Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Empirical Research Paper

Flipping the digital switch: Affective responses of STEM undergraduates to emergency remote teaching during the COVID-19 pandemic

Angela Minichiello *, Oenardi Lawanto, Wade Goodridge, Assad Iqbal, Muhammad Asghar

Utah State University, College of Engineering, Department of Engineering Education, 4160 Old Main Hil, Logan, UT, 84322, USA

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ABSTRACT

The Corona Virus Disease-2019 (COVID-19) catalyzed a global shift to distance education known as an *emergency transition to remote teaching* (ERT). While prior research investigates students' experiences during traditional online learning, fewer studies examine students' affective responses (i.e., feelings, emotions) to those experiences, particularly when remote learning is unexpected and unplanned. To understand how science, technology, engineering, and mathematics (STEM) undergraduates responded affectively to the COVID-19 ERT, researchers generated open-ended survey data with 1340 undergraduates (253 female) in 27 courses across seven U.S. institutions. Using an inductive qualitative approach, researchers developed a three-tier thematic model to synthesize the self-reported reasons underlying participants' affective responses to the COVID-19 ERT. Findings reveal a complex mix of positive and negative emotional responses among participants that included frequent occurrences of feelings of stress and uncertainty traced to a variety of external, internal, and contextual factors. Implications for STEM teaching practice are discussed.

1. Introduction

Although the emergency transition to remote teaching (ERT) event—the unplanned and rapid shift to remote education—that occurred in the wake of the 2020 novel coronavirus pandemic was not a wholly new phenomenon (Czerniewicz et al., 2019; DiCarlo et al., 2007; Gardner et al., 2007; Wright and Wordsworth, 2013), the scale and speed of this particular transition to remote instruction remains historically unprecedented (Winch et al., 2021). The near immediate global transition was, as is often said in times of abrupt change, as if 'someone had flipped a switch.' In an instant, students everywhere were forced to respond to rapidly evolving mandates for online education and school and university closures. These mandates required vast numbers of college-age students to physically relocate from residential campuses and, simultaneously, rearrange existing work and familial responsibilities or search for alternative employment opportunities at new destinations.

Although often conflated with online learning, an ERT event differs from traditional online instruction in several important ways. One prominent difference is the level of advance preparation each affords: while ERT is unexpected and unplanned, traditional online learning is deliberate and "well-planned" (Hodges et al., 2020). Understanding that effective online instruction is developed systematically over time, researchers (Means et al., 2014) have identified nine instructional dimensions (i.e., learning modality, instructional pacing, student-instructor ratio, pedagogy, instructor role, student role, communication synchrony, assessment, and feedback) essential to the design of effective online learning experiences. Each dimension contains multiple options; individually, options may be less effective than others, incompatible with others, or fixed or unavailable within a given university or disciplinary context. Judicious prior planning and coordination, therefore, are essential and distinctive hallmarks of traditional online learning that clearly distinguish it from unexpected and rapidly evolving ERT events.

Differences in how instructors prepare to teach remotely point to a second major difference between ERT and traditional online learning: the intention for the permanence of the online instructional design. Hodges et al. (2020) defined ERT as "… a temporary shift of instructional delivery to an alternate [remote] delivery mode due to crisis

Abbreviations: CGPA, cumulative grade point average; CoI, Community of Inquiry; COVID-19, Corona Virus Disease -2019; ERT, emergency remote teaching; R1, doctoral granting institutions with very high research activity; R2, doctoral granting institutions with high research activity; STEM, science, technology, engineering, and mathematics; TD, transactional distance.

* Corresponding author.
E-mail address: angie.minichiello@usu.edu (A. Minichiello).

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circumstances." During an ERT event, educators adopt and adapt remote teaching technologies and strategies to deliver courses or activities that a) would be taught using a different modality (i.e., face-to-face, blended, hybrid) if the crisis event did not occur and b) are expected to return to their original modalities after the crisis event passes (Hodges et al., 2020). Without the intention of supporting remote instructional design in the long term, ERT educators make use of existing support systems and available remote technologies, whether they have used either before or not. ERT educators may feel forced to adopt completely new or different instructional strategies (e.g., P/F assessment, open book exams, group assignments) that they had not previously considered in non-ERT settings. Thus, ERT stands in stark contrast to more traditional models of online education in which courses and activities are carefully designed and consistently assessed and improved with instructional permanence in mind.

2. Background

Substantial prior research has investigated students' experiences during online learning; a substantial portion of this literature has focused on student satisfaction and retention within traditional online learning environments. Currently, however, there is evidence (see e.g., Pokhrel and Chhetri, 2021) of a small but growing body of empirical, practice-focused research that seeks to understand student and instructor experiences during the COVID-19 ERT. For example, researchers (Doucet et al., 2020) in U.S. K-12 contexts examined how instructors adjusted and adapted their teaching approaches during the COVID-19 ERT and meshed learning activities with the disciplinary (i.e., subject) and student (i.e., age) contexts of their classes for the purpose of providing recommendations for practice. The authors suggest following an early ERT strategy of 'Maslow before Bloom', which calls for safeguarding the physical, mental, and emotional well-being of students before making formal distance education a priority (Doucet et al., 2020, p. 8). Across the globe, Sintema (2020) reported on COVID-19 ERT developments in Zambia where educators were expecting a marked drop in Grade 12 students' academic performance on STEM national exams due to reduced opportunities for students to interact with their peers and instructors during mandatory school closures. The author reported that the educators had grave concerns that reduced student performance would stall the ongoing rollout of a national STEM curriculum in that country.

In U.S. undergraduate education, Means et al. (2020) [1] reported results of a national, random-sample survey of 1008 U.S. college students. The authors found that the percentage of participants expressing dissatisfaction (i.e., selecting somewhat dissatisfied or very dissatisfied) with their learning increased from 12% to 40% after the switch to ERT. The most frequently cited challenge, which was reported by 42% of participants as a "major problem," was staying motivated to do well in their courses (Means et al., 2020, p. 12). Other challenges, such as finding a quiet place to do online coursework (20%), fitting online coursework in with home/family responsibilities (17%), not knowing where to get help in the online course (16%), feeling too unwell (physically or emotionally) to participate in the online course (14%), and fitting online coursework in with paid work schedules (8%), were reported major problems by substantially fewer numbers of participants (Means et al., 2020, p. 12). In all cases except one,[2] higher percentages of Black and Hispanic participants (higher than those of White participants) reported these challenges were major problems (instead of minor problems or non-problems) for them. This finding suggests that challenges associated with the switch to remote learning were not "uniformly distributed" (Means et al., 2020, pp. 12–13) or, rather, were not experienced uniformly by all participants. Evidence of preferential experience of challenges to remote learning hints at socio-economic and institutional inequities, such as "digital inequality" (Czerniewicz et al., 2019, p. 18), that is an area that should be directly addressed in future work.

Along with developing better understandings of the challenges that students faced during the COVID-19 ERT, a common theme underpinning the growing pandemic ERT literature is students' need for faculty expressions of care and compassion. Johnson et al. (2020, p. 16) examined survey data generated at 627 U.S. institutions during the early weeks of the pandemic and showed how faculty and administrators made deliberate and "progressive" changes (such as "lowering expectations," "ungrading," and "eliminating unnecessary work") to their teaching practices and policies in efforts to reduce students' (and sometimes their own) levels of anxiety and stress. The authors urged readers not to judge or criticize these emergency teaching practices, but rather to view them as necessities implemented to "support, care for, and enable students to succeed" (Johnson et al., 2020, p. 16).

