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*Research article*

## Predicting how a disrupted semester during the COVID-19 pandemic impacted student learning

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**Abstract:** Tertiary education faced unprecedented disruption resulting from COVID-19 driven lockdowns around the world, leaving educators with little understanding of how the pandemic and consequential shift to online environments would impact students' learning. Utilising the theoretical framework of a student's *affective field*, this study aimed to investigate how student achievement, achievement-related affect, and self-perceived well-being contributed to predicting how their learning was impacted. Questionnaire responses and academic achievement measures from students ( $N = 208$ ) in a New Zealand second-year, tertiary mathematics course were analysed. Despite a return to in-person teaching after eliminating community-transmission of the virus, students reported larger impacts of the disruption to semester on both their learning and well-being at the end of the term than during the lockdown. Hierarchical multiple regression revealed that gender, prior achievement, performance on low-stakes assessment, as well as exam-related self-efficacy and hope, made significant, independent contributions to explaining students' perceived learning impact. Even when controlling for achievement and achievement-related affect, students' perceived impact to their well-being made a significant and substantial contribution to the impact on their learning. The findings provide motivation to further investigate whether attempts to address student achievement-related affect can help mitigate the effects of major life disruptions on studying. We suggest that frequent, low-stakes assessment can identify students who are more likely to report greater negative impacts to their learning. We finally conclude that student well-being is paramount to how students perceive their own learning, even when controlling for actual measures of and about their achievement.

**Keywords:** affect, assessment, COVID-19, self-efficacy, university mathematics, student well-being

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## 1. Introduction

The COVID-19 pandemic disrupted tertiary education globally, with many universities abruptly moving to online teaching. New Zealand took immediate and extreme measures to eliminate community transmission through lockdown restrictions. This kept students safe from the virus but presented challenges to their learning as they transitioned into and out of online teaching in the middle of a semester. Research has demonstrated that affect, cognition, and achievement are all tightly interwoven [1]. Therefore, it is reasonable to suspect that student learning was not uniformly impacted by lockdowns across all students, but likely explained by their academic achievement and affective disposition. It is known that student self-reported, perceived learning is an indicator of their actual learning [2], and it may theoretically be more reliable than formal assessment during times of stress or disruption due to the many negative affective predictors of academic performance.

From studies that have been published to date, it is apparent that university students in many countries affected by the COVID-19 pandemic have experienced extremely high stress and anxiety. In a study of 914 university students in Poland, Rogowska et al. [3] found that 65% of students reported symptoms of mild or severe general anxiety disorder during the first wave of the pandemic in April 2020. During that time, 56% of students reported a high level of perceived stress. Regressing on other variables, researchers were able to explain 60% of the variance in anxiety measures through stress, self-rated health, gender, and use of emotion-oriented and task-oriented coping styles. Similarly, in a large sample of college students ( $N = 304,167$ ) in Guangdong Province China [4] as part of research to assess the psychological impact of the outbreak, researchers found that 155,077 (50.9%) of the students reported symptoms of stress.

In Spain, a study of 427 university students [5] investigated the relationship between general self-efficacy during a confinement period of the first wave of the pandemic and the level of trait and state anxiety. The researchers found an inversely proportional relationship between anxiety and self-efficacy. Men reported higher levels of self-efficacy, while women scored significantly higher on both trait and state anxiety measures. Moreover, the students who had lost a relative during the pandemic scored significantly lower in the perception of academic self-efficacy, with large effect size. Multivariate inferential analyses indicated that the higher the levels of trait and state anxiety, the worse the perception of academic self-efficacy.

Specific to mathematics education, numerous studies have been published investigating the impact of COVID-19 on the educational environment. Factors related to equity considerations such as students' diverse social, economic, and academic backgrounds and the related teachers' perspectives have been investigated [6–10]. The pandemic has laid bare social inequality, highlighting the urgent need to study how mathematics learning happens online for students across all levels of education, particularly when home environments and access to digital technologies play such significant roles [6]. In a New Zealand study of parents' perspectives on mathematics home learning during the pandemic, Darragh and Franke [11] concluded that the success of home learning depends highly on the learning resources and the support provided by the teacher or school, which varied across the country. The emergency response teaching in the context of historical disadvantage has been brought into the focus with the current social injustice issues reported in South Africa [7], Brazil [6], and the USA [12].

