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| Research Article

Student reflections on emotional engagement reveal science fatigue during the COVID-19 online learning transition

Emma R. Wester,[1,2] Lisa L. Walsh,[1] Sandra Arango-Caro,[1] Elena Bray Speth,[2] Kristine Callis-Duehl[1]

AUTHOR AFFILIATIONS See affiliation list on p. 11.

ABSTRACT Numerous quantitative studies in science education found that student engagement declined after the onset of the COVID-19 pandemic, but analyses to identify the factors that drove emotional engagement down are lacking. Emotional engagement is a multidimensional construct composed of interest in an academic discipline, value in an academic course, and anxiety. Here, we use qualitative analysis to examine how and why the emergency shift from face-to-face to online classes during and after the pandemic-induced emergency remote transition impacted student emotional engagement. We coded student responses to open-ended questions using an emotional engagement framework and compared them between March and May 2020. Students' survey responses indicate that their positive attitudes toward science and value in the course declined. In contrast, more students expressed negative values of the course in the post-survey, with students mainly critiquing instructors and learning. This qualitative analysis offers a deeper understanding of students' emotional challenges during this educational upheaval and suggests effective teaching strategies for future crises.

KEYWORDS COVID-19, education in emergencies, emotional engagement, science fatigue, student engagement

The United Nations reported that 1.6 billion learners had their education disrupted by the COVID-19 pandemic in early 2020. They estimated that school closures impacted 94% of students worldwide (1). For US universities, schools under the semester schedule had to transition from in-person classes to online classes in March 2020, while schools under the quarter schedule began their spring quarter 2020 online. As university dorms closed, students had to relocate, exacerbating existing inequalities between students (2, 3). While some students had high-speed internet, technology, and a personal room to work in, others struggled to access the internet and technology required for online learning and faced distractions, including financial insecurity, essential work requirements, and health adversity facing themselves and their families (4–6). Over 3 years later, in May 2023, the World Health Organization ended the Coronavirus pandemic (7), but higher education still faces the challenge of reconciling how the pandemic impacted students (8).

When students experience high levels of anxiety, their fight, flee, or freeze instincts kick in, limiting their ability to focus on school (4, 9). Students struggled to maintain motivation during the pandemic lockdown, driving up stress and anxiety (10). Furthermore, students experienced an increase in depression and anxiety symptoms after they left their campus housing and had to adapt to remote learning (11). Students reported their anxiety was higher when asked to complete tasks students perceived as intrusive, such as turning their microphone or camera on or entering a breakout room (4). Interestingly, training that instructors received in the Summer of 2020 to promote online active learning may have contributed to student anxiety in the Fall of 2020, especially for first-generation students, Persons Excluded from STEM due to Ethnicity or

Editor L. Kate Wright, Rochester Institute of Technology, Rochester, New York, USA

Address correspondence to Emma R. Wester, ewester@danforthcenter.org.

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Race (PEER) students (12), and those living in environments not conducive for learning (4).

While some instructors saw increased students engaging in online class discussion forums (13) and reduced withdrawal rates (14), in many other contexts, the decline in student engagement was a conspicuous negative outcome as classes transitioned from in-person to online. This decline in engagement was self-reported by students [e.g., references (6, 10)] as well as reflected in reduced attendance (8, 15), reduced participation during lectures (16), and a steady decline in camera use for synchronous class discussions (8, 17). In an extensive gateway course—a foundational course essential for students pursuing degrees in science and engineering with a high enrollment—taught at a Hispanic-serving institution, declines in student engagement were especially high for PEER and first-year students, with students' distraction and reduced self-regulation credited as factors in these trends (3). The reported declines in student engagement during the pandemic are especially concerning because engagement strengthens critical thinking skills and improves retention rates in STEM (18–20), suggesting there may be long-term impacts on the next generation of those entering STEM professions.

