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Research article

Students' online course activity, together with self-efficacy and test anxiety, predicts mathematics exam results

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Abstract: Many students find mathematics to be a challenging subject to learn, leading to anxiety and low self-efficacy. While positive self-beliefs towards mathematics encourage engagement and learning, negative emotions like anxiety restrain it. Voluntary online courses for learning mathematics may provide an opportunity to strengthen mathematical skills in a more flexible and self-paced environment, potentially helping reduce anxiety and increase self-efficacy. The present study investigated the associations among online course activity, test anxiety, and self-efficacy with mathematics performance in high-stakes settings. The analyses focused on 144 final-year high school students who completed the wide national mathematics exam after participating in a voluntary online preparation course. In addition to self-reported data, data regarding online course activity logs and national mathematics exam results from a state registry were extracted. According to our analysis, more frequent online course activity was associated with higher mathematics exam scores. Surprisingly, online course activity was not related to either students' self-efficacy or test anxiety. The regression analysis results suggest that self-efficacy was the strongest predictor of mathematics national examination results, with test anxiety and online course activity also contributing significantly. Although previous research has examined the role of self-beliefs in predicting mathematics exam results, this study offers a fresh perspective by focusing on these relationships in an online educational context, where their dynamics may differ.

Keywords: Online Course Activity, Mathematics Achievement, Test Anxiety, Self-efficacy

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1 Introduction

Education has undergone significant changes over the past several years, as the COVID-19 pandemic prompted schools to rely more heavily on technology for learning. This shift has impacted both teaching and student experiences, offering valuable lessons on how digital tools can be effectively utilised in education. As with other subjects, these changes have influenced the teaching and learning of mathematics, making it essential to understand their impact on learning.

Learning mathematics is a cognitively demanding multidimensional academic activity that can be challenging for many students. According to Räsänen et al. (2019), individuals with low mathematics achievement levels often experience the worst effects of economic turbulence. They emphasise that strong basic skills are necessary for learning new skills and managing changes in the workforce. Building on that, Gravemeijer et al. (2017) also highlight the increasing role of mathematics proficiency in the technological world. However, feeling that mathematics is difficult or challenging can lead to negative emotions such as anxiety, fear, as well as lower self-efficacy (Dowker et al., 2016). Therefore, both mathematics-related self-efficacy and test anxiety have been widely studied in relation to mathematics achievement. For instance, students' mathematics test anxiety (Ashcraft & Krause, 2007; Barroso & Ganley, 2021; Jameson et al., 2022) is negatively related, and self-efficacy (Ayotola & Adedeji, 2009; Gafoor & Kurukkan, 2015; Kim et al., 2014; Rutherford et al., 2020; Živković et al., 2023) is positively related to mathematics exam results or academic achievement in general.

Research has found that middle school students who prefer online learning may experience higher levels of mathematics anxiety (Pirrone et al., 2022). This phenomenon has not yet been widely studied, and results may vary across educational levels. Although the current study focuses on test anxiety rather than mathematics anxiety, these two constructs are distinct yet significantly positively correlated (Dowker & Sheridan, 2022; Kazelskis et al., 2000). A study involving upper secondary school students found that higher-performing students reported more negative emotions and lower-performing students less anxiety in distance learning compared to contact learning (Sydänmaanlakka et al., 2024). Lu et al. (2024) found that college students who took asynchronous online courses experienced less test anxiety when their self-efficacy was higher. Alamri (2022) found that university students' academic self-efficacy was positively associated with higher levels of learning engagement and learning persistence in MOOCs (*Massive Open Online Courses*), indicating that students who believe in their academic capabilities are more likely to engage more actively in their online courses. Previous research has found that spending more time on MOOCs is linked to better course achievement (Greene et al., 2015; Phan et al., 2016). Despite these findings, relatively little research has examined mathematics-related self-beliefs in relation to voluntary participation in online mathematics courses. It remains unclear whether students with higher levels of mathematics anxiety engage more actively in such courses as a compensatory strategy or whether less anxious students are more likely to participate. Consequently, there is a need to investigate how mathematics self-efficacy, test

anxiety, mathematics achievement, and online course activity are interrelated, as well as their relative contributions to mathematics examination outcomes.

1.1 Theoretical framework: social cognitive perspective on mathematics learning

Social cognitive theory is based on an interactional model of causation, according to which environmental events, personal factors, and behaviour interact to affect one another (Bandura, 1986). A central concept within this framework is self-efficacy, which refers to individuals' beliefs about their capabilities and influences how they think, feel, and behave (Bandura, 1986, 1995). In academic contexts, this means that students who believe they can manage examination-related demands are less likely to experience distress, whereas perceived inefficacy may increase anxiety and impair functioning (Bandura, 1995).

Within learning settings, students approach academic tasks with pre-existing self-efficacy beliefs shaped by prior experiences (Cook & Artino Jr, 2016). During task engagement, these beliefs influence cognitive engagement, emotional responses, motivation, and behavioural choices (Miao & Ma, 2022). Self-regulated learning, which can be referred as an active, constructive process in which learners set goals and monitor and control their cognitive, motivational, and behavioural activities, represents a key mechanism through which self-efficacy beliefs affect performance (Cook & Artino Jr, 2016; Pintrich, 2004). In the context of online learning, self-regulated learning is particularly meaningful, as students must independently manage their engagement with course materials and learning activities (Broadbent & Poon, 2015). In the present study, participation in a voluntary online course may be seen as an expression of self-regulated behaviour, as students must actively choose to engage with course materials. Thus, online course activity can be interpreted as a behavioural indicator of self-regulated learning.

Social cognitive theory also emphasises the role of forethought in motivated behaviour. By symbolically representing future outcomes, students transform anticipated consequences into present motivators that regulate their learning (Bandura, 1986). In high-stakes examination contexts, students may convert anticipated exam results into current study efforts. Through self-regulatory mechanisms, forethought is translated into behaviour, such as engaging in preparatory learning activities (e.g., a preparation course for an exam). In the context of the present study, self-efficacy represents a key personal factor, test anxiety reflects an emotional response, and online course activity captures behavioural engagement. From a social cognitive perspective, these components are interrelated and may shape students' high-stakes examination results. In particular, higher self-efficacy may be associated with lower test anxiety and greater engagement in preparation course activities, which together may contribute to improved examination performance.

