Paper ID #38355

Examining STEM Learning Motivation Challenges in Undergraduate Students During the COVID-19 Pandemic

Andrea Nana Ofori-boadu (Dr.)

Dr. Andrea Nana Ofori-Boadu is an Associate Professor of Construction Science and Management with the Department of Built Environment within the College of Science and Technology at North Carolina Agricultural and Technical State University. Her passion is to utilize her God-given talents to advance sustainability in construction materials, processes, and workforce development. Andrea has over 20 years of occupational experience, with her most recent experience being in teaching, research, and service. Dr. Ofori-Boadu is a dedicated instructor, advisor, mentor, and role model who has served over 1,500 undergraduate and graduate students. Andrea has received almost $2M from funding agencies to include the National Science Foundation (NSF), the Engineering Information Foundation (EIF), the National Association of Home Builders (NAHB), the National Housing Endowment (NHE), and East Coast Construction Services (ECCS). In 2019, she received her prestigious NSF CAREER grant to construct substantive theories that explain professional identity development processes in undergraduate architecture, engineering, and construction (AEC) women in the United States. In 2020, Dr. Ofori-Boadu received a National Science Foundation (NSF-RAPID) grant award to gain insights into undergraduate STEM student decision-making processes during pandemics. Through seed funds from North Carolina Agricultural and Technical State University's Department of Education (Title III) and Center of Product Design and Advanced Manufacturing (CEPDAM) grants, she investigated the utilization of agricultural waste bio-chars for partial cement replacement resulting in a patent (U.S. Patent No. 11,104,611; August 31, 2021). Her research work has resulted in numerous citations, publications, presentations, and website references such as on the International Bio-char Initiative website. In 2021, Dr. Ofori-Boadu was chosen by the NC A & T Center of Excellence for Product Design and Advanced Manufacturing (CEPDAM) to showcase her research work in a promotional video series named "Women in Design and Manufacturing" during the Women's History Month. Andrea has received several teaching, mentoring, and research excellence awards to include the 2021 Outstanding College of Science and Technology Faculty STEMinist Mentoring Award, the 2020 National Association of Home Builders (NAHB) Outstanding Educator Award, the 2020 NC A & T Junior Faculty Teaching Excellence Award, and the 2019 NC A & T Outstanding Young Investigator Research Excellence Award. Dr. Ofori-Boadu is currently the Director of the year-round Professional Development Program for undergraduate Architecture, Engineering, and Construction women and the STEAM ACTIVATED! Program for middle-school girls at NC A & T. Andrea is married to Victor Ofori-Boadu and they are blessed with three wonderful children.

Rabiatu Bonku

Alesia Ferguson

Mercy Folashade Fash

Jennifer Richmond-Bryant (Associate Professor of the Practice)

Examining Learning Motivation Challenges (LMCs) Experienced by Undergraduate STEM Students during the COVID-19 Pandemic

Abstract:

The COVID-19 pandemic disrupted global educational systems with institutions transitioning to e-learning. Undergraduate STEM students complained about lowered motivation to learn and complete STEM course requirements. To better prepare for more effective STEM education delivery during high-risk conditions such as pandemics, it is important to understand the learning motivation challenges (LMCs) experienced by students. As part of a larger national research study investigating decision-making in undergraduate STEM students during COVID-19, the purpose of this research is to examine LMCs experienced by undergraduate STEM students. One hundred and ninety students from six U.S. institutions participated in Qualtrics-based surveys. Utilizing a five-point Likert scale, respondents ranked the extent to which they agreed to LMC statements. Using Qualtrics Data Analysis tools and MS Excel, data from 130 useable surveys was analyzed utilizing descriptive and inferential statistics.

Results revealed that regardless of classification, GPA, age, or race, STEM students experienced LMCs. The top five LMCs were: *(1) Assignment Overloads; (2) Lack of In-Person Peer Interactions; (3) Uncaring Professors; (4) Lack of In-Person Professor Interactions;* and (5) *Lack of In-Person Laboratory Experiences*. Significant relationships existed between three characteristics (GPA, classification, and age) and few LMCs to include assignment overloads. Students tended to attribute lowered motivation to *Institutional* and *Domestic* challenges which were typically out of their control, rather than to *Personal* challenges which were typically within their control. Crosstab analysis suggested that *Sophomores, Asians*, as well as students with *GPAs between 2.00 and 2.49* and aged *41 to 50 years* may be the most vulnerable due to higher dependence on traditional in-person STEM educational environments. Early identification of the most vulnerable students should be quickly followed by interventions. Increased attention towards sophomores may reduce exacerbation of potential sophomore slump and middle-child syndrome. All STEM students require critical domestic, institutional, and personal resources. Institutions should strengthen students' self-regulation skills and provide increased opportunities for remote peer interactions. Training of faculty and administrators is critical to build institutional capacity to motivate and educate STEM students with diverse characteristics in e-learning environments. Pass/fail policies should be carefully designed and implemented to minimize negative impacts on motivation. Employers should expand orientation and mentoring programs for entry-level employees, particularly for laboratory-based tasks. Research is needed to improve the delivery of STEM laboratory e-learning experiences. Findings inform future research, as well as best practices for improved institutional adaptability and resiliency. These will minimize disruptions to student functioning and performance, reduce attrition, and strengthen progression into the STEM workforce during high-risk conditions such as pandemics. With caution, findings may be extended to non-STEM and non-student populations.

Introduction

The COVID-19 pandemic has affected almost 2 billion people in over 190 countries and caused large disruptions to educational institutions [1]. Institutions transitioned to e-learning which presented unique challenges to STEM students as many students complained of lowered motivation to learn and complete STEM course requirements due to COVID-19 related challenges [2][3]. Motivation and achievement play a significant role in academic performance [4]. Thus, being a highly motivated and self-regulated student plays a huge part in succeeding in autonomous e-learning environments [5]. Students who are not motivated will find it difficult, if not impossible to improve academic achievement [6]. Motivation involves the desire to participate in learning processes, which includes being both physically and mentally present. While, learning increases when students are curious, enthusiastic, or inspired, it suffers when students are bored, disinterested, and disillusioned. Learning motivation encompasses psychosocial elements that are both internal to the learner and present in social and natural surroundings [7]. Intrinsic motivation is the drive to achieve because of enjoyment or value [6]. Students who are intrinsically motivated will participate in learning processes for the sake of achieving a goal or overcoming a problem, rather than for external rewards. Motivation is particularly important for STEM students considering the challenging nature of STEM disciplines. Educators agree that it is important to enhance student motivation and involvement through strategies such as experiential learning [7-9].