Student engagement is a multifaceted construct composed of behavioral, cognitive, and emotional engagement (21)(Fig. 1). Behavioral engagement describes a student's academic activities, including class attendance and use of office hours. Cognitive engagement describes a student's self-efficacy and sense of belonging within their discipline (22). Emotional engagement describes a student's positive and negative views of their discipline and the students and instructors within the discipline (21). In a quantitative study that surveyed students at the onset of the pandemic and again at the end of the first term, we found that while behavioral and cognitive engagement did not change, emotional engagement significantly declined by the end of the term in May 2020 (6; Fig. 1A). The attitudes students held toward science declined in students as their remote learning continued. Because our quantitative approach revealed significant changes that occurred in student emotional engagement (6), we now present the complementary qualitative analysis to provide insights into why this shift in their emotional engagement occurred using the Fredericks et al. (21) framework. The framework for emotional engagement in the science classroom can be separated into three components: a student's attitude toward science, perceived value in their science course, and stress/anxiety (21, 23). In this study, we examined these three components by asking the following research questions:

1. How did student descriptions of their attitudes toward *science* change over the first COVID-19 pandemic semester?
2. How did student descriptions of their value for their *science course* change over the first COVID-19 pandemic semester?
3. How did student descriptions of their *stress/anxiety* change over the first pandemic semester?

Undergraduate students across 13 academic institutions completed three open-ended questions reflecting on their experiences during the transition to emergency online learning in March 2020 (pre-survey) and again as the first pandemic-interrupted semester concluded in May 2020 (post-survey). Student responses were thematically coded, and the codes belonging to students who answered both the pre- and post-survey were used to investigate our three research questions. These qualitative results revealed student emotional engagement suffered primarily due to modified teaching that was exacerbated by challenging course material.

METHODS

STEM faculty were recruited from Listservs in March 2020 to distribute a Qualtrics survey to their undergraduate students in biology, chemistry, and environmental science courses (Donald Danforth Plant Science Center IRB_2020_02). The survey was composed

