International Journal of Engineering Education Vol. 39, No. 1, pp. 30–47, 2023
Printed in Great Britain

0949-149X/91 $3.00+0.00

Impact of COVID-19 on Engineering Students in the Middle Phases of the Pandemic: Academic Motivation, Valued College Experiences, and Stress*

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When COVID-19 struck, engineering schools responded to unique issues, including interrupted capstone projects, cooperative education, and study abroad. Students became a focus. This led to a funded study to investigate the pandemic's impact on engineering students' academic motivation, educational valuation, learning, and perceived stress, which were connected through a conceptual model. Approximately seven months after the onset, a large sample of undergraduate engineering students at a public U.S. university (n = 1,140) responded to a survey (41.6% response), followed by focus groups. Jones' MUSIC Model of Academic Motivation and the Perceived Stress Scale (PSS-10) were key components of the conceptual model. Seventy-eight percent (78%) said their motivation was less versus before remote instruction. Two dimensions of the MUSIC Model were only at the middle point of the measurement scale – *interest* and *empowerment*. Students scored higher on the PSS-10 (M = 22.2) seven months into the pandemic compared to other groups beforehand. Medium negative correlations were found between the MUSIC dimensions and the PSS-10 score, suggesting decreased motivation accompanied by increased stress. *Remote coursework* was the most-frequent demotivator, and the valued college experience cited most was *Campus-based instruction*. The most-frequent stressor was *Academic*. In all focus groups, low or decreased motivation was mentioned. This research informs Higher Education about undergraduates' motivation and stress, in particular during COVID-19 and contributes to use of the MUSIC Model and PSS-10 with engineering students. Awareness of motivation and stress experienced during COVID is crucial for responding to future crises.

Keywords: COVID-19; pandemic; engineering education; stress; motivation; valuation

1. Introduction

This research study focuses on undergraduates' motivation, valuation of education, learning, and perceived stress during the COVID-19 pandemic, and in particular engineering students. It involved an analysis of a large sample of undergraduate engineering students seven months into the pandemic at a public university in the United States. The study serves in part to inform higher education about undergraduates during the remote instructional period of COVID-19. This is important because knowledge and structures put in place from studies such as this can strengthen academia's ability to respond effectively during future crises [1]. Initial research on the psychological impacts of the pandemic on college students had called for continued research [2]. Consequently, we sought and obtained National Science Foundation funding to study the ongoing impact of COVID-19 on students.

College students are a vulnerable population concerning mental health and psychological disorders. The proportion of students impacted by these conditions continues to increase on college campuses, and COVID-19 exacerbated these issues [3, 5]. College students have been worried about what the future will bring given the crisis's highly unpredictable and transformative nature [6]. University undergraduates were also identified as some of the most vulnerable given the strict lockdown measures and disrupted social development [7, 8]. In addition, university STEM students have experienced particular difficulties in completing projects, with the loss of internships and research opportunities, and in an uncertain job market [9]. Recent *JEE* and *PRISM* articles concluded that mental health is a growing concern in engineering education requiring increased attention with respect to resources, advocacy, and research [10, 11].

Therefore, we investigated academic motivation and the related issues of valuation of education, learning, and stress as the COVID-19 pandemic continued beyond the onset period. The MUSIC Model of Academic Motivation, which draws upon Expectancy Value Theory, was a primary component of the conceptual model for this research study [12, 13]. As part of Jones' model of motivation, learning is subsequently impacted by motivation [14]. Unfortunately, stress can result if impedi-

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* Accepted 3 September 2022.

ments, such as a loss of motivation, or other frustrations are encountered in the pursuit of one's goals [15, 16]. Therefore, these constructs and variables were examined together. The research questions that guided the analysis were as follows:

RQ1: To what degree were undergraduate engineering students academically motivated several months after the onset of the COVID-19 pandemic? What were the most prevalent reasons for motivational loss, and how did students' perception of their learning during the pandemic compare to their perception of it before the pandemic?

RQ2: Which college experiences do engineering students value most, and to what degree were they impacted by COVID-19? How did students value their education during the pandemic compared to before the pandemic?

RQ3: To what degree did engineering students perceive stress several months after the onset of the pandemic?

2. Literature and Background

2.1 Conceptual Model

The MUSIC Model of Academic Motivation served as a primary component of the conceptual model for this research. The MUSIC Model involves five key principles for motivating students, which impacts learning [14]. Jones' MUSIC Model is situated within the broader context of Expectancy Value Theory (EVT), as described by Jones and Skaggs [12]. EVT maintains that one's valuation of an activity, along with expectation for success, are key contributors to motivation to achieve, including learning and academic performance [13]. Since a loss of motivation can induce stress if attainment of one's goals are being negatively impacted or thwarted, the Perceived Stress Scale was also a component of the conceptual model [15–18]. This scale was used to assess the degree to which students perceived stress based on how unpredictable, uncontrollable, or overloading the situation appeared [19].

2.2 Motivation

For students, possessing motivation is important for their academic achievement and learning [14, 20]. Motivation, which has been extensively studied in the education field, impacts learning and performance by influencing the intensity, persistence, and quality of the behaviors undertaken by students to learn [20]. In a study of over 2,500 students at seven U.S. universities at the start of the pandemic, the most frequent change experienced was a lack of motivation and decreased productivity [21]. Therefore, the first research question focuses on academic motivation and perceived learning several months into the pandemic and reasons for any losses in motivation.

2.2.1 MUSIC Model of Academic Motivation

The MUSIC Model integrates five distinct constructs associated with promoting academic motivation. These motivation-enhancing constructs are empowerment, usefulness, success, interest, and caring [12]. Students feel *empowered* when they are able to make choices about their learning and exercise control over it, aligning with the construct of autonomy [12]. Second, the learning content and activities must be perceived as *useful*, or important and relevant to students' future goals [12, 22]. Usefulness is consistent with utility value from Expectancy Value Theory (EVT) [12, 13]. Students must believe they can be *successful* if they put forth the required effort [12]. Students who possess this belief will expect to do well, which is consistent with expectancy for success within EVT [12]. *Interest* in the course content and activities drives student motivation, as does the belief the instructor and other students *care* about the student, both academically and personally [12].

The MUSIC Model was chosen given its integrated five-construct model and its validity with college students [12]. Questions from the MUSIC Model range from *strongly disagree* to *strongly agree*, with a sample of questions as follows [23]:

- I feel that I can be successful in meeting the academic challenges in the courses.
- I find the coursework to be relevant to my future.
- I believe that the instructors care about my feelings.

2.2.2 Factors in Motivation

Educational psychologist Paul Pintrich identified both performance and social goals as key motivating factors for students [24, 25]. Social goals, such as peer interaction, assist in the shaping and development of motivation, and social and emotional well-being are associated with academic motivation [24, 26]. If perceived as supportive, the environmental context in which students study is likely to be motivation-enhancing [20]. Thus, factors such as the student's family or peers and the culture in which the student lives and learns may also impact motivation [14]. Likewise, internal, psychological variables such as the student's thoughts, emotions, and feelings, also impact motivation [14].