As part of a larger national research study investigating decision-making processes in undergraduate STEM students during the COVID-19 pandemic, factors that negatively impacted learning motivation and performance in undergraduate STEM students were identified [2][3]. These STEM learning motivation challenges (LMCs) were categorized as: *Online Instructional Delivery Methods; Professor Caring Attitudes; Professor Leniency; Professor Availability; Student Workloads; Professor Technology Proficiency; and Professor Teaching Resources. Learning struggles were categorized as: Illusion of Time, Procrastination; Lack of Focus; Challenge of Asking Questions; Poor Understanding; Poor Quality Assignments; Poor Intermediate Grades; Stresses;* and *Lowered Motivation* [2][3]. To overcome the negative impacts of the COVID-19 pandemic on STEM learning, students implemented adaptation strategies categorized as: *Refined Scheduling; Alternate Learning Resources; Professor Office Hours; Teaching Assistants; Peer Collaboration; Relaxation Strategies;* and *Pass/Fail Options.* Furthermore, improved spring 2020 GPAs were partially attributed to professor leniency, pass/fail options, and cheating [2][3]. Being that [2] and [3] were based on a qualitative study, quantitative studies utilizing larger sample sizes would validate and contribute to the generalization of findings to inform the design and implementation of more targeted interventions to reduce LMCs during future pandemics and similar high-risk conditions.

Purpose and Objectives

As part of a larger national research study investigating decision making processes in undergraduate STEM students during the COVID-19 pandemic, the purpose of this present research was to examine LMCs experienced by undergraduate STEM students during the COVID-19 pandemic. The specific objectives were:

1. To rank LMCs experienced by undergraduate STEM students during the COVID-19 pandemic;
2. To identify the characteristics of undergraduate STEM students who are most likely to experience LMCs during pandemics.

Methodology

Undergraduate STEM students aged 18 years and up from six U.S. institutions were the target population. Institutions included HBCUs, PWIs, and MSIs in different geographical locations. Recruitment involved emailing Qualtrics Survey Distribution links through various university communication systems. The Institutional Review Board approved survey was designed to gain insights into the learning experiences and decision-making processes of undergraduate STEM students during the COVID-19 pandemic. The initial section of the survey requested demographic and academic data to include age, race, GPA, and classification. One of the multiple sections of the survey required respondents to use a 5-point Likert-scale ranging from 1 (strongly disagree) to 5 (strongly agree) to rank the extent to which they agreed to LMC statements. One hundred and ninety (190) students from six U.S. institutions participated in Qualtrics-based surveys. Using Qualtrics Data and Analysis tools and MS Excel, data from 130 useable surveys was analyzed utilizing descriptive and inferential statistics ($\alpha = 0.05$). While means and standard deviations provided summary statistics on key variables, cross-tabulation analysis was used to quantitatively analyze underlying relationships between LMCs and multiple variables. Data tables were utilized to analyze the extent to which sub-groups agreed with LMC statements. The percentage of respondents in each sub-group selecting '*Strongly Agree'* and '*Somewhat Agree'* for each LMC were added to estimate the sub-group's strength of agreement with each LMC. The percentage of respondents in each sub-group selecting '*Strongly Disagree'* and '*Somewhat Disagree'* for each LMC were added to estimate the sub-group's strength of disagreement with each LMC. The Stat Test of Column Averages is a pairwise z-test and was utilized to determine if two data samples are significantly different from each other [10]. The Overall Stat Test of Percentages acts as a Chi-squared statistic and was utilized to test relationships between two variables, with the resulting p-value determining statistical significance [10].

Results

Characteristics of Research Population: Figures 1 to 4 show the characteristics of the respondents to include: GPA (N=190); Classification (N=190); Age (N = 190); and Race (N=189). Majority of respondents were between ages 18 and 25 years and had GPAs ranging between 3.50 and 4.00. Majority of the respondents were African and White Americans. Classification was almost evenly distributed. Due to the self-selection recruitment process, America Indian/Alaska Natives, students aged 50 years plus, and students with GPAs less than 2.00 were not represented in this study. Students with low GPAs are likely to assume that participation is based on high GPAs and therefore opt not to participate. The characteristics of the research population is somewhat like typical undergraduate STEM student populations in the U.S.