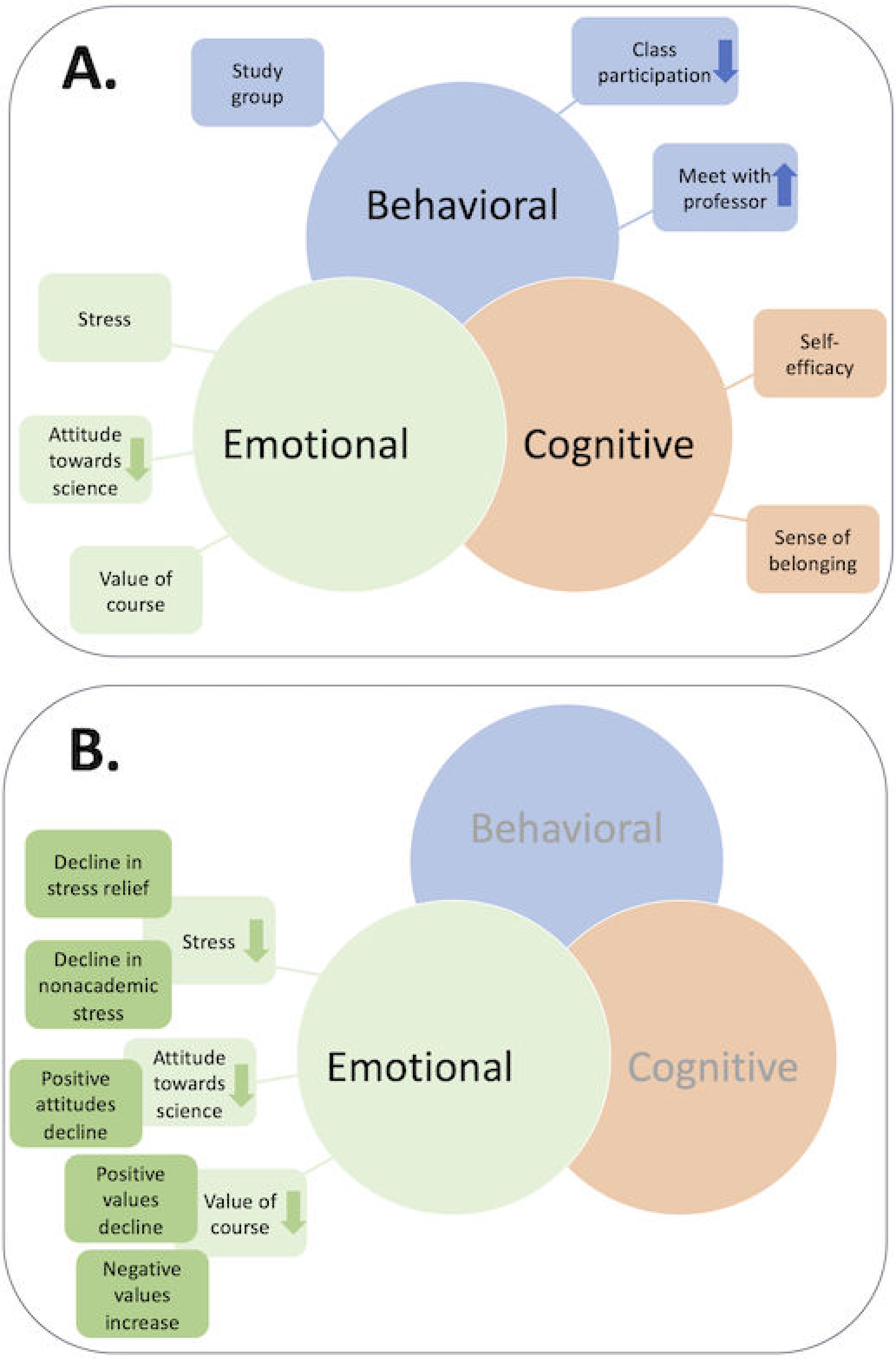

FIG 1 The student engagement framework of Fredericks et al. (21) established that engagement comprises behavioral, emotional, and cognitive components. (A) The framework is visualized with small boxes indicating how each type of engagement was quantitatively measured by Wester et al. (6), using arrows to indicate the direction of significant change in quantitative data. (B) Statistically significant changes in emotional engagement constructs for qualitative data are mapped onto the framework, using arrows to indicate the direction of change. Both quantitative and qualitative data were collected from undergraduate STEM students in March 2020 and May 2020.

of quantitative and qualitative questions to evaluate student engagement at the beginning (Pre) and end (Post) of the COVID-19 interruption to their semester. The pre-survey data were collected at the start of the emergency remote transition (March 2020), and the post-survey data were collected in early May 2020. Details on the survey and distribution methodology can be found in Wester et al. (6), along with results from the quantitative questions.

The distributed survey included three open-ended questions validated for clarity by expert reviewers (Table 1). These questions were written to better understand the student experience at the onset of the pandemic (March 2020) and through the rest of the first COVID-19-interrupted semester of 2020 (ending in May 2020). Two hundred thirty-one students completed the pre-survey, and 141 completed the post-survey. All responses were anonymized, and coders were given samples of student responses and independently asked to review the responses and create a list of emerging themes (24). Student responses were divided into individual statements so that each response may have multiple codes. These emerging themes included statements about their general experiences, attitudes toward science, their social interactions, and the impact of COVID-19 on their stress, among others. Coders then met to compile the individually created themes into a list of preliminary codes. Coders were then given a different set of responses to code independently. Coders met again to consolidate the codes and separate the codes that fell within the student engagement framework, creating a final list of codes (see Tables S1 and S2). With the final codebook, coders could then code all student responses independently. At least two coders analyzed each response. Coders met afterward to discuss any discrepancies in coding. For each code and subcode, if inter-rater reliability above 90% could not be met between the two reviewers, a third reviewer independently coded responses to finalize the decision (24).

Two researchers reviewed the finalized codebook (Tables S1 and S2) to identify themes that mapped to one of the three constructs in the emotional engagement framework (24) (Table S3). Student responses to each of the three questions were then filtered to retain only those students who had answered the question in both the pre- and post-survey, with 83 students for the analysis of Question 1 and 72 students for the analysis of Questions 2 and 3 (collectively a total of 84 different students represented in the paired data set).