In undergraduate STEM education, researchers emphasized the need for care and compassion over rigor (Engineering Education Transformations Institute [EETI], 2020a). Specifically, authors described how STEM instructors acted compassionately toward students by implementing flexibility in their teaching (Engineering Education Transformations Institute [EETI], 2020b; Gelles et al., 2020). Together, these researchers highlighted use of flexible STEM teaching practices and policies that included asking students for feedback about course workload and schedule and altering assessments (e.g., assessing student learning using projects that enable autonomy over fixed exams) (Engineering Education Transformations Institute [EETI], 2020b) and providing leniency, removing time pressure from assessments, making accommodations (e.g. P/F grading), and increasing the remote accessibility of course materials (Gelles et al., 2020).

3. Study purpose

Despite thirty years of research in traditional online learning and an expanding base of literature related to the COVID-19 ERT, there are limited empirical studies that focus on students' *affective responses* to remote learning experiences, particularly when remote learning is unexpected and unplanned. To add to the growing literature related to ERT experiences, this paper reports on qualitative analysis of open response survey data generated with 1340 (253 or 20.1% female; 5 or 0.4% nondisclosed gender; race/ethnicity data not collected) undergraduates enrolled in 27 U.S. STEM-related courses during the spring 2020 semester (when the switch to ERT occurred). Seeking to provide deeper understandings of students' emotional responses to ERT and their personalized reasons for their affective responses, this study was guided by two research questions:

In relation to their self-perceived abilities to succeed in the ERT learning environment,

1. What *affective responses* (i.e., emotions or feelings) did undergraduates report experiencing during the rapid transition to remote learning of the COVID-19 pandemic?
2. How did undergraduates *describe reasons for their affective responses* (i.e., emotions or feelings) during the rapid transition to remote learning of the COVID-19 pandemic?

By providing insights into the affective responses of STEM undergraduates and students' personalized reasons for these affective responses during the COVID-19 ERT, findings from this study will enable STEM educators, administrators, and staff to better prepare and equip students to adapt to, persevere during, and succeed amid future ERT events.

[1] Participants were randomly selected from those U.S. students whose college coursework switched from in person to online during the spring 2020 semester.

[2] Black participants (31%) reported that staying motivated to do well in the online course during the COVID-19 ERT was a major problem for them at a lower rate than White participants (42%) did.

4. Theoretical background

Research in students' affective responses during traditional online learning dates back to the 1990s. Boyd et al. (1998) reported that students experienced feelings of isolation in online learning environments due to the absence of face-to-face contact with other students and teachers. Considering education as a transaction between teachers and learners, Moore (1991, 1993) and Moore and Kearsley (2012) [both cited by Wheeler (2002)] theorized student feelings of isolation to be influenced by the *transactional distance* that is inherent to distance education environments. While transactional distance (TD) is conceptualized as a "psychological and communication space, not a physical space, to be crossed, a space of potential misunderstanding between the inputs of the instructor and those of the learner" (Moore and Kearsley, 2012), some researchers (Lennox et al., 2006; Willens, 2004) have posited that TD may also be influenced by large physical separations and, thus, may be greater for students who are geographically isolated from other actors in an online environment (e.g., rural or geographically displaced students).

As an explanatory framework for how distance education works, TD manifests within online learning environments via dialogue (i.e., two-way communication) and structure. Dialogue represents communication between educators and students; structure represents how an online environment is designed to be flexible and supportive of the unique needs of remote learners (Lennox et al., 2006). Close transactional distance (i.e., transactional presence) can be attained through accessible and always on two-way communication channels between instructors and students and has been found to be a significant predictor of student satisfaction and intentions to persist within online learning environments (Shin, 2002, 2003). Increased transactional distance, as manifested through delayed and unclear responses from teachers, can cause students anguish (Hara and Kling, 2002) and, if responses are consistently delayed and unclear, frustration (Abrahamson, 1998). Alternatively, closer TD is achieved by reducing structures that are limiting to students (i.e., practices and policies) to make courses less restrictive, more interactive, and more readily adaptable to the needs of remote learners (Horzum, 2015). In this way, increasing dialogue and/or decreasing restrictive course structures favorably influence (i.e., reduce) TD.

The current study is the conceptually framed using three key facets of TD that manifest through dialogue and/or structure and have been linked to students' affective responses (i.e., emotions and feelings) during traditional online learning: social presence, interactions with technology, and the design of learning activities and supports. In the following sections, these three facets and their empirical connections to student affective responses in distance education are described.

4.1. Social presence

Social presence is one of three key dimensions of the social constructivist Community of Inquiry (CoI) Model of learning in online and blended environments (Garrison, 2017). Social presence, along with *cognitive presence* and *teaching presence*, has been identified as a strong predictor of student satisfaction within online learning experiences (Harasim, 2012). Social presence is defined as students' ability to share their individual personalities and present themselves as 'real people,' socially and emotionally, into a remote community of learners (Garrison et al., 2000, p. 89). Social presence is considered vital for increasing active student engagement because it helps students develop a sense of belonging and fosters teamwork and student interactions as a community of learners (Miller et al., 2020). Consequently, it is theorized that an absence or lack of social presence may contribute to students' feelings of isolation, disconnectedness, or loneliness and their eventual attrition from online learning environments (Boston et al. Spring 2011; Brindley et al., 2009).

Along with examining students' social presence among their peers, research has aimed at developing approaches for establishing and deepening interpersonal and emotional connections between all communicators within online learning environments. Researchers have found that all rewarding interactions, whether with peers or instructors, are apt to positively affect online students' satisfaction, learning outcomes, and social presence (Brinthaupt et al., 2011; Swan, 2001). Others (Croxton, 2014; Dumas et al., 2013; Horzum, 2015) focused on the regulatory effects that external (e.g., time constrains, inflexible deadlines), internal (e.g., self-efficacy, task-value of the course), and contextual (e.g., feelings of social isolation, family-related issues) factors have on interactions between teachers and students and/or students and peers and how these factors dynamically play out within online environments.

4.2. Interactions with technology

Despite the rapid growth of information technology (IT), most notably the Internet, and society's increasing exposure to and confidence using technology, teachers and students continue to identify a lack of personal fluency using unfamiliar or infrequently used technology as a concern during online learning (Fu, 2013). A lack of prior experience with technology, as well as the unexpected problems that arise when implementing known technology in new environments, hinders teachers' and students' abilities to navigate remote learning environments and can ultimately lead to frustrating and dissatisfying remote learning experiences.

For example, researchers have found that students with prior computer, software, and internet experience have higher positive perceptions of their online learning experiences than those with less computer experience (Wagner et al., 2002). Feelings of frustration are often reported by students who experience technical problems with equipment, slow Internet connections, a lack of access to computers or compatible software, and/or a lack of computer skills (Schrum and Hong, 2002) Conversely, technology may also positively influence students' perception of the online classes (C. Clark et al., 2015). For example, video posts and synchronous video conferencing may make students feel more connected. As technology continues to advance, facilitated communication and interaction through technology should be put to greater use to reduce student feelings of isolation. Fundamental changes in the ways society works and communicates may further work to change students' ways of thinking and knowledge-building and help dissipate feelings of loneliness and isolation in remote learning environments.