Specific to COVID-times, a survey administered by ASEE in the summer of 2020 revealed that 61% of student respondents agreed it was difficult to remain engaged and motivated when studying from home [27]. A study of 142 Dutch undergraduates

during the COVID onset period reported less motivation compared to before the pandemic, with the top reasons being a lack of social interaction, "digital discomforts" (i.e., lack of resources for online learning), and quiet places to study [28].

2.3 Valuation of Education

At the start of social distancing and remote learning, valued college experiences were immediately impacted. This motivated the second research question about students' most-valued college experiences, COVID's impact on them, and overall valuation of education given the circumstances. *Utility value*, or how something factors into one's future plans, aligns with the *usefulness* dimension of the MUSIC Model [12, 13].

2.3.1 Valued College Experiences

The student experience during college, including students' involvement and immersion in institutional opportunities and resources, is linked to desirable college outcomes such as learning, achievement, and persistence [29, 30]. A host of experiences contribute to a full college experience. These experiences may be categorized as academic/co-curricular, extra-curricular, social/enjoyment/personal, job/volunteer, and campus resource use, based upon a review of the literature.

Academic or co-curricular experiences include going to class, being active in classroom discussions, giving class presentations, group project work, internship programs, research projects, interaction with faculty, and study abroad [29, 31, 32]. *Extra-curricular* experiences include clubs or organizations and performance in musical, artistic, or sports events [29, 31, 32]. *Social, enjoyment, and personal experiences* include living on campus in the dorms, attending a sporting or musical/artistic event, social interaction and fun activities with other students, making friends, and experiencing an old campus tradition [29, 31, 32]. *Job and volunteer work*, including a part-time campus job, has been found to correlate with propelling students to graduation and enriching the college experience [29, 31, 32]. *Campus resources*, including learning or academic support centers, libraries, and recreational/fitness facilities, provide opportunities for student development and well-being [29].

2.4 Stress

The third research question explores the important issue of stress perceived by students several months into the COVID-19 pandemic. Unfortunately, stress can have a devastating effect on one's life, including one's physical or mental health, particularly if left unmanaged [16, 33]. In an *American Psychologist* article authored by over 35 professionals from psychology and psychiatry departments at U.S. universities, psychological and mental health problems in the wake of the pandemic will likely result from stress [8]. Initial research on the impact of COVID in higher education has indicated negative stress impacts on students [2, 4, 6, 34–36].

2.4.1 Perceived Stress Scale

The Perceived Stress Scale (PSS) is a widely-used instrument for measuring the degree to which situations in one's life are appraised or perceived as stressful [17, 18]. The Perceived Stress Scale (PSS) was chosen as part of the conceptual model based on its general applicability, validity and reliability with college students, brevity (i.e., 10 items), existence of normative data for college students, favorable psychometric properties, and use by others for assessing stress during COVID-19 [2, 34–39]. Questions from the PSS pertain to the last month in time and range from *never* to *very often* [17]. A sample of questions is as follows:

- How often have you felt that you were on top of things?
- How often have you felt that you were unable to control the important things in your life?
- How often have you found that you could not cope with all the things that you had to do?

2.4.2 College Stressors

Stress among college students is a well-investigated topic, with previous research having identified common stressors specific to college students. Stressors are the stimuli or the sources of the stress and include various circumstances and events in a person's life [16, 33]. Based on a review of the research literature, various categories describe the stressors specific to college students as discussed next, although other groupings may be possible [16, 40–46].

Academic stressors include assignments, exams, grades, due dates, course workload, study habits, and time management. *Environmental* stressors may result from being in a different country or culture as well as experiencing racism, discrimination, non-inclusive treatment, or criminal victimization. *Financial Issues* may arise due to expenses, costs, limited funds, or debt and may result in the need for a job during school. *Future Uncertainties* exist for college students regarding career, major, finding a job, and graduate school decisions or acceptances. *Personal matters* leading to stress may include alcohol/drug use, addiction, physical health, mental health, loneliness, physical appearance, self-image, self-imposed pressure, or worrying. *Relationships* and *Interpersonal matters* related

to family, parental expectations or pressures, romantic issues, roommates, peers, instructors, supervisors, and college staff are also sources of stress for university students. *Support and Time constraints*, including inadequate time to complete everything or inadequate support from teammates, instructors, or staff, are often felt by students. *Transition* and *Change* can be particularly stressful when students transition to a university setting or adulthood and have to leave home, develop independence, and make new friends.

Finally, in the current age, *Pandemic/COVID-19 specific* stressors, or issues specific to the global pandemic, are aptly of concern. COVID-specific stressors were called out in an article on campus counseling centers and student challenges, where both routine college stress and the *new* stress from COVID and an international pandemic were discussed [45]. In the *American Psychologist* article cited previously, COVID-19 was identified as a "unique, compounding, multidimensional stressor." [8 pg. 2]. Multiple studies have already emerged on stress among university students during the COVID-19 pandemic. In a recent study of undergraduates at a large U.S. university, 60% of whom were engineering students, the most prevalent stressors were fears about personal and loved ones' health, difficulty with academic concentration due to distractions, disrupted sleep, lessened social interactions, and concerns about academic performance [2].

3. Methods

3.1 Research Design

A case study research approach was used for this research, in which the targeted population was all undergraduates within a school of engineering at a public university having a very high research activity in the mid-Atlantic region of the United States [47]. The case study approach consisted of the use of one questionnaire/survey in the Fall 2020, which was highly-informed by the literature, including two theory-driven and validated scales for measuring the complex psychological constructs of perceived stress and academic motivation. A second component of the case study approach was subsequent, follow-up focus groups in Spring 2021 with students who responded to the survey, which was done to investigate and understand student perspectives and affect to a greater depth as well as triangulate the survey results [47].

3.2 Participants

Participants were recruited from the population of undergraduate students (first year through senior year) majoring in engineering. Students from eleven engineering programs, including the first-year program, were approached and asked to participate by members of the research team during the weekly seminar for each engineering program. A total population of 2,742 enrolled undergraduate students were asked to participate in this fashion during the Fall 2020. During seminar, the research team introduced the study to students and asked them to complete the survey at that time. The Qualtrics system was used to distribute the survey to all students during their seminar times and collect the data. This recruitment approach enabled us to achieve a strong response rate of 41.6%, or 1,140 students, who completed the survey in full and submitted their responses. When partial survey responses are included, a total of 45.6% of students participated. The strong response rate generally sets this study apart from other COVID-related studies to this point. This is evident by response rates and/or sample sizes stated in the literature for similar studies.

As a follow up to the survey, all survey respondents were asked to participate in a focus group. A total of 26 students voluntarily participated in six focus groups that were conducted by members of the research team during the Spring 2021 semester. This study was approved by our campus Institutional Review Board (STUDY20080156). Our campus followed a flexible model of instruction and learning during the Fall 2020 and Spring 2021 semesters, in which students and instructors were offered the flexibility to attend or teach class, respectively, either at home or in-person on campus.

3.3 Survey Design

The survey for this research was designed by a team of five researchers consisting of the Associate Dean for Academic Affairs, two assistant professors and a post-doctoral associate who conduct engineering education research, and an undergraduate student. A series of weekly discussions by this diverse team enabled iterative development and vetting of the survey by the team. In addition to including validated inventories to measure the complex constructs of academic motivation and perceived stress, the survey included Likert-scale questions to gather student perspectives on their motivation, educational valuation, and learning as well as to gather reasons for motivational loss, their most-valued colleges experiences, and top stressors. One Qualtrics survey was used to compile these inventories and questions. There were 11 questions in total, although the two inventories each had multiple items. Students had the option to answer only certain questions, as we did not want to require or force responses.