1.2 Literature overview: self-efficacy, test anxiety, and online course activity

Although mathematics holds significant value, previous research suggests that many students perceive it as difficult, boring, abstract, impractical (Ignacio et al., 2006), or even

threatening (Figueira et al., 2023), although there may be considerable variation in students' experiences and attitudes. These perceptions are often associated with lower motivation and self-efficacy, a concept grounded in social cognitive theory (Bandura, 1986), and may negatively affect students' engagement and performance. Thus, exploring ways to support students in their mathematics learning and achievement may have a significant impact on their future.

Arens et al. (2022) found in their longitudinal study that students' former mathematics grades and test scores were positively related to their self-efficacy, which, in turn, was positively related to their later mathematics test scores but not their mathematics grades. Previous research has also consistently shown a negative association between mathematics anxiety and self-efficacy, indicating that students with higher self-efficacy tend to report lower levels of mathematics anxiety (Gonzales et al., 2019; Hiller et al., 2022; Kaskens et al., 2020; Rozgonjuk et al., 2020; Şanli, 2021; Živković et al., 2023).

Testing or assessment can be a particularly anxiety-inducing component of learning mathematics (Kazelskis et al., 2000; Lukowski et al., 2019). This may be especially the case in high-stakes contexts, such as national examinations, where performance has substantial academic consequences (Heissel et al., 2021). Testing assesses academic achievement, and performing well on tests can be significant for one's career (Şanli, 2021). Many studies have found a negative correlation between mathematics-related test anxiety and achievement (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Barroso & Ganley, 2021; Hembree, 1990; Jameson et al., 2022; von der Embse et al., 2018). Additionally, Quintero (2022) revealed that students who suffer from mathematics test anxiety tend to exhibit avoidance patterns in their everyday lives; this can also potentially explain poorer achievement results.

While prior research often refers broadly to mathematics anxiety without consistently distinguishing between state and trait components, the present study focuses specifically on mathematics-related test anxiety. In the present study, we use the terms mathematics-related test anxiety or mathematics test anxiety to refer to students' self-reported tendency to experience anxiety in mathematics testing and performance situations. Although test anxiety may be experienced as a state in specific examination contexts, the present measure was completed outside an actual examination and therefore does not assess momentary anxiety during a particular test. Rather, it captures a context-specific tendency to experience anxiety in mathematics-related assessment situations, consistent with common self-report approaches to test anxiety assessment (Cassady & Finch, 2020; von der Embse et al., 2013).

Research has shown that online engagement and achievement are positively correlated; however, the relationship between online engagement and self-efficacy remains unclear. Moreover, there is conflicting evidence on how test anxiety and self-efficacy relate to online course activity. Puzziferro (2008) found that self-efficacy and performance were not correlated in online courses, whereas Kadoić and Oreški (2018) found that students performed better in a course when they logged in more often. In line with this, Wang & Mousavi (2023) conducted a systematic review and meta-analysis on which log variables predict academic achievement based on 88 studies, revealing that log variables, ranging from generic metrics like log time and clicks to course-specific variables such as engagement

with online activities and weekly videos, are commonly examined in relation to predicting academic achievement. Recent learning analytics research suggests that while online disengagement consistently predicts low achievement, high levels of online engagement do not reliably indicate high achievement, particularly when engagement is measured cross-sectionally (Saqr et al., 2023). Furthermore, it has also been found that engaging in specific tasks increases individuals' familiarity with those tasks, enhancing their confidence in their ability to solve them (Borgonovi & Pokropek, 2019). Previous research suggests that self-efficacy may influence academic achievement indirectly through engagement, as engagement has been shown to mediate the relationship between self-efficacy and performance in online learning environments (Zhuofan et al., 2024). Participating in an online course allows students the opportunity to engage in various tasks multiple times, helping them become accustomed to the course material and thus enhancing their self-efficacy.

Earlier research has looked into various online courses, including Massive Open Online Courses (MOOCs). Previous studies have found that spending more time on MOOCs predicts better achievement (Greene et al., 2015; Phan et al., 2016). Results have also shown that active engagement, communication, and participation are associated with better outcomes in MOOCs (Hughes & Dobbins, 2015). Artino et al. (2008) investigated motivational beliefs in an online course setting, specifically examining task value, self-efficacy, and perceived instructional quality. They found that students' satisfaction with an online course is partly influenced by their motivational beliefs and attitudes towards the learning task. Raman et al. (2022) demonstrated that using Moodle forums can enhance students' involvement during the course. They added that even shy students can benefit from it, as it helps to develop better relationships between students and educators.

1.3 Current study

Building on social cognitive theory, the present study examines how students' self-efficacy and test anxiety (here referring to a state-like tendency to experience anxiety in examination contexts) and behavioural engagement together relate to performance in a high-stakes examination context. Self-efficacy may be related to both students' test anxiety and their online course activity. In turn, engagement in learning activities may represent a behavioural manifestation of self-regulatory processes through which forethought is translated into action (Bandura, 1986; Cook & Artino Jr, 2016).

It is worth noting that previous research on MOOCs has primarily focused on examining how online behaviour influences course achievement (Greene et al., 2015; Phan et al., 2016; Wang & Mousavi, 2023). However, in this study, we examine the relationship between online course activity and the results of the national mathematics exam, which is not just a course component but can also determine university admission. The online course examined in this study was a structured, voluntary preparatory course for the national mathematics exam, delivered via the Moodle learning management system. The course included lectures, downloadable materials, and interactive components such as forums. This type of course differs from fully online degree programmes or large-scale MOOCs, as it is specifically

designed to support students in preparing for a high-stakes national examination. Thus, anticipated exam results may serve as powerful motivators, shaping both course engagement and self-beliefs.

In this study, online course activity refers to students' engagement with various parts of the course (webinar views, file downloads, video views, and forum views). Prior research in learning analytics has shown that engagement with different online course activities, such as video viewing, resource access, and forum participation, is often positively correlated, reflecting broader patterns of behavioural engagement, although the strength of these associations varies across activity types and learner profiles (Bonafini et al., 2017; Brinton et al., 2015).

However, little research has examined the interrelationships among different activity indicators in online courses that prepare students for a mathematics exam and their connections to students' subject-specific self-efficacy and test anxiety. Additionally, we have not found studies that show whether and to what extent students' activity in an online course preparing for an exam is related to exam results. Examining the relationships among different course activity indicators is important to determine whether they reflect a coherent construct of online course activity. Establishing such coherence provides a basis for creating a composite course activity variable for subsequent analyses. Therefore, the present study addresses the following research questions and hypotheses.

- RQ1. To what extent do different indicators of online course activity (webinar views, file downloads, video views, and forum views) reflect a coherent pattern of engagement?