We performed McNemar tests in R to evaluate the frequency change for the codes related to student engagement between pre- and post-time points. The McNemar test can show a percentage change between pre- and post-non-parametric data. The McNemar test evaluates a binomial matrix (2×2) for differences, with the null hypothesis of approximate homogeneity across the matrix rows and columns, making it ideal for paired data at two time points (25). For the thematic code being investigated, the four quadrants of a matrix contain the total number of students whose open-ended

TABLE 1 Qualitative survey questions, associated constructs, themes, and example student quotes

Survey question	Emotional engagement construct	Theme	Example
In your own words, describe your experience in this class up to this point.	Attitude toward science	Positive attitude toward science	"I very much enjoyed learning about the science"
		Negative attitude toward science	"I found this material a bore"
	Value of science course	Positive value toward course	"Good job of relating the scientific concepts to real life application"
		Negative value toward course	"Learned on my own outside of class"
In your own words, describe how COVID-19 has impacted your learning and education	Stress	Reduced stress	"Being online I can get the sleep I need and that reduces my stress"
		Increased stress due to academics	"My level of stress has gone up about my classwork"
In your own words, describe how COVID-19 has impacted your level of stress and/or anxiety about this class		Anxiety due to non-academics	"My hometown has have around nine cases recently and I am a little concerned about my parents and grandma"

TABLE 2 Matrix of respondents to Question 1, "In your own words, describe your experience in this class up to this point" for whether their response included a thematic code in the pre-survey, post-survey, or both[a]

Post-survey response	Pre-survey response	
	Yes	No
Positive attitude toward science		
Yes	1	1
No	31	49
Positive value toward course		
Yes	29	1
No	34	19
Negative attitude toward science		
Yes	1	6
No	7	69
Negative value toward course		
Yes	44	27
No	7	5

[a]To assist interpretating the matrix using "positive attitude toward science" as an example, the table includes one student coded for positive attitudes at both time points (Yes, Yes), one student who was coded for positive attitudes only in the post-survey (No, Yes), 31 students who were coded for positive attitudes only in the pre-survey (Yes, No), and 49 students who were not coded for positive attitudes at either time point (No, No).

responses to the question included the thematic code (i) only in their pre-survey response; (ii) only in their post-survey response; (iii) at both time points; and (iv) neither time point (Table 2). For example, if a student's pre-survey response to Question 1 included thematic codes for positive attitude toward science and positive value for their course while their post-survey response included thematic codes for positive attitude toward science and negative value for their course, this student would belong in the "both time points" quadrant for the positive attitude toward science matrix.

RESULTS

Our respondents included 53 women, 29 men, and two who chose not to answer. We had 60 non-PEER students and 24 students who identified as PEER individuals. 55 students received the survey in a biology course (e.g., introductory biology, genetics, and evolution), 26 students received the survey in a chemistry course (e.g., introductory chemistry and biochemistry), and 3 students received the survey in an environmental studies course (e.g., natural resources).

TABLE 3 Subcode results for attitudes toward science when coding 83 student responses to Question 1, "In your own words, describe your experience in this class up to this point"[a]

Subcodes	Pre-survey count	Post-survey count
Positive subcodes		
Interesting	8	2
Useful/meaningful/applicable/essential	11	0
Other positive	5	0
Learning a lot/understanding science content	15	0
Negative subcodes		
Boring (e.g., class is boring—not clear if instruction is boring)	1	0
Useless (topic is useless)	0	2
Other negative	0	0
Difficult or dense	7	6

[a]Negative subcodes are highlighted gray to distinguish them from positive subcodes.

Attitude toward science

Out of 83 students who answered Survey Question 1 (describe your experience in this class up to this point), 32 (38.6%) expressed a positive attitude toward science in the pre-survey, while only 2 (2.4%) did so in the post-survey, demonstrating a significant decline (McNemar's χ^2 = 27.273, P < 0.001; Table 2; see Table S4 for demographic breakdown of attitudes). The most common positive attitudes toward science included understanding science content and seeing the topic as meaningful (Table 3), with one student writing, "for the first time I feel like I am learning something that actually pertains to my career."

The frequency of negative attitudes reported toward science did not change between survey time points (McNemar's χ^2 = 0, P = 1), with eight and seven students coded for negative attitudes in the pre- and post-survey, respectively. Students with negative attitudes toward science primarily took issue with the difficulty or denseness of the science topic (Table 3), with one student writing, "a lot of the material has gone over my head."

