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Ready Pupil One: Online Learning Experiences of Undergraduate STEM Majors at a Midwest Regional Comprehensive University

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Ready Pupil One: Online Learning Experiences of Undergraduate STEM Majors at a Midwest Regional Comprehensive University

by

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Abstract

Many institutions of higher education in the United States, and, indeed, around the world, are feeling multi-faceted pressures to offer course content through online delivery modes. Administrators of institutions of higher education often view such delivery as a way to raise revenue and reduce costs for the institution while also often offering students flexibility to learn at their own pace. Still, many students and faculty alike often also encounter challenges with online delivery. In this phenomenological qualitative study, I explored the positive and negative experiences of undergraduate STEM majors who had taken at least one major-required, STEM-focused, class delivered entirely online. Using a semi-structured interview format, I interviewed twenty-three undergraduate STEM majors at a mid-sized, public, four-year Regional Comprehensive University. Students described their learning experiences, which I then analyzed for emergent themes. The majority of participants reported feelings of isolation and loneliness in their classes, owing, primarily, to a lack of opportunity to interact with their peers in substantial ways. This study's findings align with previous research suggesting that best practices for online synchronous and asynchronous instruction include giving students opportunities to learn collaboratively with peers and interact regularly with their professors.

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Chapter 1: Ready, Pupil One?

In the novel *Ready Player One*, Cline (2011) provides the reader with a glimpse into a society in which people utilize a virtual reality simulator called the OASIS to escape widespread social problems. Embedded within the OASIS is a structured system of online public education, in which students who could access the internet logged onto a virtual world to attend classes using digital avatars. This computer-based delivery, devoid of constraints of real-world physics or financial concerns beyond accessing the internet, afforded teachers and students alike the opportunity to engage with academic subjects in ways not possible in conventional school settings, such as taking virtual trips to museums thousands of miles away or simulating environments in the outer reaches of the solar system. The same computer system regulated students' behavior and language, striving for an underlying sense of uniformity between student experiences while allowing teachers to teach subjects about which they were passionate, all in a digital environment.

Engaging in a real-world conversation, undergraduate STEM students Gabriella and Darrell (pseudonyms) describe their experiences as online learners at a regional comprehensive university (RCU) that offers their major-required courses online. Gabriella, a sophomore, is enrolled as a chemistry major and Darrell, a senior, is enrolled as a physics major.

> *Gabriella*: I've gotta say, I've found my online courses to be pretty interesting. They're tough, but, I mean, they're kinda supposed to be. And, even though it's sometimes hard to stay on top of the assignments, at least the professor is super organized and gives us detailed directions. Plus, they let us interact with each other during class. We also have a discussion board and we need to respond to each other's problem set solutions, so it's

kinda like we get to help each other through it. The teaching assistant holds review sessions on Zoom™, too, and that helps a lot. At least we get points for participating when we ask questions. The schedule of the course lets me chew on the material before we discuss it, and I get to try things out on my own without having to show off in front of everyone. I hate showing off in front of everyone, especially if I haven't had time to think about it. It makes me nervous. But I can work at my own pace and it gives me time to be with my family and go to my job. I kinda think the courses have been good for me.

Darrell: Really? 'Cause I'm so glad this is my last year here. I'm only taking one class online this semester, but I feel so disconnected from the material. I used to really like the topics, too, but without being able to be in the lab and get my hands-on stuff, it's really difficult for me to understand. The professor is nice, but they don't require us to turn our cameras on, so it's like talking to a blank wall for the most part. I'm not sure what I'm really learning, 'cause the lectures are prerecorded and I still can't follow along. The synchronous labs are interesting, though – at least I get to hang out with other students even if we're online. The kits we got with the course make some of the material make sense. But, the discussion boards are ridiculous; the professor doesn't check them, so the only incentive to participate on them is for points, not feedback. I never feel like I remember anything, 'cause I'm always just trying to cram stuff into my head before exams and such, I feel like my memory just isn't working. I don't think online learning is for me.

Gabriella and Darrell's exchange touched upon many issues often discussed in the context of higher education's inclusion of online content delivery of courses: student access to

content; student satisfaction; student efficacy, aptitude, and motivation; student confidence with material; and impacts on feelings of belonging (Bailey et al., 2014; Baumeister & Leary, 1995; Caprara et al., 2011; Martin et al., 2020; Roddy et al., 2017; Rollnick et al., 1999). They also acknowledged some of the advantages of online instruction (flexibility, ability to learn at their own pace, etc.), instructor and peer practices which allow them to feel successful, and some of the disadvantages and practices which make it difficult for them as learners (Bettinger & Loeb, 2017; Figlio et al., 2013). Their conversation suggests that they have had both positive and negative experiences in their online courses, which prompts a further investigation as to whether and which specific behaviors can influence overall experiences in online learning.

In this exploratory qualitative study, I assessed whether students taking online STEM courses at Long Lake University (LLU), an RCU in the United States' Upper Midwest, share Gabriella and Darrell's impressions. I also examined whether the experiences in online courses affect students' willingness to remain enrolled in their respective academic programs. This study focused on undergraduates enrolled as STEM majors taking online STEM courses for two reasons. First, there has historically been pressure on students to pursue careers in STEM for economic advancement and societal innovation (Waite & MacDonald, 2019). Second, institutions of higher education also feel increasing pressure to offer more courses through online delivery modes to contend with shifting student demographics and behaviors, the need for increased revenue, and, most recently, societal emergencies such as global pandemics (Allen & Seaman, 2017; Neuwirth et al., 2020).

Background

In recent decades, many institutions of higher education have increasingly sought to offer online learning opportunities to attract and retain students in response to academic and fiscal crises associated with large-scale economic downturns (Allen & Seaman, 2010; Allen & Seaman, 2014; Allen & Seaman, 2017; Arbaugh, 2004; Braxton et al., 2004). Increased student demand for the perceived - and often explicitly advertised - flexibility associated with virtual learning and larger-scale advances in technology have also led to an increase in online education offerings (Bettinger & Loeb, 2017; Protopsaltis & Baum, 2019; Shea & Bidjerano, 2014). Additionally, during the global Coronavirus-19 (COVID-19) pandemic, many institutions of higher education around the globe were forced to rapidly convert many of their courses online, whether they desired to adopt that delivery mode or not (Bao, 2020; Bryson & Andres, 2020). Regardless of reason, incentive, or intent, however, student attrition from online classes has remained greater than that from face-to-face (F2F) classes, sometimes by as much as 20% depending on field of study (Angelino et al., 2007; Bart, 2012; Boton & Gregory, 2015; Carr, 2000; University System of Georgia, 2006).

However, not all institutions of higher education have experienced the same rates of attrition within online undergraduate programs. Indeed, there is a wide gap in completion rates between online undergraduate programs in nonprofit (NPIs) and for-profit institutions (FPIs) at the undergraduate level, with the 6-year graduation rate for full-time students attending FPIs being 26% as compared to public and private non-profit institutions' respective 62% and 68% (NCES, 2021).

Additionally, research has shown that the benefits of online instruction are not evenly

experienced across numerous demographic identities, typically with young students, male students, African American students, Latino/a students, and part-time students faring worse in online courses at the postsecondary level (Bettinger & Loeb, 2017; Figlio et al., 2013; Jett, 2018; Johnson & Mejia, 2014). These findings indicate, then, that there is often a disparity in how students experience online learning. However, it is important to note that this is a multi-scale issue, as negative experiences at the micro- or single-student scale can potentially result in unintended consequences at the macroscale, well beyond the confines of an institution of higher education. Indeed, there is the potential for such disparities in online learning experiences to be integral in perpetuating societal patterns of socioeconomic, cultural, and racial inequity.

Problem Statement

While performance gaps and high attrition rates are detrimental to institutions for numerous reasons, attrition within STEM postsecondary academic programs is especially problematic in contexts of economic and societal impacts beyond the classroom; success and employment in STEM fields are both linked to greater economic prosperity (Pew Research Center, 2021; Xu, 2018). As discussed in Chapter Two, factors contributing to a persistent loss or driving away of students belonging to historically marginalized identities, ultimately result in disparity in the number of STEM degrees and certifications conferred (Blickenstaff, 2005; Cronin & Roger, 1999; Higher Education Research Institute, 2010). Thus, if faculty engage in online practices that discourage persistence to STEM degree acquisition, such practices could, among other things, maintain economic disparities across gender, racial, and ethnic lines within society and its degreed STEM workforce (National Academies of Sciences, Engineering, and Medicine, 2020a, 2020b; Pew Research Center, 2021).

On the other hand, researchers have also suggested that practices undertaken by faculty and administrators *can* foster online learning environments that encourage students to persist. These actions and practices can yield positive outcomes for students who persist in STEM majors, including substantial earnings benefits--at least 25 percent more than their peers who do not major in STEM fields (Melguizo & Wolniak, 2011; Pascarella & Terenzini, 2005). While I acknowledge that disparity remains *within* STEM careers across gender, racial, and ethnic lines, that discussion lies beyond the scope of this study and, thus, I did not address them directly.

Regardless, to begin investigating the reasons behind high attrition rates from online courses and STEM programs, one must first acknowledge that students are neither monolithic nor solitary individuals learning within a vacuum. On the contrary, learning – regardless of delivery mode – is a multi-faceted endeavor arising from a blend of course content delivered via texts and through interactions with entities within and outside of oneself, such as peers, professors, family, and broader societal forces (Alqurashi, 2019; Bowden et al., 2019; Joosten & Cusatis, 2020; Kuh et al., 2006). The exchanges and interactions students have with others in their academic programs shape who they are and who they become as learners in institutions of higher education and beyond, influences their confidence with program material, and impacts connections with those with whom they have interacted in an academic context (Baxter Magolda, 2001, 2004, 2008; Bowden, 2013; Crisp et al., 2009).

If a postsecondary institution is thought to be a microcosm of the larger society, then the delivery mode of course content is but a single stone that, when cast about within a pond of higher education, can cause ripple effects that propagate outward from that course. The experiences that students have within a single course offered by an institution can, as discussed

in Chapters Two and Three, have a significant impact on a their decisions to persist within or leave their academic program as well as influence their perception of where and whether they belong in their field of study beyond the immediate campus. This, as has been shown, can have ramifications in the larger workforce and society, as well. In short and as is shown, it is well established in research that a supportive and nurturing environment, be it in-person or online, is integral for student growth, development, retention, and persistence.

Finally, within the School of Computing, Engineering and Science (SCES) at LLU, individual course evaluations are seen only by the instructor of record and program exit surveys rarely go past the departmental chairs; little to no student feedback is regularly or uniformly compiled – on a university-, college-, or school-wide scale – to assess what students' experiences in online courses have been. Therefore, I purposely solicited direct input from undergraduate STEM majors at LLU to understand what some of them are experiencing in their online STEM courses. As there is already incentive (and sometimes pressure) at many postsecondary institutions to offer many courses via an online delivery mode, it stands to reason that educators and administrators should solicit and evaluate both input and feedback from the students they intend to serve. Through the subsequent data analysis and discussion thereof (Chapters Four and Five, respectively), this study was but a first of many steps to amplify the students' voices and allow for the inspection of practices which affect students' experiences.