4.3. Design of learning activities and supports

For students, self-discipline and intrinsic motivation are known to promote successful and meaningful online learning. For instructors, thoughtful learning plans and use of appropriate e-pedagogies are vital considerations for facilitating successful knowledge-building among students working remotely. Just as important as the choice of online pedagogy for instructors, however, is the level of quality and consistency of the remote learning materials they develop and provide to students within online learning environments. Researchers (Boyd et al., 1998; Swan, 2001) found that students consider high quality instructional materials essential to their success in online learning environments; students were more satisfied and more positive about their remote learning experiences if remote learning materials used consistent processes, presentation features, and procedures throughout the course.

5. Methodology

In this emergent, empirical study of undergraduate learners in STEM courses, we employed a cross-sectional, mixed-method survey research approach. Our goal was to identify in real-time, examine, and describe STEM undergraduates' affective responses, and associated rationales, to the unanticipated transition to remote learning that occurred during the

spring 2020 semester.

5.1. Study design

Shortly after the COVID-19 ERT event began in mid-March 2020, an online survey was developed, face-validated, and further refined to meet the purpose of the study and to improve the readability of the survey items. The resultant survey comprised 13 questions (i.e., 10 multiple-choice/multiple-answer and 3 open-ended text entry) as shown in Table 1. In addition to the (1) four demographic questions and (2) one selection question that asked participants to identify the features of their online course, survey items assessed participants' (3) perceptions about which online course features had a positive, negative, or no effect on their learning (3 questions); (4) feelings about their capabilities to succeed in the online course (2 questions); (5) perceptions about how their feelings changed during the online course (1 question); and (6) strategies used to adapt to the new online course environments (2 questions). Survey items are summarized in Table 1.

As part of a larger study, this paper reports on the findings of an inductive, qualitative analysis of participant responses to two survey questions that assessed participants feelings related to their capabilities to succeed in their courses remotely after the COVID-19 ERT event (Table 1, area of assessment #4).

5.2. Theoretical perspective

In this qualitative study, the researchers developed and assigned codes to interpret participants' open-ended textual responses to survey questions that asked about their emotional responses to the COVID-10 ERT event (Table 1, area of assessment #4). In doing so, the researchers adopted a social-constructivist (i.e., interpretivist) theoretical perspective (Glesne, 2016; Koro-Ljungberg and Douglas, 2008; Lincoln et al., 2011). Using this perspective, the researchers assumed that human reality is a social construction and that people "… experience the world around them in different ways" (Jawitz and Case, 2009, p. 152). The constructivist paradigm aligns with the study's purpose to examine how undergraduates recognized and described their unique affective responses (emotions) during the ERT.

Table 1
Online survey design.

Area of Assessment	Survey Items
1. Demographics	1) Select current academic status (accrued credits) 2) Select cumulative grade point average (CGPA) 3) Select gender (male, female, prefer not to disclose) 4) Select previous online learning experience (yes or no)
2. Online Course Features	1) Select and/or input features available in online course (e.g., video lectures, synchronous lectures, projects, electronically submitted assignments, virtual labs, virtual office hours, virtual tutoring, virtual group discussions, online practice quizzes, online exams, downloadable documents, etc.)
3. Contribution of Online Course Features to Learning	1) Select online course features that contributed positively to online learning experience 2) Select online course features that contributed negatively to online learning experience 3) Select online course features that had no effect on online learning experience
4. Feelings related to Success in Online Course	1) Select and/or input the feelings you experienced in relation to your capabilities to succeed in the online course (i.e., motivated, uncertain, safe, scared, confident, isolated/alone, anxious, depressed, comfortable, stressed, independent, empowered, supported, other) 2) Input the reasons why you had the feeling(s) selected or provided above
5. Change in Feelings during Online Course	1) Select how your feelings changed during the online course (i.e., grew more positive, grew more negative, did not change)
6. Effective Learning strategies used during Online Course	1) Input what you did to adapt to the new online course 2) Input effective learning strategies you used in the new online course

5.3. Research team positionality

The five members of the research team are all current or aspiring engineering educators and engineering education researchers. Three are tenured or tenure track faculty in a Department of Engineering Education, housed in a College of Engineering, at a public, land-grant institution; two of these faculty have education-related doctoral degrees. Likewise, the two graduate student members are currently pursuing doctoral degrees in engineering education. Each member of the research team earned at least one degree in an engineering discipline (i.e., civil, computer, electrical, or mechanical). All are deeply familiar with and currently embedded in the context of undergraduate engineering education. Moreover, all research team members have participated in traditional online learning, either as students and/or instructors, and have conducted prior research in traditional online education. The research team conceived of and conducted this study for the purposes of improving remote teaching practice in STEM and making learning during ERT events more effective and meaningful for STEM undergraduates.

5.4. Setting and participants

Using procedures approved by the research teams' university-sponsored Institutional Review Board and the web-based survey tool Qualtrics, an online survey was administered to 1340 students enrolled in 27 unique courses at seven institutions of higher education near the end of the spring 2020 semester. Due to the rapid development and evolving nature of the pandemic and consequently the study, convenience sampling (Creswell, 2014) was used to identify STEM courses, via prior relationships with course instructors across a wide variety of institutions, that would provide a platform for participant recruitment. The research team identified 27 courses across U.S. seven institutions for participant recruitment. These seven institutions included six public institutions, five of which were land-grant institutions, and one private institution; six institutions that are predominantly and historically White and one Historically Black College/University; three doctoral granting R1 institutions, three doctoral granting R2 institutions, and one non-doctoral granting institution; and three institutions located in the eastern United States and four institutions located in the western United States.

Participants were recruited from the following undergraduate courses: engineering (19 courses), mathematics and statistics (3 courses), technical communication for engineers (2 courses), and social sciences (3 courses). All 27 courses were designed and initially taught using a face-to-face approach and then rapidly transitioned—most within a one-week period—to remote learning formats near the mid-point of the spring 2020 semester. Following the transition, all courses were taught remotely using unique varieties of online learning features, such as asynchronous video-lectures, live synchronous remote lectures, virtual labs, and online office hours. All students in each course were invited by their instructors to complete the online survey before the course final exam. Decisions to provide incentives in the form of course extra credit varied among the course instructors and were not regulated by the researchers.

5.5. Data and data analysis

A total of 1340 students responded to the online survey. Prior to conducting data analyses, the entire set of survey responses were evaluated for completeness; incomplete and/or irregular responses were removed. After discarding all incomplete and/or irregular responses, 1237 responses remained and were considered during subsequent analyses. The data used in this work (i.e., responses to survey items shown in Table 2, #4), consisted of 1237 text-based inputs that addressed the context and the personal, social and/or institutional reasons for the emotional responses reported.

Demographic data for the 1237 participants are presented in Table 2. Data show that women were represented in the sample at approximately the same level (20%) as women are represented in U.S. engineering programs (20%) (American Society for Engineering Education, 2020). We compare our data to women in engineering since most of the participants were taking engineering courses and, therefore, we assume that they were pursuing engineering degrees. The sample was skewed toward more advanced (i.e., 71% were juniors or seniors) and higher performing students (89% reported having a CGPA above 3.00). Sixty percent of participants reported having online learning experience.

