

Perceiving Advancement: An Exploration Of Positive Experiences That Strengthened Undergraduate STEM Students' Motivation During The Covid-19 Pandemic

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Abstract

The COVID-19 pandemic was highly disruptive and Institutions of Higher Education struggled to effectively educate undergraduate Science, Technology, Engineering, and Mathematics (STEM) students who faced unique challenges in their modified and remote learning environments. Considering most empirical studies have focused on these challenges, there is limited understanding of the positive experiences of undergraduate STEM students during this high-risk period. Positive psychology theories drive the recent educational movement towards integrating school-based positive psychology in educational environments. There is a demand for rigorous research to increase understanding of interactions between positive experiences and student outcomes in various contexts. Consequently, the purpose of this present research is to explore positive experiences that strengthened undergraduate STEM students' motivation to complete STEM course requirements during the pandemic. Data was obtained from an open-ended Qualtrics-based survey question requiring research participants to explain why salient positive experiences influenced motivation. An inductive thematic analysis method was adopted to analyze statements from 131 STEM students enrolled in six U.S. institutions. Utilizing the NVivo-12 qualitative analysis software, data analysis involved coding and theme development.

The emergent theme, Perceiving Advancements, proposed that perceptions of advancements invigorated positive experiences and strengthened academic motivation in undergraduate STEM students during the pandemic. Drawing from previous lived experiences and expectations, academic motivation was attributed to the perceived capacity or potential for positive experiences to advance academic, career, and personal goals. Theoretical insights contribute to understanding motivation in STEM students during high-risk contexts, while practical implications inform interventions for resource optimization and improved student and institution resiliency during global high-risk contexts such as pandemics. Findings provide valuable insights with potential implications for school-based positive psychology and motivation research, policies, and practices.

Introduction

The COVID-19 pandemic profoundly disrupted global education, necessitating a shift to online learning, and significantly affected student engagement and academic performance (Rapanta et al., 2021; Reimers, 2022). Empirical studies have explained the multifaceted negative impacts of the pandemic on the academic landscape, revealing that students grappled with the loss of instructional time and the absence of traditional physical learning environments (Ofori-Boadu et al. 2022; Fash et al., 2021; Lee et al., 2021; & Hammerstein et al., 2021). This situation was further complicated by issues of social isolation, stress, mental health strains, financial hardships, and sedentary behaviors (Fash et al., 2021; McDowell et al., 2020). Furthermore, the exacerbation of educational inequities, as highlighted by Molock & Parchem (2022) and the National Center for Education Statistics (2020), presented significant obstacles to equitable access and success in education.

Conversely, the educational shifts necessitated by the COVID-19 pandemic also engendered a range of positive outcomes, reflective of the resilience and adaptability inherent within educational institutions and their constituents (Fash et al., 2021; Mucci-Ferris et al., 2021; August & Dapkewicz, 2021; Magableh & Alia, 2021). The forced adoption of online learning has not only maintained educational continuity but has also fostered the emergence of novel educational tools and alternate resources that enriched the learning experience beyond traditional methods (Magomedov et al., 2020; Fash et al., 2021). This period has seen a marked improvement in educator cultural awareness and a strengthening of the educator-family communication channels, as detailed by Collet & Berman (2021) and Walsh et al. (2021), which have contributed to creating more supportive and inclusive educational environments. Moreover, the integration of online learning as a fixture in students' lives has led to notable enhancements in e-learning participation, self-regulation, and the academic performance of top-tier students (Sujarwo et al., 2020; Nikou & Maslov, 2021; Zhang et al., 2021). These adaptations have not only demonstrated the potential of online learning to augment traditional education but have also highlighted the critical role of technology in facilitating learning resilience and adaptability among students

during periods of significant upheaval.

Within the specific context of undergraduate STEM education, the unique STEM learning challenges necessitated by the pandemic also unearthed motivation, adaptation, and resilience in students. The specific learning motivation challenges faced by undergraduate STEM students, included assignment overloads, the lack of in-person peer and professor interactions, and the absence of hands-on laboratory experiences, which traditionally form the cornerstone of STEM education (Ofori-Boadu et al., 2022). Despite these hurdles, studies by Lamssali et al. (2021) and Fash et al. (2021) have illuminated some positive pathways through which undergraduate STEM students navigated these challenges, leveraging technology and virtual collaboration tools to maintain academic rigor and peer connections. The shift towards self-regulated learning, as facilitated by the pandemic's constraints, underscored a significant evolution in the learning behaviors of STEM students, fostering a sense of self-discipline and independence that is poised to benefit them beyond the pandemic. Motivation, adaptability, resilience, and other unexpected positive outcomes stemming from the pandemic's challenges underscore the complex interplay between adversity and innovation in the educational journey of STEM students during high-risk contexts. The recent educational movement towards incorporating school-based positive psychology (SBPP) theories into educational environments to develop interventions that improve student psychological and academic outcomes demands additional empirical research to inform SBPP policies and practices. Therefore, the SBPP framework provides a robust theoretical lens to explore positive experiences that strengthen academic motivation in undergraduate STEM students during high-risk contexts, such as the COVID-19 pandemic.

School-Based Positive Psychology (SBPP)

Considering the impact of the 21st century complexities of life on the mental health of students, there has been a global school-based positive psychology movement requiring schools to incorporate wellbeing in student learning experiences (Waters, 2011). Originating from the broader discipline of positive psychology, which was revo-

lutionized in the late 20th century by Martin Seligman and colleagues, SBPP has been instrumental in redefining the contours of educational success (Waters, 2011; Mendes de Oliveira et al., 2022). It shifts the focus from merely addressing psychological deficits to proactively cultivating a nurturing educational environment that promotes students' well-being, resilience, and motivation (Waters & Johnstone, 2022). This paradigm asserts that the core elements of well-being—positive emotions, engagement, relationships, meaning, and accomplishments (PERMA), as encapsulated in the PERMA model—serve as critical levers for enhancing student outcomes (Seligman, 2011). By embedding these principles into the fabric of educational settings, SBPP not only aims to optimize the psychological functioning of students but also to elevate their academic performance and interpersonal connections within the educational ecosystem (Tejada-Gallardo et al., 2020). The burgeoning body of empirical research supporting SBPP underscores its effectiveness in fostering positive experiences and environments that nurture the holistic development of students, making it a credible and compelling approach for addressing the multifaceted challenges posed by the pandemic (Michopoulou, 2022; Hobbs et al., 2022; Subotic-Kerry et al., 2023). Gaps found in SBPP literature included limited incorporation of academic and context impacts (Waters & Loton, 2019). Furthermore, most existing SBPP studies were conducted during non-pandemic contexts, and no SBPP study was found to explore interactions between positive experiences and academic motivation in undergraduate STEM student during high-risk educational contexts such as the COVID-19 pandemic.

Academic Motivation

Academic motivation and positive psychology theorists have long advocated that, though somewhat underexplored, SBPP plays a pivotal role in shaping the overall psychological well-being, motivation, and academic performance of students. Embedded within this broad framework, the Deci and Ryan Self-Determination Theory of Motivation, alongside Martin Seligman's Positive Psychology Theory, emerge as critical underpinnings that shape the conceptual foundation of academic motivation in this present empirical investigation. Academic motivation refers to the cause of behaviors that somehow relate to academic functioning and success to include effort, self-regulation, choices, and persistence in educational environments (Usher & Morris, 2012). These theories collectively foreground the essential role of autonomy, capabilities, and environmental conditions in fostering academic motivation and resilience among students, thereby underscoring the significance of SBPP in educational settings (Deci & Ryan, 1985; Gable & Haidt, 2005; Waters, 2011; Seligman, 2011; Chodkiewicz & Boyle, 2017).

The Deci & Ryan Self-Determination Theory of Mo-

tivation is paramount in this present investigation and spotlights the roles of capabilities, autonomy, relatedness, needs, and environmental conditions in shaping human motivation, behavior, and persistence. This theory, thoroughly elucidated through decades of research (Deci & Ryan, 1985; Deci & Ryan, 2012; Ryan & Deci, 2017), serves as a cornerstone for understanding the intrinsic and extrinsic factors that motivate students, particularly within the challenging contexts of STEM education during the COVID-19 pandemic (Chiu, 2021). Building on this foundation, academic motivation theories such as those focusing on self-efficacy, attribution, and achievement goals delve deeper into the psyche of the learner. These theories elucidate how emotions and beliefs influence behaviors ranging from the pursuit of mastery to the avoidance of failure, thereby crafting a nuanced picture of student motivation in the face of adversity (Bandura, 1977; Weiner, 1985; Bandura, 1993; Seifert, 2004). Self-efficacy, or the belief in one's capabilities to execute a task to a specified level of achievement, emerges as a critical determinant of a student's capacity to navigate the complexities of learning, especially under the pressures of a global pandemic. This belief, akin to confidence, empowers students with high self-efficacy to adopt more self-regulated and adaptive approaches to learning, contrasting sharply with their less confident counterparts (Bandura, 1977; Bandura, 1993; Seifart, 2004). Similarly, theories of attribution and academic goal setting offer insights into how students interpret their successes and failures, and how these interpretations, in turn, shape their motivational landscapes and behavioral patterns toward achieving specific educational objectives (Dweck, 1986; Dweck & Leggett, 1988; Pintrich & Garcia, 1991). Furthermore, considering students' perceived control of the attribution process provides a nuanced perspective on their engagement and resilience in educational settings. Perceived control, or the belief in one's ability to influence outcomes, plays a pivotal role in determining whether students attribute their successes and failures to internal factors within their control (e.g., effort, strategies) or to external factors beyond their control (e.g., luck, task difficulty) (Chodkiewicz & Boyle, 2014; Fishman & Husman, 2017). This perception significantly impacts their academic motivation and behaviors, encouraging a growth mindset in those who feel empowered to affect their learning outcomes, and potentially leading to a fixed mindset in those who do not. Recognizing the importance of perceived control can therefore enhance educational strategies aimed at improving student motivation and success (Hsieh & Schallert, 2008; Chodkiewicz & Boyle, 2014).

