except for student gender, were taken from the student post-test questionnaire. Student gender was obtained from the pre-test questionnaire. For the post-test measures, students were instructed to answer all items in relation to the focal lessons on quadratic equations ("While answering the following questions, please always think about your learning during the unit on the topic of quadratic equations"). All scales were developed or adapted for the TALIS study by an international project team (Mihaly et al., 2021).

Self-concept

Student self-concept in quadratic equations was assessed via six items on a four-point Likert Scale (1 = *Strongly disagree* to 4 = *Strongly agree*). Items were adapted from the self-concept scale used in PISA (Mihaly et al., 2021). Sample items included "Learning about quadratic equations was easy for me" and "When I was taught the topic of quadratic equations, I could understand the concepts very well". The scale showed good reliability (α = .88).

Self-efficacy

Student self-efficacy in quadratic equations was assessed using five items based on the Self-Efficacy for Learning and Performance component of the Motivated Strategies for Learning Questionnaire (Mihaly et al., 2021). Items were answered on a four-point Likert scale (1 = *Not at all true of me* to 4 = *Extremely true of me*). Items included phrases such as "I expected to do well in quadratic equations" or "I believed I would receive an excellent grade for the topic of quadratic equations". The reliability of the scale was good (α = .89).

Interest

Student personal interest in quadratic equations was assessed via three items on a four-point Likert scale (1 = *Strongly disagree* to 4 = *Strongly agree*; see Mihaly et al., 2021). Items asked students to answer based on their current math lessons they had just participated in (e.g., "I was interested in the topic of quadratic equations" or "After my mathematics class on the topic of quadratic equations I was often already curious about the next mathematics class"). The reliability of the scale was good (α = .82).

Student perceptions of constructive support

The items for both facets of constructive support were answered on a four-point Likert scale (1 = *Strongly disagree* to 4 = *Strongly agree*). The facet of instructional support was assessed via three items (Mihaly et al., 2021), for example, "Our mathematics teacher helped us with our learning" or "Our mathematics teacher continued teaching until we understood". Reliability was good, with α = .86. The facet of social-emotional support was assessed via five items (Mihaly et al., 2021), for example, "I got along well with my mathematics teacher" or "My mathematics teacher really listened to what I had to say". This scale also showed good reliability, with α = .90.

Student gender
Student gender was collected in the pre-test questionnaire. Students were asked to indicate whether they were male or female. This variable was then dichotomously coded in the data set, with males as 0 and females as 1.

Analyses and missing data
All inferential analyses were conducted in Mplus Version 8.3 (Muthén & Muthén, 1998–2017). We first conducted confirmatory factor analyses (CFA) to evaluate a measurement model in order to assess the fit of the observed items to the latent variables of self-concept, self-efficacy, interest, student perception of instructional support, and student perception of social-emotional support. A CFA with all latent variables included was used as the final measurement model. Goodness-of-fit was assessed using the following fit indices: Comparative Fit Index (CFI), Tucker-Lewis index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Residual (SRMR). We considered (a) CFI and TLI > .95 and .90, (b) RMSEA < .06 and .08, and (c) SRMR < .08 as indicators of excellent and adequate model fit, respectively (Hu & Bentler, 1999).

Before moving on to the structural equation modelling, we also tested for measurement invariance across gender as a prerequisite for investigating mean differences. Specifically, we assessed configural, metric, and scalar invariance for two latent variable models: one with the three motivational outcomes of self-concept, self-efficacy, and interest, as well as one model with the two perceived constructive support facets of instructional support and social-emotional support. We used the cutoff values recommended by Chen (2007) when evaluating the measurement invariance and considered a reduction of ΔCFI ≥ .010 and ΔRMSEA ≥ .015 or ΔSRMR ≥ .010 as indicative of non-invariance.