So far, the studies reporting on practical issues faced by millions of students studying mathematics at the tertiary level have focused on data from surveying teachers and teaching

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assistants. An international team of researchers that came together as members of the Special Interest Group of Mathematical Association of America on Research in Undergraduate Mathematics Education (RUME) have surveyed STEM tertiary instructors from 23 countries about their teaching strategies and how they were challenged by teaching online [13]. The results of the survey of 101 international STEM faculty members indicated that evaluation and pedagogy were the most disrupted dimensions when they were forced to shift to online education delivery. The study found evidence that many instructors looked for ways to personalise support for learners by accounting for the influence of emotion and affect. In conclusion, the researchers noted that the affective dimension is missing in commonly used online-teaching frameworks, with most instructors emphasising sympathy and care for the students' well-being.

The importance of personal connections as part of a university mathematics education was also demonstrated in a study by Mullen et al. [14]. The researchers from Ireland and Australia investigated the dramatic changes brought by the pandemic on the operation of mathematics support centres, which provide one-on-one help to students. Through interviewing students and staff involved with the support centres during 2020, common themes identified highlighted the need for mutual connection felt by both learners and instructors [14].

From a psychoeducational perspective, very little has been studied at a university mathematics level. One study of 120 mathematics students in Ecuador explored the interaction between anxiety and learning during the first half of 2020 [15]. The selection of the sample only included students who have not been diagnosed with an anxiety disorder. A psychometric instrument (ISRA-B) was used to assess anxiety in three general response systems (cognitive, physiological, and motor), as well as in four specific traits or situational areas (evaluation anxiety, phobic anxiety, mathematics anxiety, and virtual anxiety). The results showed that, on average, students experienced severe levels of both mathematics and virtual anxiety, illustrating the changes and secondary effects of virtual activities with prolonged distancing due to COVID-19.

The need to study key psychoeducational parameters simultaneously in a mathematics education context has been advocated for extensively in the recent work by Schindler and Bakker [16], who highlight that researchers tend to investigate learners' motivation, anxiety, and other affective characteristics separately, focusing only on one theoretical construct. They present a convincing argument for research considerations to include various affective factors simultaneously to unpack their interplay. To capture this structurally, they introduced the term *affective field* to combine theoretical considerations of constructs such as emotions, attitudes, and beliefs. In this study, we respond to their concern by considering self-efficacy, achievement emotions, stress-mindset, and student well-being simultaneously in conjunction with other variables.

From the existing literature on the impact of COVID-19 in education, it is evident student learning and well-being were hindered in many cases globally and at different levels of education – but the relationship between student affect and well-being with their learning has not been sufficiently explored in this context. Our study seeks to extend existing conclusions by considering to what extent students perceived their learning and well-being to be impacted. There remain unanswered questions around what factors contributed to students' perceptions of their own learning as their courses and lives were unsettled. In such contexts, it is important to establish the significance of student well-being in relation to their learning. Further, the pandemic provides a unique opportunity to investigate what measures of academic achievement over a semester, which

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theoretically should be a measure of learning, align with impacts on student perceived learning. Gaining insight into the explanatory role played by their affective field and different measures of academic achievement may have promising equitable uses in identifying at-risk students or informing course design.

Specifically, the study aimed to answer the following research questions:

1. How did students perceive the disruption to the semester as impacting their learning and well-being?
2. How does performance on different forms of assessment contribute to explaining the extent to which students felt their learning to be impacted by the disruption to the semester?
3. How do self-efficacy, achievement emotions, and stress mindset contribute to explaining the extent to which students felt their learning to be impacted by the disruption to the semester?
4. When controlling for achievement and achievement-related affect, how greatly do the impacts on student well-being explain the impacts on their learning?

We first briefly define and summarise the research findings pertaining to the key constructs used in the study: self-efficacy, achievement emotions, and stress mindset.

## **2. Theoretical and empirical foundations**

### **2.1. Self-efficacy**

Bandura [17] 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 established as an important construct in education as it associates with and predicts academic achievement [18–20]. More recently, Alqurashi [21] identified the significant role of online learning self-efficacy in explaining student perceived learning.