To prepare for qualitative data analysis, the research team consulted the Merriam-Webster online dictionary (merriam-webster.com) as a guide to develop a set of common definitions for the 13 feelings that were provided as responses in the survey. Definitions and their wordings were discussed, revised, and agreed upon by the research team and then face-validated by another faculty member, who was not part of the research team, with expertise in professional communications and technical writing. Researchers also assigned a valence (i.e., positive, or negative) to each emotion as it related to participants' perceptions of their abilities to succeed in the online course. For example, feeling *confident* was considered an indicator of participants' *positive* perceptions of their abilities to succeed in the online course, while feeling *anxious* was considered an indicator of participants' *negative* perceptions of their abilities to succeed in the online course. The list of common definitions is provided in Table 3.

To begin data analysis, we calculated the frequency counts of each emotion (i.e., Table 1, area of assessment #4, survey item #1) and categorized them as either positive (i.e., comfortable, confident, empowered, independent, motivated, safe, supported) or negative (i.e., anxious, alone/isolated, depressed, scared, stressed, uncertain) based on valence assignments shown in Table 3. Next, we conducted a qualitative thematic analysis of the text-based responses that participants provided as reasons for their affective (i.e., emotional) responses. The goals of the thematic analysis were to (1) understand the overarching rationales that participants gave for experiencing each emotion and (2) look across emotions to understand which emotions occurred concurrently or due to similar events or situations.

Table 2
Participant demographic information.

Demographic Category	Number (% of Sample)
Gender	
Female	248 (20.1%)
Male	984 (79.5%)
Prefer not to disclose	5 (0.4%)
Current Academic Status	
Freshman	72 (6.0%)
Sophomore	283 (23%)
Junior	329 (27%)
Senior	553 (45%)
CGPA	
3.50 and above	629 (51%)
3.00–3.49	476 (38%)
2.50–2.99	110 (9.2%)
2.00–2.49	15 (1.2%)
Below 2.00	7 (0.6%)
Prior Online Learning Experience	
Yes	744 (60%)
No	493 (40%)

Table 3
Common definitions and valences of affective responses (i.e., emotions or feelings).

Emotion or Feeling	Valence[1]	Definition
Comfortable	Positive	Free from stress or tension: affording or enjoying physical relief or encouragement[2]
Confident	Positive	Full of conviction; certain; having or showing assurance and self-reliance
Empowered	Positive	Having the knowledge, confidence, means, or ability to do things or make decisions for oneself
Independent	Positive	Not subject to control by others; not requiring or relying on something else
Motivated	Positive	Having an incentive or a strong desire to do well or succeed in some pursuit
Safe	Positive	Secure from threat of danger, harm, or loss
Supported	Positive	The condition of being assisted or helped[3]
Alone or Isolated	Negative	Separated from others; exclusive of anyone or anything else
Anxious	Negative	Characterized by extreme uneasiness of mind or brooding fear about some contingency; uneasiness about an event (such as an emergency) that may but is not certain to occur
Depressed	Negative	Low in spirits; sad
Scared	Negative	Thrown into or being in a state of fear, fright, or panic
Stressed	Negative	Suffering from high levels of psychological tension[4] or feelings of nervousness that makes one unable to relax[5]

[1] Positive or negative emotion with respect to participants' perceptions of their abilities to succeed in an online learning environment.
[2] Merriam-Webster.com substituting "relief or encouragement" for "comfort".
[3] Merriam Webster.com substituting assisted or helped for "supported".
[4] Merriam-Webster.com substituting "tension" for "stress".
[5] Merriam-Webster.com substituting "feelings of nervousness that makes [one] unable to relax" for "tension".

To prepare the textual data for the thematic analysis, we iteratively analyzed 1273 responses. Because participants were able to select/input multiple emotions in the survey but were provided only one textbox to input (all of) their reasonings, textual responses often contained information related to several emotions. Therefore, we segmented the textual responses into excerpts (i.e., individual reasons) and then each excerpt was individually and interpretatively linked, or coded, to one or more of the 13 emotions, using Table 3 as a codebook. To retain analytic continuity while accounting for the inherent variation in researchers' interpretations, each excerpt was coded to emotions independently by three of the five members of the research team. Once each excerpt was independently coded by three researchers, the three researchers met virtually via ZOOM to discuss coding choices and resolve differences. Only those excerpts coded with 100% rater agreement (after researchers met to resolve any interpretative differences) were carried forward into the qualitative thematic analysis.

Of the 1273 textual responses, we coded 1192 excerpts (Table 4) to the 13 emotions and carried forward to the thematic analysis. To complete the thematic analysis collaboratively, each of the five-member research team was assigned one to three of the 13 emotions. We made the assignments based on the number of excerpts coded to each emotion. Care was taken to distribute data excerpts equally (as possible) across the research team to mitigate bias by ensuring that any single researcher did not have inordinate interpretive influence on the findings (Table 4).

Excerpt assignment resulted in the following distribution of data for thematic analysis among the research team: Author 1–368 excerpts; Author 2–207 excerpts; Author 3–277 excerpts; Author 4–145 excerpts; Author 5–196 excerpts.

Once the excerpts were assigned, the research team conducted a joint qualitative thematic analysis (Saldaña, 2021). According to (V. Clark

Table 4
Research team member coding assignments for thematic analysis.

Emotion or Feeling	Number of Coded Excerpts	Assigned Researcher
Comfortable	140	Author 3
Confident	86	Author 2
Empowered	38	Author 3
Independent	58	Author 4
Motivated	38	Author 3
Safe	13	Author 5
Supported	86	Author 4
Alone or Isolated	110	Author 3
Anxious	61	Author 3
Depressed	11	Author 2
Scared	14	Author 5
Stressed	368	Author 1
Uncertain	169	Author 5
Total	**1192**	

et al., 2015), qualitative thematic analysis is appropriate for research questions related to people's lived experiences and the factors and social processes that underpin these experiences. Each researcher began thematic analysis by grouping like excerpts (reasons) within each emotion together into categories and then labeling or "thematizing" each category with a short descriptive phrase (Brinkmann and Kvale, 2015). During this initial grouping phase, the research team met to discuss how data should be interpreted considering the codebook (Table 3) and research questions. When first pass groupings within all emotions were complete, the researchers met several times in small groups (two or three researchers) to "present" their groupings within individual emotions to the other researcher(s). Conversations related to data interpretation, groupings, and labeling of the categories that occurred within the small groups helped to propagate and integrate individual researcher interpretations among the larger group and provide time and space for researchers to think more deeply about their data and developing categories. Iterative and "cyclical" (Saldaña, 2021) analytical passes with small group presentations continued until all researchers felt satisfied with their categorizations within each emotion.

Next, the research team met as a one large group to review and refine categorizations within each emotion and to work toward the integration of the individual categories into superordinate categories, or themes, that applied across all emotions. This work took several iterations and required several research team meetings. When the research team reached agreement on an initial framework based on the emotion stressed which had the largest number of excerpts (368) and initial categories (7), the first author completed integration of the remaining 12 emotions into the framework. Individually (one by one) and using an iterative process, the researcher mapped data and categories of the other 12 emotions to the framework. At times the data and categories neatly fit within the framework and at other times changes to the superordinate categories (which then had to be propagated back through the emotions that had already gone through the process) or additions of superordinate categories was required. In the end, 8 superordinate ordinate categories and 23 subcategories were developed that encompassed the data excerpts (reasons) coded to the 13 emotions.

