Predicting mathematics exam-related self-efficacy as a function of prior achievement, gender, stress mindset, and achievement emotions

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Addressing student affect around assessment is vital, given it is tightly interwoven with cognition. This study seeks to describe the relations between exam-specific affect and stress mindset in a university mathematics course. Participants (N = 356) completed a survey assessing their exam-related self-efficacy, achievement emotions, and stress mindset. The study demonstrated significant correlations between a stress-is-enhancing mindset with positive affect and a stress-is-debilitating mindset with negative affect. When controlling for prior achievement and gender, stress mindset was significant, and student exam-related emotions were dominant in explaining exam-related self-efficacy. The results are discussed with opportunities to adapt learners' stress mindset and the development of exam-related self-efficacy.

Keywords: self-efficacy, achievement emotions, stress mindset, affect, assessment

It is now well established that student performance on assessment is not exclusively a product of their understanding but, additionally, a function of their beliefs and emotions (Zan et al., 2006). Therefore, research should address and unpack the relationships between affect and cognition, to design mathematics assessments or interventions that promote an equitable experience for all students under exam conditions.

Literature Review

Self-Efficacy

Bandura (1997) defines self-efficacy as "the beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Self-efficacy has been demonstrated to be a predictor of academic achievement (Pajares & Graham, 1999; Zimmerman, 2000). Reciprocally, in educational contexts, experiences of success positively influence the development of self-efficacy while experiences of failure impair it (Usher & Pajares, 2009). Since most postsecondary institutions measure students' progress through summative assessment, understanding and operationalizing student assessment-related self-efficacy is important for researchers and educators. Most research to date focuses on content-specific self-efficacy when considering assessment but not students' self-efficacy pertaining to context (such as beliefs around their ability to emotionally regulate). University mathematics educators do not generally have control over the prior achievement or past assessment experiences of students entering the course, so other potential factors that may contribute to explaining student self-efficacy to succeed in an exam environment must be investigated.

Achievement Emotions

Achievement emotions are emotions experienced by learners, which are related to achievement activities or outcomes (Pekrun, 2006). Research has demonstrated that positive emotions, like enjoyment, correlate positively with engagement, motivation, and performance, and negative emotions, like hopelessness, demonstrate the inverse relationship (Mega et al., 2014; Peixoto et al., 2017; Pekrun et al., 2017; Pekrun et al., 2019; Schukajlow & Rakoczy,

2016). Self-efficacy has been shown to associate positively with positive emotions and negatively with negative emotions (Pekrun et al., 2011; Luo et al., 2016). Further, it has been shown that high anxiety can undermine self-efficacy (Usher & Pajares, 2009). Pekrun et al. (2004) argue that self-efficacy relates to positive test-related emotions. Research is needed to understand how greatly students' emotions in and around mathematics assessments contribute to explaining their assessment-related self-efficacy.

Stress Mindset

Crum et al. (2013) challenge the view that stress is inherently negative and argue for the new construct of *stress mindset*, which is defined to be the extent of one's beliefs that stress has enhancing or debilitating consequences for stress-related outcomes. There is evidence to suggest that stress mindset may correlate with performance and the amount of stress psychologically experienced (Crum et al., 2013). However, there is limited research that investigates stress mindset in educational contexts, and particularly its relationship with affect. Keech et al. (2018) report stress mindset directly predicted perceived stress and indirectly predicted academic performance. Kilby and Sherman (2016) report a significant negative correlation between positive stress mindset with both perceived stress and trait anxiety. They did not find significant relationship between stress mindset and mathematics self-efficacy or mathematics anxiety. Research is needed to deduce whether assessment-specific stress mindset has relationships with achievement emotions and assessment-specific self-efficacy.

Procedure

Participants

This study is a cross-sectional analysis of the first time point in a longitudinal study over the course of a semester. The study was conducted during the second semester, 2020 at a major New Zealand university in a standard second year service mathematics course, designed to support other majors such as computer science, finance, physics, and other sciences. There were 410 students enrolled in the course at the start of the semester. Out of these, 379 provided their consent to the use of their data from the course and 364 consenting students completed the first survey. Participants were removed from the analysis if the survey was less than 50% completed or demonstrated sufficient evidence of straight-lining (N = 356). Included in the analysis were 193 students who reported their gender as male, 157 as female, three as gender diverse, and one who declined to answer. Missing data was inserted using EM-imputation.

Measures

The instruments employed in this study were first subject to pilot testing through a cross-sectional research design involving the completion of an anonymous survey by a sample of university students (N=301) procured through *Prolific* (a crowdsourcing platform based in the UK that pays individuals a nominal fee for participating in research projects).