Central to this discussion is the premise that understanding academic motivation in undergraduate STEM education environments amidst the high-risk contexts of the COVID-19 pandemic necessitates a multifaceted approach that incorporates the principles of School-Based

Positive Psychology (SBPP) and ecological systems theories. This approach underscores the importance of fostering academic environments that not only address challenges but also actively cultivate positive experiences, autonomy, and competence. Such academic environments are crucial for supporting adaptive and constructive learning among students (Seifart, 2004). Bronfenbrenner's ecological systems theory, alongside Loh's academic ecological systems model, further contextualizes these discussions, highlighting how motivators and barriers at various ecological levels can impact STEM students' motivation and persistence in their educational journeys (Bronfenbrenner, 1979; Loh et al., 2020). These theories collectively illuminate the critical need for educational frameworks that are responsive to the evolving challenges and opportunities presented by the pandemic, emphasizing the importance of gaining more insights into the role of positive psychological experiences and interventions in supporting academic motivation and well-being in high-risk learning environments.

Secondly, positive psychology, at its core, is the scientific investigation into what constitutes human flourishing, exploring how positive individual and community experiences contribute to well-being and engender meaningful behaviors. The PERMA model, developed by Martin Seligman, provides a comprehensive framework for understanding the facets of human thriving, particularly within educational contexts (Seligman, 2011). In parallel, Gable & Haidt (2005) articulate positive psychology as the study of conditions and processes that bolster the optimal functioning of individuals, groups, and institutions, echoing the central tenets of SBPP. This approach emphasizes the transformative power of positive experiences and emotions in fostering a sense of well-being, expanding cognitive bandwidth, enhancing motivation, bolstering resilience, and influencing behaviors towards constructive learning outcomes (Fredrickson, 2001; Seifert, 2010). The application of SBPP, particularly in the context of education, offers a nuanced understanding of how cultivating positive educational environments can significantly impact student motivation and academic engagement. This perspective aligns with the burgeoning call for increased empirical evidence supporting the efficacy of SBPP interventions in educational settings. Specifically, this research is propelled by the imperative to explore positive experiences and motivational dynamics among undergraduate STEM students navigating the high-risk environment of higher education institutions during the COVID-19 pandemic. It advances beyond traditional deficit-oriented approaches that focus primarily on remedying what is broken, advocating instead for a 'nurturing the best' paradigm. This paradigm seeks to identify and amplify the positive aspects of students' experiences, thereby fostering environments conducive to growth and resilience (Seligman & Csikszentmihalyi, 2000; Janssen, de Hullu, & Tigelaar, 2008). Such an approach is critically important in

the face of the COVID-19 pandemic, where STEM students encountered unprecedented challenges. These included navigating complex, evolving learning landscapes, which necessitated innovative strategies and resources to sustain motivation and ensure academic persistence (Fash et al., 2021; Ofori-Boadu et al., 2022).

In this present study, these rich theoretical landscapes of positive psychology, motivation, ecological system theories, particularly as they pertain to the school-based application of positive psychology, have been instrumental in guiding the development of the research questions and methods for this present empirical study. By weaving together these diverse but complementary theoretical strands, this present investigation seeks to utilize empirical findings to contribute to a deeper understanding of how SBPP can inform actionable insights for educators, policy makers and researchers seeking to navigate the complexities of undergraduate STEM education in high-risk contexts such as the COVID-19 pandemic.

Purpose

The purpose is to explore positive experiences that strengthened undergraduate STEM students' motivation to complete their STEM course requirements during the COVID-19 pandemic. This investigation is guided by two primary research questions: 1) "What are the salient positive experiences that strengthened undergraduate STEM students' motivation to complete STEM course requirements during the COVID-19 pandemic?" and 2) "Why did salient positive experiences strengthen undergraduate STEM students' motivation to complete STEM course requirements during the COVID-19 pandemic? By addressing these questions, the aim is to uncover not only the variety of positive experiences that students encountered but also to begin exploring the underlying mechanisms that link these experiences to enhanced academic motivation, marking a preliminary step towards identifying actionable insights for supporting undergraduate STEM education in high-risk contexts.

Methods

Grounded in the raw data, this research adopts an inductive qualitative approach to gain insights into the lived positive experiences of undergraduate STEM students in the U.S. during the COVID-19 pandemic (Aspers & Corte, 2019). Drawing from the SBPP framework, the interpretivist epistemology was adopted to understand the meanings of undergraduate STEM students' positive experiences and why they strengthened academic motivation (Dupre & Leonelli, 2022; Morse, 2015).

Approval for this study was obtained from the Institutional Review Board (IRB # 19-0198) which reviewed and approved the research protocol under expedited review procedures as outlined in 45 CFR 46.110 to ensure that

the research was conducted in accordance with ethical guidelines for human subject research studies. To ensure that the voices of diverse undergraduate STEM students across the United States were represented in the findings, the recruitment strategy targeted research participants (RPs) from six racially (Historically Black Colleges and Universities, Predominantly White Institutions, and Minority Serving Institutions) and geographically (Midwest, West, and South) diverse U.S. institutions. Faculty members disseminated Qualtrics-based survey links through various digital communication platforms to their respective undergraduate STEM student communities. Although the survey consisted of various questions, the primary focus for the analysis in this present study involved responses to one specific open-ended survey item: "Share a minimum of two positive experiences that strengthened your motivation to complete STEM course requirements during the COVID-19 pandemic. Explain why they strengthened your motivation." Out of the 247 students who attempted to complete the entire survey, only 131 students provided responses to the specific question regarding how positive experiences impacted motivation to complete STEM educational requirements. The others completed other survey items but did not respond to this specific question. This resulted in a response rate of 53% for this specific question. An important assumption is that the RPs understood the questions and thus provided truthful and accurate responses, where statements shared represent their salient COVID-related positive experiences even if it meant some of the experiences were considered positive during non-COVID times. Considering that the structuring of the survey item itself was informed by SBPP and academic motivation theories that place emphasis on interactions between positive experiences and student outcomes such as motivation, all responses are assumed to address this interaction. Furthermore, considering that the specific COVID-19 pandemic term is included in the survey item as the high-risk educational context, it is assumed that all RP responses are informed by positive experiences during the high-risk pandemic context.

Out of the 131 RPs who responded to this specific survey question, 129 RPs provided STEM discipline data indicating enrollment in Science (31.01%), Technology (11.63%), Engineering (39.53%), Mathematics (2.33%), and Computer Science (15.50%) programs. RPs included Black/African Americans (43.08%), White (34.62%), Asians (11.54%), Native Hawaiian/Pacific Islander (0.77%), and Others (10.00%). By classifications, RPs included Seniors (31.01%), Juniors (24.81%), Sophomores (24.03%), and Freshmen (20.16%).

An inductive thematic analysis approach grounded in the data was employed in the analysis of the Qualtrics-based survey responses (Braun & Clarke, 2006; Braun & Clarke, 2012; Giles, de Lacey, & Muir-Cochrane, 2016; Braun & Clarke, 2022). This bottom-up approach per-

mits themes to emerge from the data based on making sense of collective or shared meanings and experiences. The Braun & Clark (2006) six-phase approach to thematic analysis was adopted and involved six key steps: Familiarizing with the data; Generating initial codes; Searching for themes; Reviewing potential themes; Defining and naming themes; and producing the report.

To increase intimate familiarization with data and insights of interest, the first and second authors critically read and re-read RP responses to go beyond surface meanings and identify emerging patterns. Personal notes were made for memory aids and triggers for coding and analysis. Utilizing the NVivo qualitative analysis software, the first level of initial open coding analysis involved the use of gerunds (the verb form of nouns) to emphasize meanings, actions, and positive experiences that strengthened motivation as well as explained why those positive experiences strengthened motivation. As coding progressed, some existing open codes were modified to better capture emerging interpretations that better reflected collective participant experiences and meanings. The number of references (N) for each code was tracked by the NVivo software and utilized to substantiate frequency and commonality across RP experiences, meanings, and rationales. To increase the rigor of the inductive thematic coding process, only frequent codes with 100% agreement among coders were included in the findings. At the end of this phase, there were 18 open codes.

During the second level of focused coding analysis, the initial open codes that shared a unifying feature were clustered into focused codes to explain larger segments of the data (Giles, de Lacey, & Muir-Cochrane, 2016). As an example, the positive experience open codes, Relocating to Campus and Pursuing Graduation, shared a unifying feature of attaining academic milestones and led to the labeling of the emerging focused code, Attaining Academic Milestones. At the end of this phase, there were eight focused codes.

With enhanced focus on understanding why nuanced positive experiences strengthened RPs' motivation to complete STEM course requirements, the third level of analysis involved the aggregation of focused codes into sub-themes which captured broader and unifying features that explained why frequent positive experiences strengthened motivation. To reflect coherent and meaningful patterns in the data, the emerging three sub-themes were labelled as: (1) Perceiving Academic Advancements; (2) Perceiving Career Advancements; and (3) Perceiving Personal Advancements. Together these three sub-themes worked together to reflect patterns of advancement goals that influenced positive experiences and motivation. Consequently, this powerful rationale was captured through the generation of the emergent central theme, Perceiving Advancements. This central theme provides a coherent, meaningful, and lucid explanation of the salient concepts that were communicated frequently in the raw data, re-

flected RP collective meanings, and were relevant to the research question. In subsequent paragraphs, the central theme is explained and convincingly illustrated utilizing number of references per code and RP quotes.