Data on each survey respondent's gender, ethnicity, and major were retrieved from the university data warehouse. Students have the option to select male, female, or unknown when providing gender information for the warehouse. Students were asked via survey to indicate their academic level in the engineering program, as this information is not directly obtainable from the data warehouse. Students were also asked if they had been enrolled on the main campus during the Spring 2020 semester when the pandemic began. This information was used to ask only the returning students (i.e., sophomore through senior) to compare their current to pre-pandemic levels of motivation, learning, and educational valuation.

3.3.1 MUSIC Inventory and Reasons for Loss of Motivation

The five-scale MUSIC Model inventory was used to numerically assess engineering students' motivation [12, 14, 23]. Items were each rated on a scale of 1 to 6 (*strongly disagree* to *strongly agree*) [23]. The maximum score for each construct was 6, with a higher score indicating a higher level of motivation. The program-level version of the MUSIC Inventory was used for this research [23]. When analyzing the data, the sum or average of all 26 items was *not* calculated as a measure of motivation; rather, the five constructs were examined separately in accordance with the model [23].

Students were also asked to select their top three reasons for loss of motivation if they rated their motivation as decreased during the pandemic. With support from the literature describing motivational factors (section 2.2.2), a list of eleven potential reasons, as numbered below, were determined and presented to students in the survey. The reasons can be summarized under the categories of environmental context, goals, and psychological variables, as discussed in section 2.2.2. Students are motivated by supportive learning and study *environments* [14, 20]. Unfortunately, during COVID-19, students' learning environments were impacted by (1) remote coursework that was less-engaging, (2) remote coursework that was less accessible at times due to technology issues or time-zone differences, (3) physical separation from their instructors, (4) physical separation from peers, (5) living and studying at home, and (6) vastly changed routines and structure. Students are also motivated by their *academic goals* [24]. Co-curricular goals such as (7) study abroad, undergraduate research, co-op work experience, and group project work were interrupted, negatively impacting these academic goals.

Social goals are also motivating factors for students, and social well-being is associated with academic motivation [24–26]. Social interaction in college is driven by (8) extra-curricular activities (i.e., clubs, organizations, artistic performances, team sports, etc.) and (9) enjoyable, fun campus activities (e.g., sports and artistic events, recreational/fitness activities, etc.), much of which was diminished during the pandemic. *Psychological variables* related to students' thoughts, emotions, and mood also impact motivation [14]. Thus, (10) exacerbated mental health issues (anxiety, depression, etc.) and (11) COVID-specific stressors such as fears about health and safety, job loss, financial concerns, and overall uncertainty, impacted student motivation.

3.3.2 Valued College Experiences

Those students who were enrolled prior to the onset of COVID-19 were asked to select up to three college experiences perceived as most valuable to their education. These students, as opposed to first year students, had previously experienced these opportunities and activities. Upon providing their most-valued experiences, students were asked to indicate the degree to which COVID-19 had impacted each experience on a 5-point scale, from *highly negatively* to *highly positively*.

The literature was searched to identify valued college experiences, as discussed in section 2.3.1. Local sources were also reviewed, including the university website and the senior exit survey. The research team synthesized and refined the list of college experiences to present to students in the survey. The diversity of the research team (i.e., from undergraduate student to Associate Dean) was advantageous in developing this comprehensive list. Given the number of experiences available to college students today, the team encountered a challenge in maintaining the list at a maximum number of 15 items suggested in the literature [48]. However, with iterative refinement, a list of 15 college experiences was achieved for use in the survey. These 15 experiences were organized under five categories in alignment with the literature search, namely (a) academic/co-curricular, (b) extra-curricular, (c) social/enjoyment, (d) job/volunteer, and (e) campus resources. A category for *other* was also included.

In the survey, the *academic/co-curricular* category contained the specific experiences of (1) campus-based instruction with peers, (2) discipline-related work experience (e.g., co-op, internship, research etc.), (3) advising, mentoring, and tutoring interaction, (4) international opportunities, and (5) team-based project work. The *extra-curricular* category encompassed (6) athletics participation, (7) artistic performance, and (8) clubs, organizations, and societies. The category

involving *social, enjoyment, and personal* experiences included (9) attendance at artistic performances or talks/conferences, (10) living on or near campus, (11) meeting new people or friends, (12) fun or social activities with students, and (13) attendance at sporting events. The *job/volunteer* category pertained to (14) jobs not directly related to one's academic discipline or volunteer work. The *campus resources* category consisted of (15) career services, labs, libraries, academic assistance centers, health services, and fitness/recreation facilities.

3.3.3 Perceived Stress Scale (PSS-10)

Each of the 10 items of the PSS-10 was scored from 0 to 4 (*never* to *very often*). Thus, the total score ranged from 0 to 40, with higher scores indicating greater perceived stress [17]. Of the 10 items, four are worded in a positive direction and so were reverse-scored prior to summing all items to create the psychological stress score. Given the widespread use of the PSS, normative data from college students prior to COVID was available for comparison. A study in the U.K. resulted in a mean PSS-10 score of 19.79 (sd = 6.37 and Cronbach's α = 0.88) associated with n = 524 social science undergraduates [49]. In a sample of 280 undergraduates at three public U.S. universities, a mean PSS-10 score of 18.3 was obtained (α = 0.89) [37]. A sample of over 500 Turkish technical university students resulted in a mean PSS-10 score of 18.89 (sd = 6.78 and α = 0.84) [38]. In early work by the developers of the PSS-10, a sample of over 2,300 U.S. residents yielded an average of 13.02 for the PSS-10 (sd = 6.35 and α = 0.78) [17]. Two subpopulations from this general sample that may better coincide with university students include (1) respondents aged 18–29 (mean = 14.2, sd = 6.2), and (2) students (mean = 15.3, sd = 6.6) [17].

In addition to measuring student stress level using a numerical rating, it was of interest to identify the most prevalent stressor**.** A search of the literature uncovered prevalent stressors in the lives of college students, as discussed in literature review section 2.4.2. This literature on college stressors was synthesized by the research team to develop a pre-specified list of stressors that were presented in the survey. A list of nine stressor categories resulted, along with a category for "other." These survey categories therefore coincided with the most-prevalent college stressors from the literature. For example, *Academic* and *Environmental* categories were included in the survey. All students were asked to indicate their top stressor.

3.4 Analysis of Survey Data

The collected survey data was analyzed using statistical tests, correlations, and effect sizes. For comparing the means from independent populations, a large sample z-test was applied [50]. Cohen's d effect size, a measure of practical significance, was also calculated to compare means. Small, medium, and large Cohen's d effect sizes are associated with the threshold values of d = 0.20, d = 0.50, and d = 0.80, respectively [51–53].

Proportions associated with various survey categories, such as top stressors, were statistically compared between groups using either a z-test of proportions or Fishers Exact test [50, 54]. The z-test was used when the sample size was sufficiently large (i.e., the contingency table counts exceeded 5), and Fishers Exact test was used otherwise [50, 54]. The odds ratio (OR) effect size was used to assess practical significance of differences in proportions, with threshold values of 1.5, 2.0, and 3.0 considered small, medium, and large, respectively [55].