Achievement Emotions Questionnaire (AEQ). The AEQ (Pekrun et al., 2011) contains five-point Likert items ranging from *Strongly Disagree* to *Strongly Agree* designed through the lens of the control-value theory to measure achievement emotions. This study focused on four emotions – enjoyment, hope, anxiety, and hopelessness. During pilot testing, confirmatory factor analysis on the four-factor adapted exam-related AEQ scale suggested the need to incorporate the temporal component of exam-related emotions. We proceeded with exam-related *before* emotions and *during* emotions as separate measurements. Several items were removed and four

new items to measure hope and enjoyment during the assessment were introduced, based on the multi-component structure of achievement emotions as theorized in the control-value theory (Pekrun et al., 2011). Confirmatory factor analysis in this study demonstrated our *before* model offered an acceptable fit (χ/df = 2.627, CFI = .907, RMSEA = .068). The *during* model was acceptable with the inclusion of our four new items (χ/df = 3.067, CFI = .907, RMSEA = .076).

Measure of Assessment Self-Efficacy (MASE). The development and validation of this scale was reported in Riegel et al. (2020). The MASE items were developed following Bandura's (2006) recommendations and were designed to assess the participant's beliefs in their ability to understand, perform, and emotionally regulate while studying for and during an assessment. Responses to statements were measured using a slider scale from 1 to 100 (where 1 = Cannot do at all, 50 = Moderately sure can do, and 100 = Highly certain can do). Pilot testing supported a two-factor model of eight items, with latent factors "performance and comprehension abilities" and "emotional regulation". The model offered an acceptable fit in our study (χ/df = 3.015, CFI = .980, RMSEA = .075). Participants in the study responded to the scale under the following assessment scenario.

> ***Mathematics exam scenario***
> Imagine that you've enrolled in a mathematics course like Maths 2XX that has a final EXAM worth 50% of your final grade. The exam contains short and long answer questions. The exam is invigilated and is two hours long.

Stress and Stress Mindset Measure (SMM). The stress mindset measure (Crum et al., 2013) measures the extent of participants beliefs that stress is enhancing or debilitating. Participants responded on a five-point scale from *Strongly Disagree* to *Strongly Agree*. Students were prompted with the exam scenario described previously. As this was hypothetical, the verb "are" in each statement was rephrased to "would be," for example, *the effects of this stress would be negative and should be avoided.* Pilot testing suggested that exam-related stress-is-enhancing and stress-is-debilitating mindsets were separate latent factors, and that one item should be removed from the scale. This two-factor model offered an acceptable fit in our study for exam-related stress (χ/df = 3.750, CFI = .957, RMSEA = .088). Additionally, we measured stress amount through asking participants *How stressful do you perceive this* ***mathematics EXAM*** *to be?* Responses were indicated on a nine-point scale ranging from *Not stressful at all* to *Extremely stressful*.

Academic achievement. Self-reported prerequisite grades for the course were collected.

Research Questions

- How does stress mindset associate with exam self-efficacy and achievement emotions?
- Do gender or stress mindset make independent contributions to predicting exam self-efficacy when controlling for prior achievement and emotions?
- How greatly do achievement emotions contribute to explaining exam self-efficacy when controlling for prior achievement?

Results

Table 1 presents a summary of the descriptive statistics and correlations of all latent factors.

We conducted two hierarchical multiple regression analyses to explain the two factors comprising exam self-efficacy (performance/comprehension and emotional regulation),

Table 1. Descriptive statistics and correlations of latent factors

Variables	M	SD	α	1	2	3	4	5	6	7	8	9	10	11	12	13
1. SE - performance	65.19	17.21	.89													
2. SE - emotional	64.45	19.52	.86	.77**												
3. Anxiety (B)	3.34	0.75	.66	-.42**	-.45**											
4. Anxiety (D)	2.87	0.88	.86	-.37**	-.43**	.67**										
5. Hope (B)	3.27	0.67	.79	.55**	.52**	-.42**	-.28**									
6. Hope (D)	3.26	0.67	.73	.55**	.50**	-.43**	-.41**	.69**								
8. Hopeless (B)	2.41	0.79	.85	-.51**	-.54**	.53**	.53**	-.50**	-.52**							
8. Hopeless (D)	2.42	0.70	.85	-.53**	-.53**	.48**	.64**	-.41**	-.52**	.73**						
9. Enjoyment (B)	2.93	0.73	.73	.45**	.44**	-.43**	-.26**	.69**	.54**	-.37**	-.31**					
10. Enjoyment (D)	2.96	0.71	.73	.40**	.41**	-.37**	-.33**	.56**	.57**	-.35**	-.31**	.70**				
11. SMS enhancing	3.11	0.80	.83	.26**	.35**	-.27**	-.20**	.33**	.29**	-.23**	-.23**	.37**	.31**			
12. SMS debilitating	3.11	0.69	.70	-.31**	-.41**	.42**	.38**	-.23**	-.23**	.35**	.34**	-.31**	-.28**	-.59**		
13. Stress amount	6.42	1.76	-	-.29**	-.27**	.58**	.49**	-.30**	-.34**	.32**	.35**	-.30**	-.29**	-.23**	.38**	
14. Prior achievement	6.48	2.21	-	.38**	.29**	-.16**	-.11*	.29**	.31**	-.28**	-.24**	.22**	.18**	.16**	-.20**	-.12*