Results and Discussions

Research Question 1. *“What are the salient positive experiences that strengthened undergraduate STEM students’ motivation to complete STEM course requirements during the COVID-19 pandemic?”*

Notably, except for one RP, all other RPs (99.24%) described positive experiences that strengthened their motivation. Eighteen open codes are utilized to describe the most frequent positive experiences that strengthen academic motivation in undergraduate students. Adopting a descending order of frequency, these experiences are described in subsequent paragraphs:

1. Gaining Accessibility (N=71): RPs appreciated increased access to STEM learning resources because they were converted to digital forms. One aspect particularly highlighted was the availability of recorded lectures, which facilitated flexible learning schedules as explained by an RP:

“Another class had all information posted online with lectures recorded and made the tests straightforward and open notes/open book. These allowed me to learn the material when I was mentally capable of doing so instead of whenever the class was scheduled.”

With unlimited access to STEM learning resources, RPs were able to study at their preferred pace, location, and time when their learning capabilities were most heightened. The opportunity to study at one’s own pace was particularly beneficial to a study abroad RP who explained:

“Classes could be watched at my speed, my pace, and my location. This allowed me to take a class at the NCAT while studying abroad in Sweden.”

Furthermore, being liberated from the burdens typically associated with physical movements to and from in-person STEM learning spaces made online learning more accessible. As one participant noted:

“The ability to take classes easily over the summer, online without running from class to class, is easier.”

Pre-COVID commuters especially appreciated the convenience of online learning due to reduced commute time, effort, and stress as expressed by one RP:

“The online format is a lot more convenient for me personally. I save about an hour and a half of time each day by not having to commute, and I can spend that time on the course material instead. That also means a little bit of time to relax, which we know makes your work time more efficient.”

A few participants appreciated learning from home environments due to improved comfort and access to ne-

cessities such as healthier foods as shared by an RP:

“Less travel time—more time for studying and not driving. Eating at home—healthier food options because of the shutdown.”

RPs were motivated by these high levels of autonomy as they had increased opportunities for self-pacing and self-governing as they navigated new pandemic-induced learning environments. Existing theories and empirical studies have shown that similar autonomy experiences in academic settings interact with academic motivational processes in students because one innate psychological need of humans is the need to feel ownership of one’s behavior (Deci & Ryan, 2000; Wang et al., 2019). However, while such autonomy influenced academic motivation during pre-pandemic periods, autonomy during the pandemic was characterized with higher frequencies of digital technology utilization and self-care.

Research Participants (RPs) greatly valued the transition to digital learning formats during the pandemic, as it significantly increased their access to STEM resources and provided enhanced flexibility in their learning processes. The availability of recorded lectures was a key feature that facilitated this shift, allowing RPs to access learning materials asynchronously, aligning with their personal schedules and when they felt most capable of absorbing the information. This approach not only catered to individual learning preferences but also respected the natural fluctuations in students’ cognitive capacities, a principle supported by cognitive load theory, which emphasizes the importance of managing the amount of information processed at any given time to enhance learning efficiency (Sweller, 1988).

The autonomy to control the pace and timing of learning is a critical component of self-determined learning and is strongly linked to increased academic motivation. According to Deci and Ryan’s Self-Determination Theory, when students feel a sense of ownership over their learning process, their intrinsic motivation is heightened, leading to deeper engagement and retention of material (Deci & Ryan, 2000). The shift to online learning during the pandemic provided an unprecedented level of autonomy for RPs, allowing them to experiment with different learning modalities and schedules that best suited their individual needs.

Furthermore, the physical absence of the need to commute to campus daily was highlighted as a significant benefit by many RPs, especially those who previously faced lengthy and exhausting commutes. This change not only saved time but also reduced the cognitive and physical fatigue associated with traveling, allowing students to allocate more energy towards their studies. The environmental psychology framework suggests that reducing environmental stressors, such as commuting, can significantly improve cognitive function and overall well-being, thereby enhancing learning outcomes (Bell, Greene,

Fisher, & Baum, 2001).

The impact of these changes was particularly pronounced for students who engaged in international study or who had previously balanced rigorous academic schedules with other commitments. The ability to access courses from anywhere in the world also underscores the global reach and inclusivity of digital learning platforms, potentially transforming how educational programs are structured even beyond the pandemic.

2. Building Communities (N = 32): RPs expressed increased value for the interactions, bonds, and support networks formed with their peers during the pandemic to support learning and well-being. Interactions were primarily through online platforms to include video conferences, chats, and online events. These interactions became vital avenues for RPs to learn, communicate, collaborate, and support each other. These peer interactions increased motivation as they somehow appeared to simulate pre-covid in-person learning as explained by an RP:

“Being able to still communicate with friends through zoom. They helped me feel like we were still back in the classroom learning and networking.”

RPs valued sharing similar interests with peers and these interactions quickly became a critical source of learning and encouragement as stated by an RP:

“Another positive that strengthened my motivation would be seeing the work that my classmates presented. While we could not physically meet or speak, we communicated through messaging and encouraged one another to continue with the program and projects.”

Similarly, Wu et al. (2020) found that 16% of respondents cited peer support as a positive experience. The sharing of similar academic and extracurricular interests served as focal points for peer interaction leading to the building of supportive learning communities and synchronized schedules that enhanced peer learning, advising, mentoring, support, and socialization during the pandemic. The collective drive to succeed and uphold responsibilities in group settings fostered trust, camaraderie, and accountability. Existing theories and empirical studies have shown that similar social connections and relatedness in academic settings interact with academic motivational processes in students because one innate psychological need of humans is the need to feel connected with others (Deci & Ryan, 2000; Wang et al., 2019). However, while such peer relatedness influenced academic motivation during pre-pandemic periods, relatedness during the pandemic was characterized with higher frequencies of digital communication technology utilization and the sense of collective pandemic-induced suffering.

During the pandemic, Research Participants (RPs) found significant value in the interactions and bonds formed with peers through various online platforms such

as video conferences, chats, and virtual events. These digital interactions were crucial in creating a semblance of the traditional classroom environment, offering a sense of normalcy and continuity in their educational experiences. An RP highlighted how communicating with friends via Zoom helped replicate the feeling of being back in the classroom, thus sustaining their motivation and engagement in learning activities.

The importance of these peer interactions extends beyond simple communication; they became vital support networks that facilitated collaborative learning, shared motivation, and emotional support. As noted by another RP, observing the work of classmates and engaging in mutual encouragement through messaging platforms bolstered their commitment to continue with their educational programs and projects. This dynamic is supported by Wu et al. (2020), who found that peer support was a significant positive influence during the pandemic, underscoring the role of shared academic and extracurricular interests as catalysts for building robust learning communities.

Theoretical frameworks such as Deci and Ryan's Self-Determination Theory emphasize the need for relatedness, or feeling connected with others, as a fundamental psychological need that enhances intrinsic motivation (Deci & Ryan, 2000). During the pandemic, the necessity for relatedness was met through increased use of digital communication technologies, which not only bridged the physical gap between students but also fostered a sense of collective experience and empathy among peers facing similar challenges. The formation of these virtual communities helped maintain a collective drive to succeed and uphold responsibilities within group settings, fostering trust, camaraderie, and accountability among students.

Pursuing Graduation (N = 26): With a strong focus on graduation, RPs were motivated to complete STEM requirements. Many RPs adopted a failure avoidance coping strategy as described by an RP:

"Seeing the light at the end of the tunnel motivated me to succeed. I knew that if I did not do well in my organic chemistry course, I would have to take it again and that would delay my graduation."

While some RPs were motivated by perceiving graduation as a terminal point, others were motivated by perceiving graduation as a steppingstone to further academic pursuits such as medical or graduate school. Recognizing the high qualifying requirements needed for their next level of education, they were motivated to work hard as an RP explained:

"Future graduate school expectations. I needed good grades to go to medical school, so I was motivated."

The findings from our study reveal that Research Participants (RPs) pursuing graduation in STEM disciplines demonstrate a pronounced motivation driven by the

immediate goal of fulfilling degree requirements, often utilizing a failure avoidance strategy to ensure academic progression (Smith & Johnson, 2018). This reliance on avoiding the negative repercussions of academic setbacks, such as delayed graduation or the necessity to retake courses, corresponds well with the perseverance dimension of the PERMA model, which posits determination as a crucial component of well-being and success (Seligman, 2011). Furthermore, the perception of graduation as either a terminal point or a stepping stone reflects the engagement and meaning facets of the PERMA model, where students see their academic efforts as intrinsically valuable, either as an ultimate goal or as preparation for further academic pursuits (Peterson, 2013).

In conjunction with Deci and Ryan's Self-Determination Theory, these motivations can be attributed to both extrinsic and intrinsic sources. Extrinsic motivation arises from the desire to achieve specific outcomes like high grades or the completion of prerequisites, which are essential for entry into competitive fields such as medical school (Ryan & Deci, 2000). Conversely, intrinsic motivation may stem from the personal satisfaction and intellectual challenge provided by mastering complex subjects like organic chemistry, which may hold inherent interest for the students (Deci, Vallerand, Pelletier, & Ryan, 1991).

By integrating these observed motivational strategies with theoretical frameworks, it is evident that while external rewards and recognitions (as highlighted by Self-Determination Theory) play a crucial role, the internal drive and fulfillment (as articulated by the PERMA model) are equally pivotal to the educational resilience and success of RPs in STEM fields (Richardson, Abraham, & Bond, 2012). This comprehensive view of motivation underscores the complexity of educational achievements and illuminates the varied strategies students employ to navigate their academic journeys effectively.

Securing Employment (N = 26): RPs were motivated by formal employment offers extended to them for STEM and non-STEM employment. Employment opportunities included full-time employment and internships that shaped career expectations amidst the global crisis. While employment was perceived as a source of income, it also signified an external validation of their knowledge, skills, and potential to be successful in future career endeavors as captured by an RP:

"Some positive experiences that strengthened my motivation to complete my stem courses during the pandemic included getting a new internship and the pass/fail grading system. My internship makes me feel confident in my ability to become a civil engineer."