Statement of Purpose

As has been discussed, students' learning occurs because of a plethora of factors and messaging (explicit *and* implicit) originating both in and outside of a formal classroom setting. At its core, this exploratory study yielded connections between students' experiences of online

learning and instructor and student practices as well as student persistence. Using F2F interviews and analysis, the purpose of this exploratory qualitative phenomenological study was to identify the positive and negative experiences undergraduate STEM majors report while taking online, program-specific STEM courses at a single regional comprehensive university. In addition, I evaluated participant responses and assessed whether their experiences factored into their decision to remain enrolled in or leave their STEM academic program.

Research Questions

This study specifically addressed two research questions:

R1: What practices, occurring in online STEM course delivery, have led to positive and negative experiences for students who have taken the course(s)?

R2: How have these specific experiences influenced students' decisions to persist in their academic program?

Key Terms

Although many of these terms are known and familiar to those who work within institutions of higher education, it may be necessary to review a few which might be more unfamiliar, especially those tied to the lexicons of STEM pedagogy and online education. Thus, here I offer brief definitions and descriptions in the interest of elucidation.

Attrition: The action in which a student withdraws from a course and/or academic program and fails to re-enroll in the course and/or academic program.

Constructivism: A theory that suggests learner's interactions with others as well as with their surroundings contributes significantly to their formation of knowledge (Dewey, 1925, 1928; Kincheloe, 2001, 2008; Vygotsky, 1978).

Historically marginalized identities: This term refers to demographic groups who have been or continue to be under-represented and/or marginalized in STEM in higher education and other societal institutions (Martínez & Renn, 2002; NSF, 2013, 2015). These include, but are not limited to, racial and ethnic identities of African/Black American, American Indian/Indigenous or Alaskan Native, East Asian, Hispanic or Latino/a, Native Hawai'ian or Pacific Islander, or South Asian. Historically marginalized identities also refer to gender identities of woman, non-binary/Agender, and transgender, and well as persons with disabilities.

Online delivery: Online delivery, or delivery of course-related content using technology-based instruction, is a broad yet complex mode of instruction. Its methods and associated techniques rely heavily on machine-guided lectures and laboratory exercises to provide digital and audio interactions between students, faculty, and peers (Bacow et al., 2012). For the purposes of this study, I only considered students who took courses designated as "Completely Online – Synchronous" and "Completely Online – Asynchronous" eligible for participation.

Admittedly, synchronous and asynchronous are two very different delivery modes. Synchronous delivery refers to courses meeting at specific times via an online platform and which involves student-faculty and student-peer interactions occurring in real time, such as through live streaming of course material via audio and/or video means (McDaniels et al., 2016; Watts, 2016). Asynchronous delivery, however, does not typically require specific or designated meeting times for a course, relying more heavily instead on the use of email, discussion boards, and other forms of communication which do not require real-time or simultaneous interactions between course members (Watts, 2016).

In this study, the decision to use of the designations of "Completely Online - Synchronous" and "Completely Online – Asynchronous" as criteria for selecting eligible courses offered by LLU was to limit confusion for online courses which can be designated as "Hybrid" or "Mostly Online." Both "Hybrid" and "Mostly Online" are widely variable with regard to exact meaning within the different schools and colleges of LLU. For example, in some online courses, "Mostly online" means students take tests in-person while the instructor delivers all other content online, while in other courses it means that students occasionally travel to a campus classroom to learn, and so on. By limiting courses to "Completely online – Synchronous" and "Completely online – Asynchronous," I sought to best assess the "online" experience of students at LLU.

Persistence: Similar to the definitions from Edmunds et al. (2020), persistence in this study referred to the continued participation of a student in a course through the duration of a semester (course persistence) and/or participation in program-required courses through the duration of multiple semesters, ultimately resulting in a degree (program persistence).

Phenomenological research: Research that describes the lived experiences of a group of individuals experiencing a common phenomenon, ultimately affording the researcher a deeper understanding of how participants experience it (Giorgi, 2012; Starks & Trinidad; 2007).

Practice: Practice, in the context of this study, referred to repeated actions undertaken by students, their peers, and/or their professors in relation to their online course.

Regional comprehensive university: This study involved students attending a mid-sized regional comprehensive university (RCU). RCUs are defined as broad-access, student-centered, public institutions that train a significant portion (~20%) of the nation's undergraduates for regional labor markets (Orphan, 2018; Orphan & McClure, 2019). Considering that the number

of STEM-related jobs have grown significantly and are expected to continue doing so for the foreseeable future (Hinojosa et al., 2016; Vilorio, 2014), the comprehensive education and mentoring, networking, and coaching opportunities provided by RCUs and their stakeholders/partners can provide invaluable pathways for students to get their foot into the STEM workforce (Dean & Koster, 2014; Espinosa, 2011; Ma, 2011; Miller & Kimmel, 2012).

SCES: The abbreviation for the "School of Computing, Engineering, and Sciences," offering STEM courses at Long Lake University, a regional comprehensive university in the Upper Midwest.

STEM: Although there is no universally agreed-upon definition of STEM, courses falling under the designation include those that are part of Science, Technology, Engineering, or Mathematics fields of study (Bureau of Labor and Statistics, 2014; National Science Foundation, 2013, 2015, 2017). For the purposes of this investigation, "Science" referred to courses focused on explaining and exploring the organic and inorganic facets of our planet that include, but are not limited to biology, chemistry, bioengineering, chemical engineering, physics, astronomy, and the Earth sciences. "Technology" encompassed courses focused on computer and information science as well as software development. "Engineering" courses included those under the category of electrical and computer engineering as well as mechanical and manufacturing engineering. Finally, "Mathematics" courses included those relating to the study of mathematics and statistics.

Thematic analysis: In this study, thematic analysis was the qualitative analysis method I used to identify and report themes or overarching, pervasive concepts, subjects, and issues arising from participant responses (Braun & Clarke, 2006; Nowell et al., 2017). Here, I used such

analysis in conjunction with phenomenology, which underpinned my data collection (guiding my instrument questions to capture the "experiences" of online learners). In my subsequent discussion of results, thematic analysis was the technique I utilized to organize and synthesize the resulting data.

Assumptions

I made several key assumptions in the context of this study. First, I assumed that participants provided honest and candid answers to all surveys as well as interview questions. Second, while my participant pool totaled 23, I assumed that participants' personal experiences varied from course to course, owing to the contextual diversity of each class offered. This diversity, I assumed, was influenced by factors ranging from participant personality differences and motivation levels to the organization and utilization of course learning management systems and everything in between.

Additionally, as of this dissertation, while many regional comprehensive universities offer several *online-only* programs of study at both the graduate and undergraduate level, the specific pool from which the intended candidates originated does not offer any *online-only* undergraduate programs leading to a Bachelor of Science degree in any STEM field. Therefore, I assumed that some students who reported having negative experiences in (or have otherwise been dissatisfied with) their online courses may have completed the course simply to persist in their program. Finally, I assumed (and expected) that both positive and negative experiences varied greatly within online course delivery modes, owing to the potential for greater interaction (for better or worse) between students, peers, and faculty during synchronously delivered courses.

Delimitations

Once again owing to the fact that students' learning experiences are multifarious, although this study addressed *some* contributing factors to all of the above, it did not address all of them. For example, as I did not pre-select participants from specific demographic categories, I did not *purposely* seek to relate the experiences of students to their individual identities relating to gender, race, ethnicity, socioeconomic status, sexual orientation, or any other demographical identifier (and/or the intersection of any of the above) in the context of their taking an online course. However, I do recognize and acknowledge that these identities may have played (and may continue to play) an important role in interactions students have with their peers and instructors.

Further, I did not interview any faculty members in the course of this investigation. While there is always more than one side to a story and faculty may interpret their (or their students') practices in the context of an online course, this study was meant to provide insight into undergraduate students' experiences. Therefore, the faculty's perspectives fell outside the scope of this study and were not addressed or explored.

Dissertation Overview

This dissertation focused on undergraduate students taking online STEM courses to gain an understanding of which student, peer, and faculty practices result in positive and negative experiences for students taking the courses. Additionally, I asked participants to reflect on whether and how these experiences have influenced their decision to leave or remain in their STEM major academic program.

In Chapter Two, I provide an overview of the U.S. system of postsecondary education with a backdrop of the historical changes that have resulted in the initial exclusion of and eventual inclusion of specific segments of the U.S. populace. In the same Chapter, I discuss research findings that show that the system of higher education still struggles to find parity, equity, and access within STEM education and program completion, and the larger implications this has on STEM as a field of study and employment. I review the rise of online education in the context of higher education and provide a discussion of its advantages and disadvantages as known to researchers.

In Chapter Three, I review the methods and theoretical foundations guiding this study; phenomenology and social constructivism, respectively. I selected phenomenology as my research method, guided by principles set forth by Giorgi (2012) and Starks & Trinidad (2007), as its tenets align with a desire to capture the experiences and "essence" of a phenomenon; in this study, the phenomenon was online learning. However, broadly speaking, since learning is often intricately tied with and influenced by ones interactions with others, social constructivism (Dewey, 1925, 1928; Kincheloe, 2001, 2008; Vygotsky, 1978) provided the lens through which I conducted the analysis of participant replies.

Chapter Four contains the results of this study's participant surveys, with an initial discussion of how the narratives provided by participants reflect in their perceived and desired identities as STEM students. The chapter continues with a comparison of their desired and realized experiences of being STEM students in the context of online delivery modes for courses that are required by their academic majors. Chapter Four also provides a discussion of the disconnect between desired-realized experiences in the context of what behaviors students

identified in themselves, their peers, and, most often, their professors, as most influential on negative and positive experiences in their courses. I then conclude the chapter with a discussion of how and whether the experiences students had in their respective online courses influenced their decision to persist in or leave their respective academic majors. Of note to the reader, in both Chapters Four and Five, I refer to participants by their pseudonym; these names appear italicized to honor student voices and experiences, which I hoped to amplify throughout the entirety of this dissertation.

In the fifth and final chapter, I revisit the study's purpose and arguments while providing possible implications of the study's results in the context of social constructivism. I conclude by providing some final thoughts on the future of online STEM instruction practices in institutions of higher education, upon reflecting on the feedback and stories provided by study participants.

Chapter 2: Review of Literature

The purpose of the American social institution of postsecondary education has undergone many changes over the course of its existence. An idealized vision of postsecondary education is one of a pathway affording all citizens of the country an opportunity to develop and expand skill sets to become fully trained and productive members of society. However, as operated, such education has historically been inaccessible to women and other historically marginalized and/or underrepresented student populations (Martínez & Renn, 2002).

Examining the systemic inequities inherent to the United States (U.S.) system of higher education rooted in its foundation, in the present chapter, I first explore how the experiences of being a student in higher education have been vastly different from student to student. I then illustrate some of the historical context for the disparity between racial and gender lines within STEM persistence in higher education; though students of all races/ethnicities enter into STEM majors at approximately the same rate, Black and Latino students leave the major at nearly twice the rate of their white counterparts (Estrada et al., 2018; Riegle-Crumb et al., 2019). I conclude with a discussion of the literature relating specifically to trends in online STEM education in institutions of higher education and how specific teaching methods can contribute to or limit disparities found within STEM education.