5.6. Study limitations

This study is limited in at least four ways. First, all data generated and analyzed in this study were self-reported by the participants. Although data generation was conducted during the COVID-19 ERT event in mid-to-late spring semester 2020, it is possible that participants' affective responses to the ERT could have shifted or changed prior to or during data collection. To some extent, the survey design helped mitigate this limitation by asking participants to explain why they were experiencing the emotions they reported. The act of explaining the reasons for their emotional response may have encouraged participants to think more deeply and carefully about their response selections.

Second, the timespan of online learning examined in this study is considered short in that it lasted substantially less than one full semester. Thus, the affective responses of the participants, especially the responses for those who had no prior online learning experience, may have been unsteady, volatile, or more extreme during this time as participants rapidly adjusted to the online learning environment than they may have been otherwise. In addition, prior online learning experience may have mediated the affective responses of some, but not all, participants in ways that this study did not discern.

Next, due to the emergent nature of the research design as the ERT was unfolding, the demographic data generated for this study was limited in scope; demographic data that was collected did not capture information needed to determine STEM underrepresented status (i.e., race and ethnicity) of the participants and the selection options provided for gender identification were binary in nature (i.e., male, female, prefer not to disclose). Ultimately, the lack of robust intersectional demographic data limited the researchers' ability to examine if and how participants' affective responses differed along intersectional axes. However, research team efforts to sample a variety of courses offered at different types of institutions and at different institutional locations (i.e., R1, R2, teaching-focused, public, land-grant, private, HBCU, and U.S. eastern/western regions) helped to mitigate this limitation and ensure that the data examined in this research represented substantial diversity of student experience (and thus was inclusive of a wide range of emotional responses to those experiences) during the COVID-19 ERT event.

Last, participants were asked to identify their affective responses based on their perceived abilities to succeed in their ERT courses. Participants were provided a list of 13 feelings to select from and an open text box to input additional/other feeling(s) not listed. While all participants selected from the same list of 13 "common" feelings, participants were not provided the definitions of these feelings. Therefore, the possibility exists that participants selected feelings based on (varied) personal understandings of what those feelings meant, rather than a common understanding across all participants and the researchers.

6. Findings

Findings from this study are presented in the following order: findings related to the affective responses (i.e., emotions and feelings) that participants reported experiencing in relation to their perceived abilities to succeed in the COVID-19 ERT environment (Research Question 1) are presented first; findings related to the reasons participants reported for having these affective responses (Research Question 2) are presented last.

6.1. Participants' affective responses

To identify the affective responses (i.e., emotions and feelings) that the participants reported, we examined the participant selection count of each emotion (survey item #4) as shown in Table 5.

Considering all selections by all participants (i.e., the responses to Table 1, assessment area #4, item survey #1), we found that 40% of the total selections corresponded to positive emotions and 60% of the total selections corresponded to negative emotions. Of the positive emotions selected, independent (8.9%), motivated (6.9%), confident (6.7%), and comfortable (6.2%) were selected most often and empowered (2.2%) was selected least often. None of the positive emotions individually accounted for more than 9% of the total emotion selections. Of the negative emotions selected, uncertain (16.5%), stressed (14.9%), anxious (11.2%), and isolated/alone (9.1%) were selected most often and scared (3.9%) was selected least often. Uncertain, stressed, anxious, and isolated each accounted for more than 9% of the total selections. The emotions empowered (2.2%), safe (4.2%), supported (4.9%), depressed (4.3%), and scared (3.9%) each accounted for less than 5% of the total responses.

Table 5
Participants' self-reported affective responses to the COVID-19 ERT

Emotion or Feeling	Emotion Selection Count (% Total Counts)	% Total Participants Selecting this Emotion
Positive		
Comfortable	283 (6.2%)	22.2%
Confident	305 (6.7%)	24.0%
Empowered	100 (2.2%)	7.9%
Independent	401 (8.9%)	31.5%
Motivated	311 (6.9%)	24.4%
Safe	188 (4.2%)	14.8%
Supported	222 (4.9%)	17.4%
Total Positive Emotion Counts	1810 (40.0%)	
Negative		
Alone or Isolated	413 (9.1%)	32.4%
Anxious	504 (11.2%)	40.0%
Depressed	195 (4.3%)	15.3%
Scared	178 (3.9%)	14.0%
Stressed	674 (14.9%)	53.0%
Uncertain	748 (16.5%)	58.8%
Total Negative Emotion Counts	2712 (60.0%)	
Total Counts | Participants	**4522 (100.0%) |**	**1273 (100.0%)**

Considering the number of participants who selected each emotion, the most frequently selected positive emotions (i.e., independent, motivated, confident, comfortable) were each selected by approximately 22–31% of participants. The most frequently selected negative emotions (i.e., uncertain, stressed, anxious and isolated/alone) were each selected by approximately 32–59% of participants. Remaining emotions (empowered, safe, supported, depressed, scared) were each selected by less than 18% of participants.

6.2. *Participants' reasons for their affective responses*

To understand how participants explained the reasons underpinning their affective responses, we first characterized the number of the textual excerpts (reasons) (i.e., Table 1, assessment area #4, survey item #2) coded to each positive and negative emotion and then conducted a qualitative thematic analysis of the excerpts. In this section we describe the characterization of the excerpts first and then discuss the findings from the thematic analysis.

6.2.1. *Characterization of the textual responses*

The breakdown (i.e., positive emotion or negative emotion) of the textual excerpts coded to the 13 emotions is provided in Table 6. Of 1192 total excerpts, 459 (38.5%) excerpts described reasons why participants experienced positive emotions and 733 (61.5%) excerpts provided participants' rationales for having negative emotions. We note this breakdown is approximately equal to rates that participants selected positive (40%) and negative (60%) emotions; this finding provides a degree of confidence that participants were able to express (and researchers were able to interpret) rationales for experiencing positive and negative emotions to a similar extent.

The breakdown of excerpts within each emotion (Table 6), however, often differed from the emotion selection count percentage (Table 5). For example, the emotion *stressed* received 14.9% of the total selections but was coded to 30.8% of the excerpts. Similarly, the emotion *independent* received 8.9% of the total selections but was coded to 4.9% of the excerpts. This finding may suggest that 1) without being provided definitions of the emotions, participants may have been able to describe and provide rationales for some emotions more easily than others, and/or 2) while most participants selected more than one emotion, participants may have felt some emotions more strongly and focused on describing the reasons for having those emotions to a greater extent than the others.

Table 6
Distribution of Participant's positive and negative emotional responses.