RPs who obtained STEM internships increased in self-assurances regarding transitions into the STEM workforce. The results indicate that Research Participants (RPs) were significantly motivated by the prospect of securing employment, which included both full-time positions and

internships in STEM and non-STEM fields. This motivation was heightened by the external validation these opportunities provided, affirming the participants' knowledge, skills, and potential for future career success (Taylor et al., 2015). According to an RP, positive experiences like obtaining an internship notably enhanced their motivation to excel in their STEM courses during challenging times, such as the global crisis, and contributed to a heightened sense of confidence in transitioning into the professional workforce.

This external validation and consequent increase in self-assurance can be framed within Deci and Ryan's Self-Determination Theory, which emphasizes the importance of external factors in enhancing intrinsic motivation through the fulfillment of the need for competence and relatedness (Ryan & Deci, 2000). Simultaneously, the employment opportunities represent not only a source of income but also an achievement that contributes to the participants' accomplishment and engagement, key elements of Seligman's PERMA model, fostering well-being through meaningful work (Seligman, 2011).

Comparatively, studies like those conducted by Jensen and colleagues (2017) have shown similar patterns where employment opportunities during academic pursuits significantly bolster student motivation and engagement. These studies support the notion that practical, real-world experiences and the validation they confer can substantially impact student motivation, aligning closely with both theoretical frameworks.

This holistic approach, blending the validation from employment with intrinsic and extrinsic motivators, highlights the complex interplay of factors that drive academic and professional advancement among STEM students.

5. Honing Self-Regulation Skills

(N = 25): While the pandemic imposed significant challenges, it also served as a catalyst for RPs to develop critical self-regulation skills such as time management and self-motivation. These skills not only bolstered their academic performance but are also poised to be valuable assets for personal development now and beyond their college life. Self-regulation was important as RPs juggled multiple responsibilities independently in the new online learning environment with social distancing regulations. Confronted with the challenge of self-teaching and self-regulation in STEM learning during the pandemic, RPs recognized their disproportionate time allocation towards certain lifestyles and these prompted shifts in lifestyles. RPs distanced themselves from lifestyles which they now perceived as distractors to learning such as social media participation as explained by an RP:

"One positive that I experienced was the perspective that showed me how much time I spent on my phone and social media. I realized while I was rushing to get my projects done, I wasn't dedicating enough

time towards my long-term projects so this pandemic made me reassess my time management."

The pandemic, while presenting unprecedented challenges, acted as a powerful catalyst for the development of essential self-regulation skills among Research Participants (RPs). Skills such as effective time management and self-motivation were not only crucial in adapting to the new online learning modalities but also proved to be invaluable assets for personal development extending beyond their college careers. The shift to a predominantly online environment, necessitated by social distancing protocols, demanded that RPs independently manage their academic and personal responsibilities more rigorously. This adaptation process led to significant self-discovery, as RPs evaluated their engagement with distractive elements like social media. One RP noted the pandemic-induced revelation about the excessive time spent on non-academic activities, which prompted a critical reassessment of their time management strategies.

This evolution in self-regulation aligns with the component of competence in Deci and Ryan's Self-Determination Theory, which posits that developing new skills enhances one's sense of efficacy and autonomy (Ryan & Deci, 2000). Furthermore, these developments resonate with the accomplishment aspect of Seligman's PERMA model, where personal growth and overcoming challenges contribute to an individual's well-being (Seligman, 2011). Similar findings have been documented in other studies, where shifts to online learning environments have significantly influenced self-regulatory behaviors, highlighting the adaptability and resilience of students in maintaining academic integrity and performance under duress (Miller & Roksa, 2021).

By contextualizing these observations within broader theoretical frameworks, it is evident that the pandemic not only tested but also enhanced the adaptive capacities of students, preparing them for future personal and professional endeavors where self-regulation will continue to play a critical role.

Obtaining Funding (N = 24): RPs indicated that receiving, sustaining, and pursuing funding was a motivation to complete STEM requirements. In addition to providing financial relief, funds such as scholarships strengthened academic self-efficacy, as they were mostly awarded to high-performing students. As one participant described:

"...I earned a series of scholarships that covered the entirety of my semester costs. These experiences showed me that I can still make progress despite the circumstances and eased the financial pressures of paying for college."

Interestingly, participants who did not receive funds that they applied for were also motivated to work harder towards future scholarship applications. As another participant explained:

"I wasn't selected for scholarships because of my spring grades, and it made me want to do better."

Access to funding also prevented participants from channeling time and effort into the pursuit of other less convenient funding options, such as employment. One participant shared:

"I received some COVID-19 emergency funding from my school that allowed me to continue to attend my classes. Otherwise, I might have had to switch to part-time schooling and start working again."

The role of funding in motivating Research Participants (RPs) is profound, offering both financial relief and a psychological boost in academic self-efficacy. The direct correlation between scholarships and enhanced academic performance is highlighted by participants who received scholarships, affirming their capabilities, and easing the financial stress associated with higher education. This reinforcement of self-efficacy is aligned with Deci and Ryan's Self-Determination Theory, which posits that support in the form of resources like funding fulfills the basic psychological needs for competence and autonomy, thus enhancing intrinsic motivation (Ryan & Deci, 2000).

The impact of financial aid extends beyond immediate financial relief, fostering a deeper engagement in academic pursuits. For instance, students not receiving initial scholarships reported increased motivation to enhance their academic performance for future opportunities, reflecting a resilience that is crucial for long-term academic success (Zimmerman, 2000). This determination to improve and succeed despite setbacks exemplifies a growth mindset as conceptualized by Dweck (2006), which encourages viewing challenges as opportunities for growth rather than insurmountable obstacles.

Moreover, the availability of scholarships can reduce the necessity for part-time employment among students, allowing them to devote more time to their studies. This aspect is particularly critical as it supports the engagement component of Seligman's PERMA model, where students experience deeper absorption in their educational activities, leading to greater well-being (Seligman, 2011). Research by Scholar et al. (2019) confirms that students with secure funding are more likely to exhibit higher academic engagement and performance due to reduced financial stress and increased time availability for studies.

Comparative literature also shows that scholarships and grants play a vital role in shaping the educational trajectories of students. For example, studies by Thompson and colleagues (2015) found that financial aid significantly influences student retention and graduation rates, indicating the broad impacts of financial support on educational outcomes. Furthermore, the psychological benefits of receiving financial aid are echoed in the work of Patel and Jackson (2017), who reported increased feelings of belonging and validation among scholarship recipients, crucial factors that contribute to higher motivational

levels and academic success.

Sustaining STEM Learning (N = 23): RPs expressed appreciation for the direct and robust academic teaching, tutoring, assistance, and encouragement received from STEM professors and advisors through effective educational and institutional interactions. Professors' enthusiasm and dedication motivated learning described as 'mastering the material' by one RP:

"One of my professors is extremely engaging and motivated to help students get excited about stormwater coursework. The energy level of his classes keeps me interested and makes me want to master the material."

Facilitated by online platforms and tools, STEM students prioritized online interactions with their professors and expressed deep value for professor leniency. While positive interactions with professors also motivated students during pre-pandemic times, they were characterized with increased frequency, digitization, and leniency during the pandemic.

The appreciation expressed by Research Participants (RPs) for the academic support and encouragement from STEM professors and advisors underscores the critical role of effective educational interactions in sustaining STEM learning. The engagement and dedication of faculty members, as described by an RP who was particularly motivated by a professor's enthusiasm in stormwater coursework, illustrate the profound impact of teaching vigor on student motivation and engagement. This phenomenon aligns with the concept of relatedness in Deci and Ryan's Self-Determination Theory, which posits that feeling connected and valued by educators enhances students' motivation through increased perceived competence and autonomy (Ryan & Deci, 2000).

The transition to online learning platforms during the pandemic has intensified the value of these interactions. The shift facilitated more frequent, digitized, and lenient engagements, which were crucial in maintaining academic continuity and student interest in a remote environment. This adaptation highlights the flexibility and resilience of educational systems and their capacity to sustain student engagement under constrained conditions. Comparative literature suggests that positive and supportive interactions with faculty are pivotal in promoting academic persistence and deeper learning, a pattern that has been consistent even in pre-pandemic times but gained heightened significance during the pandemic (Johnson et al., 2018).

Furthermore, the pandemic-induced shift to online education necessitated an increased frequency of interactions, which, combined with greater leniency and support from professors, likely contributed to a more adaptable and responsive educational environment. Studies such as those by Anderson and Dron (2014) note that online education can enhance educational outcomes when it effectively leverages interactions between students and

educators, emphasizing the importance of adaptability in educational approaches to meet diverse student needs.

Envisioning Career Pathways (N = 16): RPs were motivated by the prospects of securing STEM employment and so explored career pathways and engaged in job search activities as noted by an RP:

"Being recommended to apply to a STEM scholarship and internship have also provided me with the motivation I need to continue to pursue my aspirations of attending medical school ..."

The power of career prospects bringing comfort and motivation was captured by an RP:

"The future career prospects that will be available to me later on strengthened my motivation to complete my requirements during the pandemic. Knowing that I'll have a secure job after graduation is a huge comfort."

Practical and mentoring experiences were valuable and fueled motivation due to the potential to advance career prospects as described by an RP:

"Doing research with my mentor, and a Ph.D. candidate allowed me to gain valuable experience in my future career field and strengthened my motivation."

Interestingly, pandemic challenges have not only shaped career interests but also significantly boosted motivation among RPs to complete their STEM requirements. One RP was particularly inspired by the need for effective communication between the health-science community and the public and stated:

"The need for healthy communication between the health-science world and lay-persons motivated me to pursue an MD and MPH."

This desire was further fueled by observations of the COVID-19 pandemic's impact on society and the healthcare system. The RP added:

"Watching how the pandemic impacted people and revealed difficulties in healthcare and medical research further motivated me to be a Health-science communicator."

The importance of delivering relevant and factual information in an understandable manner was underscored by the RP's aspiration to improve public knowledge in health sciences. They emphasized:

"People are in need of relevant, factual information relayed in an understandable manner."