Note. **Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level; SE = self-efficacy, (B) = before, (D) = during, SMS = stress mindset – specific (exam); Prior achievement (9 = A+, 1 = C-); N=356.

summarized in Table 2. The full models were statistically significant for both performance and comprehension self-efficacy R^2_{adj} = .45, $F(13, 338) = 23.21$, $p < .0005$, and emotional regulation self-efficacy R^2_{adj} = .44, $F(13, 338) = 22.29$, $p < .0005$. Prior achievement, which is known to have reciprocal effects with self-efficacy, significantly explained students' beliefs in their performance and comprehension abilities around an exam, R^2_{adj} = .14, $F(1, 350) = 58.10$, $p < .0005$, though not as greatly for their beliefs they could emotionally regulate during an exam, R^2_{adj} = .09, $F(1, 350) = 33.88$, $p < .0005$. We next included the demographic variable gender (the four students who identified as gender diverse or declined to answer were removed from the analysis). This variable was not significant for student performance/comprehension self-efficacy but made a small contribution of R^2_{adj} = .01, $F(1, 349) = 4.40$, $p = .037$ to explaining emotional regulation self-efficacy, with females feeling slightly less efficacious.

The third step added stress mindset as variable. A stress-is-debilitating mindset made a significant contribution to explaining both factors, whereas stress-is-enhancing was only significant for self-efficacy around emotionally regulating. Overall, stress mindset led to a significant increase for performance/comprehension self-efficacy in R^2_{adj} of .06, $F(2, 347) = 14.84$, $p < .0005$, and to emotional regulation self-efficacy in R^2_{adj} of .13, $F(2, 347) = 32.22$, $p < .0005$. After this we included stress amount during an exam, which significantly increased performance/comprehension self-efficacy in R^2_{adj} by .03, $F(1, 346) = 12.25$, $p = .001$, and emotional regulation self-efficacy in R^2_{adj} by .01, $F(1, 346) = 5.73$, $p = .017$.

The next four steps added the four different emotions (anxiety, enjoyment, hope, and hopelessness). The anxiety experienced before and during an exam were both significant, and resulted in increases of R^2_{adj} by .06, $F(2, 344) = 15.25$, $p < .0005$ for performance/ comprehension self-efficacy and R^2_{adj} of .08, $F(2, 344) = 19.26$, $p < .0005$ for emotional regulation self-efficacy. Enjoyment made a significant contribution to both performance/ comprehension self-efficacy of R^2_{adj} of .06, $F(2, 342) = 16.01$, $p < .0005$ and emotional regulation self-efficacy by R^2_{adj} of .04, $F(2, 342) = 14.23$, $p < .0005$. However, only enjoyment before an exam was significant. Hope increased self-efficacy for both performance/ comprehension by R^2_{adj} of .07, $F(2, 340) = 22.19$, $p < .0005$ and emotional regulation by R^2_{adj} of .05, $F(2, 340) = 14.49$, $p < .0005$. Only hope experienced before an exam was significant for explaining emotional regulation self-efficacy. Finally, hopelessness also significantly contributed to the model for performance/comprehension self-efficacy by R^2_{adj} of .03, $F(2, 338) = 32.22$, $p < .0005$ and for emotional regulation self-efficacy by R^2_{adj} of .03, $F(2, 347) = 10.36$, $p < .0005$. For both variables, only hopelessness experienced during the exam was significant.

In the final models, prior achievement, hope before an exam, and hopelessness during an exam are significant predictors of exam self-efficacy. The final model of emotional regulation self-efficacy is also significantly explained by a stress-is-debilitating mindset.