A Brief History of Higher Education in the United States

In the middle 1600s, the primary role of higher education was to provide a white, male student body with basic literacy and grammar skills necessary to perform civic duties while also serving as a center for personal development (Thelin, 2011; Johnson et al., 1975). As the American system of higher education expanded over the subsequent 200 years, its purpose

shifted to serve students seeking professional training and vocational guidance, with more emphasis placed on individualized field specializations as opposed to generalized education (Caple, 1998; Goldin & Katz, 1990; Thelin, 2011). While the demographics of the country became increasingly more diverse with regard to gender and race, access to (and benefits from) higher education was not equal across gender or race lines or academic programs; a series of sociocultural factors barred many non-white, non-male students' entry into and persistence in postsecondary education (Brazzell, 1996; Nuss, 1996). By the mid-1800s and continuing into the post-Civil War era, society developed a growing need for educated professionals to rebuild what had been lost to fighting as well as a large-scale emphasis on agricultural, mechanical, and technical fields of study (Thelin, 2011). At the time, though education in these fields was seen as valuable, postsecondary-focused education still remained overwhelmingly white and male and relatively out of reach for many who were neither (Martínez & Renn, 2002).

During the last half of the 1800s, there was also rapid expansion toward the West and an increase in the number of postsecondary institutions built in accordance with the Morrill Land-Grant Act of 1862 (Thelin, 2011). This Act partitioned federally controlled land to individual states, which in turn sold the land to establish a low-cost agricultural and mechanical college to provide professional training to poor and working-class white Christian men (Sternberg, 2014; U.S. Commission on Civil Rights, 2001; Congressional Research Services, 2019). However, this expansion of education nationwide (often referred to in glowing, utopian terms) was not without controversy and it certainly was not experienced equally across the nation. It should be noted that the granting of land was only possible via theft; specifically, from the Native Americans--over 10 million acres from over 200 tribes (Lee & Ahtone, 2020). Additionally, while the expansion

of the Morrill Act in 1890 granted men of all races and ethnicities access to the land-grant universities (Sternberg, 2014), institutions which admitted non-white men were often staffed by under-trained faculty who had limited, if any, access to federal and local assistance and/or research support (U.S. Commission on Civil Rights, 2001). This disparity in allocation to resources and personnel, then, essentially ensured that Black farmers received inferior agricultural education and put them at a further disadvantage relative to their white counterparts.

The first and second World Wars brought the need for male students to train as engineers and scientists in institutions of higher education while women primarily trained to be educators of younger students (Thelin, 2011). The Servicemen's Readjustment Act of 1944 (the G.I. Bill) provided benefits for returning WWII veterans which included payments of tuition and living expenses to attend high school college, or vocational school (Altschuler & Blumin, 2009). By the middle of the 1900s, the demand for goods associated with the production of electricity necessitated a workforce trained specifically in fields of chemistry and physics, with the number of chemists and engineers employed between 1900 and 1940 increasing by more than six-fold and seven-fold, respectively (Goldin & Katz, 1999). Further propelled by a successful launch of the Russian satellite Sputnik in 1957, postsecondary institutions in the United States subsequently placed an even greater emphasis on STEM fields of study beyond those that were previously solely associated with agriculture (Goldin & Katz, 1999; Marlin, 1988; Thelin, 2011).

Current State of U.S. STEM Postsecondary Programs

Academe's consideration of which academic programs constitute STEM has changed considerably since the early days of the U.S. system of postsecondary education. Today, broadly speaking, STEM has been expanded from programs of physics and mathematics to also include

those of agriculture, atmospheric sciences, chemistry, computer science, engineering, hydrology, and statistics, just to name a few. Despite the mainstream enthusiasm for STEM-related fields of study and industrial production and greater specialization within STEM, the educational atmosphere on campuses has often been chilly at best and, at other times, downright hostile for women and students of other marginalized identities who wish to pursue STEM degrees (Martínez & Renn, 2002; Puaca, 2014; Thurston et al., 2017). Still, it was not until the late 20th century that institutions of higher education within the United States, broadly, dedicated human, temporal, and fiscal resources to acknowledging and examining the factors contributing to the attrition of marginalized students in STEM (Martínez & Renn, 2002).

Additionally, while there has been a widening to gate to allow more and more students through to STEM program enrollment, fewer and fewer students of historically marginalized identities persist through to completion, despite initially entering programs at roughly the same rate as their peers (Blickenstaff, 2005; Cronin & Roger, 1999; Higher Education Research Institute, 2010). The literature suggests numerous reasons for this phenomenon, owing to, among other things, interpersonal dynamics and learning environment.

Interpersonal Dynamics Affecting STEM Student Persistence

Implicit and explicit biases as well as instructional practices present on institutions of higher education all contribute to STEM program attrition as well as serve as a deterrent to pursuing postsecondary degrees in the first place (Cheryan et al., 2009; Cheryan et al., 2011; Connolly et al., 2016; Seymour & Hewitt, 1997). That is to say, both implicit biases, occurring automatically/unintentionally from subconscious feelings, and explicit biases, manifesting as purposeful suppositions and assumptions arising from known prejudices, can influence the

quality of interactions that students have with their faculty and peers. The overt actions undertaken by the professor as they organize and conduct their courses can, as well. In turn, these interactions and subsequent experiences can be internalized by students and affect their ability to perform and succeed in their academic program of study (Boud, 2000; Boud & Falchichov, 2005; Brayboy, 2005; McGee, 2017; McGee, 2020; Salas, 2019; Vasquez-Colina et al., 2014). Notably, STEM students with historically marginalized identities often experience anxiety, depression, panic attacks, feelings of isolation or lack-of-fit, and even limits to their working memory due to various on- and off-campus interactions with others (Ashcraft & Krause, 2001; Collins, 2018; Henslee & Klein, 2017; Lawler et al., 2018; Lent et al., 1994; Lent et al., 2000). While not necessarily precluding students' self-actualization and self-authorship over course material or their academic success, it follows that these experiences can certainly influence the progress toward all of them and, in turn, affect persistence in academic programs.

There are also familial, cultural, and economic factors influencing STEM majors' decisions to persist within a STEM program. For example, media and societal portrayals of STEM careers as requiring time which might otherwise be spent with family rearing can influence a personal choice to not enter STEM on the part of the student (Ceci et al., 2009; Sax et al., 2016). Additionally, an immediate (or short-term) need to earn income to support a household may outweigh the desire to earn a STEM degree due to time constraints, and in some instances it is viewed as more advantageous to pursue a wide range of skillsets as opposed to focusing solely on careers requiring specific STEM degrees (Wang et al., 2013). This need or drive has been shown to be especially salient for those who identify as first-generation students as well as those from low-socioeconomic status households, who often end up being the primary

(if not sole) wage-earner and provider for their family (Kim et al., 2020; Xie et al., 2015; Xie & Goyette, 2003; Xie & Shauman, 2003; Zhang, 2021).

Researchers have also suggested that peer pressure and societal messages about the lack of success of historically minoritized individuals in STEM and the underrepresentation of marginalized identities in STEM can also negatively affect a student's perception of belonging within the field (Belanger et al., 2021; Eisenhart & Finkel, 1998; Fisher et al., 2019; Hill et al., 2010; McGee, 2017). While students are not homogeneous in their learning styles or experiences, this type of messaging is often a common factor influencing a student's self-identity as a STEM major as well as their sense of belonging and personal value. These factors, in turn, affect students' confidence levels regarding their ability to persist and succeed in STEM while in school and after.

Learning Environments Affecting STEM Student Persistence

Of course, it is not enough to examine students' internal and internalized identities or characteristics solely as they relate to their persistence in STEM programs; students do not learn within a vacuum. External factors, in-situ to traditional settings of higher education, such as physical surroundings, interpersonal interactions with faculty and peers, and systemic and systematic biases found on the micro- and macroscales all influence students' ability to thrive academically or even survive their academic programs (Fink et al., 2020; Frey et al., 2018; Mondisa et al., 2021). Unfortunately, many explicit and implicit practices occurring at the institutional or departmental level are often largely to blame for keeping underrepresented individuals from entering and persisting in STEM fields on a larger scale (Braxton et al., 2004; Haynes, 2017; McGee, 2017; McGee, 2020). These practices include, but are not limited to,

faculty and/or administrators engaging in actions such as purposeful gatekeeping, campus-wide infrastructural deficiencies such a lack of universal design in campus layout, a lack of effective communication across multiple campus channels, or a lack of understanding/familiarity with the issues pertaining to students.

There are also environmental conditions present within the classroom setting which can further contribute to STEM program attrition. For example, research has shown that instructor demeanor in a STEM classroom is often more "sterile" and less inviting than in other classrooms (Seymour & Hewitt, 1997). Additionally, male- and white-dominated classrooms may enhance a culture of tokenism and can encourage women and minoritized students' deference to more assertive and often white men. Ultimately, it has been shown, this serves to reinforce macroscale societal messaging of STEM being an unwelcoming and unsafe endeavor for all but a select few while also centering and codifying privilege bestowed to white, wealthy males (Cole & Espinoza, 2008; Davis et al., 1996; Morton et al., 2019; Museus et al., 2011; Parsons, 1997). Finally, an instructor's emphasis on lecture formats as opposed to cooperative exercises limits socialization and classroom participation, thought to be an important factor how students, especially students who are women, learn and retain information (Eisenhart & Finkel, 1998).

In truth, any of these factors can contribute to an atmosphere where students feel out of place in and disconnected from a STEM classroom, laboratory setting, or other learning environment. Further, in the case of "colorblind" faculty who strip away the unique identities of their STEM students, faculty neglect the events, environments, cultures, values, and belief systems which guide their students' interactions with their peers, professors, and the course

material, as well as their own identity as STEM students, as well (Baber, 2012; Collins, 2018; Hauge, 2007).

Unfortunately, many present-day attempts to address or rectify long-term underlying systemic problems are still playing catch-up to an academic history steeped in the concept of exclusion. That is, the original American system of higher education was intentionally designed to keep specific (read: non-white, non-male, non-Christian) populations from fully realizing its academic and socioeconomic benefits. As a result, within many STEM fields and programs of academic study and within the STEM workforce, there remains to this day an underrepresentation of many demographic identities; Black, Latino/a, and Indigenous Americans as well as persons with disabilities (National Center for Education Statistics, 2021; NSF, 2013; NSF, 2015; NSF, 2017).

However, positive impacts on student success and persistence in STEM can also come from faculty behavior, as classroom-based student-instructor and student-student dynamics play a significant role in determining whether a student completes a STEM program. There has been a strong push for faculty members at institutions of higher education offering degrees in STEM fields to also take steps to make the classroom environment and course structure more conducive to students' learning and success therein (Henderson et al., 2008; Wilson & Varma-Nelson, 2016). Shifting toward more active and collaborative instruction while also restructuring toward a learner-centered paradigm not only places the focus on improving student learning outcomes, but has also been shown to improve student performance and retention within STEM programs across gender, racial, and ethnic lines (Barr & Tagg, 1995; Fairweather, 2008).