In order to evaluate RQ1, we used a structural equation model (SEM) with gender as a predictor of student self-concept, self-efficacy, and interest. Gender was always included with males as the reference category (intercept) in order to assess the effect of "being female" on the outcome variables. We included the latent variables of student self-concept, self-efficacy, and interest all together in one model. To investigate RQ2, we simultaneously added both facets of perceived constructive support (i.e., instructional and social-emotional) to the model as additional predictors of self-concept, self-efficacy, and interest. We used the same fit indices cutoffs described above to evaluate the model fit of the SEMs.

For RQ3, we used a latent moderated structural equation modelling approach (Klein & Moosbrugger, 2000). We followed the approach for latent moderated SEMs recommended by Maslowsky and colleagues (2015), which recommends comparing models with and without interaction terms in order to test for moderation. Therefore, we used the model with gender and both facets of perceived constructive support as predictors as the model without interaction effects (Model 0). We then added two latent interaction terms between gender and each facet of perceived constructive support to create a model with interaction effects (Model 1)[1]. Traditional model fit indices are not applicable to latent moderated SEMs. We therefore used the log-likelihood ratio test as recommend by Maslowsky and colleagues (2015) to compare the fit of Model 1 relative to Model 0. The likelihood ratio test statistic (LRTS) was calculated via the following equation:

$$\text{LRTS} = -2[(\text{log-likelihood for Model 0}) - (\text{log-likelihood for Model 1})]$$

The LRTS can be evaluated using the chi-square distribution. The degrees of freedom were calculated as the difference between the number of free parameters in the model with interaction and the number of free parameters in the model without interaction. A significant result from the log-likelihood ratio test indicates that Model 0 constitutes a significant loss in fit as compared to Model 1 (the models with interaction), and therefore suggests that Model 1 is a better fit to the data. Additionally, we compared the Bayesian information criterions (BIC) of the two models. A smaller BIC value is suggestive of a better fit to the data (Lin et al., 2017).

In order to account for the nested structure of the data (i.e., students nested within classes), all analyses were conducted using a robust sandwich estimator (TYPE = COMPLEX in Mplus) to adjust standard errors of parameter estimates and correct for the non-independence of observations (Asparouhov, 2005; Muthén & Satorra, 1995). To handle the non-normality of the data, maximum likelihood estimation with robust standard errors (MLR) was used for all models. For the post-test questionnaire, 91 students (8.2%) did not participate, resulting in missing data. We handled this missing data using the full information maximum likelihood approach (Schafer & Graham, 2002). Significance was evaluated using a *p*-value cutoff of < .05. As Mplus only provides two-tailed p-values, we recalculated the p-values for the directional hypotheses to be one-tailed. The outcome variables of self-concept, self-efficacy, and interest were allowed to correlate in all models. All relevant syntaxes and corresponding materials are public and can be found on the OSF webpage for this study via the following link:
https://osf.io/q9bej/?view_only=499c86b19d964d018ed8520bee753430

RESULTS

Descriptive statistics

Descriptive statistics and intercorrelations among latent and observed (i.e., gender) variables are reported for the total sample, males, and females in Table 1. Overall, the correlation patterns suggest significant relationships between all variables of interest, except for gender and student perceptions of constructive support.

Table 1
Descriptive statistics and latent correlations for all variables

Measure	2	3	4	5	6	*M*	*SD*
Total sample							
1. Self-concept	.80*	.60*	.41*	.34*	-.09*	2.59	0.65
2. Self-efficacy	-	.51*	.31*	.27*	-.16*	2.35	0.72
3. Interest		-	.42*	.43*	.08*	2.17	0.73
4. Instructional support			-	.81*	< .01	2.87	0.77
5. Social-emotional support				-	< .01	2.99	0.74
6. Gender					-	-	-
Measure	2	3	4	5		*M*	*SD*
Males							
1. Self-concept	.83*	.60*	.37*	.33*		2.64	0.67
2. Self-efficacy	-	.52*	.28*	.24		2.46	0.72
3. Interest		-	.40*	.43*		2.12	0.74
4. Instructional support			-	.81*		2.88	0.80
5. Social-emotional support				-		2.99	0.79
Measure	2	3	4	5		*M*	*SD*
Females							
1. Self-concept	.78*	.63*	.38*	.31*		2.54	0.62
2. Self-efficacy	-	.57*	.29*	.25*		2.25	0.70
3. Interest		-	.41*	.42*		2.21	0.70
4. Instructional support			-	.79*		2.86	0.74
5. Social-emotional support				-		2.99	0.70