Moreover, the pandemic sparked a keen interest in specific scientific fields as shared by an RP:

"The pandemic introduced me to virology, genetics, and vaccine production."

This newfound interest encouraged a deeper engagement with STEM courses, as they aimed to understand the science behind these critical disciplines. They concluded:

"I was interested in finishing STEM courses to learn about the science behind these disciplines."

The motivation derived from envisioning future career pathways in STEM significantly propelled Research Participants (RPs) to engage more deeply with their academic and career preparation activities. As some RPs explored opportunities like scholarships and internships relevant to their career aspirations, such as attending medical school, these prospects not only provided immediate motivational boosts but also reinforced long-term career goals. The anticipation of secure employment post-graduation, as expressed by one RP, illustrates the profound comfort, and drive that career prospects can instill in students, aligning with the future orientation component of career development theories which emphasize the motivational impact of clear, attainable career goals (Super, 1990).

Moreover, practical experiences such as research collaborations with mentors and Ph.D. candidates enriched RPs' understanding and enthusiasm for their chosen fields, enhancing their commitment to their studies. This hands-on involvement is supported by experiential learning theory, which suggests that direct engagement in relevant professional activities enhances learning outcomes and motivation by providing contextual relevance and practical experience (Kolb, 1984).

The challenges presented by the pandemic also played a unique role in shaping career interests and motivations among RPs. The urgency for effective communication between health-science professionals and the public, particularly highlighted during the pandemic, inspired one RP to pursue dual degrees in Medicine and Public Health. This dual motivation—stemming from both a personal passion for health science and a societal need highlighted by the pandemic—exemplifies the integration of personal and social motivators, which is central to Deci and Ryan's Self-Determination Theory, emphasizing the importance of autonomy, competence, and relatedness in fostering intrinsic motivation (Ryan & Deci, 2000).

Additionally, the pandemic prompted a keen interest in fields like virology, genetics, and vaccine production, further motivating RPs to pursue and excel in their STEM courses to understand the science behind these critical areas. This connection between current global events and academic pursuits not only highlights the relevance of STEM education but also enhances its value and immediacy in the eyes of students.

Honing Resilience (N = 16): RPs expressed how the pandemic increased their ability to adapt to, recover from, or withstand the challenges and disruptions imposed by the pandemic. With a focus on long-term values and improvement of the person, RPs prided themselves in their development of resiliency as an RP explained:

"The second thing is being able to show my resilience to sudden change in my work environments. I want to be able to adjust to any situation as I feel that would overall help me improve as a person."

The pandemic has undeniably acted as a significant stressor for many, yet it also provided a unique oppor-

tunity for Research Participants (RPs) to develop and demonstrate resilience. RPs reported that the pandemic increased their ability to adapt to and recover from rapid changes and disruptions, particularly in their academic and work environments. This enhancement of resilience is not merely about enduring difficulties but also about growing from these experiences, as highlighted by an RP who expressed a desire to adapt to various situations to foster personal improvement. This perspective aligns with the psychological concept of resilience, which is not just the ability to bounce back from adversity but also includes a transformative process that leads to personal growth and improved coping strategies (Masten, 2001).

The focus on long-term values and the continuous improvement of the self as part of resilience development is supported by the theory of post-traumatic growth, which suggests that people can experience significant positive changes in their personal and philosophical lives as a result of struggling with highly challenging life circumstances (Tedeschi & Calhoun, 2004). This theory complements findings in resilience research, showing that through navigating challenges, individuals often gain a heightened sense of personal strength, reevaluate their life priorities, and foster a deeper appreciation for life (Luthar & Cicchetti, 2000).

Moreover, the ability to adjust and thrive in changing environments as expressed by RPs is crucial in the context of modern educational and professional settings, which often demand high adaptability and flexibility. The pandemic, by forcing a rapid shift to online learning and remote working, has accelerated this need for adaptability, further emphasizing the value of resilience as a key component of academic and professional success.

Embracing Familial Support (N = 13): RPs expressed that personal and close interactions with family and friends increased their motivation to complete STEM education requirements. These support networks were sources of friendships and inspirations as stated by an RP:

"Being with my family. I was able to talk and hang out with my parents consistently. Pushed me to try and be better than they were."

Quality time and unwavering support of these socializers emerged as integral pillars that reinforced emotional stability and well-being needed to support STEM learning. Furthermore, these familiar interactions fostered the pursuit of personal milestones beyond the boundaries of STEM careers as one RP explained:

"One experience that motivated me was when I saw people online finding new opportunities and getting creative during the pandemic, so I felt like I had to do something too and keep myself busy. Another one was when I saw a close friend of mine had started a business and she gave me ideas too but that motivated me."

Research Participants (RPs) emphasized the significant role that familial support and close social interac-

tions played in enhancing their motivation to fulfill STEM education requirements. Consistent engagement with family members not only provided emotional support but also inspired RPs to excel, as many aimed to surpass the achievements of their predecessors. This motivation from familial encouragement is supported by theories of social support, which suggest that the emotional and instrumental assistance provided by close relationships enhances individuals' coping mechanisms during stressful periods (Cohen & Wills, 1985).

The quality time and unwavering support from these social networks were not just pillars of emotional stability but also beacons of inspiration. During the pandemic, the importance of these relationships became even more pronounced as RPs found themselves relying more heavily on their immediate social circles for both emotional solace and motivational boosts. This phenomenon aligns with Bourdieu's concept of social capital, where the family unit acts as a crucial reservoir of capital that RPs can draw upon for both direct and indirect support in their educational pursuits (Bourdieu, 1986).

Moreover, the motivational impact of observing peers and family adapt and innovate during the pandemic highlighted another critical aspect of social influence—observational learning. According to Bandura's social cognitive theory, observing successful coping strategies and innovative behaviors in one's social circle can lead to the adoption of similar strategies and increase one's motivation to succeed (Bandura, 1977). For instance, seeing a friend start a successful business during the pandemic provided not only practical ideas but also a strong motivational impetus for RPs to pursue their own goals and remain productive.

Additionally, studies have shown that students who perceive strong social support are more likely to exhibit resilience and a positive outlook towards their educational and career objectives, which in turn enhances their academic performance and personal development (Zimmerman & Schunk, 2001). These dynamics were clearly evident among the RPs, as those with robust support systems were better equipped to navigate the academic and personal challenges posed by the pandemic, illustrating the critical role of social support in fostering educational resilience and motivation.

Maintaining Grades (N = 10): RPs stated that the maintenance of good grades was a source of motivation as they felt fulfilled and inspired to keep working towards their academic goals as expressed by an RP:

"I got a good grade on a test. This experience made me feel really good and fulfilled and I wanted to keep feeling that way, so I was motivated."

For the Research Participants (RPs), the achievement of maintaining good grades emerged as a crucial motivator in their academic journey, particularly during the challenging circumstances imposed by the pandemic. The

satisfaction and fulfillment derived from receiving high marks on assessments were reported to inspire continued effort and dedication towards their studies. This positive reinforcement is closely aligned with the concept of achievement motivation, which suggests that successes in academic performance boost students' self-efficacy and inspire them to set and pursue higher goals (Atkinson, 1964).

The feeling of fulfillment from good grades, as described by an RP, encapsulates the feedback loop often discussed in educational psychology, where positive academic outcomes enhance students' enjoyment and motivation to engage in learning activities (Pintrich & Schunk, 2002). This cycle of motivation and achievement is critical in sustaining student engagement, especially in an environment disrupted by external stressors like a pandemic.

Moreover, the role of good grades extends beyond immediate academic validation. It also plays a pivotal part in shaping students' academic identities and future aspirations. According to expectancy-value theory, the expectation of success (influenced by past achievements such as good grades) and the value placed on succeeding are fundamental drivers of motivation and effort in academic settings (Wigfield & Eccles, 2000). The encouragement RPs feel from their accomplishments reinforces their belief in their capabilities and the value of their educational pursuits.

Limiting Distractions (N = 10): RPs appreciated the reduction in learning distractions during the pandemic. With online learning and social distancing measures in place, there was a reduction in extracurricular and other socializing activities that would normally have distracted RPs during pre-covid in-person STEM education contexts. Therefore, RPs were able to dedicate more time and effort to completing STEM course requirements as explained by an RP:

"... Spending less time doing extracurriculars gave me more time to do homework."

During the pandemic, Research Participants (RPs) experienced a notable decrease in distractions typically associated with on-campus activities, as the shift to online learning and social distancing measures minimized engagements in extracurricular and socializing activities. This reduction in non-academic commitments allowed RPs to allocate more time and energy towards their STEM coursework. The decrease in external distractions aligns with theories of cognitive load, which suggest that reducing extraneous stimuli can enhance cognitive resources available for learning tasks (Sweller, 1988).

The significant shift in learning environments during the pandemic inadvertently created conditions that some students found conducive to academic focus. By limiting their involvement in extracurricular activities, RPs reported an increase in available time for academic pursuits, as one participant noted the newfound ability to devote more time to homework. This observation reflects

findings in educational psychology that a less distracted environment can lead to improved academic performance and increased task engagement (Kahneman, 1973).

Furthermore, the enforced solitude and reduction in social interactions, although challenging, provided an unexpected benefit by fostering a more controlled and less interrupted study environment. This scenario has been explored in research on environmental psychology, which examines how physical and social environments influence cognitive functioning. Studies have shown that environments with fewer disruptions are associated with higher levels of concentration and more effective learning outcomes (Mayer & Moreno, 2003).

Struggling Collectively (N = 10): RPs felt comforted by knowing that their peers were navigating similar adversities during the pandemic. Although separated physically, the collective struggles of RPs became more evident to them during online social interactions with peers as explained by an RP:

"A long discord call with my engineering friends and being able to make new connections intellectually and socially online made me more motivated to complete stem requirements. These experiences both helped me recharge socially and reminded me of how I wasn't struggling alone."