There has been a concerted effort by STEM faculty at institutions to provide undergraduate and graduate students with hands-on and experiential activities, exercises, and fieldwork, especially within the physical sciences and engineering fields, to foster greater insight into and ownership over one's own learning (Colle & Lombardo, 2013; Franhcetti, 2010; Hernandez et al., 2013; Houston, 2013; Humphrey & Srock, 2016; Humphrey et al., 2012; Humphrey et al., 2013; Reed et al., 2014; Williams & George-Jackson, 2014). Additionally, many researchers have also offered innovative ways to combat stress in these students at their institutions and thereby attempt to take a more "holistic" approach to investigate students' decisions to persist within or leave a STEM program (Braxton et al., 2004; Hemslee & Klein, 2017; De Leo-Winkler et al., 2016). These activities, in conjunction with other methods such as physically rearranging desks and encouraging cooperative learning, positively affect student learning and faculty behavior in STEM classrooms, ultimately leading to increased self-efficacy and improve student retention rates within STEM programs in traditional, F2F classroom settings (Anft, 2017; Franchetti, 2010; Herbert, 1998; Najmabadi, 2017; Raelin et al., 2012).

As shown, it is suggested that while many postsecondary STEM programs still have room for improvement, there are specific actions and pedagogical methods employed by faculty which can impact the likelihood that historically marginalized students feel welcomed and confident in the physical classroom setting (Morton, 2021; Morton & Nkrumah, 2021). Undertaking and engaging in these practices would go far to encourage students to persist to degree acquisition in STEM fields. However, the research discussed to this point has focused on in-class, traditional, F2F delivery of course content. There has also been much research into the potential impacts and implications of online course delivery methods on student retention in STEM programs.

Toward Online Content Delivery

Distance courses in education have existed in some form or another in the U.S. since 1840, when students used the Postal Service to learn from instructors despite there being a great physical separation between the two of them (Kentnor, 2015). Historically, students have turned to such courses due to familial obligations, financial or geographic limitations, or other contributing factors which would preclude their ability to attend a traditional university (Verduin & Clark, 1991). Over time, as technology has evolved to include radio, television, and, most recently, the Internet, so, too, have the delivery methods expanded to include all of these as vectors through which instruction can be shared and, beginning in the late 1980s, college degrees can be acquired (Bastedo et al., 2016; Kentnor, 2015; Thelin, 2011).

U.S. public nonprofit institutions of postsecondary education have increasingly offered online learning opportunities as a way to attract and retain students in response to academic and fiscal crises associated with large-scale economic downturns and high rates of student attrition (Allen & Seaman, 2010; Allen & Seaman, 2014; Arbaugh, 2004; Braxton et al., 2004). Since 2008, nearly three-quarters of all U.S. institutions have reported an increase in the demand for online courses and programs during downturns, while almost one-half of all institutions reported an increase in demand for F2F courses and programs (Allen & Seaman, 2010; Seaman et al., 2018).

Before the COVID-19 pandemic, the number of students in the United States taking at least one such course exceeded six million, roughly 31 percent of all postsecondary students (Seaman et al., 2018). While the general trend in offering online courses has, on average, been upward, it is important to note that there are substantial differences in perceived growth when

accounting for institution type. There has been steady growth in public institutions, similar levels of growth for private non-profit and a decline in total distance enrollment for private, for-profit institutions (Seaman et al., 2018). Further, it is the largest institutions that teach, on average, considerably more online students than institutions of any other size, resulting in a concentration of online students at a relatively small number of institutions (Allen & Seaman, 2010).

Regardless of the differences in institution type, it appears that distance learning in online delivery mode is here to stay: recent data suggests that sixty-three percent of all reporting institutions consider online learning a critical part of their institution's long-term strategy (Allen & Seaman, 2010). When taken into the context of the shrinking number of students studying on campus and the increasing number of students taking at least one online course, this increased interest in offering online learning may not be surprising and instead may be seen as an exercise in self-preservation (Seaman et al., 2018). Still, the attrition rates of students within online STEM (and non-STEM) courses and programs are often higher than that of students enrolled in F2F courses and programs. Reasons for this are often attributable to issues (both technical and social) that these students do not encounter while taking traditional/F2F courses (Angelino et al., 2007; Ferguson, 2020; Jordan, 2015; Waschull, 2001; Willging & Johnson, 2009). Examples of social issues include isolation from peers, family problems, unanticipated changes in financial circumstances, childcare, pet care, or elder care, while technical issues include a lack of access to reliable hardware, software, or infrastructure related to internet access.

Naturally, there are benefits to institutions that can fill the demands of both F2F and online courses. Researchers have suggested that the financial benefit for institutions that have changed to online delivery is greater in the long run due to a reduction in classroom, travel,

boarding, and instructional costs while appealing to a population of students who otherwise may not have pursued a postsecondary degree (Bacow et al., 2012; Bettinger et al., 2017; Michael, 2012). Additionally, by serving both a generation of students who grew up in the age of the Internet as well as non-traditionally aged students who are entering higher education in greater numbers, institutions offering online courses provide greater flexibility and fewer scheduling conflicts for students and faculty alike (Iloh, 2018; Michael, 2012; National Student Clearinghouse, 2021).

Despite the benefits of online instruction, researchers have found quite a few disadvantages of this content delivery mode. Many researchers have suggested that a change from F2F instruction in a traditional classroom setting to online-only delivery can leave students feeling a lack of confidence and ultimately ambivalent about the course and its content as well as their chosen academic program (Arbaugh, 2004; Chevalier et al., 2014). To date, another disadvantage is the tension that arises between administrators and faculty. Researchers have shown that resistance to online instruction lies with faculty perceptions that it (1) requires they get "spun-up" on unfamiliar technology without being given time to adequately do so; (2) distances them from students; (3) prevents them from customizing material they deliver; and (4) presents little opportunity for students to engage in self-initiated learning (Bacow et al., 2012; Dziuban et al., 2007; Tabata & Johnsrud, 2008). Additionally, faculty members' negative attitudes or sub-optimal pedagogical choices toward online instruction can negatively impact the quality of the course as well as the students' perceptions thereof, while positive faculty attitudes can lead to greater student satisfaction with a course delivered online (Bunk et al., 2015; Clark, 1993; Jett, 2018; Levya et al., 2021; Tabata & Johnsrud, 2008).

Compounding the challenges of online instruction is the multisensory nature of learning, comprehension, memory formation, information recall and retention, and application of concepts learned (Broadbent et al., 2018; Gnaedinger et al., 2019; Kawahara, 2007; Pichora-Fuller et al., 1995; Shams & Seitz, 2008). By their very nature, courses delivered strictly online – even synchronously – cannot provide sensory learning besides auditory and visual intake of information and data unless instructors specifically design their course assignments and assessment techniques with multisensory learning in mind. Additionally, challenges and stress associated with videoconferencing software – e.g., dropped signals, distorted audio, frozen screens, lack of eye contact due to the placement of the camera vs. placement of the viewing area on the screen – can leave much to be desired, to say the least. Even the reduction in non-verbal cues and the delay between speaking and hearing can contribute to feelings of both isolation and asynchrony as well as what has become commonly known as "Zoom fatigue" (Kinreich et al., 2017; Riva et al., 2021; Zendel et al., 2021). All of these issues may leave some students – especially those who possess multiple learning style preferences (Cassidy, 2004; Gardner, 1983; Hayes, 1996; Hernandez, et al., 2020) – feeling a sense of false intimacy with not just their instructors and peers, but their course content as a whole.

Of course, pedagogical practices that can systematically inform and perpetuate the alienation or outright exclusion of entire student populations also have impacts on *all* students, so it is important to look at said practices not just in the confines of specific demographic categories. It would seem, then, that online STEM courses would present quite the opportunity for successful, negative, *and* challenging experiences, depending on the practices undertaken by all involved.

Student Experiences in Online STEM Courses

Researchers have shown that there are commonalities between students who persist in online STEM courses and programs, some relating to students' personal characteristics and others to the interactions that students have with their professors and peers. Additionally, certain practices – on the part of both the student and the people with whom they interact in the context of their STEM course or program – can influence a student's decision to remain or leave.

Student Attitudes, Characteristics and Practices

Students often gravitate to courses delivered online due to a wealth of potential positive impacts they can provide them: a shortened time to degree; speedier interactions between students, their peers, and faculty; and an increased likelihood that they experience responsive learning environments more tailored to their learning style (Bacow et al., 2012; Dziuban et al., 2007). While economic benefits may not trickle down to students' tuition cost savings, since many online courses cost more per credit than those provided in traditional methods, savings *can* be found through eventual decreases in costs associated with transportation to and from campus and room and board (Bettinger et al., 2017; Bacow et al., 2012).

Often, highly motivated, self-reliant, independent, and organized students excel disproportionately in online courses, regardless of content (Bacow et al., 2012; Berenson et al., 2008), but there are also factors external to the student which influence their perception of what it means for them to be "successful". For example, students consider themselves most successful and satisfied in an online STEM class when they have opportunities to interact with their peers and instructor, reaffirming the findings of previous researchers who have argued that social

interactions are just as important for online courses as they are for traditional F2F courses (Lewis, 2010; Richardson & Swan, 2003).

Bowen et al. (2012) found that while there were no statistically significant differences in learning outcomes between students in traditional F2F sections and online sections, students gave the online formats a lower (-11%) overall rating than the students taking the traditional format due to a lack of the opportunities for interpersonal interaction. The overall impacts of such negative perceptions and experiences are non-trivial. In some institutions, taking a STEM course online was found to (1) reduce student grade achievement in that course by about a third of a standard deviation, (2) reduce student grades in future courses by one-eighths of a standard deviation, and (3) reduce the probability of remaining enrolled a year later by over 10 percentage points (Bettinger et al., 2017).

Again, most of the reasons behind students' negative perceptions of online courses stemmed from their feelings of being isolated from their peers, owing to a lack of F2F interactions with their peers (Arbaugh, 2004; Jordan, 2015; Tichavsky et al., 2015). Beyond the social aspects of online courses, students also express the need to be more responsible and proactive in order to succeed in online classes, which may not offer the rigid structure that comes along with in-classroom content delivery yet may still require a heavier workload outside of traditional content delivery environs (Bettinger et al., 2017). Access to technological hardware, software, and a reliable Internet signal, arguably all required to participate and succeed in online courses, can present major barriers for students (Bettinger et al., 2017; Jordan, 2015).

Still, delivery methods are but one underlying factor contributing to declines in the number of students – especially those who are of historically marginalized identities – enrolling,

persisting, and succeeding in undergraduate STEM programs (Barnard-Brak et al., 2012; Beilke & Yssel, 1999; Bettencourt et al., 2018; Dewsbury & Brame, 2019; Gobbo & Shmulsky, 2014; Gobbo et al., 2018; Haynes, 2017; Kamimura, 2019; Stodden et al., 2011). There are also specific practices of students, faculty, and administrators engaging in online learning that contribute to students' experiences and success in online courses. Again, it would behoove educators and administrators at LLU to learn from their students whether faculty attitudes toward online instruction creep into course delivery on campus and whether/how that affects their STEM students.

Faculty Attitudes, Characteristics, and Practices

Faculty-student interactions can have significant impacts on a student's success in a course and their decision to persist in a particular academic program, especially in STEM. While over 50 percent of students taking at least one distance course also took an on-campus course (Allen & Seaman, 2010), there has been much research detailing the best practices that faculty can employ which are likely to benefit students taking online courses. Research supports the notion that the learning experience is comprised of a social presence, a cognitive presence, and a teaching presence, and that students respond positively when given the opportunity for student-professor interactions, student-peer interactions, and accommodation of diverse learning styles (Garrison et al., 2000).