Note. Gender: 0 = male, 1 = female. Range of values for all scales was from 1–4. **p* < .05.

Confirmatory factor analysis and measurement invariance

The results of the CFA for the final measurement model with all latent variables (self-efficacy, self-concept, interest, perceived instructional support and perceived social-emotional support) revealed excellent model fit for all scales: CFI = .97, TLI = .97, RMSEA = .04 [.037, .045], and SRMR = .04. All items loaded strongly and significantly onto the respective latent factors.

As can be seen in Table 2, the results of the measurement invariance confirmed configural, metric, and scalar invariance across gender based on the cutoff values recommended by Chen (2007) for both the three motivational outcome variables grouped together, as well as the two facets of perceived constructive support grouped together. In other words, it can be assumed that both male and female students interpreted the perceptions of constructive support and motivational outcome measures in the same manner.

Table 2
Measurement invariance across gender

	df	χ^2	CFI	ΔCFI	RMSEA	ΔRMSEA	SRMR
Motivational outcomes							
Configural	90	339.863	.971		.052		.039
Metric	79	349.121	.972	.001	.050	.002	.040
Scalar	68	352.005	.973	.001	.047	.003	.040
Constructive support							
Configural	50	95.454	.990		.056		.021
Metric	44	102.184	.990	< .001	.053	.003	.024
Scalar	38	105.455	.990	< .001	.048	.005	.024

Main effects of gender on motivational outcomes
For RQ1, we fit a SEM with gender as a predictor of student self-concept, self-efficacy, and interest in quadratic equations. The model showed a good fit to the data, with CFI = .97, TLI = .96, RMSEA = .05 [.045, .058], and SRMR = .04. Model coefficients showed that gender (in this case, being female) significantly and negatively predicted self-concept (b = -.15, p = .02) and self-efficacy (b = -.33, p < .001) in quadratic equations. There were no significant effects of gender on interest in quadratic equations.

Main effects of teacher constructive support on motivational outcomes
To evaluate RQ2, we added both facets of perceived constructive support (instructional and social-emotional support) to the model as predictors of self-concept, self-efficacy, and interest in quadratic equations (Model 0). The results indicated good model fit (CFI = .97, TLI = .96, RMSEA = .04 [.036, .049], and SRMR = .04). Perceived instructional support had a significant positive effect on self-concept (b = .36, p < .001), self-efficacy (b = .24, p = .01) and interest (b = .20, p = .03) in quadratic equations. Perceived social-emotional support had a significant positive effect on interest in quadratic equations (b = .31, p < .001), but not on self-concept or self-efficacy in quadratic equations.

Interaction effects of gender and perceived constructive support
To answer RQ3, we added latent interactions (gender x perceived instructional support and gender x perceived social-emotional support) to Model 0, resulting in Model 1. When comparing the Model 1 to Model 0, the log-likelihood test was not significant (df = 6, χ^2 = 0.65), indicating that the model with interaction did not represent a better fit to the data. There was also no reduction in BIC in the interaction model as compared to the non-interaction model, additionally indicating that the interaction model was not a better fit to the data. The specific estimates for the interaction within the model were non-significant. Path coefficients for the model without interaction (Model 0) and the latent interaction model (Model 1) can be seen in Table 3.