Learners' beliefs about their ability to perform on a mathematics exam have recently become a focus of research investigations [22]. Students' beliefs about their ability to perform on assessments are related to, but distinct from their beliefs about their ability to do mathematics [23,24]. As most postsecondary institutions measure students' progress in learning through summative assessment, we suspect student exam-related self-efficacy is a relevant measure for how they perceive their own learning. Self-efficacy is already an important construct in mathematics education and could be a determining factor in whether student learning is impacted differently by disruptions and stressors during a semester, potentially identifying the need for targeted enhancement of self-efficacy. To the best of our knowledge, there is no research on assessment-related self-efficacy as it relates to student perceived learning.

### **2.2. Achievement emotions**

Achievement emotions are emotions experienced by learners, which are related to achievement activities or outcomes [25]. Research supports the view that positive emotions, like hope, foster student learning through, for example, demonstrating positive relationships with engagement, motivation, and performance, while negative emotions, like anxiety, do the inverse [26–30]. Thus, student emotions are an important variable to include in explaining the perceptions they have of their

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learning and could provide direction around what specific aspects of academic affect, particularly around assessment, to promote in students during times of distress or disruption.

### 2.3. Stress mindset

Crum et al. [31] argue for the construct of stress mindset, which challenges the view that stress is inherently negative. They define stress mindset as the extent of an individual's beliefs that stress has enhancing or debilitating consequences for stress-related outcomes. There is currently little research that examines stress mindset in education. Kilby and Sherman [32] report a significant negative correlation between positive stress mindset with both perceived stress and trait anxiety, but did not find a significant relationship between stress mindset and mathematics anxiety or self-efficacy. In contrast, Riegel et al. [22] report exam-specific stress mindset to be significant in explaining mathematics exam self-efficacy. Moreover, stress mindset was found to predict perceived stress and indirectly predicted academic performance [33]. Finally, Jenkins et al. [34] found that stress mindset was more predictive of student health when pertaining to controllable stressors rather than uncontrollable stressors and argued a stress-is-enhancing mindset is associated with better health. While many of these findings are intertwined with student learning, research is needed to deduce how stress mindset moderates a student's perceived learning when external stressors are imposed on a semester.

## 3. Methods

### 3.1. Background

This study took place during the COVID-19 pandemic at a major New Zealand university. In New Zealand, COVID-19 had been eliminated from the community after a seven-week lockdown starting in March of 2020. Consequently, students were able to start semester two in-person in July of 2020 when this research commenced. During week three of the semester, several breakthrough COVID-19 cases were detected in the community and Auckland was moved into a lockdown, causing learning to shift temporarily to an online environment. After community transmission was eliminated again, students recommenced in-person learning in week nine of the semester, two weeks after lockdown rules were lifted. Roughly half the semester was in-person and half online.

The course in this study is a standard second-year service mathematics course designed to support other majors such as finance, physics, computer science, and other sciences. It featured online quizzes, which students needed to complete in their own time between each lecture. There were 31 quizzes throughout the semester with the best 27 results kept. Each quiz contained two multiple-choice questions assessing the key ideas from the previous lecture. Students had 30 minutes to complete a quiz once opened and two attempts at each quiz. The quizzes were worth 12.7% of the final course grade. Additionally, the course had an hour-long, multiple-choice, mid-semester test worth 20% of the final grade. In a normal semester, this would take place in person, but due to the lockdown, it was moved online. The students had a 50% final exam, which was sat in person at the end of the semester. It contained short and long answer questions. The remaining course marks were made up by coursework such as assignments and tutorials. The data used in this analysis comes from online surveys distributed at three time points in the semester described above: in the first week, the seventh week

following the test, and the twelfth week before the final exam. An approval to conduct the study from the University of Auckland Ethics Committee was granted (approval number 024710).

### 3.2. Participants

The participants for this study were students enrolled in the course described above. There were 410 students enrolled at the start of the semester, of these, 379 provided consent to the use of their data from the course. Participants were removed from the analysis if the survey was less than 50% completed or demonstrated sufficient evidence of straight-lining. After cleaning, there were 277 students who completed all three surveys. Missing data was inserted using EM-imputation. As New Zealand borders remained closed to most international travel, 66 of these students were participating in the course from overseas and were therefore not included in this analysis about how the New Zealand lockdown impacted their learning. Three students who identified as gender diverse or declined to answer were not included in the analysis due to an insufficient sample size. There were 117 students who identified as male and 91 who identified as female. In total, we had 208 students included in this analysis.