TABLE 4 Subcode results for the value of course when coding 83 student responses to Question 1, "In your own words, describe your experience in this class up to this point."[a]

Subcodes			Pre-count	Post-count
Positive subcodes				
Instructor support			14	10
Resources (e.g., tutoring)			0	0
Instruction (positive)			44	20
Sub-subcode	*Pre N*	*Post N*		
Positive Instruction: Active learning (General)	*8*	*4*		
Active learning (Group work)	*3*	*0*		
Active learning (Lab)	*6*	*2*		
Interesting/fun/agreeable class	*24*	*2*		
Other positive instruction	*8*	*6*		
Other: Positive class statement			21	5
Studying/Working hard			11	2
Negative subcodes				
Instructor expectations			37	13
Sub-subcode	*Pre N*	*Post N*		
Negative instructor expectations: Content too much/unclear	*8*	*1*		
Too difficult (hard/challenging) (work/exams are too difficult)	*27*	*7*		
Too much time (assignments take too much time)	*6*	*1*		
Background knowledge (too much required, background knowledge, student has insufficient background knowledge)	*0*	*2*		
Other	*9*	*4*		
Instruction (Negative)			15	50
Sub-subcode	*Pre N*	*Post N*		
Negative instruction: Lecture	*1*	*4*		
Boring	*1*	*0*		
Inadequate/unhelpful	*3*	*12*		
Static (e.g., not interactive)	*1*	*18*		
Other	*2*	*6*		
Grading system	*3*	*0*		
Change of instruction from in-person to online	*4*	*36*		
Other negative class statements			8	22
Grades/exam grades			5	2
Lack of instructor support			1	2

[a]Negative subcodes are highlighted gray to distinguish them from positive subcodes. Sub-subcode results are nested within the table in italics.

Value of course

Out of 83 students who answered Survey Question 1 (describe your experience in this class up to this point), 63 (75.9%) expressed a positive value toward their course in the pre-survey, and 30 (36.1%) did in the post-survey, demonstrating a significant decline in positive attitude responses (McNemar's χ^2 = 29.257, P < 0.001; Table 2). Fifty-one (61.4%) students had negative attitudes toward their course in the pre-survey, and 71 (85.5%) had negative values toward their course in the post-survey, demonstrating a significant increase as the semester ended (McNemar's χ^2 = 11.765, P < 0.001; Table 2). The most common positive value the students saw in the course was instruction, especially noting that learning in the class was fun (Table 4). On their instructor, one student wrote, "She is always the most interesting thing in the room, which makes learning a lot easier." The most common factors that explained a student's negative value toward their science course included their instructor's expectations, especially making the course too challenging, and poor instruction due to changing from an in-person to a remote modality that was less helpful and not interactive enough (Table 4). One student wrote to summarize both factors simultaneously: "Genetics is already a very hard subject and moving the course online has been a major shock."

Stress—general learning and education

Out of 72 students who answered Question 2 (describe how COVID-19 has impacted your learning and educational experience), significantly more students (N = 18, 25%) discussed reduced stress in their pre-survey response than students in the post-survey (N = 7, 9.7%; McNemar's χ^2 = 5.882, P = 0.015; Table 5). The frequency at which students discussed increased academic stress due to COVID-19 remained steady between pre- and post-survey responses (N = 67, 69 respectively; McNemar's χ^2 = 0.125, P = 0.724; Table 5).

Stress–specific class

Out of 72 students who answered Question 3 (describe how COVID-19 has impacted your level of stress and/or anxiety about this class), there was no significant change in the frequency of responses that included either reduced stress (Pre-N = 13, Post-N = 17; McNemar's χ^2 = 0.346, P = 0.556) or increased academic stress (Pre-N = 62, Post-N = 59; McNemar's χ^2 = 0.173, P = 0.677; Table 6).