Faculty providing timely feedback and oversight for assignments and assessments as well as being available to answer questions by holding regular office hours (even if remote) is associated with students reporting that they feel welcomed, comfortable, and safe (Grant & Thornton, 2007; Liu et al., 2005; Picciano, 2017). Offering and monitoring discussion boards

where students can pose questions and have discussions with each other while also providing meaningful activities extending beyond individualized "busy-work" and instead encourage collaborative learning has also been shown to boost students' sense of freedom as well as confidence (Belland et al., 2017; Douglas et al., 2020; Flowers et al., 2013; Grant & Thornton, 2007). Finally, respecting diverse skills and learning preferences of students, especially when building upon students' prior content knowledge, has been shown to foster student engagement, drive active learning, and increase the relevance of self-constructed knowledge (Chevalier et al., 2014; Clark, 1993; Keengwe & Kidd, 2010; Kilburn et al., 2014; Spaniol-Matthews et al., 2016; Sutton, 2014).

Further, biases that faculty display in relation to their students' capability to succeed in their STEM course or program can have significant impact on a student's feelings of vulnerability and greater imposter feelings (Blackwell et al., 2009; Bunk et al., 2015; Clark, 1993; Muenks et al., 2020 Tabata & Johnsrud, 2008). When professors teach through a lens of their own personal biases regarding specific student aptitude and identities, students report feeling less engaged and motivated within their classes at best and downright unwelcomed at worst, leading to higher rates of attrition for both STEM courses and programs (Canning et al., 2019; Muenks et al., 2020). Perhaps unsurprisingly, this bias also further serves to widen the gender and racial achievement gaps within STEM courses; when faculty showed a "growth" mindset as opposed to a "fixed" mindset, however, these achievement gaps were about half as large (Canning et al., 2019).

Administration Attitude, Characteristics, and Practices

In addition to the characteristics discussed above, researchers have also found that just as faculty demeanor and behavior impacts student retention in online courses and programs, so, too, do the practices of their institution's administrators. For example, while there is a greater chance for student retention when faculty are enthusiastic about the material they are sharing with their students, faculty are more likely to possess these characteristics when they have support from their institutional administrators (Booker et al., 2016; Hollowell et al., 2017; Tabata & Johnsrud, 2008). These authors suggest that offering faculty training programs specific to online instruction to provide infrastructure, training, and skill development for instructors who may find themselves unfamiliar with new online instruction platforms and pedagogy is overwhelmingly beneficial. Further, by providing meaningful and sustained professional development opportunities to faculty, administrators foster an environment in which faculty are encouraged toward innovation and creativity, both of which are key in maintaining faculty motivation (Tabata & Johnsrud, 2008). While this study did not focus on faculty perspectives, one could argue that maintaining faculty motivation would have a large impact on how enthusiastically they engage with both course content *and* students.

Summary

As evidenced by literature, there are many factors affecting student success and persistence in online STEM courses and programs. As STEM students are not monolithic in person or learning style, there can never be a single "right" or "all-encompassing" answer to the questions posed by this study. However, it is this multi-faceted background in previous research that formed the investigative bedrock on which I conducted this study of students who have taken online STEM courses at LLU.

Chapter 3: Methods

Long Lake University (LLU) is a regional comprehensive university (RCU) located in the Upper Midwestern United States. Like many other RCUs, LLU is a broad-access institution of higher education serving a diverse student body and its operations reflect a spirit of student-centeredness as well as public-minded, purposeful collaboration with a wide variety of local and regionally based employers (Henderson et al., 2008; Soo, 2011). Faculty teaching undergraduate courses at LLU serve their students intending that said students subsequently enter the local and regional workforce resulting from the formal and informal education received during their time at the school (Orphan, 2018). Through its offering of academic programs, internships, on-the-job training, and with an emphasis on civic engagement and service, LLU cements a relationship between the institution of higher education, its surrounding communities, and both the private and public sectors.

Though its academic origins are as a normal school, placing heavy emphasis on F2F instruction and practica, in recent years, the School of Computing, Engineering, and Science (SCES) at LLU has experienced pressure to deliver more of its courses using an online format. Some of this pressure has been external; as recently as the Spring 2020 semester, the institution was required to migrate all courses online in response to the national novel coronavirus-19 (COVID-19) pandemic. Other pressure, however, has originated from within the institution and the statewide system of higher education, long before the pandemic, to attract new students and increase the retention rates of the students currently enrolled in SCES programs.

As a current faculty member in a science, technology, engineering, and mathematics (STEM) program at an RCU, I recognize that course delivery modes are only one factor

contributing to declines in the number of students – especially those of historically marginalized identities - enrolling and persisting in undergraduate STEM programs. Professors' interactions with students, student interactions with peers, and even external messaging relating to a sense of belonging and place in the field have all played a role (Barnard-Brak et al., 2012; Beilke & Yssel, 1999; Bettencourt et al., 2018; Dewsbury & Brame, 2019; Gobbo & Shmulsky, 2014; Gobbo et al., 2018; Haynes, 2017; Kamimura, 2019; Phipps, 2013; Stodden et al., 2011). Building on this prior research, I explored the specific experiences students have had in their program-required, online STEM courses at LLU. In addition, I examined whether these experiences factored into students' decisions to persist in their respective academic programs.

To accomplish the goals of this study, I engaged in phenomenology (Giorgi, 2012; Starks & Trinidad, 2007), framed by the theory of social constructivism (Dewey, 1925, 1928; Kincheloe, 2001, 2008; Vygotsky, 1978). I interviewed undergraduate STEM students at an RCU who have taken at least one online STEM course as part of their academic program in order to answer the following research questions:

R1: What practices, occurring in online STEM course delivery, have led to positive and negative experiences for students who have taken the course(s)?

R2: How have these specific experiences influenced their decisions to persist in their academic program?

Methodology

In this exploratory qualitative study, I used a phenomenological approach to find commonalities and differences between students' experiences in the context of the phenomenon of online learning as well as examine whether their experiences influenced their decision to

persist within their academic STEM major. Since participants' experiences are fundamentally subjective and difficult to delineate through use of a quantitative analysis, qualitative research lent itself well to this study. Qualitative research, as described by Merriam and Tisdell (2016), allows both researcher and participants to explore and interpret the effects that environment has on participants' lives, allowing for rich description and a richer, more in-depth analysis than quantitative research would afford.

Phenomenology

Phenomenological qualitative investigations afford researchers insight into a specific phenomenon and a deeper understanding of how their participants experience it (Giorgi, 1970, 1997, 2000; Holroyd, 2001; Moustakas, 1994). Participants share their recollections, stories, and impressions with the researcher, yielding information about how participants construct their understanding of a particular phenomenon or set of phenomena occurring within their environment, including those that arise from interactions with others (Giorgi, 2012; Starks & Trinidad, 2007). Since I sought to understand what participants' experiences have been in their online STEM courses, I considered their online STEM course to be their environment, and their narratives to be reflective of their experiences with the phenomenon of learning in said online environment. In the analysis phase, I adhered to the phenomenological traditions described by Merleau-Ponty (1945; 1964b; 1969 and, later, Kee, 2019), who shunned the more abstract, transcendental nature of phenomenology and instead was receptive to the idea of there being multiple ways to interpret not only the reflections and interactions provided by participants, but the entirety of the phenomenological method itself.

Merleau-Ponty's later works (1964b, 1969) also suggested that the methods of

phenomenology and empirical sciences have more in common than not, placing emphasis on the importance of recognizing one's own bias when engaging in research, which also aligns with my personal view and approach to this study. Therefore, I engaged in purposeful actions, including bracketing, memoing, and member checks (described in detail later in the "Methods" section of this chapter), to mitigate potential effects of my preconceptions.

Theoretical Framework

Sense-making and conceptual understanding of scientific facts in the context of STEM and STEM education are multi-faceted processes requiring a complex co-creation of knowledge. Verbal and non-verbal exchanges between pupils, their instructors, their peers, and other external entities, often strongly influence students' success, self-confidence levels, and sense of belonging within a course and academic program (Auster & MacRone, 1994; Espinosa, 2011; McCoy et al., 2017; Tatum et al., 2013; Tenenbaum et al., 2014). In this study, while the students were not physically in the same room as their peers or instructor due to the courses being online, interactions between them all – and a lack thereof – *were* found to contribute to the participants' experiences of taking said course, as evidenced by participants' various responses provided in Chapter 5. Therefore, social constructivism was this study's primary theoretical framework, since its tenets lie with the assumption that learners construct their understanding, development, and sense of place, belonging through interactions with others (Dewey, 1925, 1938; Lippmann, 1922; Picciano, 2017).

Social Constructivism

This study was guided by the theory of social constructivism (Dewey, 1925, 1938; Vygotsky, 1978) as it specifically relates to learners' interactions with others as a vector towards

forming common foundations of knowledge about a particular field of study (STEM). The fundamental tenet of social constructivism is that not only is knowledge not a finite entity; it is constantly expanding due to continuous interactions with others. However, it is also not a solitary endeavor; a learner's ability to form foundational understanding, and in later stages application of concepts, are learned through and in the context of their interactions with others having mindsets and experiences different from their own.

Researchers have discussed the influences of environmental factors on student academic success and persistence for decades (Beilke & Yssel, 1999; Belland et al., 2017; Blackwell et al., 2009; Bunk et al., 2015; Clark, 1993; Dewey, 1925, 1928; Douglas et al., 2020; Muenks et al., 2020; Tabata & Johnsrud, 2008; Vygotsky, 1978). The underpinnings of the theory of social constructivism, then, align with the study's lens that student learning is not isolated within a vacuum (Dewey, 1925, 1928; Vygotsky, 1978). Indeed, these intersubjective, shared interactions (i.e., the *social* part of "social constructivism") naturally shape the content knowledge that students are able to learn; they fundamentally influence *how* and *whether* the students are exposed to the concepts in the first place (Zenzen & Restivo, 1982). Further, this theory also provided a guiding role in the understanding of how these students' interactions – or a lack of interactions – with online course materials, professors, and peers may influence choices regarding persisting through STEM programs at their home institution.

As is the case with many, if not all, STEM fields, processes leading to inquiry and understanding are often, and arguably *must* be, iterative; as a result, characteristics inherent to both environment and observer necessarily influence each other (Dewey, 1925, 1928; Vygotsky, 1978). On one hand, actions taken by a learner – including tools and skills they use to aid their

actions - fundamentally influence the environment in which they are acting. On the other hand, actions *not originating* with the learner yet still occurring within the learners' environment *also* influence the learner's ability to take in information, apply it, and feel a sense of belonging and attachment to their communities of learning (Baumerister & Leary, 1995; Brown, 2008). For example, a student who receives positive, prompt, and meaningful feedback from their faculty or peers throughout a course may feel more confident in their ability to perform well in the course; a student who does not receive such feedback may feel unsure about their academic aptitude (Chickering & Gamson, 1987; Kuh et al., 2006; Pascarella, 2001; Pascarella & Terezini, 2005). Central to social constructivism, then, is the notion that higher mental processes (including understanding and mastery of a skill or concept) have their origins in social processes involving learners' interactions with other external factors appearing in their environments.