### 3.3. Measures

#### 3.3.1. Assessment self-efficacy

Assessment self-efficacy was measured by a purposefully designed instrument: the Measure of Assessment Self-Efficacy (MASE). The development and validation of the MASE was reported in Riegel et al. [35]. The exam-related MASE items assess participants' beliefs in their ability to understand, perform, and emotionally regulate while studying for and during an exam. Students were prompted with the following exam scenario:

##### *Mathematics exam scenario*

Imagine that you've enrolled in a mathematics course like Maths 208 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.

Responses to statements are 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*). The model offered an acceptable fit in our study ( $\chi^2/df = 3.04$ , CFI = .972, SRMR = .020). The scale and item factor loadings can be found in Appendix A. Responses to the scale used for this analysis were collected in week twelve of the semester.

#### 3.3.2. Achievement emotions

An adapted version of the Achievement Emotions Questionnaire (AEQ) [36] was used to measure students' exam-related emotions. The scale uses five-point Likert-type responses (1 = *Strongly Disagree* to 5 = *Strongly Agree*). The scale was adapted following pilot testing to measure four emotions (anxiety, enjoyment, hope, and hopelessness) experienced *before* an exam and provided an acceptable fit for our data ( $\chi^2/df = 2.29$ , CFI = .908, SRMR = .064). The scale and item

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factor loadings can be found in Appendix B. Responses to the scale used for this analysis were collected in week twelve of the semester.

### 3.3.3. *Stress mindset*

The Stress Mindset Measure – General (SMM-G) [31] measures the extent of participants' beliefs that stress is enhancing or debilitating. Participants responded on a five-point Likert scale from *strongly disagree* to *strongly agree*. Pilot testing suggested that 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 ( $\chi^2/df = 2.16$ , CFI = .966, SRMR = .045). The scale and item factor loadings can be found in Appendix C. Responses to the scale used for this analysis were collected in the first week of the semester.

### 3.3.4. *Learning and well-being impact*

As we became interested in the effects of the Level 3 lockdown (requiring individuals to stay at home except for essential services) on students during the semester, we included the following two statements in the week seven questionnaire: “How much do you feel the level 3 lockdown in Auckland and Maths 208 moving online negatively impacted your learning in the first half of semester?” and “How much do you feel the level 3 lockdown in Auckland and Maths 208 moving online negatively impacted your mental well-being in the first half of semester?” Similarly, we included the following statement in the week twelve questionnaire: “How much do you feel the level 3 lockdown in Auckland and Maths 208 moving online negatively impacted your learning during the semester?” and “How much do you feel the level 3 lockdown in Auckland and Maths 208 moving online negatively impacted your mental well-being during the semester?” Students responded on Likert scales from one to nine where 1 = *not at all*, 5 = *somewhat*, and 9 = *significantly*.

### 3.3.5. *Achievement*

Self-reported prerequisite grades for the course were collected as a measure of prior achievement (9 = A+, 1 = C-). Additionally, we included data from each student's performance in the course. In this analysis, we have incorporated their quizzes, test, and exam results.

## 4. Results

To address research question one, Table 1 presents descriptive statistics and t-tests for the changes in students' perceived impact of lockdown on their learning and well-being, as well as the change in performance on major assessments (the test and the exam) from the middle of the semester to the end of the semester. Results demonstrate that, on average, students felt their learning and well-being were at least somewhat impacted by the disruption to the semester. Both these measures increased significantly by the end of the semester, with students reporting feeling more impacted, though the effect sizes were small ( $d = 0.28, 0.22$ ). Student performance on major assessments decreased, on average, by around 15%. Though this is a reasonably large effect size ( $d = 0.66$ ), this drop in marks is not unusual for this course.

**Table 1.** T-tests for changes in learning impact, well-being impact, and performance

	Mid-semester		End of semester		95% CI for				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	mean difference	<i>t</i>	<i>p</i>	<i>d</i>	
Learning	5.46	2.63	6.09	2.45	-0.95, -0.32	-3.97	.000	0.28	
Wellbeing	5.25	2.59	5.69	2.47	-0.72, -0.17	-3.16	.002	0.22	
Performance	74.47	20.29	59.56	29.06	11.80, 18.02	9.44	.000	0.66	

Note. *N* = 208.