This collective struggle mindset eased social isolation and other pandemic related burdens as RPs felt they were not alone and that feeling of collectively experiencing pandemic-induced burdens reduced the pain of the burdens and motivated completion of STEM education requirements.

During the pandemic, Research Participants (RPs) found solace in the shared experiences of adversity with their peers. Although physical separations were enforced, the use of online platforms enabled meaningful social interactions, making the collective struggles more visible and palpable. An RP described how long discussions with engineering peers over Discord not only facilitated new intellectual and social connections but also reinforced the sense that they were not enduring these challenges alone. This sense of communal coping, where individuals perceive themselves as part of a collective facing and managing stress together, has been shown to ease feelings of isolation and enhance personal motivation (Lyons, 1991). The collective struggle mindset, facilitated through digital communications, played a critical role in reducing the emotional burdens associated with the pandemic. Knowing that others were facing similar challenges provided a form of emotional support that is crucial during times of crisis. This phenomenon aligns with the concept of social comparison theory, which suggests that individuals evaluate their own situations by comparing with others. In this case, seeing that peers were also navigating similar hardships helped normalize the experiences and reduce feelings of isolation (Festinger, 1954).

Moreover, the shared experiences of adversity fostered

a communal sense of purpose and resilience among RPs, motivating them to continue with their STEM requirements despite the challenges. This aligns with research on social resilience, which highlights how shared struggles can lead to enhanced collective efficacy, encouraging individuals to persevere through hardships (Cox & Hamlen, 2015).

Receiving Care (N = 8): RPs expressed appreciation for the guidance, accommodations, and support received from authority-figures in their STEM institutions because they were presented opportunities and had their persistence strengthened as expressed by an RP:

"Additionally, meeting with my advisor and talking about the opportunities strengthened my motivation because she explains how she understands this timing is hard, but to make the best of it and still work hard."

Expressions of understanding and provision of accommodations by authority-figures gave RPs hope as captured by an RP:

"... meeting and encouragement from my advisor... having professors that are understanding what we're going through and accommodating us. These two experiences strengthen my motivation because it gave me hope that so would be successful during this time."

Research Participants (RPs) deeply valued the guidance and accommodations they received from authority figures at their STEM institutions during the pandemic. Meetings with advisors and supportive interactions with professors not only presented them with opportunities but also reinforced their determination to persevere through challenging times. An RP highlighted how discussions about career opportunities and encouragement from an advisor bolstered their motivation, emphasizing the importance of understanding and support from faculty during difficult periods.

This type of support from authority figures is crucial in fostering an educational environment where students feel cared for and motivated. According to the theory of transformational leadership, leaders who demonstrate empathy and provide appropriate support can significantly influence their followers' satisfaction and performance (Bass, 1985). In the context of education, professors and advisors who adopt this approach can enhance students' academic engagement and resilience.

Furthermore, the provision of accommodations and the understanding attitude of professors were not just administrative measures but also sources of emotional support that gave RPs hope and confidence in their ability to succeed. This aligns with the concept of academic buoyancy, which refers to students' ability to successfully navigate typical academic challenges, including managing stress and bouncing back from setbacks (Martin & Marsh, 2008). The support from authority figures effectively reduced emotional barriers, facilitating a more conducive learning environment that enabled RPs to focus on

their academic goals despite the adversities posed by the pandemic.

Accessing pass-fail systems (N = 8): RPs appreciated the availability of pass-fail policies. To maintain satisfactory performance needed for academic progression in rigorous STEM programs, RPs concerned about their self-perceived 'unsatisfactory' grades took advantage of the pass-fail (satisfactory/unsatisfactory) policies. It sustained their current GPAs and reduced stress levels as explained stated by an RP:

"The university deciding to allow pass/fail grade system. It has alleviated a little bit of the stress I was feeling about grades and let me allow myself to take more classes in this difficult time (knowing if something happened, I would have this option that does not impact my GPA)."

With less risk associated with declining GPAs, RPs felt supported by their institutions and were willing to take more and tougher courses in these turbulent times as stated by one RP:

"The flexibility of a pass-fail system motivated me to take very hard classes during summer, fall, and spring."

In the light of less risks with course enrollment, this pass-fail system was perceived as 'back-up' plan and a source of motivation as explained by an RP:

"The pass/fail option for courses. This helped me feel like there was a backup plan, so I was motivated to keep going."

The availability of pass-fail grading options was highly valued by Research Participants (RPs), especially those concerned about maintaining satisfactory performance in the demanding environment of STEM programs. By opting for pass-fail grades, RPs were able to sustain their GPAs and alleviate some of the stress associated with potentially receiving lower grades. An RP described how the university's decision to implement a pass-fail grading system reduced their anxiety about academic outcomes and enabled them to enroll in more courses during challenging times, secure in the knowledge that their GPA would not be adversely affected.

This strategic use of pass-fail policies reflects principles from decision theory, particularly regarding how individuals make choices under conditions of uncertainty (Tversky & Kahneman, 1981). The pass-fail system provided a safety net that reduced the perceived risks associated with enrolling in challenging courses, thereby supporting bolder academic endeavors. Furthermore, the option acted as a psychological buffer against the fear of failure, a significant stressor that can impede academic performance and motivation.

The implementation of pass-fail grading systems during the pandemic also aligns with findings in educational psychology that suggest reducing performance pressures can enhance learning outcomes and increase willingness to engage in challenging educational activities (Pekrun, 2006). With less risk of damaging their GPAs, RPs felt supported by their institutions' understanding of the extraor-

dinary circumstances and were motivated to take on and navigate tougher courses.

Returning to campus (N = 5): RPs indicated that returning campus increased their motivation to learn as stated by an RP:

"The ability to move back on campus greatly improved my motivation to complete STEM course requirements because I felt I would be better equipped to handle the classes if I was on campus."

Some RPs appeared more dependent on the physical and social resources available with physical presence on their campuses as explained by an RP:

"Staying on campus has also been positive because it has allowed me to physically interact with a small group of people that are like-minded in goals. Without them I would not have a close bubble of friends to keep me motivated."

For some Research Participants (RPs), the opportunity to return to campus was a significant motivational booster for completing their STEM course requirements. One RP highlighted that being physically on campus made them feel more equipped to handle their courses, suggesting that the campus environment itself plays a critical role in fostering an academic mindset and motivation. This connection between physical presence and academic performance is supported by environmental psychology, which posits that certain spaces can enhance cognitive functioning and motivation due to their association with learning and intellectual activity (Kaplan, 1989).

Additionally, the physical return to campus enabled RPs to engage more directly with peers who shared similar academic goals. This access to a like-minded community created a supportive network, crucial for maintaining motivation. As one RP noted, the ability to interact with a close group of friends provided not only social support but also a shared drive towards academic success. This phenomenon aligns with Vygotsky's social development theory, which emphasizes the importance of social interactions in cognitive development and learning (Vygotsky, 1978).

The presence of physical and social resources on campus, such as study spaces, access to faculty, and peer support groups, contributes significantly to academic engagement and motivation. This is particularly true in STEM disciplines, where collaborative learning and hands-on experiences are often integral to the educational process. Research indicates that students who feel part of an academic community are more likely to be motivated and succeed in their studies (Tinto, 1997).

Research Question 2: *Why did salient positive experiences strengthen undergraduate STEM students' motivation to complete STEM course requirements during the COVID-19 pandemic?*

Research Question 2 explores why salient positive experiences were instrumental in strengthening undergraduate STEM students' motivation to complete their course requirements during the COVID-19 pandemic. At the on-