Previous research has shown that different forms of online learning activity tend to co-occur and reflect broader patterns of behavioural engagement (e.g. Bonafini et al., 2017; Brinton et al., 2015). Based on this, we propose the following hypothesis.

- H1. Indicators of online course activity are expected to be positively interrelated, reflecting overall engagement.
- RQ2. How is online course activity related to students' test anxiety, self-efficacy, and mathematics exam results?

Previous research has shown that achievement is positively related to self-efficacy and negatively to test anxiety (e.g. Barroso & Ganley, 2021; Jameson et al., 2022; Rutherford et al., 2020; Živković et al., 2023). Based on this, we propose the following hypothesis.

- H2. Greater online course activity and higher self-efficacy are expected to be associated with better mathematics exam results, whereas higher test anxiety is associated with lower exam results.
- RQ3. Does online course activity contribute to explaining exam results beyond mathematics self-efficacy and test anxiety?

Previous research indicates that behavioural engagement uniquely contributes to academic achievement in online learning environments (e.g. Greene et al., 2015; Soffer & Cohen, 2019; Wang & Mousavi, 2023). Based on this, we propose the following hypothesis.

- H3. An online course activity is expected to explain additional variance in mathematics exam results beyond self-efficacy and test anxiety.

2 Methods

2.1 Procedure and Sample

In Estonia, to graduate from upper secondary education, students must take a mandatory mathematics exam; however, they can choose between a more comprehensive ("wide") and a simplified ("narrow") exam (*HARNO*, n.d.; Rozgonjuk et al., 2021). The exam results can significantly impact students' futures, as universities accept students to their schools based on those results. Hence, these exams could also be labelled "high-stakes" exams for the students. The wide examination is typically chosen by students pursuing mathematically demanding study paths, whereas the narrow examination is more common among students with less mathematics-intensive goals. As the online course examined here was designed for students preparing for the wide examination, the sample may not be fully representative of all students and may include students with varying levels of motivation, prior achievement, and engagement.

In spring 2021, the schools in Estonia were on distance learning. The Estonian Ministry of Education ordered the University of Tartu to create a free course for students graduating from upper secondary school so everyone had equal chances to participate. The main aim of the four-month course was to support students as they prepared for the national mathematics exams.

The course was held in Moodle (*Modular Object-Oriented Dynamic Learning Environment*), and it enabled students to learn the content online and assess their understanding with automated feedback. Moodle provides the option to obtain log files that detail how frequently students log into the course and what they do while logged in. Log files can provide insight into how effectively students will manage the course and what outcomes they will achieve.

Data for the present study were collected using an online questionnaire administered at the end of the course. Participation in the survey was voluntary. Students were informed at the beginning of the course about data collection and its purpose, and informed consent was obtained online before completing the questionnaire. Gender was collected as a self-reported variable.

2.1.1. Sample

The study sample comprises students who took the mathematics exam preparation course in the spring of 2021. The course was open to anyone considering taking the national

mathematics exam, even though it was intended for high school seniors graduating that year. In total, 1430 students signed up for the course, of which 569 (39.8%) initially intended to take the "narrow" exam, and 861 (60.2%) intended to take the "wide" exam.

National mathematics exam results (ranging from 0 to 100 points) were subsequently obtained from the Estonian Ministry of Education and linked to the survey data. As the mathematics exam was not mandatory in 2021 due to the COVID-19 pandemic, not all surveyed students took the exam. Of the 213 survey respondents, 195 took the national mathematics exam: 51 (26.2%) completed the narrow exam (M age = 19.86, SD = 4.08; 45 female, 6 male), and 144 (73.8%) completed the wide exam (M age = 18.65, SD = 1.97; 118 female, 26 male).

Given the differences between the narrow and wide examinations in terms of content, difficulty, as well as the study's focus on performance in a high-stakes assessment context, the primary analyses in the present article focus on students who completed the wide mathematics exam, resulting in an effective sample size of 144 for the analyses.

High dropout rates are rather common in online courses, as well as in MOOCs, where it can be as high as 90%(Hew & Cheung, 2014; Jarvis, 2015). Although the drop-out rate can be high initially, it usually stabilises after the first weeks (Evans et al., 2016). Similar patterns may also be expected in voluntary online courses such as the one examined in the present study. Hence, it is likely that a considerable number of students who initially enrolled in the course, chose not to participate in the survey during the second week of enrolment. This context may partly explain the difference between initial enrolment numbers and the number of students who completed the survey and subsequently participated in the national examination.

2.2 Measures

Background demographic variables, including gender, were collected via self-report using the questionnaire.

2.2.1 Mathematics national exam results

National mathematics exam results were obtained from the Estonian Ministry of Education and used as an indicator of mathematics achievement. Exam scores ranged from 0 to 100 points. However, due to COVID-19 restrictions, the national mathematics exams were optional in the spring of 2021; thus, students could choose not to take the exam.

2.2.2 Mathematics self-efficacy and test anxiety

The mathematics self-efficacy and test anxiety were assessed using a motivational scale adapted from Liu & Lin (2010) for the current project, which was translated into Estonian by researchers with doctorates in psychology and education. The scale originally had six subscales (intrinsic and extrinsic goal orientations, task value, control value, self-efficacy, and test anxiety) (Liu & Lin, 2010); however, we used only two of them: self-efficacy and test anxiety. All items are mathematics learning specific. For each question, the response ranges

from 1 (completely disagree) to 5 (completely agree). Item scores were summed to create composite indices of mathematics self-efficacy and mathematics test anxiety, with higher scores indicating higher levels of the respective constructs.

Self-efficacy was assessed with a 5-item questionnaire. Example items are: "I believe that I will have excellent mathematics grades in mathematics class", "Mathematics is not difficult for me", and "I believe that I can master every topic in mathematics class". Cronbach's α = .85 indicates that the scale has good internal consistency in our sample.

Mathematics-related test anxiety was assessed with a 7-item questionnaire. Example items are: "Before taking the mathematics exam, I am too wary of getting a good sleep", "In taking the mathematics exam, I am totally blank and cannot remember what I have learned before", and "In taking the mathematics exam, I will have a negative thought that I am inferior to other classmates". Cronbach's α = .83 indicates that the scale has very good internal consistency in our sample. The scale assessed students' tendency to experience anxiety in mathematics examination contexts and did not capture anxiety experienced during an actual test situation.