Emotion or Feeling	Number of Excerpts (% of Total)	Example Excerpt (Reason(s) for having the selected emotion)
Positive		
Comfortable	140 (11.7%)	Online classes have been a huge blessing for more [sic]. They allows [sic] to work from home and do the homework on my time and terns [sic], which allows me to enjoy learning and attending school more.
Confident	86 (7.2%)	I have taken online classes before, so it was not a problem for me.
Empowered	38 (3.2%)	I have the freedom to take education into my own hands, choosing what I will learn and participate in.
Independent	58 (4.9%)	I enjoy the greater opportunity to be independent in my time management and in some courses not limited to a certain time to learn and apply material.
Motivated	38 (3.2%)	I was still motivated to accomplish my assignments. My professors were very good at sending reminder announcements and updates often. Expectations were very clear and plenty of resources were provided.
Safe	13 (1.1%)	The online environment is helpful during the pandemic because it reduces my exposure to large groups.
Supported	86 (7.2%)	Our teach was so hands on and so interactive with us. If I ever messaged him, I know it would be less than an hour before hearing back from him. He communicated all the time and never left anything to question.
Total Positive	**459 (38.5%)**	
Negative		
Alone or Isolated	110 (9.2%)	It all felt like a bad dream. I never saw anyone, and got no feedback for submitted work. The assignments just kept coming.
Anxious	61 (5.1%)	I know i [sic] can do it but worry that i [sic] am misunderstanding the instructions or am not going to be able to get help from my professor.
Depressed	11 (0.9%)	Many professors decided to implement MORE work than normally allocated while attending physically. This led to falling behind and feeling hopeless very quickly.
Scared	14 (1.2%)	Trying to finish school when you feel that the world is ending is difficult at times.
Stressed	368 (30.8%)	My schedule has been thrown out the window, it's harder to stay on top of everything, I have mostly week-long assignments but I don't have daily reinforcement of concepts.
Uncertain	169 (14.2%)	The online learning environment is different from a classroom. It often takes more time, and I am unsure how a professor feels about my work.
Total Negative	**733 (61.5%)**	
Total	**1192 (100.0%)**	

Emotions *comfortable* (140 excerpts or 11.7%), supported (86 excerpts or 7.2%), and *confident* (86 excerpts or 7.2%) were the positive emotions with the most coded excerpts and the emotions *stressed* (368 excerpts or 30.8%), *uncertain* (169 excerpts or 14.2%), and *isolated* (110 excerpts or 9.2%) were the negative emotions with the most coded excerpts. The remaining seven emotions (*empowered*, *independent, motivated, safe, anxious, depressed,* and *scared*) were each described by a 5.1% or less of the total excerpts. In other words, there were approximately four times more excerpts describing why participants felt *stressed* (368 excerpts or 30.8%) than why they felt *confident* (86 excerpts or 7.2%).

6.2.2. Thematic analysis findings

The coded excerpts were developed into eight superordinate themes, with a combined 23 subcategories, that describe participants' self-reported reasons for the emotions (either positive or negative) they experienced during the COVID-19 ERT. Themes and their associated subcategories were then grouped as external (institutional), internal (personal or interpersonal), and contextual factors that influenced, both positively and negatively, the unique affective responses of the participants (Fig. 1).

In the following sections, the effects of these external, internal, and contextual factors on the participants' affective responses are further described.

6.2.2.1. External factors. External factors comprise affordances and/or constraints provided or induced by institutions existing outside of an individual's control. External factors were identified as multi-faceted changes catalyzed by ERT, implications of remote learning, and remote course design and delivery. The mapping of the three external factors to each emotion via the number of excerpts is shown in Table 7.

As shown in Table 7., external factors played a substantial role in participants' experience of both positive and negative emotions.

6.2.2.1.1. Multi-faceted changes catalyzed by ERT. Somewhat surprisingly, and in several ways, the multi-faceted changes catalyzed by the ERT helped participants feel *comfortable*, *confident*, and *safe*. Participants who described themselves as adaptive, self-directed learners prior to the ERT expressed that they were comfortable with and confident about the rapid switch to remote learning. For these participants, the pace and unplanned nature of the switch had no real affect because they already possessed well-developed skills for directing their own learning. Others felt comfortable during the rapid transition to remote learning based on their belief that the change in learning environment would result in lowered expectations from instructors for student performance. In addition, the change of physical locations for learning to a place where learning could take place in one's own home helped participants feel safe. As one participant noted, "I can get most things done on my own time and from the comfort of home."

For others, the ERT changes induced negative feelings. The newness of remote learning, its rapid pace and unplanned nature, and the disruption it caused to personal work routines and schedules combined to produce substantial amounts of *stress* and *uncertainty*. Participants wrote how "the learning environment feels chaotic," "my day-to-day life has no structure," and "I lost all sense of routine which is a big part of my personal success." Some participants described difficulties making schedules for remote learning, especially if instructors did not post lectures and materials in accordance with the face-to-face class schedule. Changes to physical learning environments also influenced negative feelings. Some participants struggled with disruptions and poor work environments at home, while others missed the routine of physically attending class at a place distinct from home. As one participant wrote, "I sign up for physical lectures to force some structure into my learning." Last, students felt stressed when their perceptions that course expectations would be lowered were not met. Participants described how, "The expectations for this class we're still associated with the regular in person attendance format, so the workload became overwhelming." Some wrote how "Teachers weren't necessarily making class easier" and a few commented that they "felt it was unfair" that teachers were purposefully "making things more difficult like taking away points for what can only be called as being petty or if assignments

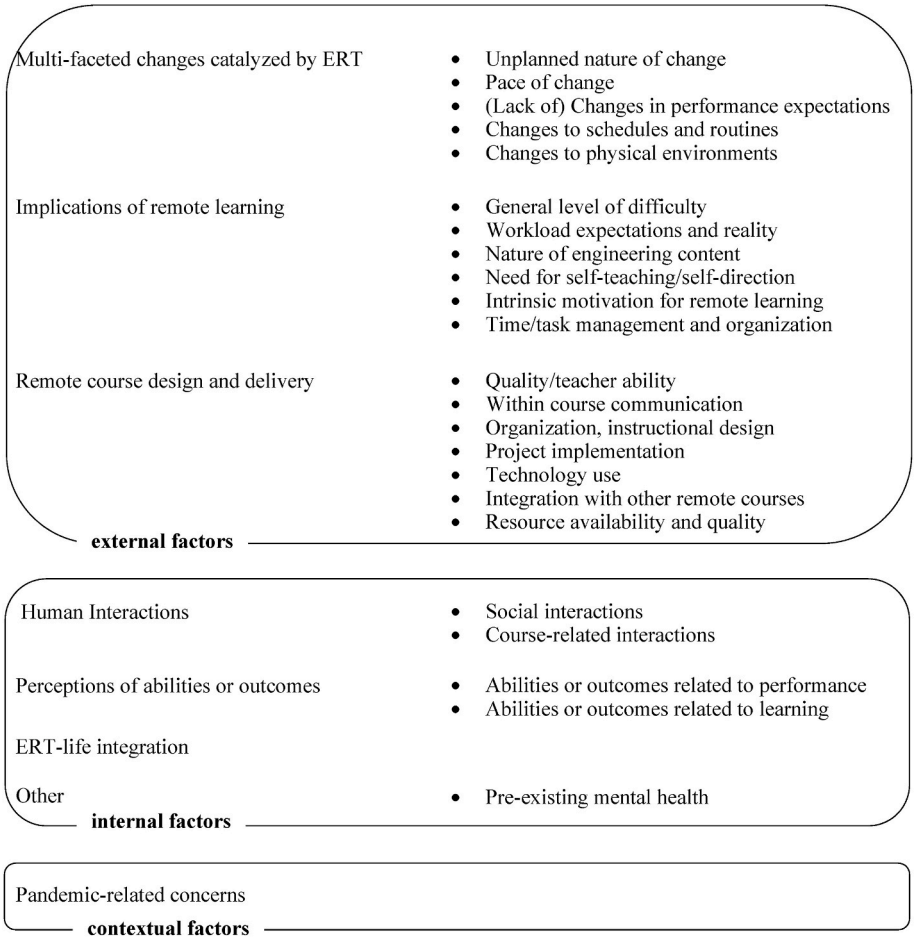

Fig. 1. Thematic model of STEM students' reasons for affective responses during the COVID-19 ERT.

Table 7
Mapping of external factors (reasons) to participant affective responses (emotions).