Table 3
Path coefficients of the main effect model (Model 0) and the latent interaction model (Model 1) for gender and perceived instructional support

	Model 0			Model 1		
Outcome and predictor	Est. (*SE*)	Std. est.	*p*	Est. (*SE*)	Std. est.	*p*
Self-concept						
1. Gender	-0.15 (0.07)	-0.14	.016	-0.15 (0.07)	-0.14	.016
2. Instructional support	0.36 (0.10)	0.34	<.001	0.36 (0.16)	0.34	.011
3. Social-emotional support	0.05 (0.08)	0.05	.271	0.05 (0.15)	0.05	.361
4. Gender × Instructional support				0.01 (0.20)	0.01	.492
5. Gender × Social-emotional support				-0.01 (0.20)	-0.01	.491
R^2	.15			.15		
Self-efficacy						
1. Gender	-0.33 (0.07)	-0.31	<.001	-0.33 (0.07)	-0.31	<.001
2. Instructional support	0.24 (0.10)	0.23	<.001	0.25 (0.15)	0.24	.045
3. Social-emotional support	0.06 (0.11)	0.06	.287	0.04 (0.15)	0.04	.388
4. Gender × Instructional support				-0.01 (0.18)	-0.01	.476
5. Gender × Social-emotional support				0.04 (0.17)	0.04	.405
R^2	.10			.10		
Interest						
1. Gender	0.16 (0.07)	0.15	.992	0.17 (0.07)	0.15	.992
2. Instructional support	0.20 (0.10)	0.18	.028	0.17 (0.13)	0.15	.101
3. Social-emotional support	0.31 (0.11)	0.28	<.001	0.33 (0.13)	0.29	.008
4. Gender × Instructional support				0.06 (0.16)	0.05	.350
5. Gender × Social-emotional support				-0.02 (0.15)	-0.02	.439
R^2	.19			.20		
Goodness-of-fit						
AIC	46698.235			46709.586		
BIC	47082.475			47123.009		

Note. Est. = unstandardized parameter estimate; Std. est. = standardized estimate; AIC = Akaike information criterion; BIC = Bayesian information criterion.

DISCUSSION

Despite more attention in recent years to gender equality in education, female students continue to display lower levels of motivational outcomes than males in STEM subjects, including mathematics. The question of how to reduce these gender differences is not new in educational research and has been a topic of discourse for many years. Numerous interventions have been conducted that attempt to promote motivational outcomes in gender stereotypical subjects and therefore reduce differences between male and female students (for a meta-analysis, see Lesperance et al., 2022). While these interventions are a promising avenue for reducing gender differences, they do not refer to daily classroom learning and instruction. Although it has been shown that constructive support is positively connected to various motivational outcomes (e.g., summarized by Cornelius-White, 2007), there are still very few studies examining whether constructive support can especially bolster these outcomes for female students in mathematics. The present research therefore aimed to evaluate the main effects of student gender and perceived constructive support on the student motivational outcomes of self-concept, self-efficacy, and interest in quadratic equations in secondary school mathematics classrooms, as well as to investigate whether perceived constructive support moderated the relationship between gender and self-concept, self-efficacy, and interest.

Although our analyses focused on the specific mathematical topic of quadratic equations, a thorough understanding of quadratic equation concepts is also necessary for more advanced mathematical topics such as geometry and calculus (López et al., 2016) and can therefore be considered as a core concept of mathematics educations. Although there has been no systematic analysis of the specific differences in quadratic equations to date, we would not assume that there are particularly extreme differences in the area of quadratic equations from other areas of mathematics, making it appropriate to relate to the literature on general mathematics education.