Discussion

This study first sought to understand the relationship between exam self-efficacy, stress mindset, and emotions. The correlations between variables were in line with existing literature and theory. Self-efficacy correlated positively with positive emotions and achievement, and negatively with negative emotions and stress amount. As expected, a stress-is-debilitating mindset correlated positively with the reported amount of stress experienced, while a stress-is-enhancing mindset correlated negatively (Crum et al., 2013). Additionally, our results show that a stress-is-

Table 2. Hierarchical regression coefficients for exam self-efficacy

	β for exam performance and comprehension self-efficacy								β for exam emotional regulation self-efficacy							
Variable	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Prior achievement	.38***	.38***	.33***	.32***	.30***	.27***	.19***	.17***	.30**	.31***	.23***	.22***	.21***	.18***	.12*	.09*
Gender		-.06	-.06	-.05	-.01	-.02	.02	.01		-.12*	-.11*	-.11*	-.06	-.07	-.05	-.06
SMS enhancing			.11	.11	.10	.03	-.03	-.02			.18**	.18**	.17**	.10	.06	.07
SMS debilitating			-.18**	-.12	-.04	-.05	-.11*	-.08			-.25***	-.21**	-.12*	-.13*	-.18**	-.14*
Stress amount				-.18**	-.02	.00	.03	.02				-.12*	.05	.07	.09	.08
Anxiety (B)					-.22**	-.12	-.09	-.09					-.19**	-.11	-.08	-.06
Anxiety (D)					-.14**	-.14*	-.10	.04					-.20**	-.19**	-.17**	-.05
Enjoyment (B)						.20**	.03	.04						.17*	.02	.03
Enjoyment (D)						.11	.01	.03						.12	.05	.07
Hope (B)							.27***	.23**							.26***	.21**
Hope (D)							.19**	.12							.11	.04
Hopeless (B)								-.04								-.12
Hopeless (D)								-.25***								-.17*
R^2_{adj}	.14***	.14***	.20***	.23***	.29***	.35***	.42***	.45***	.09***	.10***	.23***	.24***	.32***	.36***	.41***	.44***
ΔR^2_{adj}		.00	.06***	.03**	.06***	.06***	.07***	.03***		.01*	.13***	.01*	.08***	.04***	.05***	.03***

Note. ***p < .0005; **p < .005; *p < .05; (B) = before, (D) = during, SMS = stress mindset – specific (exam), N = 352.

enhancing mindset correlated positively with exam self-efficacy, positive achievement emotions, and prior achievement, and negatively with negative emotions, while stress-is-debilitating did the opposite. These correlations provide motivation to further investigate if stress mindset contributes to shaping exam-related beliefs and emotions, which in turn influence students' performance and experience of mathematics.

We also sought to understand the role of gender and stress mindset for exam self-efficacy when controlling for prior achievement. Nearly 50% of all exam self-efficacy variance is explained by prior achievement, stress mindset, and student emotions. Prior achievement is a known predictor of academic self-efficacy, however, our study indicates that it is not as great a predictor of students' beliefs they can emotionally regulate in exam conditions as it is for the belief in their ability to understand and perform. This could mean that repeated experiences of success do not as greatly develop beliefs they can remain calm or optimistic in the face of assessment, suggesting it may be important to separately address students' affect on assessments.

Gender accounted for a small but significant decrease in self-efficacy for women around emotional regulation. This distinction between performance/comprehension self-efficacy and emotional regulation self-efficacy may contribute to explaining why there have been mixed findings with this relationship historically (Hackett & Betz, 1989).

Stress mindset made a meaningful contribution to explaining both self-efficacy factors when controlling for prior achievement and gender, but more greatly for the emotional regulation factor of self-efficacy. A stress-is-debilitating mindset remained significant in the final model for explaining this factor. Self-efficacy has been shown to have reciprocal effects with academic achievement but can be slow to change through methods such as the accumulating mastery experiences. On the other hand, stress mindset has been shown to be malleable through short video interventions (Crum et al., 2013; Crum et al., 2017). Manipulating students away from a stress-is-debilitating mindset may provide a realistic opportunity to develop exam-related self-efficacy more rapidly. This would need to be investigated through a longitudinal study to determine if there is a causal relationship.

Finally, we were interested in the contribution of emotions to predicting exam self-efficacy. On both factors of exam self-efficacy, the addition of the four emotions accounts for around 20% of the variance, emphasizing the importance of considering student emotions when addressing self-efficacy. Hope before and hopelessness during an exam stayed significant in the final models for exam self-efficacy. Optimism before an exam aligns with the belief that they can succeed, but this perhaps also suggests that what influences the development of self-efficacy is how hopeful students have historically walked into exams and how despairing they have felt while taking an exam. This highlights how greatly a single assessment can damage the development of a learner's self-efficacy.

Limitations and Future Research

The MASE will be further validated using the data from the longitudinal study, specifically testing for measurement invariance. Our regression analysis has not yet considered possible interactions between variables, which could reveal nuanced relationships in the data. Finally, the data was collected during the Covid-19 pandemic and the previous semester had a lockdown, possibly influencing students' academic affect. However, we think it is unlikely it dramatically altered the relationship between the variables in this study. Stress mindset may have played a role in how students coped with these events, which we aim to understand in future research. Analysis of the longitudinal data will inform potential causal effects between these variables and relationship with exam performance in that semester.

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