Further, Dewey (1925) also argued that experiences arise from physical give-and-take with their surroundings; some actions undertaken by the actors change their relationship to their environments without changing the structure of the environment itself, while other actions can result in a fundamental re-arranging of the actor's surroundings. Thus, to successfully navigate a specific learning situation (e.g., an academic degree), learners can utilize tools and skills that are constructed by the learner and that often stem from interactions with others.

Ultimately, the theory of social constructivism dovetailed with this study's methodology, since I sought to find similarities and common themes between responses from individual participants who obviously cannot possess identical psyches but who may still share and report experiences resulting solely from interactions with others or a lack thereof. It is important to acknowledge that in this study, I did not do a pre-test/post-test experiment wherein I evaluated

participants' retained knowledge about a particular topic, as this was not aligned with the temporal limitations of my study's design. However, participants' reported impressions of their experiences and comfort levels within their class were intricately and intimately tied with their interactions with others (or lack thereof) in their online course. While Dewey could not have possibly envisioned the experiences associated specifically with online course delivery at the time of his writings, I explored how intrapersonal and interpersonal actions and experiences manifest in an online-delivered learning environment as well as what effects they have on students' STEM degree completion.

Methods

At its core, I conducted this study to amplify the voices of students who have taken STEM courses online. However, I also sought to report the "essence" of being an online STEM student, and, while every student is different and certainly not a monolithic learner, I wanted to discover whether there were experiences specific to the students who have taken part in the phenomenon of online learning within their STEM program at an RCU. Therefore, I chose phenomenology as my study's primary method. Throughout the data collection phase of the study, participants were encouraged, by way of a semi-structured interview, to share their experiences as students taking part in the phenomenon of taking an online STEM course. I subsequently compiled their responses, looking for and iterating upon emerging patterns and themes in their responses. After speaking with my participants and while bracketing my own experiences, reactions, and potential biases, I then analyzed the data to identify and analyze emergent themes common between them.

Design

Through semi-structured, face-to face interviews with undergraduate STEM students at LLU, I sought to understand the experiences they had in their online courses as well as whether the course-related experiences have influenced their decision to persist in their academic program. Due to COVID-19 pandemic restrictions (Centers for Disease Control and Prevention, n.d.), I offered to use remote conferencing software such as Zoom™ or Skype™ (Archibald et al., 2019; Sullivan, 2012) as a way to conduct interviews, though the majority of the interviews (21 of 23) were conducted F2F at the request of the participants.

This study was similar in design to those employed by Haynes (2017) and Kamimura (2019), both of whom collected basic demographic data via a campus-wide survey with survey questions to determine who would be eligible for participation. The demographic data I collected to determine eligibility included participant academic major and age; no other data factored into the eligibility of a participant. In turn, when I deemed a participant eligible for participation, I engaged in follow-up interviews with them and subsequently analyzed their responses for emerging themes.

Participants. To investigate the intended research questions, I limited my participant pool to students meeting the following criteria: (1) aged 18 or older; (2) enrolled in and completed a course delivered completely online between the Fall 2016 and Fall 2019 semesters or after the Spring 2020 semester; (3) a current STEM major who (4), completed an online STEM course required by their major and offered through a STEM department; and (5) completed the course within the past 10 semesters (including Summer semesters), dating back to the Fall 2016 semester. A sixth criterion was also used: The online-only STEM course(s) that a participant took must have occurred outside of the Spring 2020 semester; midway through the

spring semester of 2020, all courses at LLU were required to go to online-only content delivery due to the national and global COVID-19 pandemic.

The first criterion, limiting participant age to 18 years or older, ensured that only consenting adults of a legal age were involved in the study. The second criterion pre-emptively limited any potential confusion for online courses designated as "Mostly Online," which has shown to be widely variable with regard to exact meaning. For example, in some courses, tests are taken in person while all other content is delivered online, while in others it means that students occasionally travel to a campus classroom to learn synchronously, and so on.)

I placed the third and fourth criteria to ensure that both the participants and courses fit within the desired scope of this study. The fifth criterion was set to ensure the best chances of interviewing a STEM student who was still enrolled in their academic STEM program (i.e., who has not yet graduated) at the time of the study. The sixth criterion was used because including courses from the Spring 2020 semester could potentially yield an undue bias in the data as not all faculty, students, staff, and administrators were prepared for a sudden change in content delivery, and thus these courses will not be considered part of the data set. Ultimately, I obtained a list of all STEM courses offered by the SCES which fell within this timeframe (N = 439) and parsed the data to include only courses that were offered completely online, yielding a total of 258 STEM courses from which to pull potential study participants.

Recruitment. With the assistance of the office managers of STEM academic programs at the institution and general collaboration with the Registrar's Office at LLU, I sent out a recruitment email inviting STEM majors aged 18 or older students to participate in the study and directing them to begin the demographic survey. The recruitment e-mail included information

about the purpose of the study and contact information should they wish to participate in the study, including mentioning the incentive of a gift card to Amazon for participation (see Appendix A). I conducted interviews with a total of 23 students, at which point I believed I reached saturation in participant answers.

Admittedly, the concept of saturation in qualitative analysis can be somewhat vague owing to the fact that there is no exact number of responses constituting an adequate "cut-off" point (Saunders et al., 2017). As a result, I referred to principles set forth by Guest et al. (2006) and O'Reilly and Parker (2012): Saturation was reached when, upon conducting interviews, no new themes emerged from collected data and, therefore, no new coding was possible.

In the final discussion of this study's results, I refer to participants by pseudonym, but, as appropriate and as deemed germane to the study, I also discuss their self-disclosed demographic information obtained during the recruitment, pre-interview phase of the study. Demographic data for this study's participants originated from the initial demographic survey provided in my initial recruitment email (see Appendix B). This survey, delivered via the Qualtrics™ platform, included prompts for participants to answer regarding the following demographic information: age; gender identity; racial/ethnic identity; preferred pseudonym; how many online STEM courses they have taken; academic standing (year); and academic major. All choices in the survey had a "Prefer not to answer" option in case they did not wish to identify as belonging to one or more specific categories.

I opted to collect demographic information even though, in the interview process, I was not entirely sure whether participants would refer to experiences in the context of all of this information. Ultimately, I did not ask questions that expressly or explicitly asked for their

experiences in the context of specific identities such as gender identity or racial/ethnic identity. However, answers to questions about academic major, academic standing, age, and, for obvious reasons, pseudonym provided tangible context for their experiences in their courses. I fully acknowledge that, as discussed in Chapter Four, their experiences *may* have been influenced, as well, by their gender or racial/ethnic identities, but none of the participants explicitly stated this was the case.

Demographic responses were aggregated into a spreadsheet wherein their responses were matched to their pseudonym (if they did not enter any text into the "preferred pseudonym" textbox, one was provided for them) for reference and use during the analysis phase. Upon receiving responses to the survey, I alone reviewed the results to determine students' eligibility according to criteria two through six. Once a student was considered eligible to participate (having met all six criteria), I contacted them to arrange a time for an interview.

Confidentiality and Participant Privacy. I kept participant identities confidential and used participants' pseudonyms during the interview and analysis stage. To give participants more ownership over their stories and experiences, I encouraged them to choose their own pseudonyms; in the one case where a participant was unwilling/unable to come up with one for their own self, I had them randomly select one name from a list prior to me engaging in any interview with them. Additionally, as there was the potential for negative consequences affecting faculty as a result of a study like this, I anonymized any professor mentioned by name, and do not report out on specific course or faculty-specific identifiers in this study. I assured confidentiality and privacy for each participant prior to and during the interview process and upheld them throughout the entirety of this study.

I maintained all electronic data associated with the study, including audio and video files, spreadsheets, and research log entries, on two separate off-site computers, housing the audio recordings and their (encrypted) transcriptions. The thumb drive used to transport the files back and forth from the site where interviews were conducted to the two computers was wiped after each use. All files associated with the study are stored on the two aforementioned off-site computers until a maximum of two years post-study, at which time they will be destroyed, as prescribed by the forms submitted to the Internal Review Board (IRB). In both locations, these files are password protected and in encrypted file formats. Finally, all electronic data that could be traced back to the identity of any one participant (initial email communication, etc.) was downloaded and kept on only one physical thumb drive, located off-site, in a secure location accessible only to myself; I will destroy this, too, at the end of the two-years post-study period has passed. All physical data, including written notes and signed consent forms (Appendix C) was stored in an off-campus lock box. Notes taken during each interview as well as the annotated transcripts were written in shorthand and are to be destroyed at the end of the two-year post-study period, as well.

Data Collection. Once a student agreed to participate in this study, I emailed out a link to the aforementioned Qualtrics™ survey to attain student demographic information. Upon completion of their survey, I ensured their eligibility to participate and compiled their survey responses into a confidential and encrypted spreadsheet for later analysis. Once I determined their eligibility, I contacted the participant and together we subsequently arranged a time to meet either in person, as CDC and institutional guidelines allowed, or via conferencing platform Zoom™ (Archibald et al., 2019).

Prior to interviews, I asked participants for their permission to have their responses recorded via a microphone recorder during F2F interviews. In the case of video conferencing interviews, I first asked the participant's preference as to whether their interview would include video and audio or just audio recording, depended on their own personal comfort levels with either option. In total, two participants opted for Zoom™ and they both indicated they preferred both audio and video interviewing and recording.

Interview Questions. I asked approximately 15 questions during my interviews with participants (Appendix D). While these were the questions intended to be presented in a set order, from time-to-time the order of the questions was rearranged or questions proved to be duplicates when respondents answered multiple questions at once (Abrica et al., 2020; Mozahem et al., 2019; Pfeifer et al., 2020). Additionally, I did not intend for these interview questions to be the only way participants shared their experiences; I fully expected them to add more details and expand on their comments, prompting them with follow-up questions when appropriate. Therefore, these interviews are best described as "semi-structured" (Creswell, 2013).

To begin exploring the experiences of students, I asked them general questions pertaining to how they got interested in STEM, why they decided to enroll in their respective programs at LLU, and whether they had any prior experience with online learning. Subsequent questions focused more explicitly and purposely on their positive and negative experiences within their online courses at LLU, at times asking them to summarize in three words or fewer, other times asking them to give rich descriptions of what actions they engaged in or circumstances they encountered in their courses. The interviews all culminated with prompts asking for their

suggestions for both future students and future instructors of the online courses they had taken, as well as whether they had any additional insights they wished to share with me.

Interview Transcription. Within a half day of each interview, I transcribed the data: answers to open-ended questions within a semi-structured interview lasting roughly one hour. The rationale behind doing self-transcription was two-fold. First, it maintained a chain of custody, greatly reducing the likelihood that an entity external to the study was privy to responses given. Second, transcribing the interviews shortly after conducting them allowed the interview to remain fresh in my mind. I decided that I was more likely to remember smirks, shifts in body language, the contexts of spontaneous utterances, etc. if it happened recently than waiting for days after and hoping that I can induce recall. After each student and I completed an interview, I offered them the opportunity to receive a copy of the transcript of their interview and seek feedback from them to ensure that what I heard and transcribed was accurate in their opinions. I acknowledge that while I destroyed all email correspondence between myself and the participants that included transcripts, I cannot guarantee that they destroyed them on their end. To date, although I sent each participant a copy of their respective transcript, none provided feedback indicating that they disagreed with what appeared therein.