Nonacademic anxiety

Significantly more students discussed nonacademic stress in the pre-survey than in the post-survey when answering Questions 2 and 3 (Pre-N = 26, Post-N = 11; McNemar's χ^2 = 6.759, P value = 0.009). In the pre-survey, one student who was anxious due to non-academic circumstances wrote:

TABLE 5 Matrix of respondents to Question 2, "In your own words describe how COVID-19 has impacted your learning and educational experience," for whether their response included a thematic code in the pre-survey, post-survey, or both[a]

Post-survey response	Pre-survey response	
	Yes	No
Reduced stress		
Yes	4	3
No	14	51
Increased stress due to academics		
Yes	64	5
No	3	0

[a]To assist interpretating the matrix using "reduced stress" as an example, the table includes 4 students coded for reduced stress at both time points, 3 students who were coded for reduced stress only in the post-survey, 14 students who were coded for reduced stress only in the pre-survey, and 51 students who were not coded for reduced stress at either time point.

TABLE 6 Matrix of respondents to Question 3, "In your own words, describe how COVID-19 has impacted the level of stress and/or anxiety about this class" for whether their response included a thematic code in the pre-survey, post-survey, or both[a]

Post-survey response	Pre-survey response	
	Yes	No
Reduced stress		
Yes	2	15
No	11	44
Increased stress due to academics		
Yes	49	10
No	13	0

[a]To assist interpretating the matrix using "reduced stress" as an example, the table includes 2 students coded for reduced stress at both time points, 15 students who were coded for reduced stress only in the post-survey, 11 students who were coded for reduced stress only in the pre-survey, and 44 students who were not coded for reduced stress at either time point.

> "I hate the stress that comes with it. I have two parents that are doctors that have been working in clinics, ER's, and acute respiratory care. I am constantly worried that they are going to catch the virus, my father has just found out that he has a non-functioning gallbladder too and he needs surgery on it, but of course all elective surgeries have been canceled... and he did not have surgery because he was seeing patients that needed them more. Yesterday a patient came in and past away after two days with the virus, and a nurse tested positive in the ER, my dad works in the ER and it is a small hospital... My twin sister passed away from the last viral epidemic H1N1, you ask me in this, at any moment whether I am absolutely terrified that my parents are going to die whether I really care about my studies at any moment?"

DISCUSSION

How did student descriptions of their attitudes toward science change over the first COVID-19 pandemic semester?

The analysis of student responses revealed a significant shift in attitudes toward science over the first semester impacted by the COVID-19 pandemic. While 38.6% of students expressed a positive attitude in the pre-survey, only 2.4% did so in the post-survey, indicating a notable decline. Positive attitudes were commonly associated with a meaningful understanding of science content, but negative attitudes, primarily related to the perceived difficulty of the subject matter, remained consistent. This significant decline in student attitudes toward science is consistent with the quantitative data from the same survey (6; Fig. 1). The association between student attitudes and grasping course content displayed in our results is consistent with research prior to the pandemic that found student attitudes toward science were positively associated with both student learning and course performance (26).

Even before the COVID-19 pandemic, it was common for students in gateway science courses, including introductory chemistry and biology, to experience declines in their attitudes toward science over the semester (27, 28). However, inquiry-based and student-centered biology courses, including course-based undergraduate research experiences (CUREs), demonstrated significant improvements in their students' attitudes toward science, along with increased confidence, interest, and engagement (29–31). Additionally, students who saw science as relevant and capable of solving real-world problems were more likely to develop a positive attitude toward it and consider science careers (32, 33). Our results, combined with previous research, indicate that student attitudes toward science can be fortified from future emergency disruptions to education by using active learning strategies, highlighting the utility value of course content (34), and prioritizing student learning over the volume of course content.

How did student descriptions of their value toward their science course change over the first COVID-19 pandemic semester?

In the pre-survey, 75.9% of students wrote a positive statement about their science course, which sharply declined to 36.1% of students in the post-survey. Conversely, the number of students who wrote negative statements about their science courses increased from 61.4% to 85.5% over the same period (Table 1, Table 4). Positive statements were often associated with enjoyable instruction, but negative sentiments were linked to challenging expectations and a less effective transition to remote learning. The findings suggest that the shift to online instruction, coupled with the challenges of the pandemic, significantly impacted students' perceptions of the value and quality of their science courses. Quantitative data collected from the same population of students did not find a significant change in the student's valuation of their STEM course (6), demonstrating that when allowed to reflect on their course in an open-ended manner, rather than rating their experience through Likert scale multiple choice, the students focused more on negative aspects of their course at the end of the semester compared to March 2020.