External Factors	Positive emotions							Negative emotions					
	comfortable	confident	empowered	independent	motivated	safe	supported	alone/isolated	anxious	depressed	scared	stressed	uncertain
Changes Catalyzed by ERT	15	14	–	–	–	14	–	10	–	3	8	121	65
Implications of Remote Learning	64	9	36	29	9	–	–	–	19	–	2	164	16
Remote Course Design and Delivery	23	3	7	7	7	1	96	14	12	2	–	163	58
	Number of Excerpts												

are late they don't make accommodations."

6.2.2.1.2. Implications of remote learning. The inherent characteristics and requirements of remote learning, including its general level of difficulty, workload, anywhere and anytime nature, and need for self-direction and time management and organizational skills, carried implications that influenced participants' affective responses positively and negatively. For some, these characteristics combined to enable positive feelings of *comfort, empowerment, independence,* and *motivation*. By and large, participants accredited their positive feelings to the flexibility, in terms of place, time, and schedule, that remote learning affords. As one participant wrote, "I know that I am a motivated person and will work at my own pace. I really enjoy being able to set my own schedule and get things done as fast as I want and be able to work ahead."

Participants' perceptions about the difficulty and workload of remote learning and the lack of constraints on the time and place for learning, however, energized negative emotions including *stress, anxiety,* and *uncertainty*. Many participants expressed how they felt remote learning encompassed more work and took longer. One participant noted this writing, "It feels like I have a lot more work than I used to. I don't, at least I don't think I do, but the amount of time I spend on schoolwork feels so much longer when I'm doing it at home." Another participant wrote, "My workload tripled having to learn everything myself with still the same number of assignments." Several participants considered engineering content to difficult to learn remotely, simultaneously comparing remote learning to self-teaching. One participant described feeling stressed by writing, "I felt like it was 100% on me to teach myself all the material" and another wrote that "engineering topics should not be self-taught." Several participants described how the need for constant self-teaching degraded their motivation for learning, which in turn amped up their feelings of anxiety and stress. Participants also struggled with time management and knowing how to organize their work, especially across multiple remote courses. One participant recounted, "Nothing had a time value. I didn't have set dates or times when I would do things and so I would do a lot of them all at once and then forget about the next ones and [had to] scramble to do those before the deadline."

6.2.2.1.3. Remote course design and delivery. The design and delivery of the ERT remote courses also influenced both positive and negative affective responses among the participants. Interestingly, remote course design and delivery was the single factor in our model that was reported influenced the way participants felt supported. Remote course design and delivery helped participants feel supported and *comfortable* through the implementation of adequate, well-designed, and open communication channels, which were commended as being especially helpful during the one-week transition period. Providing high-quality course materials (e.g., video lectures, lecture notes) and support resources (virtual office hours, teaching assistant support, and peer help available through working groups) were also common reasons that participants wrote made them feel supported.

Alternatively, remote course design and delivery influenced feelings of *stress* and *uncertainty* via "unengaged teaching" and poor instructor communication that led to uncertainty about due dates and course expectations. Alternatively, some participants defined poor communication as over-communication writing, "There are too many emails to keep track of everything. So, the information is there, but can be overloaded." A lack of structure and/or inconsistencies in policies and procedures within a single course and across courses in the same degree program was also noted as a cause of stress and uncertainty. Participants expressed how "Every class and professor is [sic] running things differently and it can be hard to keep up with everything." Group projects were often mentioned as being stressors, and some participants noted that group projects "were still pursued despite being much less practical when done remotely." Group projects were considered stressful when there was poor communication between group members, when some group members did not participate, and when there was difficulty

accessing resources in closed maker spaces and laboratories that were needed to complete projects. Some participants noted course technology issues as being stress-inducing, such as when communication tools didn't work properly, the internet became unreliable, needed software didn't work on home computers, and instructors struggled to use course technology properly or effectively.

6.2.2.2. Internal factors. Internal factors comprise personal and interpersonal abilities, actions, and attitudes that are unique to everyone. Internal factors that were identified as reasons for participants' affective responses include interactions, perceptions of abilities or outcomes, ERT-life integration, and other. An "other" category was added to account for excerpts that related pre-existing mental health conditions as reasons for feeling depressed. The mapping of the four internal factors to each emotion via the number of excerpts is shown in Table 8.

6.2.2.2.1. Human interactions. Lack of human interactions was predominantly reported as a reason for feeling negative emotions such as *isolated*, *stressed*, and *uncertain*. One participant summed up these sentiments by writing, "All I do every day is sit quietly by myself, trying to stay afloat with all my online classes." Other participants described how they felt the combined effects of isolation, stress, and uncertainty writing, "… engineering is hard and the group work atmosphere was mostly gone, even with the use of Webex chats." Others stated that the "… disconnect from the other students adds so much stress and uncertainty about the quality of work I am able to produce." Still others noted feeling uncertainty and stress due to difficulties interacting online and not being able to get their usual or desired amount of reassurance and reinforcement from regular interactions with instructors and teaching assistants.

6.2.2.2.2. Perceptions of abilities or outcomes. Participants' perceptions of their abilities and potential outcomes were described as reasons for feeling both positive and negative emotions. On the one hand, participants described feeling *confident* and *comfortable* about their abilities to succeed due to their prior online learning experiences or high self-efficacy for learning gained during previous STEM courses. Others described how they felt *confident* that their strong performance in the course thus far would carry them through the remainder of the semester. Some participants described how they felt *comfortable* and *confident* because they possessed certain attitudes, such as a strong work ethic and a positive mental attitude, that they could count on to help them stay motivated in the ERT environment. Having *confidence* and being *comfortable* while learning in a remote environment also led some participants to experience feelings of *independence*; as one participant wrote, "I enjoy putting the work in on my own time, especially when I am able to work ahead."

On the other hand, self-perceptions about their personal remote learning abilities or potential outcomes led other participants to feel *anxiety*, *stress*, and *uncertainty* about "how doing everything online would affect understanding and performance." Many described that it was "much harder to grasp the material on my own" or how they were anxious and stressed that they "would forget about something and then have it impact my grade negatively." One participant summed up how his self-perceptions affected his emotions writing, "Online is not my style and my grades reflect that right now. It's very frustrating and stressful which makes me do worse."

6.2.2.2.3. ERT-life integration. Challenges integrating ERT with life were also cited as reasons for having negative feelings such as *stressed*. Participants described having to find new jobs, revise working schedules, or work overtime as the pandemic wore on. These situations increased participants' stress levels and took time away from studying. Others wrote about "coming home and trying to figure out how to learn" with young children at home, too. Increased personal responsibilities at home, and having to be home while studying, led many participants to reduce the time they spent on schoolwork, further adding to their stress.

Table 8
Mapping of internal factors (reasons) to participant affective responses (emotions).

Internal Factors	Positive emotions							Negative emotions					
	comfortable	confident	empowered	independent	motivated	safe	supported	alone/isolated	anxious	depressed	scared	stressed	uncertain
Human Interactions	–	1	–	–	8	–	4	56	–	1	1	39	29
Perceptions of Abilities or Outcomes	44	50	6	18	17	–	–	–	19	4	1	32	18
ERT-Life Integration	–	–	–	–	–	–	–	–	–	–	–	16	1
Other (Pre-existing Mental Health)	–	–	–	–	–	–	–	–	–	2	–	–	–
Number of Excerpts													

Overall, participants cited internal factors as reasons for experiencing positive and negative emotions.