The impact of gender on student motivational outcomes

Our hypothesis regarding the effect of gender on self-concept, self-efficacy, and interest in secondary school mathematics lessons on quadratic equations (H1) was partially supported. Consistent with previous findings on gender differences in math self-concept (Marsh & Yeung, 1998; Nagy et al., 2010; Watt, 2004) and self-efficacy (Huang, 2013; Pajares, 2005; Zander et al., 2020), female students reported lower levels of these outcomes than male students. However, we did not find any significant effect of gender on interest in quadratic equations. These results are in contrast to other studies that have found girls to report lower levels of interest in mathematics, especially in secondary school (Frenzel et al., 2010; Köller et al., 2001; Watt, 2004). However, there is also some evidence to suggest that the gender gap in math interest may not be as prominent as the gap in competency-related outcomes. For example, Ganley and Lubienski (2016) found that the differences between male and female students' math interest were substantially smaller than differences in confidence in their math abilities (although differences in interest were present). Furthermore, some studies have found no gender differences in math interest, even while still finding gender differences in math competency beliefs (Fredricks et al., 2018; Jacobs et al., 2002; Simpkins et al., 2006). Combined with the results of the current study, this suggests that while gender differences have been observed in both math competency-related outcomes (e.g., self-concept, self-efficacy) and math interest, the gender differences in competency-related outcomes seem to be stronger and more consistent. Therefore, it is possible that the persistent gender gap in mathematics-related areas is less a result of females not being interested in math, but rather more due to beliefs concerning their own capabilities in these areas.

Drawing on prior research, these lower levels of competency-beliefs in quadratic equations found in female students in our study may be due to learned gender stereotypes that students have incorporated into their own identities. Indeed, studies have shown that students who endorse traditional gender stereotypes in STEM-related subjects tend to display more gender stereotypical self-beliefs about their competencies in those subjects (e.g., female students do not perceive themselves as competent compared to male students) (Casad et al., 2015; Correll, 2001; Koul et al., 2016). Stereotype threat could provide one explanation for this mechanism. When female students are cognizant of the stereotype that females are not seen as competent or capable in STEM subjects such as math or science, this awareness can affect their self-assessment of their own abilities (Inzlicht & Schmader, 2012; Pennington et al., 2016; Shapiro & Williams, 2012).

The positive impact of perceived constructive support on motivational outcomes

Our findings partially supported our second hypothesis (H2). We found that while both perceived instructional support and perceived social-emotional support had a significant, positive effect on student interest in quadratic equations, only perceived instructional support had a significant, positive effect on self-concept and self-efficacy in quadratic equations. These results provide valuable insights into the unique effects of these two facets of perceived constructive support on specific student motivational outcomes.

The positive effect of both facets of perceived constructive support on student interest in quadratic equations corroborates prior research that has demonstrated the significance of a supportive learning environment for student interest. The significant effects found in our study suggest that when students perceive that their teachers provide clear feedback, helpful resources, and guidance, as well as foster a sense of belonging, empathy, and emotional well-being, they are more likely to develop a genuine interest in a given subject (Lazarides et al., 2019; Lazarides & Ittel, 2013; Prewett et al., 2019).

However, our results showed an interesting distinction in regards to self-concept and self-efficacy in quadratic equations. We found that for these two motivational outcomes, only the facet of perceived instructional support had a significant and positive effect. This implies that while perceived instructional support plays a crucial role in shaping students’ perception of their own competence and efficacy in quadratic equations, perceived social-emotional support may not. When placing these results in the context of prior research, it is important to acknowledge that many studies on the relationship between perceived constructive support and student motivational outcomes do not distinguish teacher support into two facets as we have done in our study, but rather use an overall measure, with aspects of both facets creating a single factor or just one facet as a measure. Studies combing both facets into a single factor also find significant effects on competency-related beliefs (Ahmed et al., 2008; Lapointe et al., 2005; Yu & Singh, 2018). However, it is difficult to determine what aspects of perceived constructive support are driving these effects when they are combined in one model. A sparse number of studies looking at the sole effect of perceived instructional support also found positive effects for self-efficacy and self-concept (Liu et al., 2018; Ma et al., 2021; Yildirim, 2012). While some of the few studies investigating solely perceived social-emotional support have found that it is not related to student competency outcomes (Ruzek et al., 2016), there is sparse evidence for relations between perceived social-emotional support and self-efficacy (Yang et al., 2021).