2.2.3 Indicators of online mathematics course activity

During the course, students had full access to the course materials, including forums, online lectures, and tests. There were weekly online lectures in which the university lecturer explained each topic on the national exam. Students could ask questions and solve different mathematical problems during the lecture with the lecturer. The lectures were recorded so the students could watch them throughout the course. During the course, four different components of frequency of course activity were retrieved: webinar views, file downloads, video views, and forum views. All these were standardised and aggregated into a single measure of online course activity frequency by using principal component analysis (PCA).

2.3 Analysis

The data were analysed in RStudio version 4.4.0 (R Core Team, 2024). Pairwise exclusion of missing data was used throughout the analyses. Spearman correlation analysis (p-values adjusted using Holm's method) was applied to investigate the relationships among national mathematics exam scores, test anxiety, self-efficacy, and online course activity indicators, using the corr.test() function from the *psych* package (Revelle, 2024). We classify correlations in accordance with Cohen (1988), according to which effect values between .10 and .299 are small, .30 and .499 are medium, and .50 and higher are large. ‘

To summarise multiple indicators of online course activity into a single composite measure, principal component analysis (PCA) was conducted, and the first principal component was used as an index of overall course activity. Missing values were treated as absent activity and recoded as zero. Inspection of eigenvalues (Kaiser criterion) and the scree plot indicated a clear dominance of the first component, which, based on standardised activity indicators, explained 65.9% of the variance, was retained as a composite indicator of overall online course activity and used in subsequent analyses.

Finally, we also ran a regression model in which the exam results variable was the outcome, predicted from students' test anxiety, self-efficacy, and course activity variables.

3 Results

3.1 Preliminary results

Table 1 below presents correlations among the indicators of online mathematics course activity.

Table 1. Correlation analysis results for different indicators of online course activity

Variable	N	M	SD	Min	Max	1.	2.	3.	4.
1. Online course activity	144	.00	1.68	-1.57	6.66	1			
2. Webinar Views	101	5.78	6.50	1	37	.61***	1		
3. File Downloads	137	21.45	18.42	1	78	.88***	.26**	1	
4. Video Views	114	10.70	13.24	1	63	.79***	.48***	.55***	1
5. Forum Views	133	12.77	15.60	1	91	.83***	.43***	.69***	.62***

Notes. N – sample size; M – mean; SD – standard deviation. * p < .05, ** p < .01, *** p < .001

As shown in Table 1, the indicators of online course activity were positively correlated with one another. The strongest correlations were observed between file downloads and overall online course activity (ρ = .88, p < .001), as well as between forum views and course activity (ρ = .83, p < .001). Video views also showed strong correlations with course activity (ρ = .79, p < .001). Moderate correlations were found between video views and forum views (ρ = .62, p < .001), and between forum views and file downloads (ρ = .69, p < .001). These results indicate that students who engaged more frequently in one type of activity tended to be active across multiple components of the online course.

Table 2 below presents descriptive statistics and correlation analyses for mathematics exam scores, test anxiety, self-efficacy, and online course activity.

Table 2. Descriptive statistics and correlations among mathematics exam scores, online course activity, self-efficacy, and test anxiety

Descriptive Statistics

Variable	**N**	**M**	**SD**	**Min**	**Max**	**1**	**2**	**3**
1. Exam score	144	58.28	25.34	11	98	1		

2. Online course activity	144	.00	1.68	-1.57	6.66	.18*	1	
3. Self-efficacy	140	15.45	4.646	5	25	.51***	.04	1
4. Test anxiety	140	22.77	5.99	11	35	-.35***	-.08	-.51***

Notes. N – sample size; M – mean; SD – standard deviation. * p < .05, *** p < .001

As shown in Table 2, a large negative effect-sized correlation was found between test anxiety and self-efficacy (ρ = -.51, p < .001). Mathematics exam scores were moderately negatively correlated with test anxiety (ρ = −.35, p < .001) and strongly positively correlated with self-efficacy (ρ = .51, p < .01). Online course activity showed a small but statistically significant positive correlation with mathematics exam performance (ρ = .18, p < .05).

3.2 Main results

Results of the regression analysis predicting mathematics exam performance are shown in Table 3.

Table 3. Results of the regression model for predicting mathematics national exam results.

	B	β	SE	t	p
Intercept	42.70		13.71	3.11	< .01
Gender	-8.35	-.13	4.81	-1.74	.08
Test anxiety	-.81	-.19	.36	-2.25	< .05
Self-efficacy	2.32	.41	.47	4.91	< .001
Online course activity	2.51	.16	1.11	2.27	< .05
Model statistics					
R^2	.30				
Adjusted R^2	.28				
F (df)	14.76 (135) ***				

Note. B – unstandardised coefficient; β – standardised coefficient; SE – standard error; t – t-value; p – significance level

The overall model was statistically significant, $F(4, 135) = 14.76$, $p < .001$, explaining approximately 30% of the variance in exam scores (adjusted $R^2 = .28$). Multicollinearity was assessed using variance inflation factors (VIFs), and all values were below 2, indicating no problematic multicollinearity among the predictors. Self-efficacy emerged as a strong positive predictor of exam performance ($\beta = .41$, $p < .001$), indicating that students with higher self-efficacy achieved higher exam scores. Test anxiety was a significant negative predictor ($\beta = -.19$, $p < .05$), such that higher anxiety was associated with lower exam performance. Online course activity also emerged as a significant positive predictor of exam results ($\beta = .16$, $p < .05$), indicating that higher levels of engagement in the online course were associated with better exam performance, even when controlling for self-efficacy and test anxiety. Gender was not a statistically significant predictor ($\beta = -.13$, $p = .08$).

4 Discussion

The main contribution of this study is to demonstrate how students' online course activity, test anxiety, and self-efficacy levels predict exam results. From a social cognitive theory perspective, this study highlights the important role of students' self-efficacy in regulating their emotional responses (test anxiety) and behavioural engagement (online course activity), which, together, can shape academic performance (Bandura, 1986, 1995). The findings showed that online course activity was not only positively related to exam performance at the correlational level but also emerged as a significant positive predictor when self-efficacy, test anxiety, and gender were taken into account. This suggests that students' engagement with online course resources contributes uniquely to exam performance, beyond students' self-beliefs. This study was conducted within a voluntary online course, which may also have influenced the findings. Students in voluntary courses may have a greater sense of autonomy, which can enhance their self-efficacy and reduce anxiety, as they are engaging in the course out of personal interest rather than obligation. To foster positive affect, it is important to enhance students' motivation in the classroom (Schweinle et al., 2006). Positive affect reduces negative feelings, including the perception that mathematics is difficult or complicated. Engaging in activities perceived as interesting or important is influenced by past experiences where needs were either satisfied or hindered (Deci & Ryan, 2000).