To answer the other research questions, we conducted a hierarchical multiple regression analysis to explain students' perception of how their learning at the end of the semester was impacted by the lockdown. In performing the regression, we found several variables to be too highly correlated (>.70) in our data to be both included in the analysis. The two MASE subscales presented this issue, so we removed the "emotional regulation" subscale and proceeded with the "comprehension and execution" subscale to preserve the widest variety of variables. We aimed to assess the predictive power of positive emotions in one step of the regression but found that enjoyment and hope were too highly correlated. We, therefore, made the decision to proceed with hope as the only positive emotion and removed enjoyment, as we anticipated that achievement-related hope would have greater predictive power over perceived learning than achievement-related enjoyment. We grouped the negative emotions in the following step and found this step was damaging the adjusted  $R^2$ , so we first removed hopelessness from the model, identifying anxiety as more conceptually distinct from the previously included variable of hope. However, anxiety alone was still damaging the model, so negative emotions were removed entirely from explaining perceived learning impact. Table 2 presents a summary of the descriptive statistics and correlations of the variables included in the analysis.

**Table 2.** Descriptive statistics and correlations of latent factors in the hierarchical regression

	<i>M</i>	<i>SD</i>	$\alpha$	1	2	3	4	5	6	7	8	9	10
1. Learning impact	6.09	2.45	-										
2. Gender	1.44	0.50	-	-.14*									
3. Prior achievement	6.54	2.12	-	-.17*	-.05								
4. Test	74.47	20.29	-	-.17*	-.11	.59**							
5. Exam	59.56	29.06	-	-.20**	-.08	.56**	.63**						
6. Quizzes	88.19	16.98	-	-.28**	-.04	.54**	.56**	.57**					
7. Self-efficacy	59.31	19.53	.94	-.26**	.04	.35**	.42**	.44**	.35**				
8. Hope	3.03	0.69	-	-.26**	-.07	.26**	.34**	.35**	.28**	.60**			
9. Stress-is-enhancing	3.04	0.79	.78	.06	-.03	.10	.18*	.10	.04	.11	.10		
10. Stress-is-debilitating	3.22	0.73	.75	-.04	.03	-.17*	-.18**	-.15*	-.14*	-.12*	-.11	-.55**	
11. Well-being impact	5.69	2.47	-	.79**	-.11	-.16*	-.12*	-.08	-.19**	-.24**	-.19**	.04	.02

Note. \*\*Correlation is significant at the 0.005 level; \*Correlation is significant at the 0.05 level; Gender (Male = 1, Female = 2); *N* = 208.



As anticipated, learning impact at the end of the semester associated negatively with performance measures, self-efficacy, and hope. The achievement measures correlated reasonably strongly and positively with each other, in addition to self-efficacy, as expected. Self-efficacy further correlated with the positive emotion hope. A stress-is-enhancing mindset did not have any significant correlations besides a small positive correlation with the test score. Contrastingly, a stress-is-debilitating mindset correlated negatively with all achievement measures and self-efficacy. The impact that students perceived the semesters' disruption had on their well-being correlated negatively with prior achievement, test, and quizzes, as well as self-efficacy and hope. It had a very strong positive relationship with students' perceived learning impact.

Table 3 presents a summary of the hierarchical multiple regression. The full model was statistically significant  $R_{adj}^2 = .65$ ,  $F(10, 197) = 39.66$ ,  $p < .001$ . We first included the demographic variable of gender,  $R_{adj}^2 = .02$ ,  $F(1, 206) = 4.16$ ,  $p < .05$ , followed by prior achievement,  $R_{adj}^2 = .03$ ,  $F(1, 205) = 7.09$ ,  $p < .01$ , for the course and found that each of these variables made significant contributions to predicting learning impact. Both students who identified as female and higher achieving students reported less impact to their learning.