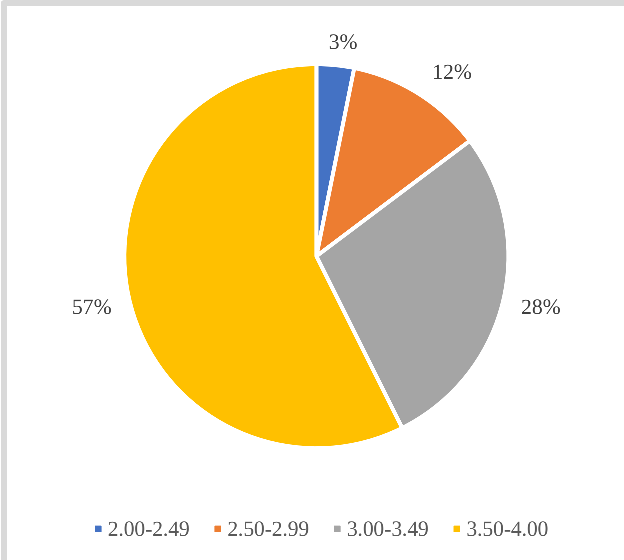

Figure 1: GPA

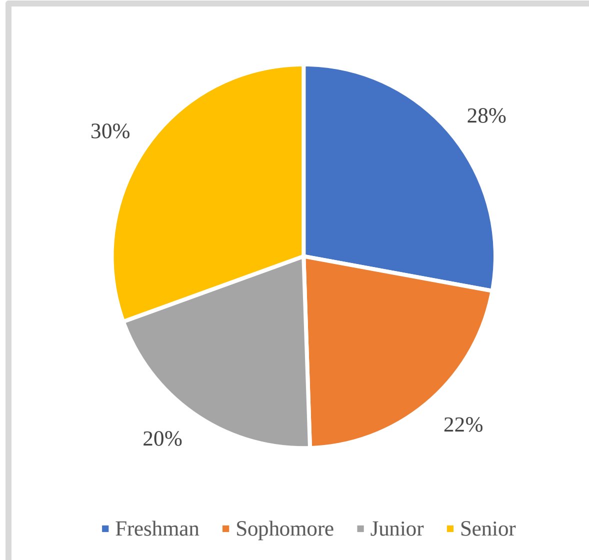

Figure 2: Classification

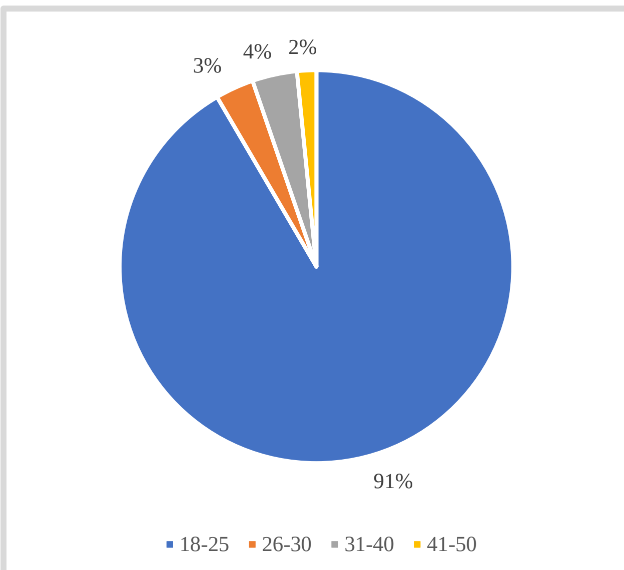

Figure 3: Age

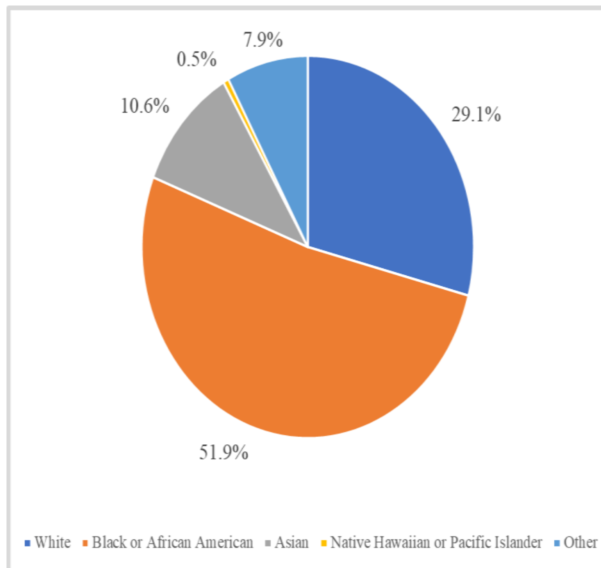

Figure 4: Race

Learning Motivation Challenges (LMCs): As shown in figure 5, the means of all LMCs are greater than 3.00 indicating that respondents mostly agreed that these challenges had negative impacts on their motivation to learn and complete STEM course requirements during the COVID-19 pandemic.

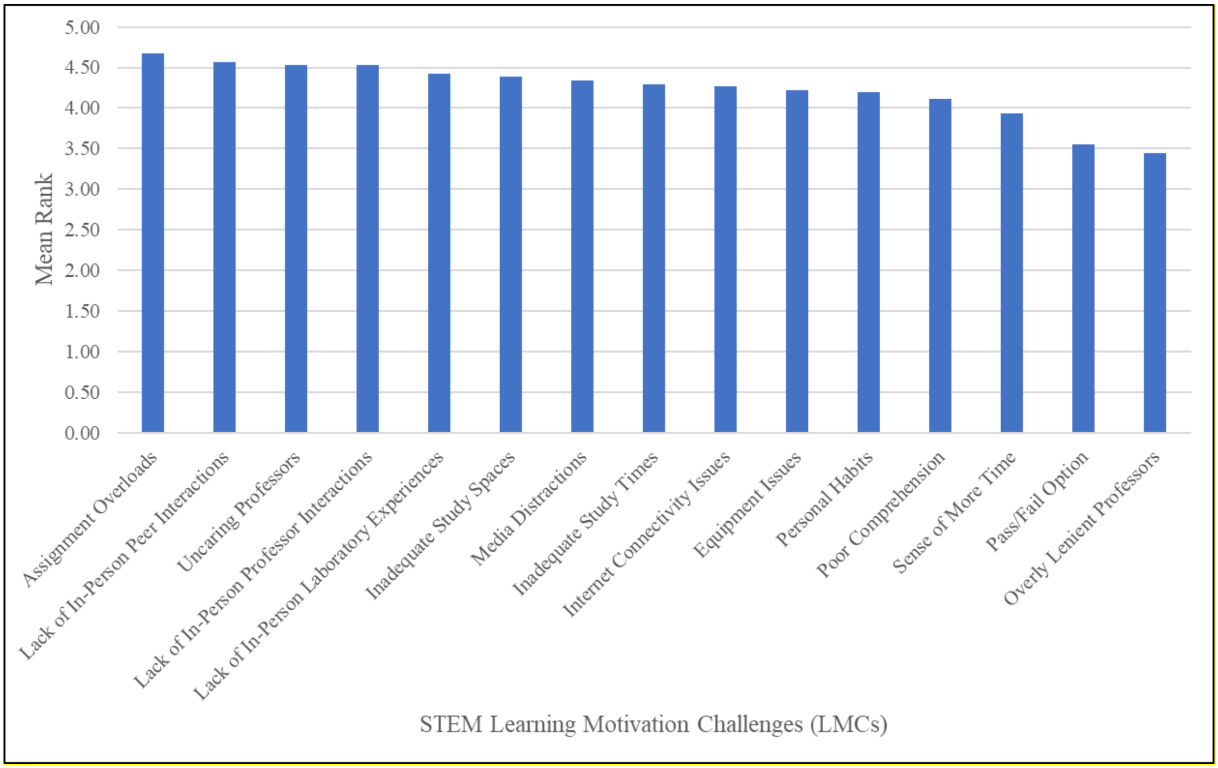

Figure 5. STEM Learning Motivation Challenges

Notably, the first five LMCs involved unfavorable interactions with STEM learning environments and communities. Although only slight differences existed among the means, *assignment overloads* emerged as the most frequent challenge indicating that most respondents felt overwhelmed with assignments. Furthermore, with e-learning, respondents felt isolated from peers and professors. Restricted interactions lowered learning motivation as some respondents did not even feel like asking questions [3]. *Uncaring professors* worsened learning experiences as respondents sensed their lack of concern [3]. Considering that hands-on and experiential learning is critical in STEM education, laboratory e-learning experiences was demotivating. Physical and technical limitations associated with *inadequate study spaces, study times, internet connectivity, and equipment* made learning cumbersome in domestic environments. With these significant differences between pre-COVID (in-person) and COVID (e-learning) environments, respondents struggled to stay motivated, especially if they frequently had a *sense of having more time*. Respondents struggled with *media/social media distractions, poor comprehension*, and *personal habits*. Notably, the *pass/fail* option and *overly lenient* professors received the lowest means as fewer respondents agreed that these two LMCs had negative impacts on motivation. After all, they provided pathways that eased learning experiences and minimized negative impacts on grades.