To measure bivariate relationships between the variables in our conceptual model, Pearson's correlation coefficient r was used [56]. For Pearson's r, which is an effect size measure, the following ranges were used to interpret the size of the effect: small ($\pm$0.1), medium ($\pm$0.3), and large ($\pm$0.5) [56].

3.5 Focus Group Data

To obtain more in-depth data and triangulate the results, all survey respondents were asked to participate in a Zoom-based focus group in the Spring 2021 semester. Given approximately 1,200 survey respondents, students were recruited in subgroups by email. Six focus groups were ultimately conducted by the first author and two of the co-authors, with the first author participating in all six groups and each co-author participating in three of the groups (i.e., two facilitators per focus group). Between three and six students participated in each one-hour, semi-structured focus group for a total of 26 participants [57]. The questions that were posed are given in Table 1 and complemented and expanded upon the survey data. The focus group questions probed the issues and topics of on-campus presence, stressors, motivation, learning, academic performance, perceived value in higher education, valued college experiences, and social connections. The same team that developed the survey also developed the focus group questions in an iterative fashion.

To analyze the focus group responses, initial coding was done by the first author [58]. The initial coding involved reviewing all responses line-by-line and developing an initial list of themes that were relevant, interesting, or recurrent in the data [58]. This data-driven approach led to the development and refinement of an emergent coding scheme (shown in Table 2) to be used for the content analysis [59]. The sub-categories in Table 2 under

Table 1. Focus Group Questions

1. How often did you go to campus to attend class during the Fall 2020 semester? For example, for how many of your courses did you go to campus for class sessions, or how many days per week (on average) did you go to campus for class sessions?
2. If you did not go to campus to attend class, can you discuss why you did not go? (This can be in general or for particular courses).
3. For the Spring 2021 semester, how do you intend to attend your class sessions – remotely, in-person, or a mixture?
4. If you are not planning to go to campus this semester to attend class in person (but could attend in person), what would it take for you to go to campus?
5. Discuss the top stressor you felt during the Fall 2020 semester and/or for the current semester. Note, if it was or is Academic-related, can you elaborate on that stressor?
6. Discuss your motivation level during the Fall 2020 semester and reasons for it.
7. Discuss your level of learning during the Fall 2020 semester compared to prior semesters and possible reasons for this.
8. Discuss your level of academic performance (e.g., grades and scores) during the Fall 2020 semester compared to prior semesters and possible reasons for this.
9. How do you define "value" relative to higher education, and to what extent have you valued your university education since the start of the COVID-19 pandemic and why?
10. Discuss those college/university experiences that you have not been able to experience since the start of the COVID-19 pandemic that you *most* want to be able to experience again.

Table 2. Focus Group Coding Scheme

Campus Presence (Q1–Q4)	**Perceived Value (Q9)**
Limited in-person instruction available/offered	Declined due to career preparation
Never went to campus at all	Declined due to hands-on learning or lab activity
Went to campus only handful of times	Declined due to extra-curricular activities/clubs
Only went to campus for lab, makerspace, software, or facility use or to TA	Declined due to access to campus facilities & resources (i.e., makerspaces, art spaces, labs, computer labs, campus-only based software, printers)
Conveniences of not being on campus, including use of equipment at home, not having to wear a mask, or not having to use Zoom in the classroom	Declined due to collaboration, social interaction, connections
Health and safety concerns	**Experiences Missing (Q10)**
Very few other students in class so why attend?	In-person group work or collaboration
Stressors (Q5)	In-person instruction and being in class
Missing peer support for coursework	Hands-on lab work
Lack of academic motivation, including tasks taking longer and distractions	Fun or social campus activities, including sports events
Motivation (Q6)	Use of campus resources and facilities
Low or decreased	**Helpful/Beneficial**
Learning & Academic Performance (Q7-Q8)	Zoom recordings
Learning declined	Open book/notes exams
Group work suffering	**Concerns**
Senior design experience negatively impacted	Remote learning negatively impacting mental health or resulting in isolation or not leaving one's residence
Performance or learning not impacted by remote instruction	
Performance or learning better with remote instruction	

the main highlighted categories of campus presence, stressors, motivation, etc. were the coding categories. The main highlighted categories served to organize the coding scheme and coincided with the focus group questions. The emergent coding scheme in Table 2 is shown in two columns simply for display efficiency. Two analysts (i.e., the first and fourth authors) conducted the content analysis by independently reviewing all focus group notes using the coding scheme to identify the presence (or not) of each sub-category. They then discussed the codes they assigned and made final coding decisions based on consensus. The focus group data was therefore double-coded by two analysts. Their first-time interrater reliability was Cohen's κ = 0.68, indicating fair initial agreement [60].

4. Results

4.1 Survey Respondents

Given the large response rate, the survey responses were highly representative of the school's undergraduate engineering population from a demographic standpoint. Survey responses were received from 21.5% first-year, 27.0% sophomore, 22.5% junior, and 29.1% senior students. In addition, we received data representative of the distribution of the various majors, genders, and AHNH students in the engineering school. An AHNH student is any student who identified with one or more of the following races/ethnicities: African American/Black, Hispanic, Native American/Alaska Native, or Hawaiian/Pacific Islander. Use

Table 3. MUSIC Model Results in Fall 2020 of All Survey Respondents

MUSIC Dimension	Average (n = 1,147)	*sd*
Empowerment	3.95	0.97
Usefulness	4.49	0.83
Success	4.09	1.03
Interest	3.48	0.97
Caring	4.68	0.79

Note: 1–6 scale

of the abbreviation AHNH, versus possibly that for under-represented minority, has been suggested in the literature as preferable [61]. Although we recognize that calls are being made to disaggregate race and ethnicity data, the AHNH students were grouped given existing engineering education data practices that identify each as under-represented in the engineering workforce compared to the U.S. adult population [62, 63]. This workforce representation variable was of interest in our study. Also, examining ethnicities or races individually was problematic given the small sample sizes. Of the survey responses submitted, 62% were from male students, 38% were from female students, and 10% were from AHNH students.

4.2 Motivation

The average scores for the five MUSIC dimensions are shown in Table 3 for all undergraduate engineering respondents. The MUSIC Model uses a 1-6 scale, with a higher score indicating higher levels for the motivation dimension. The middle of the scale is therefore 3.5, and so the *interest* dimension, which indicates the degree to which the coursework is engaging and holds the student's interest, was below the scale midpoint at 3.48. The *empowerment* dimension, which indicates the degree to which students feel they can make decisions about their learning and have some control and flexibility, was somewhat above the middle of the scale at 3.95. These two motivational dimensions were thus of concern since their averages were only near the middle of the scale. Based on informal communication with the developer of the MUSIC Model, scores above 5 are a desirable benchmark (Personal Communication with Brett Jones, 2020). Note that although n = 1,140 students completed the survey in its entirety, Table 3 contains additional responses from partially-completed surveys. The Cronbach's alpha values associated with our sample were α = 0.885, α = 0.903, α = 0.914, α = 0.896, and α = 0.879 for the dimensions of empowerment, usefulness, success, interest, and caring, respectively. These suggested good reliability with engineering students [60].