The differential effects of perceived instructional support and perceived social-emotional support on student self-concept, self-efficacy, and interest in quadratic equations underscore the multifaceted nature of perceived constructive support in mathematics classrooms. Of the three outcomes evaluated, interest has been shown to be the most affective in nature, is very closely tied to positive emotions experienced while performing a given task, and relies heavily on interactions and experience (Frenzel et al., 2010). Therefore, it may be possible that the personal and emotional implications of perceived social-emotional support are especially important for student interest. In contrast, it seems as though it is instructional support that plays the more critical role in fostering students' confidence and beliefs about their abilities in quadratic equations. This is in line with the nature of self-concept and self-efficacy, which both involve more cognitive appraisals of ones' capabilities and are therefore heavily tied to learning and instruction (Bong & Skaalvik, 2003). Additionally, these results imply that even when students perceive their teachers as warm, caring, and personally interested in their emotional well-being, this has little effect on their evaluations of their own competency expectations. This underscores the nuanced nature of the associations between expectancy-related outcomes and contextual factors such as constructive support compared to the associations observed between value-related outcomes and these same contextual factors.

The interaction of perceived constructive support and gender

Our findings did not support our hypothesis regarding the interaction of gender and perceived constructive support (H3). There were no significant effects of the interaction between gender and perceived constructive support for any of the student motivational outcomes, indicating that while perceived constructive support has positive effects for students with regard to motivational outcomes, our study did not support the hypothesis that these effects might be stronger for female students in mathematics than for boys. One possible explanation for the lack of interaction effects could be due to the design of the data. The data used was cross-sectional and only assessed student motivation in the classroom of interest at one time point. Although the instruments used attempted to measure the motivational constructs as specifically as possible in a state context (e.g., "I was interested in the topic of quadratic equations", "I expected to do well in quadratic equations"), it is possible that detecting interaction effects in this design is not feasible. Motivational outcomes are continuously shaped over the entire course of a student's life and therefore may need to be investigated over the long-term.

Another possible explanation for the lack of interaction effects may be that constructive support is equally beneficial for male and female students. Through the framework of the academic risk perspective, it is plausible that females would especially benefit from high levels of perceived constructive support due to the risk of them having lower levels of motivational outcomes in mathematics. However, our results suggest that the effect of perceived constructive support on student motivational outcomes does not differ in regards to gender. While it is positive to confirm that perceived constructive support has beneficial effects for all students, this might signify that even with highly supportive teachers, female students still display lower levels of motivational outcomes in mathematics, which may be due to factors outside of the classroom, and therefore may require more targeted approaches to combat these deficits.

Limitations and future research

Although this study takes a crucial first look at the role of perceived constructive support for gender differences in student motivational outcomes, there are a few limitations that should be considered when interpreting the results. First, the variables used were measured as states. In order to investigate the long-term effects of perceived constructive support on student motivational outcomes, it may be crucial to examine these relationships as traits using longitudinal data. While the current work took a first step in evaluating if any interactions exist between these variables, assessing them over longer periods of time would allow for a more detailed view, as well as the possibility to evaluate how perceived constructive support is related to changes in motivational outcomes over time. Students already start to display gender differences in motivational outcomes in primary school (Eccles et al., 1993). Therefore, these differences tend to already exist by the time they enter secondary school and may require a longer period of time to evaluate what factors influence their development. Additionally, the current data did not allow us to take reciprocal effects into account, however, results from other studies have suggested that some motivational outcomes, for example, interest, may also have an effect on how students perceive their classroom environment over longer periods of time (Lazarides & Ittel, 2012). Future research should therefore consider using longitudinal designs when examining these relationships.