**Table 3.** Hierarchical regression coefficients for perceived learning impact at the end of semester

Variable	$\beta$ for student perception of learning impact								
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9
Gender	-.14*	-.15*	-.16*	-.16*	-.16*	-.14*	-.16*	-.16*	-.07
Prior achievement		-.18*	-.11	-.07	-.02	.00	-.01	-.01	.06
Test			-.12	-.06	.00	.04	.05	.03	.03
Exam				-.14	-.07	-.03	-.01	-.01	-.12*
Quizzes					-.25*	-.23*	-.23*	-.23*	-.12*
Self-efficacy						-.17*	-.07	-.08	.05
Hope							-.18*	-.18*	-.12*
Stress-is-enhancing								.05	-.01
Stress-is-debilitating								-.06	-.08
Well-being impact									.75**
$R_{adj}^2$	.02*	.04**	.05**	.05**	.09**	.10**	.12**	.12**	.65**
$\Delta R_{adj}^2$		.03*	.01	.01	.03*	.02*	.02*	.00	.53**

Note. \*\* $p < .005$ ; \* $p < .05$ ;  $N = 208$ .

We next sequentially controlled for the measures of student performance throughout the semester in explaining how impacted they perceived their learning. While the model remained significant at each step, both test performance,  $R_{adj}^2 = .01$ ,  $F(1, 204) = 2.08$ ,  $p > .05$ , and exam performance,  $R_{adj}^2 = .01$ ,  $F(1, 203) = 2.21$ ,  $p > .05$ , failed to significantly contribute to explaining to what extent students felt their learning was impacted. However, performance on the regular quizzes throughout the semester significantly contributed to the model,  $R_{adj}^2 = .03$ ,  $F(1, 202) = 7.80$ ,  $p < .01$ , with

higher achievement associated with a lower perceived impact on learning.

We then sought to investigate and control for student exam-related self-efficacy and found that it made a significant contribution to explaining learning impact,  $R_{adj}^2 = .02$ ,  $F(1, 201) = 5.05$ ,  $p < .05$ , with greater self-efficacy predicting a decreased perception in learning impact. Next, we included a measure for student hope before an exam and found this also made a small and significant contribution,  $R_{adj}^2 = .02$ ,  $F(1, 200) = 4.58$ ,  $p < .05$ , with more hopeful students reporting their learning was less impacted. Our final control measure pertaining to students' affective field was their stress mindset; however, this was not found to be significant to the model,  $R_{adj}^2 = .00$ ,  $F(1, 198) = 1.07$ ,  $p > .05$ .

After controlling for student gender, achievement, and achievement-related affect, we found that the perceived impact to their well-being made by far the largest contribution to explaining how greatly students felt their learning was impacted,  $R_{adj}^2 = .53$ ,  $F(1, 197) = 303.22$ ,  $p < .001$ . Students reporting a greater impact on their well-being predicted greater impacts on their perceived learning. In the final model, performance on the quizzes and hope remained significant, in addition to the exam performance beta becoming significant once the measure for well-being was included.

## 5. Discussion

Our first research question aimed to address how students perceived the disruption to the semester as impacting their learning and well-being. We found that, on average, students felt both their learning and well-being were at least somewhat impacted by the lockdown. When they completed the final survey in week twelve, the students had been back in person for several weeks, but at this point, they, in hindsight, perceived the lockdown as having had a greater impact on both their learning and well-being than they did completing the survey during the period of online learning. While this increase in both variables is only small, it nonetheless suggests a shift in students' assessment of the experience and a possible delayed impact of the lockdown. In the case of their learning, this could be a consequence of students not realising they are falling behind on learning in the course, or of only gauging their learning through receiving performance feedback later in the semester. This demonstrates a need to connect with students who are falling behind, identifying these students through their engagement and performance on smaller assessments like the quizzes. Further, educators should seek to find ways to encourage students to evaluate their own learning progress throughout the entire semester and not simply in relation to major assessments.