The average MUSIC dimension scores for the seniors were lower than those for our first-year students. In addition, the seniors' *interest* and *empowerment* dimensions were only near the scale midpoint of 3.5. Based on an independent samples z-test for large samples, there were significant differences in the means of first-year students versus seniors for the dimensions of *empowerment, usefulness*, and *interest*, as shown in Table 4 [50]. Further, the differences remained significant even after application of the highly-conservative Bonferroni correction for multiple comparisons [64]. For *empowerment, usefulness*, and *interest*, the values for Cohen's d were 0.38, 0.46, and 0.46, respectively, with the latter two approximating medium effect sizes [51–53].

Although national norms do not exist for the MUSIC Model, studies with the MUSIC model have been done with first year and senior engineering students with the use of game-based learning and are included in the last two columns of Table 4 for comparison purposes [65, 66]. For seniors in the present study, the dimensions of *empowerment* and *interest* were well below those of the comparison group, as shown in Table 4.

The findings from the MUSIC Model were triangulated by results from a Likert Scale question. We asked those respondents who were enrolled in the Spring 2020 semester (before the pandemic) to compare their current motivation level to their pre-pandemic level. These students were generally sophomores, juniors, and seniors and were a subset of the total survey respondents of n =

Table 4. MUSIC Model Results in Fall 2020 from First-Year & Senior Survey Respondents

MUSIC Dimension	First-Year Average (n = 253)	Senior Average (n = 332)	p	Cohen's d effect size	First-Year Comparison (n = 150)	Senior Comparison (n = 200)
Empowerment	4.24	3.88	< 0.0005	0.38	4.31	4.72
Usefulness	4.69	4.32	< 0.0005	0.46	4.11	4.41
Success	4.28	4.18	0.185	0.10	4.83	4.85
Interest	3.80	3.37	< 0.0005	0.46	3.80	4.90
Caring	4.80	4.71	0.439	0.12	5.13	4.85

Standard Deviations for Empowerment, Usefulness, Success, Interest, and Caring, respectively: First-Year: 0.89, 0.75, 0.99, 0.91, 0.68; Seniors: 1.01, 0.86, 1.02, 0.97, 0.81.

Table 5. Academic Motivation in Fall 2020 of Survey Respondents vs. Before Remote Instruction

Response	% of Respondents	Respondents
Much less now	43.6%	405
Less now	34.2%	317
About the same	16.6%	154
More now	4.6%	43
Much more now	1.0%	9
Total	100%	928

1,140. As shown in Table 5, approximately 78% of respondents said their motivation was *less* or *much less* compared to before the switch to remote instruction. Thus, decreased motivation was a pervasive problem during the Fall 2020 semester seven months after the onset of the pandemic and the changed instructional environment.

If students rated their academic motivation as decreased, they were asked to select the top three reasons for their decreased motivation. *Remote (not-in-person) coursework that was less engaging* received the greatest number of responses at 561, or 26.4% of the responses. *Mental health issues* (e.g., anxiety and depression) was second, associated with 12.0% of the responses (255 responses), and *Living at home*, where study and home environments were not separate, was associated with 9.8%, or 207 responses. The top-ranked demotivating reasons are given in Table 6, in which *Diminishment of enjoyable campus activities* ranked 4th (9.6% of responses) and *Physical separation from instructors* ranked 5th (9.2%). The remaining reasons (in order of ranking) were as follows: diminished extra-curricular activities, physical separation from peers, change in routine, remote access issues, diminished co-curricular opportunities, and COVID-specific issues. De-motivators specific to the COVID-19 pandemic represented only 2.4% of the responses. Of those students who provided reasons for their decline in motivation, 96% selected three reasons for it, and an additional 3% of students selected two reasons.

4.3 Learning

Motivation impacts learning and academic performance [14, 20]. When asked in the Fall 2020, *How do you rate your learning now versus before the switch to remote instruction*, students responded as shown in Table 7. Thus, the decrease in motivation was accompanied by a perceived decrease in learning, with approximately 71% of respondents indicating their learning was less or much less now.

4.4 Valuation of Education

We asked those respondents enrolled during the Spring 2020 (prior to the pandemic) the degree to which they valued their University education in the Fall 2020 versus before the switch to remote instruction. As shown in Table 8, approximately 63% of respondents said their university education was less or much less valuable to them versus before the switch to remote instruction.

When students were asked to indicate their top three most-valued college experiences, *Campus-based, in-classroom instruction* was associated with the greatest number of responses at 621, or 22.5% (Table 9). *Social interaction or fun activities* received

Table 6. Reasons for Loss of Motivation for Survey Respondents (Fall 2020)

Rank	De-Motivating Reason	% of Responses	Responses
1	Coursework remote and not in-person, resulting in less engagement	26.4%	561
2	Mental health, including anxiety, depression, etc.	12.0%	255
3	Living at home; study/home life not separate; non-ideal study environment	9.8%	207
4	Enjoyable or fun campus activities diminished (e.g., social activities, sporting events, musical/artistic/cultural events, gym exercise, etc.)	9.6%	204
5	Physical separation from instructors or T.A.s, possibly impacting assistance, help, test-taking, etc.	9.2%	195

Table 7. Learning in Fall 2020 of Survey Respondents vs. Before Remote Instruction

Response	% of Respondents	Respondents
Much less now	24.9%	231
Less now	46.2%	429
About the same	21.8%	202
More now	6.1%	57
Much more now	1.0%	9
Total	100%	928

Note: sophomores to seniors.

Table 8. Valuation of University Education in Fall 2020 of Survey Respondents vs. Before Remote Instruction

Response	% of Respondents	Respondents
Much less valuable to me now	15.1%	140
Less valuable to me now	48.1%	446
About the same	31.3%	290
More valuable to me now	4.0%	37
Much more valuable to me now	1.6%	15
Total	100%	928

Note: sophomores to seniors.

Table 9. Impact on Top Valued College Experiences of Survey Respondents (Fall 2020)

Rank	Valued University Experience	% of Responses	Average Impact (1–5; 1 = highly negatively)	Responses
1	Campus-based, in-classroom instruction, including peer interactions	22.5%	1.57	621
2	Social interaction or fun activities with other students (e.g., hanging out, parties, shared meeting spaces, study groups, recreation/exercise, campus traditions, etc.)	13.8%	1.45	382
3	Co-op, internship, engineering work experience, campus research, teaching assistant position (T.A.), tutoring position	10.5%	2.39	291
4	Student clubs, organizations, societies, programs (e.g., fraternity/sorority, student government, SWE, French Club, etc.)	9.7%	1.90	269
5	Meeting new people or making new friends/connections	8.3%	1.56	229

13.8%, or 382, of the responses, followed by *Co-op, internship, campus research* at 10.5% (291 responses). The remaining valued college experiences not shown in Table 9 in order of ranking were as follows: interaction with faculty/staff, living on/near campus, team-based project work, athletics participation, campus resources, job/volunteer work, study abroad, artistic performance, attendance at sporting events, and attendance at artistic performances. Of those students who indicated their most-valued experiences, 96% identified three experiences, and an additional 3% of students identified just two experiences.