LMC Categories: Further categorization yielded three LMC categories: (1) *Domestic;* (2) *Institutional;* and (3) *Personal.*

With the highest mean of means (X=4.30), the *Domestic* category was the highest ranked category as most respondents completed STEM requirements from domestic environments which lacked critical STEM learning resources (figure 6).

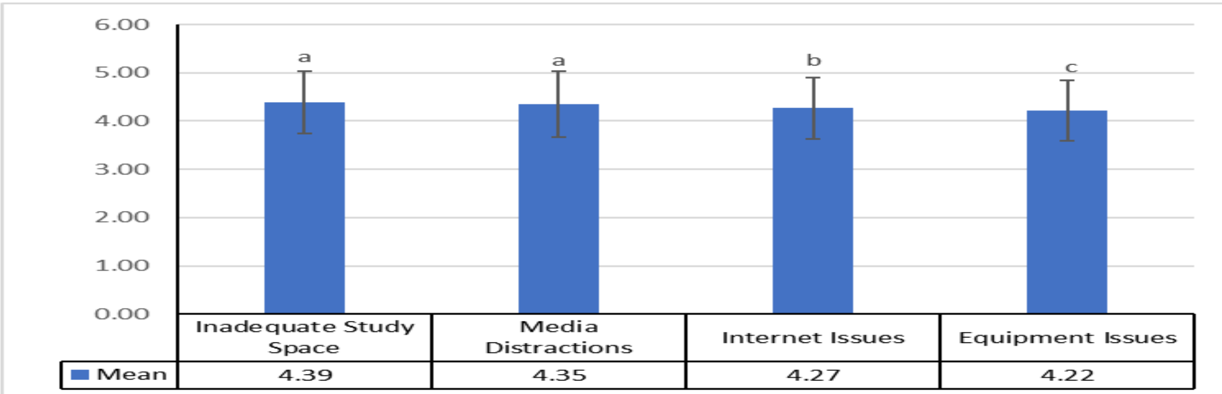

Figure 6: Domestic Challenges

With the second highest mean of means (X=4.24) as shown in figure 7, the *Institutional* category was the second highest ranked category as COVID-modified e-learning, instructional methods, and institutional policies made learning less meaningful and lowered motivation.

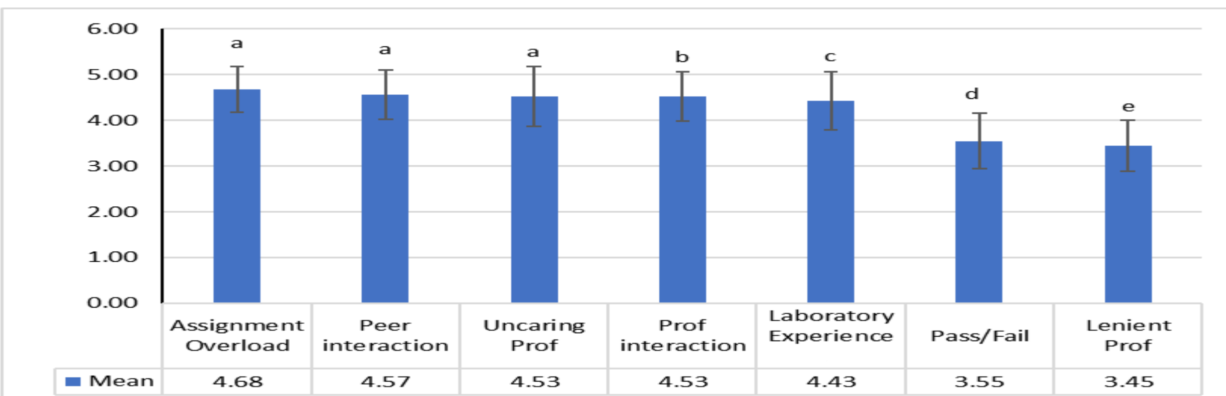

Figure 7: Institutional Challenges

With the lowest mean of means (X=4.14) for the *Personal* category (figure 8), it appeared that respondents were more likely to attribute lowered motivation to *Domestic* and *Institutional* challenges which appeared mostly out of their control, rather than to *Personal* challenges which appeared mostly within their control.

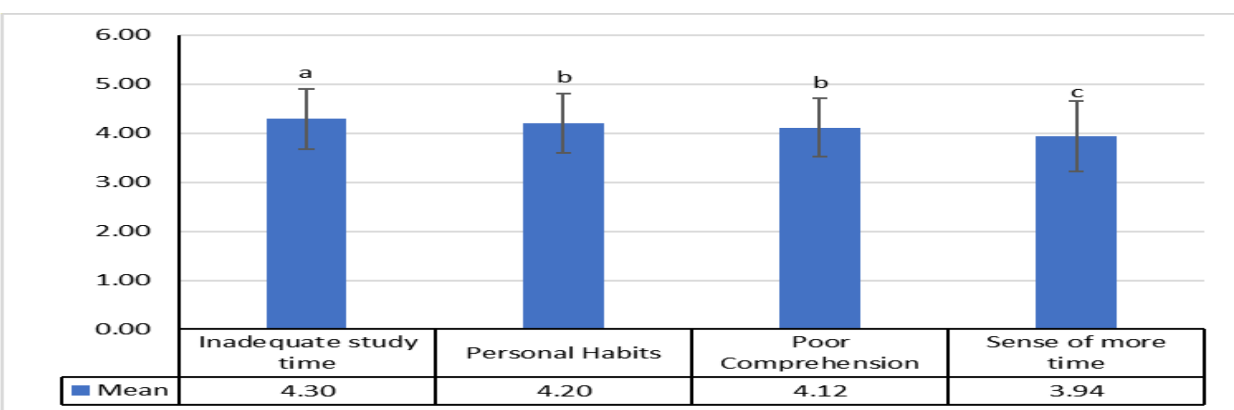

Figure 8: Personal Challenges

For more in-depth analysis into underlying relationships between LMCs and student characteristics (GPA, Classification, Race, and Age), cross tabulation analysis was conducted. Regardless of classification, GPA, age, or race, over 50% of respondents agreed with all LMCs except *overly lenient professors*, *pass/fail options,* and *sense of having more time*.