Our first research question examined how different students' activities in an online course (webinar attendance, file downloads, video views, forum views, and composite online course activity) correlated with one another. We found that the correlations among those variables were relatively high, indicating that more active students tended to participate in all parts of the course. These findings support treating online course activity as a coherent construct rather than as separate, unrelated behaviours.

In the introduction, we posed the question of whether more mathematics-anxious students participate more actively in online courses than less anxious students, or vice versa. However, our analysis did not reveal any significant relationship between students' levels of anxiety and their participation in the online course. One explanation for why there was no

statistically significant correlation between online course activity and test anxiety is that, on the one hand, more anxious students might feel the need to participate more actively on Moodle to increase their self-efficacy. Conversely, more anxious students frequently display avoidance patterns (Ashcraft & Moore, 2009; Daker et al., 2021) and are thus less active in the course. It is also worth noting that these findings are based on a sample of students who chose the "wide" mathematics examination. As such, the absence of a significant relationship between test anxiety and online course activity may not generalise to all students, and different patterns may emerge in more diverse student populations. Ultimately, these conflicting ideas suggest that the relationship between test anxiety and online course participation may be more complex than initially anticipated, and further research is needed to explore these dynamics in more depth. From a social cognitive theory perspective, anxiety may interfere with self-regulatory processes when students perceive limited control over high-stakes exams (Bandura, 1995), but such effects may vary depending on contextual and individual factors.

Our second research question examined how online course activity is related to students' test anxiety, self-efficacy, and mathematics exam results. We found that, at the bivariate level, students who take a more active role in an online course tend to achieve higher scores on the mathematics exam. These results are partially consistent with previous research, which has found that being more active and spending more time on MOOCs are also predictors of higher achievement (Greene et al., 2015; Kadoić & Oreški, 2018; Phan et al., 2016). However, we found no statistically significant correlations between online course activity and students' self-efficacy. Thus, our results did not confirm Alamri's (2022) findings, as we did not observe a significant relationship between students' higher self-efficacy and more active participation in the online course. One possible explanation for this is that we did not specifically examine course-related self-efficacy and test anxiety. Instead, we assessed students' general self-efficacy and test anxiety in mathematics, which may not directly correlate with their engagement in the specific online course. It is likely that students' confidence in their general mathematical abilities does not necessarily translate into increased activity or participation in an online learning environment. Our findings also support previous research (Ayotola & Adedeji, 2009; Kim et al., 2014; Živković et al., 2023), showing a positive correlation between mathematics exam results and self-efficacy.

Given that the present sample consisted predominantly of female students, it is particularly relevant to consider how gender-related differences in mathematics self-beliefs may have influenced the findings. Previous research has shown that female students often report lower levels of mathematics self-efficacy and higher levels of anxiety compared to male students, despite demonstrating similar levels of performance (Ross et al., 2012; Xu et al., 2026). From a social cognitive perspective, such differences may reflect prior experiences, feedback, and broader social, cultural, or educational expectations rather than actual ability differences. In the context of the present study, such patterns may have influenced the observed relationships between self-efficacy, test anxiety, and exam performance, and should be taken into account when interpreting the results.

The third research question examined whether online course activity contributes to explaining mathematics exam results beyond students' self-efficacy and test anxiety. We conducted a regression analysis to predict the results of the mathematics exam. The model included predictors such as gender, test anxiety, self-efficacy, and online course activity. The results suggest that lower levels of test anxiety and higher levels of students' self-efficacy significantly predict students' academic achievement in mathematics. The significant influence of self-efficacy aligns with previous research, which shows that higher levels of self-efficacy are associated with better achievement levels (Street et al., 2022; Youn et al., 2010). The results also align with previous research, which shows that higher anxiety levels can hinder academic performance in mathematics (Ashcraft & Krause, 2007; Barroso & Ganley, 2021; Jameson et al., 2022). Self-efficacy was one of the strongest predictors of exam results in the present study, underscoring its central role in academic achievement. This finding also aligns with social cognitive theory, which demonstrates that self-efficacy is related to persistence and resilience in challenging situations and thus affects performance outcomes (Bandura, 1986, 1995). Zimmerman (2000) similarly found that students' self-efficacy, rather than anxiety, has a greater impact on their academic performance.

In addition, online course activity was also a significant positive predictor of mathematics exam performance, even when gender, test anxiety, and self-efficacy were included in the regression model. This indicates that online course engagement may contribute uniquely to mathematics exam performance beyond students' self-beliefs. This aligns with the role of forethought described in social cognitive theory, which suggests that anticipated exam outcomes may motivate students to engage more actively in exam preparation (Bandura, 1986). This finding suggests that students' engagement with online course resources contributes uniquely to exam outcomes, beyond the effects of self-efficacy and anxiety. However, the relatively smaller effect size of online course activity compared to self-efficacy indicates that behavioural engagement may support, rather than replace, motivational factors in high-stakes exam contexts. In this respect, the findings partially align with those of Soffer and Cohen (2019), who reported a positive relationship between course engagement and academic achievement. From a self-regulated learning perspective, students' engagement in the online course may reflect their ability to actively manage their learning processes, particularly in a voluntary learning context. This may help explain why online course activity emerged as a significant predictor of mathematics exam performance: students who engage more actively in the online course are also likely to be more actively involved in their own learning processes.

Despite the significant findings of this study, several limitations need to be considered. First, the sample size in this study was relatively small, limiting the generalisability of the results. Second, the sample was skewed towards women, and voluntary participation may have introduced bias, as more motivated individuals were more likely to participate. Additionally, because exams were optional rather than mandatory in 2021, participation may have been biased towards more motivated or confident students. Consequently, the exam results may not accurately reflect the true academic abilities of the entire student cohort. Third, the questionnaire response rate was low, potentially limiting the

representativeness of the results. Given students' busy schedules during exam season, it is understandable that only a limited number of responses were received to the questionnaires.

It is also relevant to consider that the present analyses were conducted on a sample consisting only of students who chose to take the “wide” mathematics examination. These students may differ from the general student population in terms of motivation, prior achievement, or attitudes toward mathematics. As such, the findings should be interpreted with caution and may not be directly generalisable to all students. Future research should examine whether similar patterns are observed in more diverse samples, including students with different levels of mathematical engagement and achievement.