Negative values in the course were primarily due to the switch to online learning, the instructor's expectations, and the lack of engaging instruction. No student said they learned much or felt the material was helpful in post-survey. To address the issues students raised in their open-ended responses, instructors must be trained to bring value and relevancy to their online courses (5). The number of students citing positive instruction as a value of their course dropped by more than 50% in the post-survey, further supporting the need for instructors to learn how to teach online. Students highly value effective communication, accessible support, adjusting expectations, and leveraging technology appropriately for online engagement (5). Some creative instructors found specific ways to promote student engagement during the COVID-19 impacted terms: adding COVID-19 content within courses where relevant (35), bringing laboratory and field activities to undergraduate students' homes (36–38), and using trauma-informed pedagogy (39).

How did student descriptions of their stress/anxiety change over the first pandemic semester?

In the quantitative data (6) and the course-specific qualitative stress/anxiety question, the reported stress did not change for the sampled student population. However, student descriptions of stress changed over the first pandemic semester in the context of general learning and nonacademic life. The pre-survey was collected during the first weeks of online learning. Based on responses, for many students, this coincided with a return to their childhood homes. With students discussing not having to pay rent or pay for campus parking, not having to travel to class, and having their pets "attend" class with them, these new amenities may explain why more students discussed reduced academic stress in the pre-survey than in the post-survey. With over 93% of students discussing academic stress, it may seem counterintuitive that several students also discussed reduced stress in the same response. Still, it demonstrates the silver lining that some students saw during the early stages of the pandemic. For example, one student wrote:

> "COVID-19 has forced every one of my classes to go online so now I am unable to interact with people in person to study. On the one hand, it does feel good to be on my own and be able to be in a relaxing environment (my own room) but at the same time, it is also stressful to have tests be taken in radically different ways than normal."

Fewer students reported factors that alleviated academic stress, such as "enjoying the comforts of studying from home in North Dakota." However, as the semester progressed, the allure of these comforts may have lessened, leading to fewer mentions of such stress-relieving factors. This is further supported by the reduced number of students who discussed nonacademic anxiety in the post-survey compared to the pre-survey. These results indicate the pandemic's complex and multifaceted impact on students' stress experiences, suggesting the need for targeted support and interventions to address their evolving challenges during this unprecedented semester [e.g., references (40, 41)].

The open-ended responses we collected reveal the myriad of experiences that students faced in the early months of the pandemic and highlight the challenges that socioeconomic status and familial status disproportionately placed on some students:

> "I've noticed it has distracted me and hasn't allowed me to continue with my studying for my course. I also got sick and didn't allow me to do anything. Besides that I basically lost my full time job. All this really triggers my anxiety a lot."

> "I have a hard time sleeping wondering if at a point my grocery job along with my sisters is going to have to pay our house bill if our father isn't allowed to work anymore. We just hope it does not get that far and long and people figure it out."

Student responses reveal science fatigue

An unprecedented global focus on scientific research and public health information characterized the first few months of the COVID-19 pandemic. The constant bombardment of COVID-19 information, not all of which was accurate or consistent, led to feelings of information overload, anxiety, and stress for the public (42–44). Interestingly, both our qualitative results presented here and the previously published quantitative results (6) revealed that STEM undergraduate students also demonstrated a decline in overall enthusiasm and positivity toward science among the student cohort sampled.

Here, we refer to this phenomenon exhibited by the STEM students as "science fatigue," in which the overwhelming and continuous influx of scientific information leads to decreased engagement and interest in scientific content. This response is tied to broader psychological and cognitive reactions to prolonged crises, manifesting as apathy, skepticism, or outright rejection of new information (45). While these reactions have been observed as they relate to behaviors directly tied to public health crises (e.g., pandemic fatigue or infodemic) (46), we believe we are one of the first to capture this as it relates to educational attitude. The overwhelming influx of scientific information about COVID-19, combined with the constant changes in public health guidelines, may have contributed to science fatigue. This phenomenon, where students become desensitized or disinterested in science due to the overwhelming volume and complexity of information, was reflected in our qualitative data.