LMCs by Classification subgroups: Relationships between Classification and two LMCs, *equipment challenges* (p=0.00) and *assignment overload* (p=0.01), were found to be statistically significant. Compared to upperclassmen comprising of seniors (76%) and juniors (71%) as shown in Table 1, higher percentages of underclassmen comprising of sophomores (93%) and freshmen (92%) agreed to the *lack of in person professor interactions* LMC. Maturity and familiarity with STEM program resources and requirements may have enhanced the capacity of upperclassmen to work more independently [11]. Similarly, while only 68% of juniors and 76% of seniors agreed to the lack of *in person peer interaction* LMC, 86% of sophomores and 92% of freshmen agreed. Freshmen (84%) seemed most concerned about lack of *in-person laboratory experiences*, compared to juniors (68%), seniors (67%), and sophomores (62%). This may be because with minimal prior engagement in physical undergraduate STEM laboratories, they may have struggled with STEM laboratory e-learning requirements. However, compared to juniors (74%), sophomores (68%), and seniors (61%), only 20% of freshmen agreed to the *equipment challenges* LMC. This was statistically significant and may be because entry level STEM courses are less challenging and require minimal STEM specialized resources. This correlates with the fact that while sophomores (93%), juniors (90%), and seniors (83%) agreed to *assignment overload* LMC, only 72% of freshmen agreed.

Overall, sophomores were most likely to agree to LMC statements, making them appear most vulnerable. They had the highest percentage of agreement with seven of the 15 LMCs: *assignment overload* (93%), *lack of professor interactions* (93%), *media and social media distractions* (83%), *STEM study spaces* (79%), *internet connectivity* (79%), *STEM study times* (69%), and *poor comprehension* (66%). Compared with freshmen, sophomores were significantly more likely to agree with the *assignment overload* LMC. Compared with juniors, sophomores were significantly more likely to agree to the *lack of professor interactions, poor comprehension,* and *media/social media distractions* LMCs. The inclination for sophomores to experience higher LMCs may be associated with the sophomore slump, which is characterized by developmental confusion, transition from structured first year to more independent second year, uncertainty in career or personal identity, changing academic majors, redefining social engagement, and the middle-child or forgotten year syndrome because they are no longer the center of attention [11-13]. Also, sophomores were found to spend the least amount of time studying and therefore experience a dip in grades for courses in which they are unprepared [12]. In agreement with these previous researchers, it is hypothesized that unlike freshmen who have just begun the college journey and have significant resources dedicated to their success, or juniors and seniors who anticipate graduation, sophomores may have fewer reasons to stay motivated in high-risk STEM educational environments such as the COVID-19 pandemic-challenged environments.

Table 1. Cross Tabulation Analysis (LMCs by Classification subgroups)

STEM Learning Motivation Challenges (LMC) / Number of Respondents	Likert Scale	Total	Freshman	Sophomore	Junior	Senior
A. Lack of in-person INTERACTIONS with my professors reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	3.8%	0.0%	0.0%	9.7%	4.4%
	Somewhat disagree	8.5%	4.0%	3.4%	9.7%	13.3%
	Neither agree nor disagree	6.2%	4.0%	3.4%	9.7%	6.7%
	Somewhat agree	42.3%	36.0%	44.8%	41.9%	44.4%
	Strongly agree	39.2%	56.0%	48.3%	29.0%	31.1%
B. Lack of adequate STEM STUDY SPACES reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	7.7%	4.0%	6.9%	6.5%	11.1%
	Somewhat disagree	11.5%	20.0%	6.9%	12.9%	8.9%
	Neither agree nor disagree	9.2%	12.0%	6.9%	16.1%	4.4%
	Somewhat agree	38.5%	28.0%	44.8%	29.0%	46.7%
	Strongly agree	33.1%	36.0%	34.5%	35.5%	28.9%
C. Lack of adequate STEM STUDY TIMES reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	6.2%	4.0%	0.0%	9.7%	8.9%
	Somewhat disagree	16.9%	32.0%	17.2%	12.9%	11.1%
	Neither agree nor disagree	16.9%	20.0%	13.8%	12.9%	20.0%
	Somewhat agree	31.5%	24.0%	24.1%	32.3%	40.0%
	Strongly agree	28.5%	20.0%	44.8%	32.3%	20.0%
D. Lack of in-person STEM LABORATORY EXPERIENCES reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	8.5%	4.0%	6.9%	12.9%	8.9%
	Somewhat disagree	8.5%	12.0%	10.3%	6.5%	6.7%
	Neither agree nor disagree	13.8%	0.0%	20.7%	12.9%	17.8%
	Somewhat agree	27.7%	24.0%	27.6%	22.6%	33.3%
	Strongly agree	41.5%	60.0%	34.5%	45.2%	33.3%
E. Lack of in-person INTERACTIONS with other STEM students reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	3.8%	0.0%	0.0%	9.7%	4.4%
	Somewhat disagree	6.2%	0.0%	6.9%	12.9%	4.4%
	Neither agree nor disagree	10.8%	8.0%	6.9%	9.7%	15.6%
	Somewhat agree	31.5%	40.0%	34.5%	25.8%	28.9%
	Strongly agree	47.7%	52.0%	51.7%	41.9%	46.7%
F. Overly lenient professors reduced my MOTIVATION to complete STEM course requirements. (N = 125)	Strongly disagree	50.4%	56.0%	31.0%	60.0%	53.7%
	Somewhat disagree	25.6%	20.0%	51.7%	20.0%	14.6%
	Neither agree nor disagree	12.0%	8.0%	13.8%	6.7%	17.1%
	Somewhat agree	8.8%	12.0%	3.4%	10.0%	9.8%
	Strongly agree	3.2%	4.0%	0.0%	3.3%	4.9%
G. Equipment challenges reduced my MOTIVATION to complete STEM course requirements. (N = 125)	Strongly disagree	11.2%	28.0%	7.1%	6.5%	7.3%
	Somewhat disagree	12.8%	16.0%	10.7%	12.9%	12.2%
	Neither agree nor disagree	18.4%	36.0%	14.3%	6.5%	19.5%
	Somewhat agree	36.8%	16.0%	46.4%	45.2%	36.6%
	Strongly agree	20.8%	4.0%	21.4%	29.0%	24.4%
H. Internet connectivity challenges reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	13.1%	16.0%	10.3%	12.9%	13.3%
	Somewhat disagree	6.2%	12.0%	3.4%	6.5%	4.4%
	Neither agree nor disagree	20.0%	20.0%	6.9%	22.6%	26.7%
	Somewhat agree	36.2%	40.0%	44.8%	32.3%	31.1%
	Strongly agree	24.6%	12.0%	34.5%	25.8%	24.4%
I. Uncaring professors reduced my MOTIVATION to complete STEM course requirements. (N = 130)	Strongly disagree	9.2%	20.0%	3.4%	6.5%	8.9%
	Somewhat disagree	6.9%	4.0%	10.3%	3.2%	8.9%
	Neither agree nor disagree	6.9%	0.0%	10.3%	3.2%	11.1%
	Somewhat agree	23.1%	40.0%	13.8%	19.4%	22.2%
	Strongly agree	53.8%	36.0%	62.1%	67.7%	48.9%
J. Overload of assignments from professors reduced my MOTIVATION to complete STEM education requirements. (N = 126)	Strongly disagree	2.4%	4.0%	0.0%	0.0%	4.9%
	Somewhat disagree	6.3%	4.0%	3.4%	3.2%	12.2%
	Neither agree nor disagree	6.3%	20.0%	3.4%	6.5%	0.0%
	Somewhat agree	23.8%	20.0%	17.2%	19.4%	34.1%
	Strongly agree	61.1%	52.0%	75.9%	71.0%	48.8%
K. Knowing that the PASS/FAIL option was available to me reduced my MOTIVATION to complete STEM course requirements. (N = 126)	Strongly disagree	42.1%	56.0%	34.5%	45.2%	36.6%
	Somewhat disagree	27.0%	24.0%	27.6%	22.6%	31.7%
	Neither agree nor disagree	16.7%	8.0%	31.0%	16.1%	12.2%
	Somewhat agree	7.1%	12.0%	3.4%	6.5%	7.3%
	Strongly agree	7.1%	0.0%	3.4%	9.7%	12.2%
L. My own sense of having MORE time reduced my MOTIVATION to complete STEM course requirements. (N = 126)	Strongly disagree	23.0%	20.0%	17.2%	32.3%	22.0%
	Somewhat disagree	23.0%	16.0%	34.5%	22.6%	19.5%
	Neither agree nor disagree	11.9%	16.0%	10.3%	12.9%	9.8%
	Somewhat agree	27.0%	36.0%	27.6%	19.4%	26.8%
	Strongly agree	15.1%	12.0%	10.3%	12.9%	22.0%
M. Media and social media distractions reduced my MOTIVATION to complete STEM course requirements. (N = 126)	Strongly disagree	11.9%	12.0%	3.4%	25.8%	7.3%
	Somewhat disagree	14.3%	16.0%	13.8%	16.1%	12.2%
	Neither agree nor disagree	7.1%	12.0%	0.0%	6.5%	9.8%
	Somewhat agree	34.9%	20.0%	37.9%	32.3%	43.9%
	Strongly agree	31.7%	40.0%	44.8%	19.4%	26.8%
N. My poor comprehension of STEM content reduced my MOTIVATION to compete STEM course requirements. (N = 126)	Strongly disagree	11.1%	4.0%	0.0%	19.4%	17.1%
	Somewhat disagree	18.3%	12.0%	13.8%	29.0%	17.1%
	Neither agree nor disagree	18.3%	20.0%	20.7%	12.9%	19.5%
	Somewhat agree	41.3%	60.0%	48.3%	29.0%	34.1%
	Strongly agree	11.1%	4.0%	17.2%	9.7%	12.2%
O. My own personal habits reduced my MOTIVATION to complete STEM education requirements. (N = 126)	Strongly disagree	10.3%	4.0%	6.9%	19.4%	9.8%
	Somewhat disagree	13.5%	12.0%	13.8%	12.9%	14.6%
	Neither agree nor disagree	20.6%	16.0%	27.6%	19.4%	19.5%
	Somewhat agree	38.1%	40.0%	27.6%	35.5%	46.3%
	Strongly agree	17.5%	28.0%	24.1%	12.9%	9.8%