Despite these limitations, this study has several strengths. First, the study examined indicators of online course activity, providing valuable insights into students' behaviour during the course. Rather than relying solely on self-reported engagement, using Moodle log data enabled an objective description of how students interacted with different course components. These findings may help to understand how students interacted with the learning management system, and this can also help instructional designers gain confidence that the use of educational technology is worthwhile. We showed that students who were more active in one type of online course activity tended to be more active in other activities as well, indicating consistency in their engagement patterns. Second, the study used both exam results and self-reports to analyse students' academic performance, behaviour, and self-beliefs, providing a comprehensive understanding of the topic.

Conclusions

In conclusion, examining the relationships among online course activity, test anxiety, self-efficacy, and mathematics achievement provides important insights into students’ learning and performance in an online exam-preparation context. The study combined online course log data, self-reported measures, and national mathematics exam results to examine how behavioural and emotional factors relate to mathematics exam performance. Our results showed that at the bivariate level, online course activity was positively associated with mathematics exam scores; moreover, regression analyses indicated that online course activity, self-efficacy, and test anxiety each contributed uniquely to exam outcomes, with self-efficacy emerging as the strongest predictor.

These findings underscore the central role of students’ self-beliefs and emotional experiences in high-stakes mathematics assessments, while also highlighting the added value of students’ behavioural engagement in online learning environments. From an educational perspective, the results suggest that supporting students’ self-efficacy and addressing test anxiety may be particularly important components of effective exam preparation alongside encouraging active engagement with online course resources. Educators and online course designers may benefit from integrating instructional strategies that simultaneously promote engagement, foster positive self-beliefs, and help students manage anxiety.

Research ethics

Author contributions

G.A.: formal analysis, data curation, writing – original draft.
K.T.: conceptualisation, methodology, investigation, data curation, writing – review & editing
D.L.: investigation, formal analysis, writing – review & editing
K.L.: writing – review & editing
All authors have read and agreed to the published version of the manuscript.

Artificial intelligence

Artificial intelligence (Grammarly and ChatGPT) was used solely for grammatical proofreading. All scientific content and conclusions were created solely by the authors.

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This study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Informed consent statement

Informed consent was obtained from all research participants.

Data availability statement

The data are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

Alamri, M. M. (2022). Investigating Students' Adoption of MOOCs during COVID-19 Pandemic: Students' Academic Self-Efficacy, Learning Engagement, and Learning Persistence. *Sustainability*, *14*(2), 714. https://doi.org/10.3390/su14020714

Arens, A. K., Frenzel, A. C., & Goetz, T. (2022). Self-Concept and Self-Efficacy in Math: Longitudinal Interrelations and Reciprocal Linkages with Achievement. *The Journal of Experimental Education*, *90*(3), 615–633. https://doi.org/10.1080/00220973.2020.1786347

Artino, A. R. (2008). Motivational beliefs and perceptions of instructional quality: Predicting satisfaction with online training*. *Journal of Computer Assisted Learning*, *24*(3), 260–270. https://doi.org/10.1111/j.1365-2729.2007.00258.x

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General*, *130*(2), 224–237. https://doi.org/10.1037/0096-3445.130.2.224

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, *14*(2), 243–248. https://doi.org/10.3758/BF03194059

Ashcraft, M. H., & Moore, A. M. (2009). Mathematics Anxiety and the Affective Drop in Performance. *Journal of Psychoeducational Assessment*, *27*(3), 197–205. https://doi.org/10.1177/0734282908330580

Ayotola, A., & Adedeji, T. (2009). The relationship between mathematics self-efficacy and achievement in mathematics. *Procedia - Social and Behavioral Sciences*, *1*(1), 953–957. https://doi.org/10.1016/j.sbspro.2009.01.169

Bandura, A. (1986). Social Foundations of Thought and Action. In D. Marks, *The Health Psychology Reader* (pp. 94–106). SAGE Publications Ltd. https://doi.org/10.4135/9781446221129.n6

Bandura, A. (Ed.). (1995). *Self-efficacy in changing societies*. Cambridge University Press.

Barroso, C., & Ganley, C. M. (2021). *A Meta-Analysis of the Relation Between Math Anxiety and Math Achievement*. 35.

Bonafini, F. C., Chae, C., Park, E., & Jablokow, K. W. (2017). How Much Does Student Engagement with Videos and Forums in a MOOC Affect Their Achievement? *Online Learning*, *21*(4). https://doi.org/10.24059/olj.v21i4.1270

Borgonovi, F., & Pokropek, A. (2019). Seeing is believing: Task-exposure specificity and the development of mathematics self-efficacy evaluations. *Journal of Educational Psychology*, *111*(2), 268–283. (2018-20920-001). https://doi.org/10.1037/edu0000280.supp

Brinton, C. G., Buccapatnam, S., Chiang, M., & Poor, H. V. (2015). *Mining MOOC Clickstreams: On the Relationship Between Learner Behavior and Performance* (arXiv:1503.06489). arXiv. https://doi.org/10.48550/arXiv.1503.06489

Broadbent, J., & Poon, W. L. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education*, *27*, 1–13. https://doi.org/10.1016/j.iheduc.2015.04.007

Cassady, J. C., & Finch, W. H. (2020). Revealing Nuanced Relationships Among Cognitive Test Anxiety, Motivation, and Self-Regulation Through Curvilinear Analyses. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.01141

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed). L. Erlbaum Associates.

Cook, D. A., & Artino Jr, A. R. (2016). Motivation to learn: An overview of contemporary theories. *Medical Education*, *50*(10), 997–1014. https://doi.org/10.1111/medu.13074

Daker, R. J., Gattas, S. U., Sokolowski, H. M., Green, A. E., & Lyons, I. M. (2021). First-year students' math anxiety predicts STEM avoidance and underperformance throughout university, independently of math ability. *NPJ Science of Learning*, *6*(1), 17. https://doi.org/10.1038/s41539-021-00095-7

Deci, E. L., & Ryan, R. M. (2000). The 'What' and 'Why' of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, *11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics Anxiety: What Have We Learned in 60 Years? *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.00508

Dowker, A., & Sheridan, H. (2022). Relationships Between Mathematics Performance and Attitude to Mathematics: Influences of Gender, Test Anxiety, and Working Memory. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.814992

Evans, B. J., Baker, R. B., & Dee, T. S. (2016). Persistence Patterns in Massive Open Online Courses (MOOCs). *The Journal of Higher Education*, *87*(2), 206–242. https://doi.org/10.1080/00221546.2016.11777400