Although the various college experiences were valued to different degrees by the students, all were negatively impacted by COVID-19 and its safety concerns in the eyes of the students. The average impacts are also given in Table 9 for students' top-valued experiences. The impact was measured on a 1 to 5 scale, with 1 = highly negatively, 2 = negatively, 3 = not at all, 4 = positively, and 5 = highly positively. For example, the impact on the top-ranked experience (i.e., *Campus-based instruction*) was 1.57 (i.e., between highly negatively and negatively impacted). All other experiences had an average impact score of 2.40 or less, with *Living on or near campus* having the most-positive score of 2.40.

4.5 Stress

On the PSS-10, respondents had an average score of 22.2 (sd = 6.8) and a median score of 22 out of a possible 40. This was based on n = 1,122 respondents. Cronbach's alpha was α = 0.89 for this sample, which suggested good reliability with engineering students [60]. For the sample associated with females, α = 0.87, and for males, α = 0.89. The average score was higher for females versus males (24.3 vs. 20.9, respectively). Based on an independent samples z-test for large samples, the difference in mean PSS-10 scores between female and male students was significantly different from zero ($p < 0.0005$). Cohen's d = 0.53, pointing to a medium effect. For AHNH vs. non- AHNH students, the average scores were very similar at 22.5 vs. 22.2, respectively. The PSS-10 comparison studies will be reviewed in the Discussion section with respect to our results.

When asked about their top stressor during the Fall 2020, the overwhelming response was *Academic*, associated with 61.4% of respondents (Table 10). This category was related to items such as assignments, exams, grades, due dates, workload, study habits, and time management. *Future uncertainties* (e.g., career-related) was the greatest stressor for 11.7% of respondents, *Personal*

Table 10. Top Stressors of Survey Respondents (Fall 2020)

Rank	Top Stressor	% of Respondents	Respondents
1	Academic (assignments, exams, grades, due dates, course workload, study habits, time management, etc.)	61.3%	698
2	Future uncertainties (career, major, finding a job, graduate school decision/acceptance, etc.)	11.7%	133
3	Personal matters (alcohol/drug use, addiction, physical health, mental health, loneliness, physical appearance, self-image, self-imposed pressure, worrying, etc.)	7.3%	83
4	Relationship/Interpersonal (family, parental expectations/pressure, romantic, roommate, peers, other students, instructors, supervisor, staff, etc.)	5.2%	59
5	Pandemic/COVID-19 specific (issues specific to the COVID-19 global pandemic)	4.9%	56

Table 11. Differences in Top Stressors of Survey Respondents by Gender (Fall 2020)

Stressor	Female (n = 432)	Male (n = 706)	p	Odds Ratio
Academic	61.6%	61.2%	0.90	1.02
Future Uncertainties	9.2%	13.1%	0.038	1.49
Personal Matters	8.1%	6.8%	0.42	1.21
Relationship/Interpersonal	5.1%	5.2%	0.91	0.97
Pandemic/COVID-19 specific	5.1%	4.8%	0.84	1.06

Table 12. Differences in Top Stressors of Survey Respondents by Representation in Engineering (Fall 2020)

Stressor	AHNH (n = 107)	Non-AHNH (n = 1031)	p	Odds Ratio
Academic	62.6%	61.2%	0.77	1.06
Future Uncertainties	8.4%	12.0%	0.21	1.49
Personal Matters	7.5%	7.3%	0.94	1.03
Relationship/Interpersonal	5.6%	5.1%	0.84	1.10
Pandemic/COVID-19 specific	2.8%	5.1%	0.48	0.53

Table 13. Correlations between Study Variables

	Usefulness (MUSIC)	Success (MUSIC)	Interest (MUSIC)	Caring (MUSIC)	PSS-10	Learning (Likert Scale)	Valuation of Education (Likert Scale)
Empowerment (MUSIC)	0.529	0.574	0.623	0.558	–0.416	0.411	0.339
Usefulness (MUSIC)		0.496	0.666	0.544	–0.305	0.363	0.362
Success (MUSIC)			0.645	0.490	–0.549	0.454	0.304
Interest (MUSIC)				0.495	–0.432	0.561	0.489
Caring (MUSIC)					–0.372	0.278	0.230
PSS-10						–0.335	–0.280
Learning (Likert Scale)							0.517

matters was the greatest stressor for 7.3%, and *Relationship/interpersonal* was greatest for 5.2%. Stressors specific to the *COVID-19 pandemic* were reported as the top stressor by only 4.9% of respondents, similar to the reasons for loss of motivation. The remaining top stressors (in order of responses received) were as follows: financial issues, support/time constraints, transition/change, and environmental, which were described in literature review section 2.4.2.

We investigated differences in the proportion of the top stressors in Table 10 by gender. *Future uncertainties* were more prevalent for males, and *Academic* and *Personal matters* were more prevalent for females. Based on a difference in proportions z-test, there was a statistically significant difference in the proportions of the *Future uncertainties* stressor ($p = 0.038$) by gender, as shown in Table 11. The odds ratio was 1.49, which indicates a small effect.

Likewise, we investigated differences in the proportion of the top stressors in Table 10 by the representation-in-engineering variable, as operationalized by comparing AHNH students to non-AHNH students. *Future uncertainties and COVID-19 specific* stressors were more prevalent for non-AHNH students. Based on difference in proportions tests, there were no significant differences by representation-in-engineering, as shown in Table 12. However, the odds ratios for *future uncertainties* and *COVID-19 specific* stressors were 1.49 and 0.53, respectively.

4.6 Correlations in the Conceptual Model

An analysis of the relationships between the variables in our conceptual model, including those from the MUSIC Model and PSS-10, was done using a bivariate correlational analysis . Pearson's r was calculated as the measure of correlation. The variables in Table 13 consist of the five components of the MUSIC Model of Motivation, the PSS-10 scale score, and Likert-scale variables for perceived learning and valuation of education during the pandemic versus beforehand. The correlations in Table 13 were all non-zero statistically ($p < 0.0005$) and remained significant after applying the Bonferroni correction for multiple comparisons.

Each MUSIC Model construct measures a particular aspect of motivation, as evident in the positive pairwise correlations between them in Table 13, which were each minimally of medium effect size [56]. The correlations between each MUSIC Model

construct and perceived learning were also positive and at least of medium effect size, which aligns with Jones' model of the impact of motivation on learning [14]. The correlations between each MUSIC Model construct and the PSS-10 score were each negative and at least medium in effect size. Thus, as all aspects of motivation decreased, perceived stress increased, in accordance with the conceptual model. Negative correlations were also found between perceived learning and the PSS-10 score as well as between valuation of education and the PSS-10 score. Since the most-frequently-mentioned reason for loss of motivation was *Less-engaging remote coursework* and the most-valued college experience was *Campus-based instruction*, the finding that *Academics* was the top stressor supports the conceptual model.

4.7 Focus Group Results

In alignment with the focus group questions (Table 1), student responses were grouped into the categories of campus presence, stressors, motivation, learning and academic performance, perceived value, missed college experiences, and other benefits and drawbacks. In *all six* focus groups, the following items were mentioned and discussed by students: (1) conveniences resulting from not having to go to or be on campus, (2) limited in-person instruction, (3) low or decreased motivation, and (4) missing of fun or social campus activities.