LMC by GPA subgroups: Relationships between GPA and three LMCs, *equipment challenges* (p=0.01), *pass/fail option* (p=0.01), and *lack of laboratory experiences* (p=0.04) were found to be statistically significant. Overall, lower GPA (2.00 - 2.49) respondents were most likely to agree with LMC statements, making them appear most vulnerable. In fact, 100% of them agreed that in addition to *uncaring professors* and *assignment overloads*, the *lack of in-person study spaces*, *laboratory experiences*, and *peer interactions* lowered motivation. Contrary to higher GPA (≥2.50) respondents with less than 15% of them agreeing to the *overly lenient professor* LMC, 50% of lower GPA respondents agreed. Also, compared to respondents with GPAs above 3.50, lower GPA respondents were significantly more likely to agree to the *overly lenient professor* LMC. *Overly lenient professors* are less strict and reduce the sense of urgency to complete course requirements, especially in lower GPA respondents who had 75% of them agree to the *personal habits* LMC. Notably, compared to over 50% of higher GPA respondents agreeing to the *poor comprehension* LMC, it is unclear why only 25% of lower GPA respondents agreed. Further research may provide additional insights.

LMC by Age subgroups: Relationships between Age and two LMCs, *lack of professor interactions* (p=0.04) and *lack of peer interactions* (p=0.01) were statistically significant. Respondents aged 41 to 50 years old had the highest levels of agreement with LMC statements, making them appear most vulnerable. They had the highest percentage of agreement with six of the 15 LMCs: *lack of professor interactions (100%), personal habits (100%), lack of study times (67%), overly lenient professors (50%), pass/fail option (50%), and sense of more time (50%).* Also, 100% of them liked to procrastinate. Approximately 33% of them had GPAs less than 3.00, compared to 18-25 years (8%), 26 – 30 years (20%), and 31 – 40 years (0%). Their vulnerability may be because they were likely to live out of state (100%), have pre-existing medical conditions (50%), live with people who needed care (33%) and have lower GPAs (33%). Compared to respondents aged 41 to 50, respondents aged 18 – 25 years were significantly more likely to disagree with the *pass/fail* LMC. Nevertheless, respondents aged 18 to 25 years old appeared to be the second most vulnerable agreeing to *media and social media distractions (69%), poor comprehension (54%),* and *personal habits (57%)* LMCs. Also, they appeared more dependent on professor and peer interactions. Compared to respondents aged 31 to 40, they were significantly more likely to agree to *lack of professor interactions LMC*. Also, compared to respondents aged 26 to 30 years, they were significantly more likely to agree to the *lack of peer interactions*. Furthermore, they may have been vulnerable because they were likely to procrastinate (67%), participate in extra-curricular activities (59%), and live with noisy people (53%).