Our data showed increased anxiety and decreased engagement in science courses during the pandemic. One student epitomized science fatigue when they wrote, "The nonstop updates about COVID-19, combined with trying to keep up with my science classes, made it hard to stay focused and interested." The shift to online learning alone posed significant challenges. Even students not overwhelmed by COVID-19 news reported decreased engagement due to less interactive and supportive instruction. Thus, both the pandemic's informational overload and the abrupt transition to remote learning contributed to the decline in student engagement.

The mechanisms driving science fatigue include cognitive overload, where the brain is inundated with complex information faster than it can process, and emotional exhaustion from constant vigilance regarding health risks and shifting guidelines. These factors make it challenging for individuals to maintain a proactive interest in ongoing scientific discussions. As discussed by Sweller (47), cognitive load theory suggests that excessive information can inhibit learning and understanding, leading to disengagement. While researchers recommend combatting pandemic fatigue in the public [e.g., references (48)], STEM faculty and higher education administrators must identify educational and communication strategies to sustain engagement and interest in science during prolonged crises.

Limitations

Students most overwhelmed by an emergency disruption to learning are less likely to participate in voluntary pedagogical research (49), and fewer students completed the post-survey. In general, only students who could access and complete the Qualtrics surveys are included in our study, and only students with something to say would have finished each open-ended question for qualitative analysis. While our survey participant attrition is a limitation, given the lack of research on education during emergencies, the data are still important to collect to help prepare for future educational disruptions as they will help instructors make trauma-informed education decisions through the lens of science.

Conclusion

The shift to remote and online learning due to the COVID-19 pandemic brought significant changes to the learning environment and dynamics between students and instructors, reshaping the emotional engagement of undergraduates. Student engagement declined during the COVID-19 pandemic (6, 10, 15–17). The phenomenon of science fatigue became evident, reflecting a broader desensitization to constant scientific updates and pandemic-related information. This fatigue likely contributed to declining students' emotional engagement with their coursework, particularly in science-related subjects. The inundation of often conflicting information about the pandemic made it increasingly difficult for students to maintain a proactive interest in scientific discussions, essential for their academic development in STEM fields.

Future research should focus on the long-term effects of science fatigue on academic success and career trajectories in STEM fields and the effectiveness of educational interventions designed to reduce science fatigue and improve engagement. These studies will provide valuable insights into how educational strategies can be adapted to enhance resilience and adaptability in the face of future challenges. Science fatigue directly impacts students' learning processes, particularly in STEM fields, where understanding complex scientific data is crucial (50). To combat science fatigue, education researchers should evaluate strategies such as simplifying communication, engaging multimedia resources, and incorporating active learning techniques. These techniques make learning more interactive and less passive, potentially maintaining student interest and engagement during crises (51). Furthermore, integrating mental health resources into the academic curriculum can address the psychological impacts of science fatigue, supporting students' overall well-being (52). Additionally, educators should consider integrating lessons from the pandemic to foster resilience and adaptability in their teaching strategies (5), potentially mitigating the impacts of science fatigue by presenting information in more digestible and engaging ways. As we prepare for future disruptions—whether pandemics or other crises—it is vital that our educational institutions are equipped to support students effectively, ensuring that learning continues uninterrupted and that students remain engaged and motivated despite challenging circumstances. It is possible that by presenting information in more digestible and engaging ways, educators can mitigate the impacts of science fatigue.

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AUTHOR AFFILIATIONS

[1]Donald Danforth Plant Science Center, St. Louis, Missouri, USA

[2]Saint Louis University, St. Louis, Missouri, USA

AUTHOR ORCIDs

Emma R. Wester http://orcid.org/0000-0001-9964-0961
Lisa L. Walsh http://orcid.org/0000-0003-0311-5455

AUTHOR CONTRIBUTIONS

Emma R. Wester, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review and editing | Lisa L. Walsh, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review and editing | Sandra Arango-Caro, Methodology, Writing – review and editing | Elena Bray Speth, Writing – original draft, Writing – review and editing | Kristine Callis-Duehl, Project administration, Software, Supervision, Writing – review and editing

ADDITIONAL FILES

The following material is available online.

Supplemental Material

Supplemental Material (jmbe00093-24-s0001.docx). Tables S1 through S4.

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