6.2.2.3. Contextual factors. Contextual factors comprise influences of an individual's surroundings and social milieu. One contextual factor was identified as pandemic-related concerns. The mapping of the contextual factor to each emotion via the number of excerpts is shown in Table 9.

Participants provided pandemic-related reasons for feeling negative emotions, particularly *anxious*, *stressed,* and *scared*. Participants wrote they were *anxious* about family members getting ill and the circulating rumors of follow-on semesters going online. Participants wrote they were *stressed* and *scared* about the "global crisis," "deteriorating state of the world," and "bigger problems such as the coronavirus." One participant commented, "Had there not been a global pandemic, I feel as though it would have been a fine transition." Others linked the pandemic to their degrading mental health, feelings of depression, and difficulties focusing on school.

7. Discussion

Our findings provide new insights about the unique and varied affective responses of STEM undergraduates during the COVID-19 ERT. Our data show a mix of positive (40%) and negative (60%) emotional responses among participants; this finding aligns with those of a national, random-sample survey of undergraduates during the COVID-19 ERT (Means et al., 2020). While both studies identified trends of more undergraduates feeling negative toward/less satisfied with their STEM-related courses during the ERT, both studies also identified smaller groups of undergraduates who reported feeling more positive toward/satisfied with their STEM courses during ERT. These findings highlight the complexity, contextuality, and individuality of students' affective responses and is an area for future research.

In our study, uncertainty and stress were the most frequently reported affective responses to the ERT. More than one-half of participants reported experiencing each of these emotions as they transitioned to and participated in remote learning. Additionally, more participants described reasons why they experienced uncertainty and stress than they described reasons for experiencing any other emotion. The ability and/or willingness of participants to describe their experiences of uncertainty and stress in greater frequency and detail may hint at how strongly participants experienced these emotions. These results come at a time when recent reports describe increasing depression, anxiety, and suicidal ideation among college students (Danowitz and Beddoes, 2020; Duffy et al., 2019). Concurrently, there are increasing calls to shift "engineering stress culture" from "one of suffering to one of thriving" (Jensen, 2021), and to integrate new knowledge about non-cognitive and affective factors (e.g., stress, social support, mindfulness) into definitions and measures of STEM student success (Krest et al., 2020). Our findings add to these and other conversations regarding the need for STEM educators to take compassionate action to reduce anxiety, stress, and uncertainty among undergraduates, particularly during future ERT events.

Our resultant three-tiered, thematic model provides educators with a conceptual way to consider how external (i.e., institutional), internal (i.e., personal and interpersonal), and contextual factors influence STEM undergraduate emotions during ERT events. Looking across the three factors, we can identify concrete actions, aligned with TD theory (Moore, 1991, 1993; Moore and Kearsley, 2012), that educators can take to reduce stress and uncertainty among STEM students during an ERT:

1) Consider ERT course requirements and expectations and whether they can be adapted. (This includes the need for projects and how projects can be adequately supported remotely). Keep in mind that students may be expecting requirements and expectations to lessen and that assignments may take longer if students are working alone remotely. Clearly communicate expectations to students.
2) Consider that student schedules may be in flux and infuse flexibility into courses to the maximum extent possible. If moving to

Table 9
Mapping of contextual factors (reasons) to participant affective responses (emotions).

Contextual Factors	Positive emotions							Negative emotions					
	comfortable	confident	empowered	independent	motivated	safe	supported	alone/isolated	anxious	depressed	scared	stressed	uncertain
Pandemic-related concerns	–	–	–	–	–	–	–	3	19	3	7	11	2
Number of Excerpts													

asynchronous online course formats to maximize flexibility, communicate with students how an asynchronous format differs from a synchronous style course (they may not know). Consider that students may be keeping their personal study schedules intact, since they are taking multiple courses remotely, and expect course material postings and assignments to adhere to original class schedule.

3) Consider that students may struggle with task management and organization, particularly when there are no synchronous meetings when they are reminded of assignment dates and requirements. Consider sending out frequent but measured messages or announcements, perhaps once per week, to help keep students on track and ensure they are not deluged with messages.
4) Be personally available online. Quickly establish communication mechanisms for students to communicate in small groups with each other. Continue to encourage student to student communication throughout the ERT.
5) Organization is key. Clear and simple instructional design is likely to keep students engaged. Consider integrating with other courses in the same program so that exams don't overlap and policies and procedures are consistent as possible across courses.
6) Consider students as actors in the global context who are most likely stressed about events beyond the purview of the course. Instructors can act with compassion by acknowledging struggles and providing maximum course flexibility.

While most participants reported feeling uncertain and stressed during the ERT, reports from smaller groups of participants who felt more comfortable, confident, and independent during the ERT provide hope for the future and makes us ask, 'What was different?' Apart from appreciating the flexibility of remote learning and well implemented course design and delivery, participants' positive feelings during the ERT came from internal factors such as their previous online learning experiences and positive perceptions of themselves as self-directed learners who could self-teach and stay positive amid trying times. These skills and mindsets, however, aren't easily or immediately activated through activities that we add to our ERT courses and assume students will absorb.

As 21st century educators situated in the wake of the COVID-19 ERT, our obligation to expand our knowledge of educational technology, LMS course design, and e-pedagogy and improve our skills, abilities, and courses in preparation for future ERT events is clear. This research, we believe, further suggests that educators are perhaps equally obligated to actively and purposefully support STEM students in their personal development as resilient, self-regulated learners. As one participant wrote, "It seemed *unfair* to have the same expectations for us and our learning online when *we were not prepared to take classes online and the professors could not necessarily do everything that would help us online.*" Given the individuality and contextuality of experiences that occurred during the COVID-19 ERT, it appears that no single ERT course will fulfill the needs of every student; educators will not able *to do everything* to help all students once an ERT begins. Our data suggest that many participants did not have prior exposure to, or were not prepared for, remote learning and that, once the ERT began, it was indeed an unfair situation for many students. Our findings lead us to consider how part of doing everything we can to compassionately reduce students' stress, uncertainty, and discomfort during ERT events includes helping students learn to support themselves in online learning environments. Progess toward this goal can be achieved by providing low risk opportunities for students to engage in remote learning activities and developing non-ERT STEM courses that include specific objectives for students to self-direct and self-regulate their own learning.

8. Conclusions

Student's affective responses to their educational environment play a substantial role in their ability and desire to learn and succeed. Our study, which examined the affective responses of 1340 STEM undergraduates across 27 U.S. institutions during the outbreak of the COVID-19 pandemic, indicates that most participants reported experiencing negative emotional reactions, including anxiety, uncertainty, stress, and isolation, when considering their abilities to succeed in the ERT learning environment. At the same time, a smaller group of participants reported feeling comfortable, confident, and independent in the same learning environments. A three-tiered thematic model representing the reasons participants experienced positive and negative emotions was developed. The model showed that while both internal and external factors influenced participants' feelings of stress and uncertainty, internal factors supported participants' feelings of comfort, confidence, and independence as remote learners in ways that went beyond course design and delivery and instructor actions. Findings suggest that, along with compassionate course design and delivery during actual ERT events, STEM educators can begin shifting students' affective responses toward *future* ERT events *now* by providing more online learning opportunities and proactively training STEM students as self-directing and self-regulating learners in their current (non-ERT) courses.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Nothing to declare.

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