LMC by Race subgroups: No statistically significant relationships existed between race and any LMC. Overall, Asians were most likely to agree with LMC statements, making them appear most vulnerable. They had the highest percentage of agreement with seven of the 15 LMCs: *lack of peer interactions (93%), media and social media distractions (93%), lack of STEM study spaces (79%), equipment challenges (72%), internet connectivity (64%), sense of more time (50%),* and *pass/fail option (29%).* Compared to African Americans, Asians were significantly more likely to agree to *pass/fail option* and *media/social media distractions* LMCs. Also, compared to Native Hawaiians/Pacific Islanders, Asians were significantly more likely to agree to *media/social media distractions* and *lack of peer interactions* LMCs. Further research is needed to investigate if these findings may be related to their strong collectivist culture which emphasizes group identity. Notably, Native Hawaiians/Pacific Islanders appeared least vulnerable. Compared to all other races, they were significantly more likely to disagree to the *lack of professor interactions*, *study times* and *peer interactions* LMCs.

Discussions

Regardless of classification, GPA, age, or race, STEM students encountered domestic, institutional, and personal challenges. Domestic challenges such as different housing arrangements and lack of resources made studying difficult, sometimes preventing students from even joining online classes [14]. Some families sacrificed home spaces to support studying. However, being at home came with its own set of distractions to include television, social media, and household members [14]. Furthermore, family duties limited time needed to focus on courses and made education a lesser priority. The lack of reliable internet access and equipment such laptops, cameras, or tablets was a challenge; and, between 9 and 12 million US students were without reliable internet connectivity for e-learning at home [15]. While some institutions provided hotspots and computers to students, other students relied on their phones [14].

Institutional challenges such as lack of in-person professor and peer interactions reduced motivation, especially in STEM students who were more dependent on in-person STEM education resources. Considering that motivation is boosted when students interact with instructors and gain hands-on laboratory experiences [9], the separation of students and professors was an institutional challenge during the pandemic. According to studies, students who have personal connections with professors, staff, and friends are more likely to stay at a college. When in-person learning shifted to online, 55% of study participants reported a decline in their motivation to study during the COVID-19 pandemic [10]. In the study, students said they feel inspired when they look in the eyes of their professors while they teach, have discussions with peers, and improve their communication skills. Numerous STEM students indicated that when learning via a computer screen, they are unable to focus as readily or retain as much information, resulting in a loss of motivation [17]. Prior to the pandemic, students relied on university services like libraries, computer laboratories, and campus wi-fi to complete their educational requirements; however, these were lost due to school closures [14]. Considering that young people with disabilities do better in supportive environments, preliminary reports indicated that they struggled during the pandemic [18]. These multiple and interacting challenges during the pandemic caused several U.S. institutions to implement the pass/fail option so students could maintain good GPAs. However, without effective design and implementation, the pass/fail option resulted in some STEM students falling behind because it reduced motivation to learn and obtain the best possible grade. Approximately 27% of STEM students chose the pass/fail option since it was a good method to boost their GPA [3].

Personal challenges such as procrastination and personal habits reduced motivation, especially in students with low self-regulations skills [2][3]. Although e-learning has been demonstrated to improve information retention and require less time [19], undergraduate STEM students indicated that e-learning lowered their motivation. Poor understanding of STEM content may be attributed to the extra focus, effort, and time needed to focus in e-learning environments.

Interactions among these multiple LMCs worsen negative impacts on STEM performance. Consequently, all undergraduate STEM students require critical domestic, institutional, and personal resources. In particular, early identification of the most vulnerable students (Sophomores, Asians, students with GPA between 2.00 and 2.49, and students aged 41 to 50 years) should be quickly followed by interventions to reduce LMCs [2]. STEM student households should be encouraged to maintain quiet learning spaces with efficient equipment and internet access. Where possible, institutions should provide devices, hot spots, software, and even laboratory kits for conducting experiments safely in domestic experiments. Institutions should provide targeted training and resources that will enhance the capacity of STEM professors to be effective instructors in e-learning environments. Faculty should be trained to build their capacity to educate and motivate students with diverse characteristics, especially the most vulnerable students. Faculty training should include innovative instructional strategies and emotional intelligence to support student learning and mental health. Faculty should provide opportunities for innovative experiential learning such as remote field trips. Virtual communication platforms should be made available to enhance remote peer interactions. Regular and private office hours and tutoring sessions should be available to all students. Overly lenient professors should consider increasing course requirements that reward effort. Institutions should acquire efficient virtual laboratory simulations that allow students to explore and advance their understanding of STEM concepts without being in a physical laboratory. Accommodations such as extended time, closed captioning, alternate communications styles, different testing conditions, note taking support, multiple formats for directions, non-screen options, and other course modifications could enhance learning for students with disabilities [16]. Institutions should carefully consider the advantages and disadvantages of pass/fail options. Empirical data should inform the development of efficient and balanced pass/fail option policies that are well-crafted to minimize de-motivation in students. Furthermore, students and advisors should be educated about these policies to ensure that students make the best decisions. Ongoing research into the development of effective e-laboratory learning experiences should continue to receive support from stakeholders to include funding agencies such as the National Science Foundation.

Being that successful e-learning demands effective independent learning strategies, STEM institutions should assist students strengthen self-regulation skills. This is especially critical for the most vulnerable students. Self-regulation has positive effects on behavior and acquisition of skills [20]. Self-regulated learners perceive acquisition as a process that is systematic and controllable and so they accept greater responsibility for the outcomes of their achievement [21]. Educational institutions should continue to prioritize supporting the development of self-regulation skills in undergraduate STEM students as such skills support student advancement and persistence, even in difficult and unprecedented situations as experienced during the COVID-19 pandemic. Increased institutional resources and collaboration between faculty and the university administrators will provide a coherent online learning environment that will motivate students and improve STEM e-learning experiences during pandemics and other high-risk situations [2][22]. Motivation variables had stronger correlations with e-teaching materials and e-assessments rather than to e-discussion, e-grade checking and feedback [23]. While with little preparation the rapid transition into e-learning environments was burdened with challenges, ongoing advancements in institutional resources and educational technologies seem promising and are likely to improve e-learning in future high-risk situations [19]. However, further research is recommended to gain more insights into the learning experiences and interventions needed to minimize LMCs in the most vulnerable undergraduate STEM students.

Future employers of COVID graduates may have to provide enhanced orientation and mentoring to enhance transitions into entry-level positions. This is particularly important for positions that rely heavily of physical STEM laboratory skills. Furthermore, frequent private sessions should be organized to identify and meet more specific needs.

Conclusion

Domestic, institutional, and personal challenges are key sources of STEM learning motivation challenges in students during the COVID-19 pandemic. Significant relationships existed between three characteristics (GPA, classification, and age) and few LMCs to include assignment overloads. Sophomores, Asians, low GPA students, and students aged 41 to 50 years may be most vulnerable. Overall, it appeared that students are more likely to associate their lowered learning motivation to domestic and institutional challenges, rather than to personal challenges. In addition to critical domestic and institutional resources, self-regulation is critical for students to stay motivated and complete STEM course requirements. Findings inform future research, as well as lessons and best practices for improved STEM student and institutional adaptability and resiliency. These will minimize disruptions to student functioning and performance, reduce attrition, and strengthen progression into the STEM workforce during high-risk conditions such as pandemics. With caution, findings may be extended to non-STEM and non-student populations. Future studies will focus on long term impacts of COVID-19 pandemic on STEM performance.