Figueira, P. V. S. T., Gusmão, T. C. R. S., & Freitas, P. M. de. (2023). Effects of the Math Anxiety of Parents and Teachers on Students. *Psico-USF*, *28*, 1–12. https://doi.org/10.1590/1413-82712023280101

Gonzales, B. B., Iraola-Real, I., Choquehuanca, E. G., Talledo, R. A., & Vargas, Y. I. F. (2019). Self-Efficacy And Its Effect On Anxiety And Performance In Mathematics In Aspiring to Career in Engineering. *2019 International Symposium on Engineering Accreditation and Education (ICACIT)*, 1–4. https://doi.org/10.1109/ICACIT46824.2019.9130366

Gravemeijer, K., Stephan, M., Julie, C., Lin, F.-L., & Ohtani, M. (2017). What Mathematics Education May Prepare Students for the Society of the Future? *International Journal of Science and Mathematics Education*, *15*(S1), 105–123. https://doi.org/10.1007/s10763-017-9814-6

Greene, J. A., Oswald, C. A., & Pomerantz, J. (2015). Predictors of Retention and Achievement in a Massive Open Online Course. *American Educational Research Journal*, *52*(5), 925–955. https://doi.org/10.3102/0002831215584621

HARNO. (n.d.). Retrieved 17 February 2023, from https://harno.ee/eksamid-testid-ja-uuringud/eksamid-testid-ja-lopudokumendid/riigieksamid#valimine

Heissel, J. A., Adam, E. K., Doleac, J. L., Figlio, D. N., & Meer, J. (2021). Testing, Stress, and Performance: How Students Respond Physiologically to High-Stakes Testing. *Education Finance and Policy*, *16*(2), 183–208. https://doi.org/10.1162/edfp_a_00306

Hembree, R. (1990). The Nature, Effects, and Relief of Mathematics Anxiety. *Journal for Research in Mathematics Education*, *21*(1), 33. https://doi.org/10.2307/749455

Hew, K. F., & Cheung, W. S. (2014). Students' and instructors' use of massive open online courses (MOOCs): Motivations and challenges. *Educational Research Review*, *12*, 45–58. https://doi.org/10.1016/j.edurev.2014.05.001

Hiller, S. E., Kitsantas, A., Cheema, J. E., & Poulou, M. (2022). Mathematics anxiety and self-efficacy as predictors of mathematics literacy. *International Journal of Mathematical Education in Science and Technology*, *53*(8), 2133–2151. https://doi.org/10.1080/0020739X.2020.1868589

Hughes, G., & Dobbins, C. (2015). The utilization of data analysis techniques in predicting student performance in massive open online courses (MOOCs). *Research and Practice in Technology Enhanced Learning*, *10*(1), 10. https://doi.org/10.1186/s41039-015-0007-z

Ignacio, N. G., Nieto, L. J. B., & Barona, E. G. (2006). The Affective Domain in Mathematics Learning. *International Electronic Journal of Mathematics Education*, *1*(1), 16–32. https://doi.org/10.29333/iejme/169

Jameson, M. M., Dierenfeld, C., & Ybarra, J. (2022). The Mediating Effects of Specific Types of Self-Efficacy on the Relationship between Math Anxiety and Performance. *Education Sciences*, *12*(11), 789. https://doi.org/10.3390/educsci12110789

Jarvis, D. H. (2015). MOOCs: By Jonathan Haber. MIT Press, Cambridge, MA. 2014, 227 pp. MIT Essential Knowledge Series. ISBN 978-0-262-52691-3 (pbk), ISBN 978-0-262-32297-3 (e-book). *International Review of Education*, *61*(4), 573–575. https://doi.org/10.1007/s11159-015-9499-4

Kadoić, N., & Oreški, D. (2018). Analysis of student behavior and success based on logs in Moodle. *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 0654–0659. https://doi.org/10.23919/MIPRO.2018.8400123

Kaskens, J., Segers, E., Goei, S. L., Van Luit, J. E. H., & Verhoeven, L. (2020). Impact of Children's math self-concept, math self-efficacy, math anxiety, and teacher competencies on math development. *Teaching and Teacher Education*, *94*, 103096. https://doi.org/10.1016/j.tate.2020.103096

Kazelskis, R., Reeves, C., Kersh, M. E., Bailey, G., Cole, K., Larmon, M., Hall, L., & Holliday, D. C. (2000). Mathematics Anxiety and Test Anxiety: Separate Constructs? *The Journal of Experimental Education*, *68*(2), 137–146. https://doi.org/10.1080/00220970009598499

Kim, C., Park, S. W., & Cozart, J. (2014). Affective and motivational factors of learning in online mathematics courses. *British Journal of Educational Technology*, *45*(1), 171–185. https://doi.org/10.1111/j.1467-8535.2012.01382.x

Liu, E. Z. F., & Lin, C. H. (2010). The survey study of mathematics motivated strategies for learning questionnaire (MMSLQ) for grade 10-12 Taiwanese students. *The Turkish Online Journal of Educational Technology*, *9*(2), 13.

Lu, K., Zhu, J., Pang, F., & Liu, Z. (2024). Understanding college students' test anxiety in asynchronous online courses: The mediating role of emotional engagement. *International Journal of Educational Technology in Higher Education*, *21*(1), 50. https://doi.org/10.1186/s41239-024-00482-1

Lukowski, S. L., DiTrapani, J., Jeon, M., Wang, Z., J.Schenker, V., Doran, M. M., Hart, S. A., Mazzocco, M. M. M., Willcutt, E. G., A.Thompson, L., & Petrill, S. A. (2019). Multidimensionality in the measurement of math-specific anxiety and its relationship with mathematical performance. *Learning and Individual Differences*, *70*, 228–235. https://doi.org/10.1016/j.lindif.2016.07.007

Miao, J., & Ma, L. (2022). Students' online interaction, self-regulation, and learning engagement in higher education: The importance of social presence to online learning. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.815220

Phan, T., McNeil, S. G., & Robin, B. R. (2016). Students' patterns of engagement and course performance in a Massive Open Online Course. *Computers & Education*, *95*, 36–44. https://doi.org/10.1016/j.compedu.2015.11.015

Pintrich, P. R. (2004). A Conceptual Framework for Assessing Motivation and Self-Regulated Learning in College Students. *Educational Psychology Review*, *16*(4), 385–407. https://doi.org/10.1007/s10648-004-0006-x