Secondly, all scales included in the study were self-reported by the students. Self-report data is susceptible to common method bias (Podsakoff et al., 2012). It is also possible that social desirability influenced the self-reported information. We chose to only use student data in this study because we were interested in the individual experiences of each student and how that related to their motivational outcomes. However, future studies could consider drawing information about constructive support from additional sources such as teacher reports or third-party observations to reduce the possibility of biases from purely self-reported data.

It is also important to mention that the secondary school system in Germany consists of different school types, each with a distinct curriculum. The students in the current data set were mainly (82%) from the *Gymnasium* school type, which can be considered as the most academically rigorous type. The high percentage of students from this school type in the data did not allow us to assess any differences between school types, however, it is plausible that gender differences may present as more or less pronounced in different types of schools. Indeed, gender differences have been shown to vary in regards to ability level (Preckel et al., 2008). Additionally, schools with a stronger vocational focus tend to have a different study body composition in regards to socioeconomic status.

Socioeconomic status can also have an effect on gender differences in academic contexts (Cascella & Pampaka, 2020). Therefore, future research should also strive to include a more diverse sample of schools when continuing studies in the German secondary school system.

Moreover, future research could further explore additional contextual variables that have also been associated with variations in gender differences in motivational outcomes such as gifted versus average-ability students (Preckel et al., 2008; Rudasill et al., 2009; Zhou et al., 2017) and teacher gender (Duffy et al., 2001; Gong et al., 2018; Martin & Marsh, 2005). These factors have been previously associated with gender differences in motivational outcomes, however, due to the focus and scope of our present research questions, they were not explicitly examined. Expanding the investigation to include these variables would provide a deeper understanding of the relationships between these various factors.

Implications and conclusions

This study is one of the first to examine the potential of perceived constructive support as a moderator of gender differences in student motivational outcomes in secondary school mathematics. Concurrent with prior research, our results showed that female students display lower levels of both self-concept and self-efficacy in mathematics. However, contradictory to prior research, we did not find the same negative effect for female math interest. While more research is needed to examine the concrete gender differences in these outcomes, our results hint that when trying to encourage female students in mathematics, it might be more pertinent to focus on their competency beliefs. This is valuable as many educational initiatives that focus on females in STEM subjects tend to address a wide range of outcomes, and knowledge of which motivational constructs are most affected by gender is crucial going forward. These results also highlight the importance of developing a more differentiated view of gender differences in motivational outcomes in mathematics.

This study also illustrates that perceived constructive support continues to be an important predictor of student motivational outcomes in mathematics, and that there are nuanced relationships between specific facets of perceived constructive support and specific motivational outcomes. These findings emphasize the need for educational practitioners to support students in ways that not only promote interest but also enhance students' self-perceptions and feelings of competence in their mathematical abilities. Perceived constructive support should continue to be studied by researchers in more diverse contexts and populations to deeply understand the magnitude and variation of these effects. Additionally, these results provide evidence for teacher training and continuing teacher education that training teachers to be supportive, caring actors in students' lives can make an important impact on student motivation, and subsequently, future educational outcomes.

While we did not find the hypothesized interaction effects between gender and perceived constructive support, this line of research is, to our knowledge, one of the first studies to approach this topic. Future studies should continue to investigate the interplay of these variables and their effects in various contexts and with different populations. These results provide a starting point for that research. Additionally, this study highlights the relative scarcity of studies that investigate how various aspects of teaching quality and classroom environment may influence gender differences in mathematics. Continued research in this area is crucial for understanding what educators can do to combat gender differences in mathematics and create an environment where all students can reach their full potential, regardless of gender.

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ENDNOTES

[1] Due to the high correlation between perceived instructional support and perceived social-emotional support, we also ran two separate latent moderation SEMs in order to ensure that the lack of interaction effects was not due to the high correlation between these two facets. However, we also did not find any interaction effects for the separate models with just perceived instructional support or just perceived social-emotional support.

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