Acknowledgements

This material is based upon work supported by the National Science Foundation (NSF-RAPID) program under Grant No. (NSF 2028811). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

[1] A. Aristovnik, D. Keržič, D. Ravšelj, N. Tomaževič, and L. Umek, "Impacts of the COVID-19 pandemic on life of Higher Education Students: A global perspective," *Sustainability*, vol. 12, no. 8438, pp. 1 – 34, Oct. 2020.

[2] A. N. Ofori-Boadu, A. Ferguson, & A. White, "Mitigating our Diminishing STEM- SELF SYNDROME (DS CUBED): The voices of STEM students during COVID- 19 pandemic. *2021 Virtual National Science Foundation – HBCU – UP/ CREST PI/PD Meeting, February 2021*. [Online[Available: https://emerging-researchers.org/2021-hbcu-up-crest-pi-pd-presentation-videos/ [Accessed: 22-April-2022]

[3] M. Fash, A. N. Ofori-Boadu, R. Bonku, W. Alford, A. Ferguson, and A. White, "An examination of professor-student interactions, stem learning challenges, and student adaptation decisions during covid-19 pandemic," *2021 ASEE Virtual Annual Conference Proceedings*, July 26 - 29, 2021, 2021.

[4] M. Komarraju, S. J. Karau, and R. R. Schmeck, "Role of the big five personality traits in predicting college students' academic motivation and achievement," *Learning and Individual Differences*, vol. 19, no. 1, pp. 47–52, 2009.
[5] A. R. Artino and J. M. Stephens, "Academic motivation and self-regulation: A comparative analysis of undergraduate and Graduate Students Learning Online," *The Internet and Higher Education*, vol. 12, no. 3 - 4, pp. 146–151, 2009.
[6] A. Usher and N. Kober, "Student motivation an overlooked piece of school reform Summary". *ERIC Clearinghouse*, 2012. [Online]. Available: https://files.eric.ed.gov/fulltext/ED532666.pdf , [Accessed: April 22, 2022]
[7] W. Harlen and D. R. Crick, "A systematic review of the impact of Summative Assessment and tests on students' motivation for learning." *London: EPPI-Centre, Social Science Research Unit, Institute of Education*, 2002.
[8] J. Reeve, *Understanding Motivation and Emotion.* New York, NY: John Wiley, 2018.
[9] Y. Kong, "The role of experiential learning on students' motivation and classroom engagement," *Frontiers in Psychology*, *vol. 12*, pp. 1 – 4, 2021.
[10] Qualtrics XM, "Crosstabs," [Online]. Available: https://www.qualtrics.com/support/survey-platform/data-and-analysis-module/cross-tabulation/cross-tabulation-overview/ [Accessed: May 9, 2022]
[11] R. Kalman, M. Macias Esparza, and C. Weston, "Student views of the online learning process during the COVID-19 pandemic: A comparison of upper-level and entry-level undergraduate perspectives," *Journal of Chemical Education*, vol. 97, no. 9, pp. 3353–3357, 2020.
[12] V. Nelson. "When College Is a Four-Year Journey: Sophomore Year," Collegiate Parent, 2021. [Online]. Available: https://www.collegiateparent.com/academics/four-year-journey-sophomore-year/ . [Accessed: April 21, 2022]
[13] J. Gahagan, and M. S. Hunter, "The Second-Year Experience: Turning Attention to the Academy's Middle Children," *About Campus: Enriching the Student Learning Experience*, vol. 11, iss. 3, pp. 17 – 22, 2006.
[14] A. Acosta, L. Romo-González, and E. Johnson, "What students and colleges faced during the pandemic," *New America*, 27-Jan-2021. [Online]. Available: https://www.newamerica.org/education-policy/edcentral/what-students-and-colleges-faced-during-pandemic/. [Accessed: 27-Dec-2021].
[15] M. Lieberman, "Most students now have home internet access. but what about the ones who don't?," *Education Week*, 28-May-2021. [Online]. Available: https://www.edweek.org/technology/most-students-now-have-home-internet-access-but-what-about-the-ones-who-dont/2021/04. [Accessed: 28-Dec-2021].
[16] M. A. Gernsbacher, "Video captions benefit everyone," *Policy Insights from the Behavioral and Brain Sciences*, vol. 2, no. 1, pp. 195–202, 2015.
[17] T. Simonton, "College students cope with shortcomings of online learning during coronavirus," *TribLIVE.com*, 20-Apr-2020. [Online]. Available: https://triblive.com/local/pittsburgh-allegheny/college-students-cope-with-shortcomings-of-online-learning-during-coronavirus/. [Accessed: 21-Dec-2021].
[18] Z. Meleo-Erwin, B. Kollia, J. Fera, A. Jahren, and C. Basch, "Online support information for students with disabilities in colleges and universities during the COVID-19 pandemic," *Disability and Health Journal*, vol. *14, no.* 1, pp. 1 – 6, 2021.

[19] C. Li and F. Latani, "The COVID-19 pandemic has changed education forever. this is how," *World Economic Forum*, 29-Apr-2020. [Online]. Available: https://www.weforum.org/agenda/2020/04/coronavirus-education-global-covid19-online-digital-learning/ . [Accessed: 23-Dec-2021].
[20] R. Reid, "Implementing self-monitoring interventions in the classroom: Lessons from research," *Monograph in Behavior Disorders: Severe Behavior Disorders in Youth, vol. 16,* pp. 43 – 54, 1993.
[21] B. J. Zimmerman and M. Martinez-Pons, "Student differences in self-regulated learning: Related grade, sex, and giftedness to self-efficacy and strategy use," Journal of Educational Psychology, 82, pp. 51 – 59, 1990.
[22] M. Lamssali, O. K. Nicholas, A. C., Ferguson, A. N., Ofori-Boadu, and A. M. White, "Faculty Perceptions of STEM Student and Faculty Experiences During the COVID-19 Pandemic: A Qualitative Study (WIP). *2021 ASEE Virtual Annual Conference Proceedings*, July 26 - 29, 2021.
[23] E. Elshareif and E. Mohamed, "The effects of e-learning on students' motivation to learn in higher education," *Online Learning, vol. 25, no. 3,* pp. 128-143, 2021.