Pirrone, C., Di Corrado, D., Privitera, A., Castellano, S., & Varrasi, S. (2022). Students' Mathematics Anxiety at Distance and In-Person Learning Conditions during COVID-19 Pandemic: Are There Any Differences? An Exploratory Study. *Education Sciences*, *12*(6), Article 6. https://doi.org/10.3390/educsci12060379

Puzziferro, M. (2008). Online Technologies Self-Efficacy and Self-Regulated Learning as Predictors of Final Grade and Satisfaction in College-Level Online Courses. *American Journal of Distance Education*, *22*(2), 72–89. https://doi.org/10.1080/08923640802039024

Quintero, M., Hasty, L., Li, T., Song, S., & Wang, Z. (2022). A multidimensional examination of math anxiety and engagement on math achievement. *British Journal of Educational Psychology*, *92*(3), 955–973. https://doi.org/10.1111/bjep.12482

R Core Team. (2024). *R: A Language and Environment for Statistical Computing*. [Computer software]. R Foundation for Statistical Computing. https://www.R-project.org/

Raman, A., Thannimalai, R., Rathakrishnan, M., & Ismail, S. N. (2022). Investigating the Influence of Intrinsic Motivation on Behavioral Intention and Actual Use of Technology in Moodle Platforms. *International Journal of Instruction*, *15*(1), 1003–1024.

Räsänen, P., Laurillard, D., Käser, T., & von Aster, M. (2019). Perspectives to Technology-Enhanced Learning and Teaching in Mathematical Learning Difficulties. In A. Fritz, V. G. Haase, & P. Räsänen (Eds), *International Handbook of Mathematical Learning Difficulties* (pp. 733–754). Springer International Publishing. https://doi.org/10.1007/978-3-319-97148-3_42

Revelle, W. (2024). *psych: Procedures for Psychological, Psychometric, and Personality Research* (Version 2.5.6) [Computer software]. https://cran.r-project.org/web/packages/psych/index.html

Ross, J. A., Scott, G., & Bruce, C. D. (2012). The Gender Confidence Gap in Fractions Knowledge: Gender Differences in Student Belief–Achievement Relationships. *School Science and Mathematics*, *112*(5), 278–288. https://doi.org/10.1111/j.1949-8594.2012.00144.x

Rozgonjuk, D., Kraav, T., Mikkor, K., Orav-Puurand, K., & Täht, K. (2020). Mathematics anxiety among STEM and social sciences students: The roles of mathematics self-efficacy, and deep and surface approach to learning. *International Journal of STEM Education*, *7*(1), 46. https://doi.org/10.1186/s40594-020-00246-z

Rozgonjuk, D., Täht, K., & Vassil, K. (2021). Internet use at and outside of school in relation to low- and high-stakes mathematics test scores across 3 years. *International Journal of STEM Education*, *8*(1), 27. https://doi.org/10.1186/s40594-021-00287-y

Rutherford, T., Liu, A. S., Lam, A. S., & Schenke, K. (2020). Impact on mathematics self-beliefs from a mastery-based mathematics software. *Journal of Research on Technology in Education*, *52*(1), 79–94. https://doi.org/10.1080/15391523.2019.1689210

Şanli, C. (2021). The Relation Between Task Value, Test Anxiety and Academic Self-Efficacy: A Moderation Analysis in High School Geography Course. *Participatory Educational Research*, *8*(1), 265–278. https://doi.org/10.17275/per.21.15.8.1

Saqr, M., López-Pernas, S., Helske, S., & Hrastinski, S. (2023). The longitudinal association between engagement and achievement varies by time, students' profiles, and achievement state: A full program study. *Computers & Education*, *199*, 104787. https://doi.org/10.1016/j.compedu.2023.104787

Schweinle, A., Meyer, D. K., & Turner, J. C. (2006). Striking the Right Balance: Students' Motivation and Affect in Elementary Mathematics. *The Journal of Educational Research*, *99*(5), 271–294. https://doi.org/10.3200/JOER.99.5.271-294

Soffer, T., & Cohen, A. (2019). Students' engagement characteristics predict success and completion of online courses. *Journal of Computer Assisted Learning*, *35*(3), 378–389. https://doi.org/10.1111/jcal.12340

Street, K. E. S., Malmberg, L.-E., & Stylianides, G. J. (2022). Changes in Students' Self-Efficacy When Learning a New Topic in Mathematics: A Micro-Longitudinal Study. *Educational Studies in Mathematics*, *111*(3), 515–541. https://doi.org/10.1007/s10649-022-10165-1

Sydänmaanlakka, A., Häsä, J., Holm, M. E., & Hannula, M. S. (2024). Mathematics-related achievement emotions – Interaction between learning environment and students' mathematics performance. *Learning and Individual Differences*, *113*, 102486. https://doi.org/10.1016/j.lindif.2024.102486

von der Embse, N., Barterian, J., & Segool, N. (2013). Test Anxiety Interventions for Children and Adolescents: A Systematic Review of Treatment Studies from 2000–2010. *Psychology in the Schools*, *50*(1), 57–71. https://doi.org/10.1002/pits.21660

von der Embse, N., Jester, D., Roy, D., & Post, J. (2018). Test anxiety effects, predictors, and correlates: A 30-year meta-analytic review. *Journal of Affective Disorders*, *227*, 483–493. https://doi.org/10.1016/j.jad.2017.11.048

Wang, Q., & Mousavi, A. (2023). Which log variables significantly predict academic achievement? A systematic review and meta-analysis. *British Journal of Educational Technology*, *54*(1), 142–191. https://doi.org/10.1111/bjet.13282

Xu, Y. J., Cheng, Q., & Wu, Y. (2026). How self-concept, self-efficacy, and grit contribute to gender differences in middle school mathematics learning in Shanghai: An analysis of global teaching insights data. *Asian Journal for Mathematics Education*, *5*(1), 51–71. https://doi.org/10.1177/27527263251405886

Youn, S., Moll, A. J., & Berg, S. A. (2010). *The Role of Intrinsic Goal Orientation, Self-Efficacy, and E-Learning Practice in Engineering Education*. *10*(1), 16.

Zhuofan, H., Hidayat, R., & Ayub, A. F. M. (2024). The mediating effect of engagement in the relationship between self-efficacy and perceived learning in the online mathematics environment among Chinese students. *Discover Sustainability*, *5*(1), 469. https://doi.org/10.1007/s43621-024-00586-8

Zimmerman, B. J. (2000). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology*, *25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016

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*. https://doi.org/10.1007/s11218-023-09760-8