The significant correlations identified in this study reaffirm findings from previous research [18–20, 22, 26–30, 33, 34], as well as uncover some notable relationships. Importantly, self-efficacy is associated positively with all measures of performance, positively with hope, and negatively with learning impact and a debilitating stress-mindset. These results reiterate the value of finding new interventions to promote student self-efficacy. We also discovered more about stress mindset in the context of education. Interestingly, while a debilitating view of stress had small, but significant negative correlations with achievement and assessment affect, an enhancing view of stress did not present the inverse relationships. This finding perhaps suggests that it is easy for stress to be damaging but difficult to position as constructive in education. The result could be useful as stress mindset has been shown to be malleable through short video interventions [31,37]. There is a possible opportunity to shift student mindset away from a debilitating view and alleviate the negative effects it has on student affect and performance in academic situations

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Our second research question sought to unpack whether all achievement measures are useful in explaining students' judgement of their own learning. Notably, performance on major summative assessments such as the test and exam was not significant in explaining how impacted students felt their learning to be by the disruption to the semester. Instead, student prerequisite achievement for the course and performance on regular online quizzes were significant predictors of their perceived learning impact. This finding has several possible implications. One could be that major one-off summative assessments are not always representative of what students have learned. In this case, it is critical research seeks to address, for example, affective barriers, such as anxiety [38,39], which can inhibit students from accurately demonstrating their learning on these types of assessment. Another is that students may not be active or accurate judges of their own learning progress, specifically, that they do not notice if they are falling behind in real time. They had not yet sat the final exam when reporting their learning impact, so perhaps assessments are only useful to them gauging their learning after knowing how well they performed.

In contrast, performance on the quizzes throughout the semester was significant in predicting learning impact when introduced and stayed significant in the final model. As discussed earlier in the paper, the quizzes were designed to provide students with the greatest opportunity to succeed if they engaged with them. Most students who took a quiz were able to receive full marks [40], so high final quiz grades may be an indication of students who are regularly engaging with the course, while low grades are likely to indicate students who have not been taking the quizzes or keeping up with the content. The first consequence of this finding is that the inclusion of low-risk, frequent assessment provides an avenue for students to feel their learning is less impacted by disruptions to the semester. Perhaps, this results from regular engagement [41] or personal accountability on their progress. Secondly, in a course of this magnitude, it is difficult for a lecturer to detect students who are struggling, particularly in times of major stress or disruption to the semester. Monitoring performance of students in frequent, low-risk assessments could help lecturers identify students who are not engaging and, consequently, whose learning is suffering. This does not always have to be as universal as a pandemic, but an individual's own life. Similarly, the significance of prior achievement when it is introduced suggests that historically lower-achieving students can be identified as more at risk of falling behind in their learning under such circumstances.

Our third research question aimed to interpret students' affective field by investigating what roles self-efficacy, achievement emotions, and stress mindset play in explaining how impacted students perceived their learning to be. We found that both self-efficacy and hope made significant contributions to predicting students' learning impact, with hope remaining significant in the final model. Educators do not have control over the self-efficacy that students enter the course with, but through interventions like the quizzes aimed at promoting mastery experiences [40], we can seek to develop student self-efficacy to prevent a large impact on their learning from disruptions to semester. This again emphasises the importance of self-efficacy as a construct - not only does it predict achievement, but students' own perceptions of their learning. The role of hope in explaining students' impacted learning illuminates the significance of promoting positive achievement-related affect. There is currently a dearth of comprehensive research on this topic. The finding of this study emphasises that it is not sufficient to simply mitigate the effects of negative emotions, but that students are likely to benefit from enhanced positive emotions.

Finally, even when controlling for student achievement and achievement-related affect, student

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perceived impact of the disruption to the semester on their well-being made by far the largest contribution to explaining how greatly their learning was impacted. This finding emphasises that student life is not compartmentalised into education and personal life, but that these two (or more) facets significantly interact with each other, determining the outcome of the other. As outlined previously, the pandemic is something everyone has experienced together, and research demonstrates educators have taken that concern for their students into their work. However, even in normal semesters, students suffer major life events that may not be known to teachers, which take a toll on their well-being and, in turn, learning. As a practical implication, our finding suggests that educators must be mindful of the magnitude of the potential impact and scale of this relationship and investigate ways to both encourage student well-being and mitigate the effects of it on their personal learning journey during a semester. In terms of implications for theory, our research underscores the need for comprehensive operationalisation of well-being within students' *affective field* and warrants further theoretical conceptualisations of the existing relationships between affective and performance-related constructs.