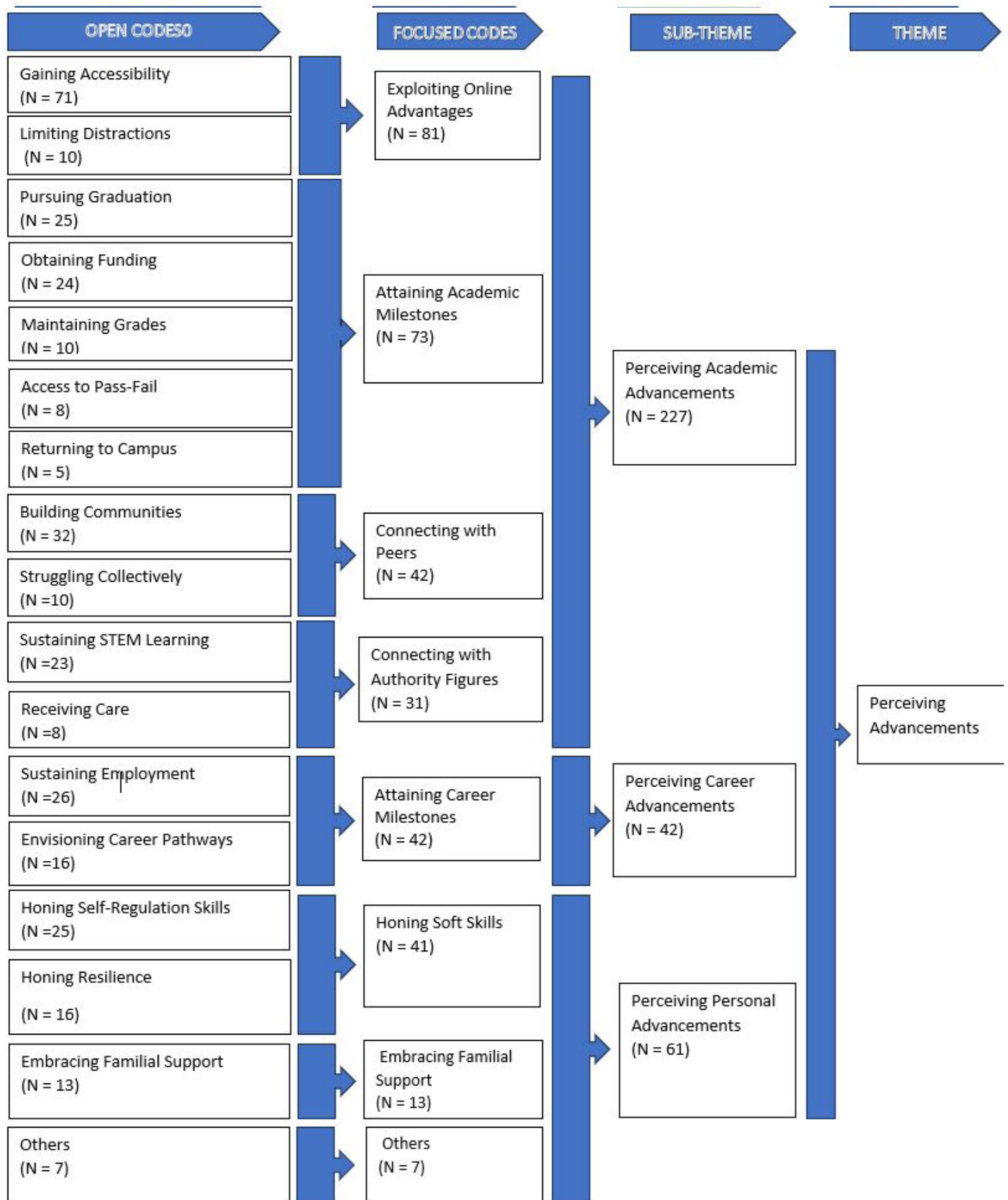


Figure 1. Theoretical coding structure

set of the pandemic, educational systems worldwide were disrupted, compelling students and institutions to adapt rapidly to unprecedented circumstances. This research seeks to understand why, amid such disruptions, certain positive experiences could significantly enhance students' academic motivation, suggesting a complex interplay between students' psychological needs and their academic environment.

In this context, the "Perceiving Advancements" theme emerged as a key explanatory concept. It posits that during high-risk educational scenarios, like those induced by the pandemic, the ability of students to perceive and appreciate positive experiences plays a crucial role in sustaining their motivation. These experiences, ranging from improved access to resources to enhanced support from faculty, helped students navigate through the complexities of remote learning and isolation. Importantly, this theme suggests that recognizing the potential benefits of these experiences encouraged students to align their academic efforts with their broader future aspirations.

Through the lens of positive psychology, this study explores the interactions between these beneficial experiences and students' motivation. By adopting this perspective, the research highlights how positive interventions, even when implemented under crisis conditions, can effectively bolster student resilience and drive. The three sub-themes—Perceiving Academic Advancements, Perceiving Career Advancements, and Perceiving Personal Advancements—further operationalize this concept, detailing how students interpret and integrate their experiences into their motivations for academic advancement. Prior to this research, school-based positive psychology had been mostly utilized as a lens to understand and develop positive interventions to promote the well-being of students in non-pandemic contexts. Adopting this lens, this study aimed to explore interactions between positive experiences and academic motivation in undergraduate STEM students during high-risk educational contexts. This new understanding is captured in the emerging "Perceiving Advancements" theme, which is essential to defining this pivotal concept and the importance of salient positive experiences in strengthening academic motivation in undergraduate STEM students. Utilizing three unifying sub-themes, the "Perceiving Advancements" theme explains why specific types of positive experiences motivate the completion of STEM course requirements from the perspectives of undergraduate STEM students. The theme specifically refers to RP understanding and appreciation of the potential that these salient positive experiences have in propelling them toward their future goals and expectations. The utilization of the first term, Perceiving, is underpinned by RPs' awareness or recognition that their specific positive experiences have the potential to significantly contribute to their current and future academic, career, and personal goals and growth. The second term, Advancement, captures the potential growth in the

three critical aspects of students' future goals – academic, career, and personal goals. Therefore, this concept is operationalized through three interconnected sub-themes: *Perceiving Academic Advancements*, *Perceiving Career Advancements*, and *Perceiving Personal Advancements*. These sub-themes represent the spectrum of future advancement areas identified by RPs as being positively impacted by their undergraduate STEM education experiences during the pandemic.

Adopting the Gioia approach for illustrating the theoretical coding structure, figure 1 captures the linkages among the codes that support this theme (Gioia et al., 2013; Reay et al., 2019). Grounded in the data, the *Perceiving Advancements* theme, explained why positive undergraduate STEM experiences motivated the completion of STEM course requirements. RPs attributed the motivation generated through their positive experiences to the perceived capacity or potential for those nuanced positive experiences to contribute to their academic, career, and/or personal advancements. The boxes and arrows are utilized to show different levels of coding with the number (N) of references for each code as raw data was aggregated to the focused codes embedded in the three sub-themes (Perceiving Academic Advancements; Perceiving Career Advancements; and Perceiving Personal Advancements) which capture the three patterns of advancement within this central advancement theme.

An example of an RP statement highlighting the "Perceiving Career Advancements" sub-theme involved the RP making strong and direct associations between positive pandemic-induced technological advancements project experiences and academic motivation to complete STEM educational requirements to advance into the workforce. As a computer science student, the pandemic allowed this RP to gain a new understanding and realization of interactions between STEM discipline and pandemic solutions. This new and expanded awareness and appreciation of potential career options was perceived as a positive experience that strengthened academic motivation as the RP wanted to progress and make an impact on the world as stated:

"Probably the technological advancements made during the pandemic and personal projects that I was working on boosted my motivation to complete my classes. Seeing the computer science field thrive during the pandemic made me want to finish my classes so I can enter the industry and start making an impact on the world. With the pandemic, I have had a bit more free time to start working on my projects and it made me want to finish my classwork faster so I can make more progress on my personal projects."

RPs such as this computer science RP provided detailed and relevant statements in responses to the survey item. They described two positive experiences and explained why they considered those experiences as positive. Conversely, a counterexample involves an engineering RP making a short statement with no explanations about

why that experience strengthen motivation. This RP made this statement:

"My academic advisor was present for me during the pandemic and provided a valuable line of communication."

It is obvious that interactions with academic advisor was considered as a positive experience by this RP. However, this RP did not provide additional descriptions of the advising experience nor explain why the experience strengthened academic motivation. Such distinctions are critical for understanding the scope of "Perceiving Advancements" within this research.

The motivation of RPs to complete STEM course requirements was inspired by the perceptions that their salient pandemic-induced positive experiences had the capacity to help them advance towards their future academic, career, and personal goals and expectations. In fact, the outcomes of pre-pandemic lived experiences, whether good or bad, had contributed significantly to shaping these future academic, career, and personal expectations and goals. For example, the elevation of the importance of good grades as important academic outcomes from past STEM education experiences had contributed to RPs' perceptions that good grades were extremely important for academic advancement. These past outcomes influenced their understanding and perceptions of the effective strategies and nurturing conditions required to attain their pre-pandemic expectations and goals.

Therefore, experiences such as good grades that enhanced the attainment of academic advancement were perceived as positive and enhanced motivation. Prior to the pandemic, RPs had well-rehearsed academic strategies for success in traditional in person STEM education environments. With the occurrence of the pandemic, planned pre-pandemic strategies were challenged and derailed by unfavorable pandemic conditions (ex. social distancing) that affected their learning (ex. online learning) and socializing (social isolation) environments.

Therefore, RPs often explored alternative ways to pursue effective strategies needed to advance towards their future goals and expectations. Any new pandemic-modified lived experiences that helped RPs maintain original pre-pandemic strategies or provided alternative resources and support to help RPs advance towards their pre-pandemic goals and expectations generated positive feelings and were described as positive experiences. In describing these positive experiences and feelings, RPs often compared their pre-pandemic experiences with their pandemic lived experiences thereby establishing a baseline and premise for their new experiences. These positive feelings of wellbeing reduced the anxieties and stresses associated with STEM learning during the pandemic, and thereby motivated RPs to complete STEM course requirements. Energy, effort, and time that would have been consumed in managing excessive pandemic-induced stresses were re-directed to STEM learning.

Building on this quantitative foundation, we now pro-

ceed to examine the three sub-themes generated from our analysis, each reflecting a distinct dimension through which RPs perceived advancements in their academic, career, and personal spheres during the COVID-19 pandemic.

Sub-Theme 1: Perceiving Academic Advancements

This sub-theme captured experiences that RPs described as positive due to their perceived potential to advance academic achievements. In turn, this potential drove motivation to complete STEM education requirements. This sub-theme is comprised of four focused codes:

1. Exploiting Online Advantages: This positive experience category highlights taking advantage of the benefits and conveniences of online technologies. RPs were grateful for improved access to STEM learning resources and fewer learning distractions compared to pre-pandemic in-person STEM learning contexts.

2. Attaining Academic Milestones: This positive experience category highlights attainment of academic milestones. RP expressed strong focus on graduation, financial awards, grades, pass-fail systems, and campus presence that support the attainment of academic milestones.

3. Connecting with Peers: This positive experience category highlights peer collaborations and support during the pandemic. RPs appreciated peer collaborations and support. They highlighted a sense of comfort and belonging as they struggled through the pandemic.

4. Connecting with Authority Figures: This positive experience category highlights interactions with academic instructors and advisors during the pandemic. RP expressed appreciation for the guidance, assistance, and encouragement, care, and accommodations received from authority figures to sustain STEM learning and motivation.

Sub-Theme 2: Perceiving Career Advancements

This sub-theme captured experiences that RPs described as positive due to their perceived potential to advance career achievements. In turn, this potential drove motivation to complete STEM education requirements. This sub-theme comprised of one focused code.

1. Attaining Career Milestones: This positive experience category highlights STEM career opportunities and growth trajectories encountered during the pandemic. RPs expressed appreciation for STEM and non-STEM employment. They valued opportunities to explore STEM career pathways.