Data Analysis. After I conducted and transcribed the interviews, I subsequently used a system of thematic analysis to identify patterns of language, commonalities, differences, insights, and themes that emerge from repeated readings (Berg, 1989; Braun & Clarke, 2006). I opted to engage in open coding for this study because I did not think it prudent to have a set of codes selected prior to the interviews; by the very nature of phenomenological inquiry and the

individual nature of learning experiences, the results were likely to be highly variable from participant to participant.

Thematic Analysis. Widely used in qualitative research, thematic analysis involves the identification, analysis, and reporting out of themes found within a set of participant responses (Braun & Clarke, 2006). While there have been debates as to whether thematic analysis is itself a tool to be used for qualitative analysis (Boyatzis, 1998; Holloway & Todres, 2003) or as a method itself (Braun & Clarke, 2006; King, 2004; Nowell et al., 2017), I intended to use it as the former. Such analysis examines the overarching and enduring themes found throughout the responses given to my interview questions and provided a foundation for me to address how the separate data points (the responses and/or portions thereof) meld together in a meaningful way (Julien, 2008; Siegesmund, 2008). It also required that I ensured the data (and their subsequent categories, subcategories, themes, subthemes, causal connections, and so on) were organized in ways that are comprehensive and mutually exclusive to increase trustworthiness of my analysis (Braun & Clarke, 2006; Siegesmund, 2008).

The steps I followed to engage in thematic analysis during this study aligned with the approach laid forth by Braun & Clarke (2006). Even though Nowell et al. (2017) make the argument for thematic analysis to be its own standalone qualitative method, the formers' step-by-step approach would work just as well as a technique or tool to use while analyzing a phenomenological dataset. This technique required that I sit immersed in and engaged with the data on multiple occasions, allowing for multiple interpretations (Terry et al., 2017).

Step One: Transcription. For the first step of my thematic analysis, I transcribed each interview by playing and replaying the interviews' audio and recording the transcript into a word

processing application (Microsoft Word™). As mentioned earlier, I did this within a half day of conducting the interview to maintain mental freshness.

Step Two: Reading and Familiarization. In the second step, I read and familiarized myself with the data by reviewing the interview transcripts and notes multiple times, though, as Braun and Clarke (2013) point out, familiarization with the data also occurred during the first step. Regardless, in Step Two I reviewed the interview transcripts and notes multiple times as well as examine the demographic data collected from each participant, allowing me to take notes as well as mentally map the answers with the individuals.

Step Three: Coding. I broadly reviewed my textual data to look for common matching words, phrases, or concepts and parsed them accordingly in an electronic spreadsheet (Excel) into discrete parts (codes) for organizational purposes. In this way, the parsed data themselves were the point of origin for my subsequent analysis (Terry et al., 2017). In line with recommendations from Braun and Clarke (2006, 2013), I kept the codes distinct from one another. Broadly speaking, the codes emerged from responses that specifically recounted interactions between the learner (participant), their peers, and instructors as they occurred in the context of the online learning environment.

Following the open coding, I used axial coding to review and relate the initial data together to reveal codes, categories, and subcategories (Benaquisto, 2008). The iterative process of revisiting the data numerous times (literally, until no additional themes are found) will allow me the opportunity to uncover any links between the responses and this study's theoretical framework (Berg, 1989; Braun & Clarke, 2006; Nowell et al., 2017). Throughout my analysis, I assessed codes iteratively to retrieve both semantic and latent themes (Braun & Clarke, 2006,

2013). The semantic themes stemmed from participant responses, and derived from looking at common, repeated words or phrases given by the participants. On the contrary, latent themes emerged from my repeated re-examination and interpretation of the more implicit meanings behind the responses.

Step Four: Searching for Themes. According to Braun & Clarke (2006, 2013), themes are broader than codes in that they constitute a central, organizing concept. Meaning, themes are a collection of codes or ideas originating from the data. At first pass, I combined common codes or ideas under what Braun & Clarke (2013) referred to as "sub-themes," which could then be combined into larger, overarching themes. To accomplish this, I sought patterns within the sub-themes and evaluated whether it was possible to group them together in a coherent and sensible manner.

Step Five: Reviewing and Defining the Themes. I engaged in Step Five with much scrutiny to ascertain which code matched up with which theme or sub-theme, but I also recognized that sub-themes and themes were subject to change as my analysis necessitated. To ascertain whether adjustments were necessary, I reviewed the themes, requiring multiple read-throughs (Braun & Clarke, 2006). Ultimately, I defined, chose, and utilized themes that provided a best fit to answer/address my research questions.

Step Six: Analysis and Write-up. Upon examining all the themes and sub-themes and assessing their semantic meanings, I linked them back to the theoretical framework guiding my research questions and write up my findings. I followed this with a discussion of the significance of the findings as well as future work that could build upon the data I collected during this study.

Additionally, I addressed potential implications relating to online postsecondary education on a broader scale.

As mentioned earlier, thematic analysis is highly flexible, non-linear, and lends itself well to different interpretations (Maguire & Delahunt, 2017), a technique I thought aligned well with the unpredictability of the responses the participants provided. For example, the initial themes stemming from the first few interviews were scattered seemingly everywhere, unrelated to one another, which necessitated that I revisit data from *all* of the interviews many times before I could group them together.

Trustworthiness

As I acknowledged the subjectivity inherent to thematic analysis and iteration, I needed to engage in multiple activities to ensure study trustworthiness, rigor, and credibility. Further, I understood the importance of limiting potential biases that might have arisen throughout the study. Therefore, I intend to utilize several mechanisms of trustworthiness, including bracketing, peer debriefing, maintaining a research log, and the use of member checks.

Bracketing. Bracketing, in the context of phenomenological research, required that I, as researcher, was aware of my biases, assumptions and previous experiences while exploring a specific phenomenon (Husserl, 1913; Gearing, 2008). To me, this meant being aware of my pre-conceived notions of what it means to teach and take courses online as well as my feelings toward both activities. In line with Gearing (2008), I engaged in elements of bracketing by acknowledging both internal and external presumptions might impact the phenomenon in its natural state. While I did not anticipate needing to intentionally or formally apply bracketing during my data collection phase (I was asking questions, students were answering prompts, etc.),

during the analysis phase I was hesitant to engage in trying to find latent themes, relying, more so, on semantic themes to avoid bias as much as possible. I also acknowledged any internal/external suppositions I bracketed out during my analysis phase. Further, I acknowledged that my personal assumptions regarding what my participants might have given are immaterial to the study and that I also needed to address my interpretations, suppositions, and assumptions that I purposely bracketed needed to be addressed in the discussion section of this study's results (Gearing, 2008). I achieved this through a combination of journaling and memoing, which allowed me to record my own reflections on the data I am collecting (Gearing, 2008; Giorgi, 2012).

Peer Debriefing. As a former STEM major, a current STEM educator, a student who has taken online courses, and an instructor who has taught online courses, I felt I had at least some familiarity with some of this study's participants' experiences. Still, I engaged in peer debriefing (Creswell, 1998; Lietz et al., 2006; Padgett, 1998) to make sure that my interpretations of the results aligned with how others interpret them. To accomplish this, once my initial analysis was complete, I spoke with colleagues and students, unaffiliated with LLU, to see whether they agree with my assessments and/or interpretations of the themes that I was seeing. I did not share any names – real or pseudonym - in any discussion with anyone outside of the study. Through this form of peer debriefing, I received multiple perspectives on my data, thereby enriching my understanding of the data themes.

Maintaining an Audit Trail. The use of multiple methods or data sources, including interviews, journal entries, field notes, and other research artifacts in qualitative research necessitates the use of a detailed, organized method for keeping track of each item. Therefore, I

kept an electronic audit trail clearly describing the steps I took throughout the study. Stored off-site in a location known only to myself, it specifies where I can find each piece of data pertaining to the study (Johnson & Waterfield, 2004; Lietz et al., 2006). Additionally, within this audit trail, I kept reflexive notes and personal reactions that I had to the interview process, responses, and analysis phase; in essence, the file served as a mini journal, providing an additional opportunity for reflexivity (Creswell; 1998; Creswell & Miller, 2000; Lietz et al., 2006).

Member Checks. There has been some disagreement over several decades as to whether member checks provide a sufficiently thorough assessment of trustworthiness for any form of qualitative research (Angen, 2000; Birt et al., 2016; Buchbinder, 2011; Candela, 2019) with some researchers even suggesting that participants may be harmed as a result of engaging in the practice (Hallett, 2013). However, since the main goal of this study was to amplify the voices of the students who have taken or are currently taking online courses in their STEM academic programs, it was logical that I engage of multiple forms of member checks to ensure my interpretations of their responses were valid (Carlson, 2010; Creswell & Miller, 2000; Rodriguez et al., 2019). I also acknowledge that the privileged racial, gender-based, and socioeconomic identities that I currently exhibit also result in my having different experiences from those of many of my study's participants, which could have influenced not only the responses that participants gave, but also how I interpreted them.

Therefore, I engaged in member checks with my participants by (1) allowing them to review the transcript of their interview; (2) giving them opportunities to correct or expand upon the transcript; (3) touching base with them after the interview to see if wished to add anything; and (4) sharing preliminary findings with them. While I intended to defer to any participants'

recounting of an exchange within an interview, no participant provided any indication that their interpretation differed from mine. No members asked me to alter their transcript in any way, even when given multiple opportunities to do so.

Positionality

A key component to this study was my personal lens/worldview during data collection and analysis (Denzin, 2009; Denzin & Lincoln, 2011; Dibley, 2011; Fusch & Ness, 2015; Holloway et al., 2010). As an instructor of STEM classes primarily delivered in in-person, F2F modes, I recognize that I came to every interview with a value set and inherent biases of my own. As a result, this study required that I engage in multiple forms of reflexivity and bracketing (Ahern, 1999) when developing questions prior to holding interviews, when engaging in dialogue and interviews with participants, and during my analysis when I was looking for themes, commonalities, and contradictions between their stories. Further, when presented with information with which I was unfamiliar, I asked follow-up questions to ensure I accurately understood what participants shared with me.

Additionally, since I am an instructor of STEM classes at an RCU, there may have been a perception of specific power dynamics between the participants and myself. I expected to be older than the majority of this study's participants, and the fact that I am an assistant professor may also have been intimidating to some. However, to combat this, I made the interview environment as welcoming and relaxed as possible to set a tone of alliance – as opposed to one of adversarial - with the participants (Razon & Ross, 2012). To achieve this, I (1) scheduled interviews around times most convenient for participants; (2) reminded participants that they could stop the interview process at any point; (3) encouraged them to expand on experiences

even if they begin to go a bit off topic during the interview, allowing them to lead; and (4) reminded participants that they could opt out of the study at any point, even after they have signed the consent form and even after their interview has been transcribed.

Summary

Utilizing a theoretical framework of social constructivism to guide this study's interview process as well as its data analysis, I conducted a phenomenological study involving undergraduate STEM majors at LLU. By engaging in face-to-face interviews with participants, I collected information to gain a deeper understanding of what they are experiencing in their online STEM courses. Of course, this was only the first step toward exploring and addressing implications from their experiences with online STEM course delivery; I subsequently analyzed their responses for common themes.