## 6. Conclusions and Limitations

The hierarchical regression in this paper has not considered possible interactions between variables, which could reveal nuanced relationships in the data and could be investigated in future studies. A further limitation is that the data was collected solely in a tertiary New Zealand mathematics course, so generalisations about the pandemic's impact globally should be considered carefully. Most studies into the effects of the coronavirus pandemic call for research into preventative undertakings to assist students under such circumstances. Difficult circumstances and disruptions will likely happen in the future affecting entire cohorts of students. Additionally, we regularly see individuals experiencing major life disruptions like illness or death of loved ones, causing distress and forcing them to abruptly shift their learning into a virtual space where universities have this option available. One major implication of this study is in charting a possible avenue of further investigations into how we can influence and aim to mitigate the negative impact these events have on student learning. Courses of action that educators have control over include interventions aimed at encouraging assessment-related self-efficacy and hope, as well as incorporating regular low-risk assessments to monitor student progress throughout the semester. The main conclusion of the study is that student perceived learning is not necessarily reflected by their experiences of achievement, but rather, in order for students to feel they are learning it is critical for educators to support student well-being and understand that their perceived well-being and perceived learning in a semester go hand-in-hand. This theoretical insight paves the way for future theoretical and empirical investigations about the role of well-being on student learning. Such investigations would be particularly worthwhile if undertaken in conjunction with the use of well-established psychometric constructs, which may help to make substantial advances in the field.

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## Appendix A

### Measure of Assessment Self-Efficacy – Exam (MASE-E)

#### *Comprehension and execution*

I can understand the content and skills needed for the assessment. (.89)

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I can fully master the requirements I need for this assessment. (.88)

I can understand the questions in the assessment. (.91)

I can correctly answer the questions on the assessment. (.89)

### ***Emotional Regulation***

During my preparation, I am able to cope with my negative emotions toward the assessment. (.87)

While studying, I am able to stay positive about my ability to succeed. (.95)

Even when I struggle during the assessment, I am able to stay positive about my ability to succeed. (.88)

*Note.* Loadings are standardised beta weights.

## **Appendix B**

### **Achievement Emotions Questionnaire (AEQ)**

Mathematics EXAMS can induce different feelings. Before responding to the following statements, please recall some typical mathematics exams which you have experienced.

#### **BEFORE TAKING THE MATHEMATICS EXAM**

The following questions pertain to feelings you may experience BEFORE a mathematics exam. Indicate how you feel, typically, before taking a mathematics exam.

#### ***Anxiety***

I worry whether I have studied enough. (.47)

I feel sick to my stomach. (.70)

I get so nervous I wish I could just skip the exam. (.80)

I worry about whether the exam will be too difficult. (.53)

#### ***Enjoyment***

I look forward to the exam. (.77)

Because I enjoy preparing for the exam, I'm motivated to do more than is necessary. (.72)

Before taking the exam, I sense a feeling of eagerness. (.64)

I look forward to demonstrating my knowledge. (.73)

#### ***Hope***

I start studying for the exam with great hope and anticipation. (.67)

I have great hope that my abilities will be sufficient. (.61)

I'm quite confident that my preparation is sufficient. (.73)

I think about my exam optimistically. (.71)

My confidence motivates me to prepare well. (.72)



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### *Hopelessness*

- My hopelessness robs me of all my energy. (.75)  
 I have lost all hope that I have the ability to do well on the exam. (.81)  
 I feel so resigned about the exam that I can't start doing anything. (.73)  
 I'd rather not take the exam because I have lost all hope. (.82)  
 I get depressed because I feel I don't have much hope for the exam. (.78)

*Note.* Loadings are standardised beta weights.

## **Appendix C**

### **Stress Mindset Measure – General (SMM-G)**

#### *Stress-is-debilitating*

- The effects of stress are negative and should be avoided. (.77)  
 Experiencing stress depletes my health and vitality. (.60)  
 Experiencing stress inhibits my learning and growth. (.56)  
 Experiencing stress debilitates my performance and productivity. (.68)

#### *Stress-is-enhancing*

- Experiencing stress facilitates my learning and growth. (.75)  
 Experiencing stress enhances my performance and productivity. (.77)  
 The effects of stress are positive and should be utilized. (.70)

*Note.* Loadings are standardised beta weights.

### **Author's biography**

**Kaitlin Riegel** is a doctoral candidate in Mathematics Education at the University of Auckland, following a background of postgraduate study in Mathematics. Her research interests include academic affect, centered particularly around higher education, assessment, and online learning.

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