4.7.1 Convenience and On-campus Presence

The conveniences resulted from not having to commute to campus or find parking, especially for 8AM classes or during bad weather; not having to wear a mask; not having to find quiet campus space to view remote classes between their in-person classes; ability to live at home with family or in other locations; time and money savings; and the use of computer equipment and Zoom at home. In five of the focus groups, students discussed going to campus only for lab work, makerspace or other facility use, software use, or as part of teaching assistant duties. Students described never going to campus at all in four of the groups and/or only a handful of times in five of the focus groups. Health and safety concerns were discussed in four of the groups as a reason that limited students' on-campus presence. Another factor that limited student presence, as discussed in three focus groups, was the fact that their peers were not attending in-person, so why attend a class with just a few other students?

4.7.2 Motivation

The low or decreased motivation discussed in all six focus groups triangulated the motivation results from the Fall 2020 survey, in which approximately 78% of survey respondents said their motivation was *less* or *much less* compared to before remote instruction. The perplexing finding is that students discussed various convenience, personal-choice, or low-hurdle issues (beyond health concerns) as to why they didn't attend class in-person when they could have. For example, "*By not going to campus, it saves time*," and "*If I stay home, I can have coffee and a snack and not worry about having to remove my mask to have them.*" Yet, during the focus groups, they also frequently discussed feelings of low or decreased motivation and had previously identified their top de-motivator as *coursework remote and not in-person, resulting in less engagement* (i.e., 26.4% of responses in Fall survey, Table 6).

Further, students discussed in four of the six focus groups that remote learning was negatively impacting their mental health or contributing to isolation by not requiring them to leave their residences. In the Fall survey, students had identified their most-valued university experience as *campus-based, in-classroom instruction, including peer interactions* (22.5% of responses, Table 9). Thus, why not attend in-person when feasible to do so? Unfortunately, these findings paint a difficult picture of students' mindset during the middle phases of the pandemic-induced remote learning. For example, "*. . . my mental health is taking a dive by being remote. I like to walk to and between classes. There is no physical break between classes. However, my own 'self' is telling me that I need to start going to campus.*"

4.7.3 Stressors and Missed Experiences

In alignment with students' top stressor being related to *academics* (61.3% of survey respondents, Table 10), *missing peer support for coursework* was discussed most often during the focus groups as a stressor (i.e., 3 of 6 focus groups). Interestingly, a lack of academic motivation was discussed as a stressor in two of the groups, further demonstrating a connection between motivation and perceived stress in alignment with the conceptual model. For example, a student responded to focus group question 5 about top stressors as follows:

> "I have a lack of motivation from always working at home. I tend to do chores instead of my coursework. I have a lack of motivation from not seeing people and from being trapped in my house. A coursework task that should take one hour now takes three hours, and this causes stress."

Social interaction and fun activities were second in line to campus-based instruction as a most valued university experience in the Fall survey (13.8% of responses, Table 9). In line with this, *fun or social campus activities including sporting events* were discussed in all six focus groups as a missed uni-

versity experience. For example, "*I would like to have that camaraderie with students who are taking the same courses as me. I would like to go to lunch with them, and I want social activity and networking.*" Also discussed as a missed experience in four of the groups was the *use of campus resources and facilities* and *in-person group work or collaboration*. Finally, *in-person instruction and being in class* was a missed experienced discussed in three of the groups.

4.7.4 Perceived Value

Perceived value had decreased based on the focus group discussions, in line with the survey results in which 63% of respondents said their university education was *less* or *much less* valuable versus before remote instruction. The following were each discussed in two of the groups in relation to a decline in perceived value: (1) hands-on learning or lab activity, (2) career preparation, and (3) extracurricular activities. For example, "*Value involves the ability to be prepared for one's career and be effective in the workplace later. This has dropped off.*" Also, "*Value was lost with labs and hands-on activity as well as with extra-curricular activities and clubs that involved physical activity (e.g., rock climbing club).*" Further, the following were discussed in three of the groups relative to a decline in value: (4) access to campus facilities and resources including computer labs, printers, and maker-type spaces, and (5) collaboration, social interaction, and connections. Sadly, during the focus groups, students frequently discussed making no new friends or connections during the period of remote instruction.

4.7.5 Learning

Interestingly, although learning was perceived as decreased per the survey results (i.e., 71% of respondents, Table 7), it was actually discussed in a mixed fashion during the focus groups. During the focus groups, learning was discussed by students in all of the following ways: declined (4 groups), better with remote instruction (5 groups), and not impacted by remote instruction at all (5 groups). The senior design experience was discussed as negatively impacted (2 groups) as was group work in general (2 groups). For example, "*Group work is almost gone. We just split up the work and do it separately, so that we don't have to schedule Zoom meetings.*"

In relation to their learning and performance, students discussed in four of the groups that Zoom class recordings were helpful and beneficial, and they hoped recordings would be made available to them going forward. In addition, open-note/open-book exams were perceived as beneficial both in terms of study processes and the enhanced level and type of testing that resulted, with student hopes of continued use (3 groups). For example, "*Open-notes exams require more critical, deep thought now, and I value this.*" It's possible that many solutions implemented during the pandemic in higher education may indeed continue and endure [67].

5. Summary and Discussion

In the present study, a large sample of all undergraduate students from a school of engineering at a public U.S. university with very high research activity was studied in the middle phases of the COVID-19 pandemic. This was done during the Fall 2020 and Spring 2021 semesters with a focus on academic motivation, learning, valuation of university experiences, and perceived stress. The present study was situated within the larger, emerging literature base of COVID-era studies and pre-COVID educational studies on perceived stress and academic motivation. The conceptual model for this study consisted of the MUSIC Model of Academic Motivation and its impact on learning and performance. The Perceived Stress Scale was also a component of the conceptual model, since impediments to one's goals, such as loss of motivation, can induce stress [14, 15].

Student motivation was a significant concern associated with remote teaching and learning during the COVID-19 pandemic, and as our results indicate, intentionally cultivating motivation among students may be a desirable, if not necessary, action at such unprecedented times [22]. Averages for the *interest* and *empowerment* dimensions of the MUSIC Model of Motivation were only near the middle of the measurement scale (i.e., 3.48 and 3.95, respectively). Seventy-eight percent (78%) said their motivation was less or much less compared to before remote instruction, and 71% said the same about their learning. Although the PSS has been used and studied extensively, the MUSIC Model of Motivation was developed more recently and has not been used or tested with a large sample of engineering students from the first through senior years. Specifically, the MUSIC Model was previously studied with students in pharmacy, veterinary medicine, undergraduate business courses, undergraduate STEM courses, middle and high-school music courses, and elementary classrooms, but studies with engineering studies were less evident upon a search of the literature [68–73]. Thus, the present study makes an important contribution to the engineering education literature regarding the use and testing of the MUSIC Model.

With regard to valued experiences, students rated *Social interaction or fun activities* and *Professional experiences* (e.g., co-op jobs, internships, etc.) as the

second and third most-valued experiences, respectively, with negative impacts to both due to COVID. College students have experienced disrupted social lives as a result of the pandemic, including having to return home after establishing independence as part of college life [8].