Sub-Theme 3: Perceiving Personal Advancements

This sub-theme captured experiences that RPs described as positive due to their perceived potential to advance personal achievements. In turn, this potential drove motivation to complete STEM education requirements. This sub-theme is comprised of three focused codes:

1. Honing Soft Skills: This positive experience category involved the progressive attainment of several self-regu-

lation skills and resilience during the pandemic. as they adapted to, recovered from, or withstood challenges.

2. Embracing Familial Support: This positive experience category involved familial interactions through which RPs received support from friends, family, and significant others within their communities.

3. Others: This positive experience category highlights the few and divergent experiences that did not align with any preceding code. For example, one RP expressed that survey participation was a positive experience.

Discussion

The purpose of present research was to explore positive experiences that strengthened undergraduate STEM students' motivation to complete STEM course requirements during the COVID-19 pandemic. Analyzing data through an inductive thematic analysis approach resulted in the emergence of the central theme, Perceiving Advancements, which explains how positive experiences were attributed to their perceived potential to support academic, career, and personal advancements. The recent emphasis on the need for improved academic motivation and positive psychology in educational settings make these insights valuable because they inform research and practice to advance the design and implementation of effective interventions for the motivation of undergraduate STEM students during high-risk contexts such as the COVID-19 pandemic (Waters, 2011; Seligman, 2011).

First, the findings revealed that undergraduate STEM students in the U.S. encountered positive experiences to include exploiting online advantages, attaining academic and career milestones, connecting with peers and authority-figures, honing soft skills, and embracing support. Despite the isolation and learning challenges encountered by undergraduate STEM students, they still encountered positive experiences and emotions that support the well-being of humans, especially in high-risk contexts (Waters, 2011; Seligman, 2011).

Secondly, students who valued autonomy more than relatedness were likely to associate academic motivation with positive experiences such as online learning which allowed self-governance with fewer restrictions and more control over learning space, time, and pace. On the other hand, students who valued relatedness more than autonomy were likely to associate motivation with positive experiences such as peer and authority figure connections which fostered more structure, interdependence, accountability, sense of belonging and struggling collectively.

Furthermore, findings confirmed that intentional and planned pandemic-driven nationwide institutional reinforcements and interventions such as online learning systems, COVID-related funding, and pass/fail policies were effective in fortifying STEM students' positive experiences and motivation in these high-risk contexts. The efficient and rapid integration of technology in education was identified as a particularly significant advantage

(Magomedov et al., 2020; Mishra et al., 2020; Mercatelli et al., 2021). Also, emergency grants provided by federal programs were beneficial. These grants, covering diverse expenses from food and housing to course materials and technology, aided students' physical and mental well-being (McKinnon-Crowley, 2021). This was particularly critical considering the reported increase in food insecurity and decrease in mental well-being among students due to financial instability during the pandemic (Owens et al., 2020; Son et al., 2020). Students explained that modifications to typical STEM education and institutional policies and environments reduced COVID induced stress and anxiety; thereby, allowing them to have the energy and motivation to better manage their adaptation strategies. For example, with COVID funding, some STEM students, especially from low-income families, did not have to find employment to earn money to support themselves and their families. The effort and time for maintaining employment was dedicated to learning and supporting academic advancement.

Thirdly, STEM students were also motivated by unplanned and unintentional positive experiences that emerged spontaneously during their efforts to adapt to the changing STEM education environment. Positive experiences like spontaneous peer connections, authority figure care, collective struggle mindset development, and support from family members enhanced and the development of critical self-regulation skills and resilience needed for STEM learning during the pandemic (Kusumaningrum et al., 2020; Jemini-Gashi & Kadriu, 2022). Socialization during the COVID-19 pandemic was critical in supporting cognitive and emotional well-being in most students (Cutri et al., 2020; van der Spoel et al., 2020; Ofori-Boadu et al., 2020; Momtazmanesh et al., 2021; Fash et al., 2021; Ofori-Boadu et al., 2022; Lamssali et al., 2021, 2022). While peer socialization contributed to STEM learning, it also spurred social comparisons and social support that generated positive feelings to reduce anxiety and stress experienced by students during the pandemic. Considering that students moved from campus into domestic environments, parental and family support and guidance replaced typical support from STEM educational communities. These findings suggest that institutions should seriously consider devising domestic-based interventions and policies that will strengthen student motivation in high-risk situations.

Fourthly, salient experiences were perceived as positive and improved motivation to complete STEM course requirements because students perceived that those experiences were critical for their academic, career, and personal advancement. The outcomes of past pre-COVID experiences shaped students' expectations and perceptions about interventions that would support their advancements during the pandemic. Therefore, students were motivated to pursue these interventions and considered

them as positive because they associated those experiences with their success. As an example, Connecting with Authority–Figures, was an important code, because from their past and current experiences, students knew that professor interactions were important to their academic success. Therefore, they considered such interactions as positive and motivating. During such interactions, they gained the knowledge and understanding, and encouragement needed to complete STEM course requirements. Except for one student who denied encountering any positive experiences, all other students attributed their motivation to at least one of the following three patterns advancements:

Academic advancements: With focus on academic goals, positive experiences involved short term advancements and milestones within the boundaries of STEM education communities. Furthermore, this was characterized by a strong dependence on accessing institutional learning resources to include online technologies, funds, peer communities, and authority figure support. In effect, institutions should continue to devise effective strategies to target these high institution-dependent students and provide them with STEM educational and institutional interventions such as institutional counselling and funding to improve their motivation to complete stem course requirements.

Career advancements: With focus on career goals, positive experiences involved medium term advancements and milestones within the boundaries of STEM and non-STEM employment communities. Furthermore, this was characterized by a strong dependence on accessing employment resources to include mentoring and hands-on STEM career experiences (Feldman, 2021). In effect, institutions should devise effective strategies to target these medium institution-dependent students and provide them with STEM employment and career opportunities to improve their motivation to complete stem course requirements.

Personal advancements: With focus on personal goals, positive experiences involved long term advancements and milestones that were beyond the boundaries of STEM education and employment communities. Furthermore, this was characterized by a strong dependence on familial and personal resources to parental support, self-regulation, and self-motivation. (Brennan et al., 2023). They involved lifelong skills and goals that spanned beyond STEM and sometimes involved families for persistent / grounded support and broader society aspirations. These students had the tendency to exhibit strong independence from STEM educational settings, but some dependency on resources provided through their family, friends, and external communities. In effect, institutions may not have to invest as many resources into these more independent STEM students; however, opportunities for personal development to include online entrepreneurial workshops

may be beneficial and improve their motivation to complete stem course requirements.

Fifthly, while positive experiences such as connecting with peers and authority figures occurred during pre-pandemic times and demonstrated how relatedness interacts with academic motivation, they were characterized by increased frequency, interdependence, digitization, physical remoteness, and a unique sense of struggling collectively during the pandemic.

Sixthly, these findings suggest that institutions will benefit from continuing to explore external collaborations to support the development of STEM students, even during high-risk contexts such as pandemics.

Lastly, in agreement with the Deci and Ryan Self-Determination Theory of Motivation and Martin Seligman's Positive Psychology Theory, these insights expand academic motivation and school-based positive psychology frameworks to include insights from undergraduate STEM and high-risk (pandemic) contexts. It establishes confirms that positive experiences involving autonomy and relatedness are still capable of supporting the well-being and motivation of undergraduate STEM students, even during high-risk contexts. The associations between positive experiences and motivation are clearly explained with emphasis on the role of perceptions and advancements in motivating completion of STEM course requirements. These insights justify further research to explore motivation and positive psychology in educational settings and high-risk contexts. Our findings offer valuable insights that could be applicable in understanding motivation and developing interventions for diverse populations beyond the STEM disciplines, student demographics, and the U.S., thereby enriching positive psychology and motivation research, policies, and practices globally.

In our exploration of the positive experiences that bolster undergraduate STEM students' motivation, we have taken initial steps towards addressing the complex question of causality—how these experiences may act as a driving force in motivating students. While our methodology has illuminated a rich array of motivating experiences, it inherently possesses limitations in definitively establishing causal relationships. This study has begun to hint at potential causal frameworks, suggesting that perceptions of advancements in academic, career, or personal domains can significantly influence motivation. However, elucidating the precise mechanisms by which these perceptions translate into motivation requires a more nuanced approach, possibly involving longitudinal studies or experimental designs capable of capturing the dynamism of these motivational processes over time.

Recognizing these limitations, our findings lay the groundwork for future research aimed at unraveling these causal connections. We advocate for further investigation, supported by robust methodologies, to delve deeper into the causality question. This next phase of research, which

we hope will be facilitated by substantial support from funding bodies like the NSF, promises not only to enrich our understanding of student motivation in STEM fields but also to inform the development of targeted interventions designed to enhance student engagement and persistence. Our study serves as a preliminary yet crucial step towards this goal, highlighting the importance of positive experiences while acknowledging the journey ahead in fully understanding their motivational impact.

While our findings illuminate the positive experiences of STEM students during the pandemic, it's important to acknowledge the potential underrepresentation of challenges and negative experiences within our dataset. Our focus on motivational narratives may have inadvertently sidelined less positive, yet equally significant, aspects of student experiences. This selection bias highlights the limitations of relying solely on self-reported data for understanding the complex landscape of academic motivation. Future studies might benefit from incorporating a broader methodological approach, including longitudinal and observational research, to capture the full spectrum of student experiences—both positive and negative—thereby providing a more comprehensive view of what truly motivates academic persistence in STEM fields during times of crisis.

Conclusion

The Perceiving Advancements theme explained why positive experiences influenced undergraduate STEM students' motivation to complete STEM education requirements. Insights expand understanding and application of academic motivation and school-based psychology theories in undergraduate STEM education and high-risk education contexts.

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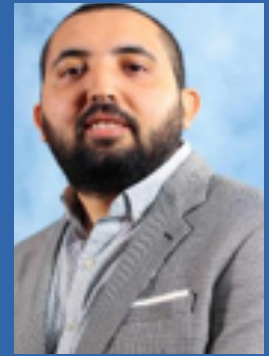
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