Based on the Perceived Stress Scale (PSS-10), students experienced higher perceived stress seven months into the pandemic compared to other undergraduates before the switch to remote instruction. Relative to studies of undergraduate students prior to COVID in the literature, the students in the present study scored higher on average (at 22.2) on the PSS-10 [37, 38, 49]. These average PSS-10 scores before COVID ranged from 18.3 to 19.8. Upon comparing our PSS-10 average to those from the pre-COVID studies, Cohen's *d* effect sizes of 0.37, 0.49, and 0.59, respectively, were obtained, with the latter two signifying medium effect sizes. Female students in our study had a significantly higher PSS-10 score than male students. A higher PSS score for females is often seen in the literature [18, 34, 37, 38]. *Future uncertainties*, including career-related, were the second-ranked stressor. STEM students have experienced particular difficulties during COVID in the loss of internships and research opportunities, completion of research projects, and uncertain employment futures [9].

Further, *Personal matters* was the third-ranked stressor, while *Mental health* was the second reason for loss of motivation. Research is quickly emerging on the mental-health and psychological impacts of COVID-19 on college students. Recent studies have documented significantly greater depression and anxiety symptoms among college students at the outset of the pandemic compared to beforehand as part of existing longitudinal studies [74, 75].

A correlational analysis supported and demonstrated the study's conceptual model. The correlations between each of the MUSIC Model constructs and perceived learning and educational valuation were all positive and of medium effect size. The correlations between each MUSIC Model construct and the PSS-10 score were negative and at least of medium effect size. Thus, as all aspects of motivation decreased, perceived stress increased. Since the most-frequently-mentioned reason for loss of motivation was *Less-engaging remote coursework* and the most-valued college experience was *Campus-based instruction*, the finding that *Academics* was the top stressor supports the conceptual model of this study.

In the focus groups, the topics or themes discussed most frequently (i.e., in all six groups) coincided with and triangulated the survey results. These most-frequent focus group topics were as follows: (1) limited in-person instruction, (2) low or decreased motivation, (3) missing of fun or social campus activities, and (4) conveniences resulting from not having to go to or be on campus. Unfortunately, topics 1 and 4 above each contributed to the limited campus presence by students, which was necessary to experience their most-valued college activity – *Campus-based instruction with peers*.

Thus, as educators, we must keep college student experiences and challenges in mind during unprecedented times and exhibit awareness, flexibility, understanding, empathy, and action [76]. Given the concerning results of this research study and the importance of taking action, our institution began to conduct weekly wellness checks during the Spring 2021 with students (both undergraduate and graduate) via the Qualtrics survey system to identify students in need of additional support or a caring ear. This one-minute, simple questionnaire contained two questions and a supportive message from the Associate Dean. If students indicated difficulties in managing their academic or personal lives at the time, they were provided with options for health-care resources, including resources directly available in the School of Engineering. Students who indicated difficulties also received follow-up contact from an undergraduate coordinator or professional staff member to determine if further help was needed. Regular check-ins "tell" students they are not alone and that support is available. Electronic check-ins can remind or inform students of these resources and establish a line of communication. Thus, higher education institutions can use software to reach out to a large number of students simultaneously to obtain feedback or warnings about distress and/or disengagement. Feedback and information from students may be more important than ever during times of crises or significant change.

Considering this further, formal mental health education and training may be desirable for *all* students in higher education, including as part of the required curriculum, and mental health care should emphasize not only coping but prevention and resilience ([76]. In direction relation to this, COVID has created the need for adaptations in mental health care, including new practices in the field of clinical psychology, as advocated in the *American Psychologist* article co-authored by a myriad of psychologists and psychiatrists at U.S. universities [8]. Fortunately (or perhaps unfortunately), reforms often come about due to crises [1]. Interventions should be early, holistic, and address gender differences, which we found were significant for perceived stress during this unparalleled, extraordinary time in our global history [4].

5.1 Limitations

Self-selection bias, in particular with regards to the focus group participants, was a limitation of this study [77]. Students who felt motivated to participate in the focus groups may have differed from the larger population with regards to this key variable, although a lack of academic motivation was discussed in all six focus groups. A relatively small number of students volunteered to participate in the focus groups, which may have resulted (in part) from the need for virtual groups via Zoom. Students were experiencing fatigue with virtual meetings over Zoom [78]. Unfortunately, we also found students to be less talkative in these Zoom-based focus groups versus during pre-COVID, in-person focus groups.

In asking respondents to compare their motivation, learning, or valuation in the Fall 2020 versus before the onset of COVID, there was an approximate seven-month difference in the time periods. Thus, some recall bias may have existed, although the question didn't ask students to estimate their levels prior to COVID but rather compare the two periods on a 5-point scale. A before vs. after (paired comparison) study would have been optimal. However, this would have required anticipating the *impact* of the COVID pandemic in February 2020 and collecting similar data at the time, before COVID impacted U.S. universities in March 2020. However, nobody could have anticipated the degree of societal disruption due to COVID-19 [1]. Further, when asking students to compare their learning, we overlooked reminding them of the numerous aspects that comprise their learning, which may have impacted their responses. These aspects include foundational knowledge, higher-level thinking, problem solving (including design and hands-on work), and professional skills (e.g., teaming, communication, judgment, ethical reasoning, etc.) [79, 80].

Although it was not ideal that the PSS-10 comparison studies were mainly of students from other countries and cultures, these were the studies available at the time. We included them to provide at least some context for our findings. Our results may be generalizable only to other engineering or STEM students at public universities in the U.S. and beyond, although this represents a considerable number of students. Finally, since the university data warehouse provides options for gender of male, female, and unknown, this may have limited our analysis of students identifying as non-binary or transgender.

6. Conclusions

The results of this study suggest an environment during the remote instructional period of COVID-19 characterized by decreased academic motivation, decreased educational valuation, decreased learning, and increased perceived stress. The top valued college experience, de-motivating reason, and stressor each related to the academic lives of students, with the first two directly relating to instruction that was not in-person nor on-campus. Students had trouble remaining motivated and engaged during remote instruction, and they missed in-person interactions with their peers in the classroom and with group work. This study adds to the literature on the use of the Perceived Stress Scale (PSS-10) and MUSIC Model of Motivation with undergraduate students (and in particular engineering students) during an unprecedented time of global crises.

It is important to research student experiences and mindsets during times of crisis, since knowledge gathered during such times provides a foundation and jumping-off point for managing crises in the future. In addition, the student experiences and challenges uncovered in this research were already situated within a backdrop of inherent or existing challenges for college students. The literature describes college students as inherently vulnerable with respect to mental health, and the emerging literature describes the negative mental-health and psychological impacts of COVID-19 on college students. In addition, STEM students have experienced professional-related disappointments as the result of COVID, such as cancellation of co-op opportunities or internships.

The need to solicit student concerns and difficulties, express care and empathy to them, and potentially take further supportive actions in times of change and/or social disruption may be the *key* takeaway for educational administrators from studies of the instructional period during the COVID pandemic. This study contributes to this emerging body of higher education literature, and in particular with regard to engineering students. It can serve to inform educators during our ongoing struggle with COVID as well as during future crises.

Acknowledgements – We wish to thank undergraduate researchers Veronica Radin, Yiqi (Verna) Tian, and Alex Cohen for their contributions to the initial phases and design of this research. This research was also made possible by the Engineering Education Research Center (EERC) in the Swanson School of Engineering at the University of Pittsburgh.

Funding – This work was supported by the National Science Foundation Award No. 1830735, Supplement Amendment 2042620.

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