Chapter 4: Results

This study comprised of interviews with 23 undergraduate STEM majors at LLU, whose demographic information appear in Table 1 in alphabetical order of chosen pseudonym. Participants' responses suggested a variety of self-identities spanning three distinct age ranges, two genders, and eight ethnicity/race categories. Further, each participant belonged to one of seven departments, and, together, represented the following STEM programs, as defined by the National Science Foundation: Mathematics (MATH), natural sciences (NS), engineering (ENGR), and computer and information sciences. (CIS). Aggregate categories were used to further de-identify specific courses so that they could not be directly linked to any specific academic program. Of the 23 participants, 19 students reported having taken more than one online course required by their respective STEM major.

Altogether, participant responses yielded a total of five biology/biomedical-focused courses, four chemistry-focused courses, two software engineering/computer science-focused courses, six mathematics-focused courses, and three physics-focused courses. This variety of courses owes to the fact that most academic majors (including STEM majors) at LLU require interdisciplinary coursework as part of fulfilling degree requirements. The distribution of all classes, identified by participants and broken down by subject/content matter as well as home department, appears in Figure 1.

Table 1

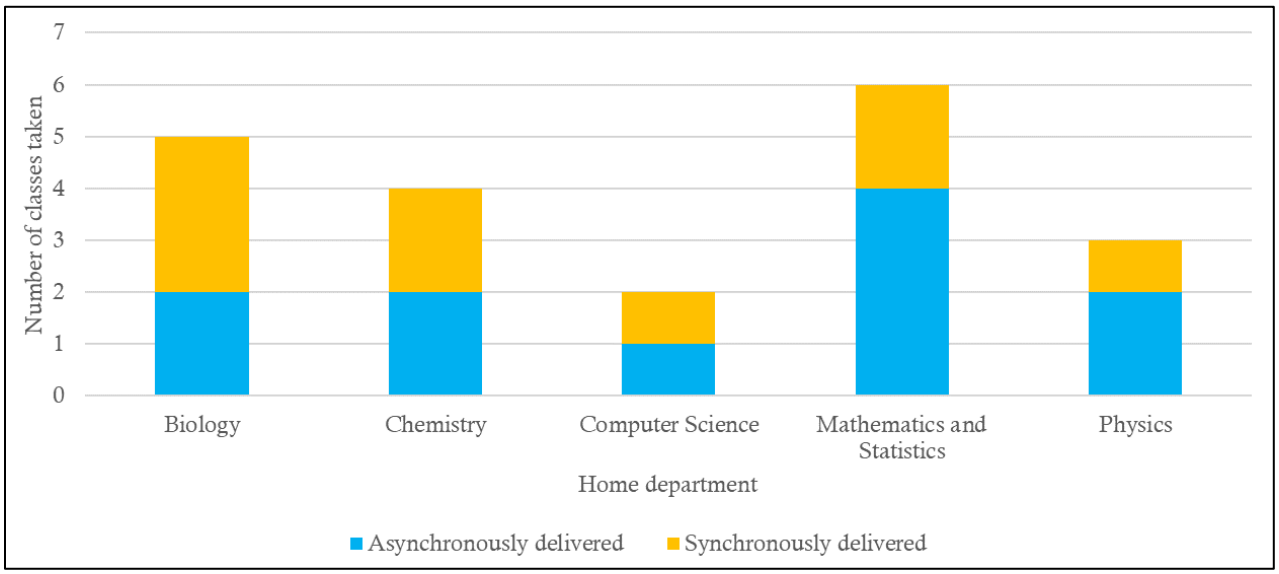
Demographic composition of RPO study participants

Participant	Age	Gender	Ethnicity / Race	Academic Major	Program Year	# Online Major Courses
Amanda	18-24	W	w	MATH	Senior (Sr)	3
Amon	18-24	M	H/L	NS	Sr	2
Asha	25-34	W	AA/B	CIS	Freshman (Fr)	1
Bruce	35-44	M	W	CIS	Junior (Jr)	1
Eve	25-34	W	W	MATH	Jr	3
Faisal	18-24	M	NH/PI	CIS	Jr	2
G	25-34	M	SA	CIS	Jr	3
Janice	18-24	W	W	NS	Sr	2
Kanraj	18-24	M	EA	CIS	Jr	2
Katie	25-34	W	W	ENGR	Sophomore (So)	3
Marie	25-34	W	W	MATH	Sr	3
Mei	18-24	W	A	CIS	So	3
Midi	18-24	M	SA	NS	So	2
Penny	25-34	W	W	NS	So	2
Ranjan	18-24	M	SA	CIS	Jr	3
Ronald	25-34	M	H/L, w	NS	Jr	1
Sam	18-24	M	W	NS	Fr	1
Saman	18-24	M	A	CIS	Jr	1
Sarah	18-24	W	W	NS	So	1
Thomas	18-24	M	W	CIS	Sr	2
Willie	18-24	W	W	NS	Fr	1
Zelda	18-24	W	AA, H/L, MR, w	NS & MATH	Jr	2
Zeus	18-24	M	H/L, w	ENGR	Jr	3

Note. Participant demographics. Abbreviations of W, M were used for gender self-identifications of “Woman” and “Man,” respectively, while A, AA/B, EA, H/L, MR, NHPI, SA, and w were used for “Asian, “African American/Black,” “East Asian,” “Hispanic/Latino/a,” “Mixed Race,” “Native Hawai’ian/Pacific Islander,” “South Asian,” and “white,” respectively.

Figure 1

Distribution of Major-required, Online Classes Taken at LLU by Study Participants



Note. Distribution of courses delivered online and required by majors pursued by participants. The "Home Department" refers to the department offering the course and does not *necessarily* refer to the home department of the participant's major.

In addition, I synthesized participant responses to open-ended questions into themes and sub-themes that I then tied back to the initial research questions to capture the experience of online learning in STEM courses:

R1: What practices occurring in online STEM course delivery have led to positive and negative experiences for students who have taken the course(s)?

R2: How have these specific experiences influenced students' decisions to persist in their academic program?

Questions and responses relating most closely to research question 1 (R1) yielded several themes (and sub-themes) relating to (1) their experiences with and identities in the context of STEM, (2) their decision to pursue a STEM degree at LLU and (3) their expectations their online STEM learning environment. Further, when subsequently asked to describe their *actual* experiences in required online STEM courses, participants primarily centered their responses on interactions and behaviors they and their instructors engaged in which led to (1) positive and (2) negative learning experiences in their course(s). Questions and responses relating most closely to research question 2 (R2) yielded answers suggesting that most respondents' decisions to persist in their academic programs were not heavily influenced either way by the experiences they had in their online course(s).

In the novel *Ready Player One*, a central plot point involved characters from all over the physical world seeking and finding specific digital rewards hidden throughout OASIS (Cline, 2011). As an homage, in this chapter I present participant responses in three discrete, though related, themes relating to experiential processes of finding and seeking. In "Finding and Seeking STEM Identities Outside the LLU Classroom," participants' identities in and exposure to STEM

outside the classroom setting are discussed. The next theme, “Finding STEM at LLU,” features participant experiences relating to and influencing their decision(s) to enroll in a STEM program of study at this specific institution of higher education as well as their expectations as STEM majors at LLU. Then, in “Seeking and Finding Online STEM Education at LLU,” I compare and contrast participants’ expected experiences with their actual found experiences, both positive and negative. I follow this with a discussion of observed behaviors and practices contributing to these experiences and a summary of their experiences in their own words (resulting from a word association exercise undertaken as part of the interview instrument.) Finally, the chapter concludes with analysis of whether, how, and why these experiences influenced participants’ decisions to remain enrolled in their major program of study.

Finding and Seeking STEM Identities Outside of the LLU Classroom

To help contextualize the experiences participants had in their online STEM courses, I asked questions relating to their sense of self and relationship with STEM. At first, identities provided by participants were those assigned to them through virtue of their enrollment in their institution of higher education. Generally, these institution-based identities focused on participants’ year of standing in the program, their status as a transfer student, and, as some participants indicated, their identity as an international student (see Table 1).

Beyond this basic demographic information, internally ascribed identities emerged from participants’ description of themselves either in the context of their scientific field of study, their prior education, or their lives outside their current institution of higher education. Participant responses generally fell under one of two sub-themes: “Finding” and “Seeking.” The “Finding” themes reflected something of a passive occurrence; participants experienced and found their

identities in STEM as a result of exposure to STEM-related events or occurrences happening in and around them, and them participating in said events. “Seeking,” on the other hand, referred to instances where the participants specifically sought out opportunities to participate in STEM for purposes beyond their immediate selves, such as learning skills to assist in procuring employment, assist others, or be a role model. Whether associated with “Finding” or “Seeking,” these experiences suggested that the majority of participants had a long-standing and keen interest in their field of study as well as other STEM fields long before they got to their post-secondary level of education.

Finding Identities in STEM

For the majority of respondents, first exposures to STEM occurred fairly early in life, with most respondents indicating they had interests in science and mathematics since they were children. Experiences with STEM were almost exclusively positive, most often involving hands-on exploration of topics at a young age, which encouraged further investigation. For *Marie*, a Mathematics major, “it was a way to learn about the world around me but also make sense of things by looking for patterns.” For *Thomas*, a Computer and Information Systems major, “it allowed me to work with others toward a goal that we [Thomas and his elementary school classmates] shared but have fun doing it at the same time.” Regardless of their eventual programs of study, early (most often tactile) experiences in biology, computer-based gaming, mathematics, and astronomy factored heavily in their STEM exposure; many reported going to science museums and sky watching as their primary entrance into the realm of STEM.

Further, participants shared that their early experiences with STEM were, for the most part, a way for them to feel connected to those around them while still allowing them to be

individuals. For some participants, their identities in STEM tied in with their interactions with family members. As *Midi*, a Natural Sciences major, explained,

> In my family, many family members are either hand labor[ers] or they work in the medical field or in labs. My little brothers look to me as what to be, and for them, they look to me as role models. I feel good and a part of my family when I can still be there with them [after graduating] because they have been an inspiration to me for so long since I was a little kid. From a young age, I see myself in my field. I still see me doing great things in my field so I always push myself to be successful. I will make it on my own but will still also always have them [family] as part of who I am and I am part of them.

In this excerpt, *Midi* saw himself as both a person who had an innate drive for succeeding in STEM as well as a source of inspiration for those closest to him. For him, his success in STEM would be his family's success, as well.

Similarly, for *Mei*, a Computer and Information Systems major, family tradition began and fostered her interest in STEM: "I do enjoy solving problems, and my family are all either teachers of math or science. I went into computing [major] because it's part of what we do in my family." She went on to explain that her relationship with (and identity in) STEM was positive because it allowed her to utilize her curious nature in a way that still allowed her to be somewhat creative. "I think I'm with this field because yes, tasks must get done, but I can also do other things when I'm done. The job [after graduation] would still let me stop at a certain time and focus on other things." *Mei* also indicated that her confidence in her ability to succeed in STEM

was in no small part because she often had the chance to share her information with younger members of her family.

For *Asha*, a Computer and Information Systems major, prior exposure to STEM was a social, collaborative experience:

> My friends and I were all into STEM as kids. We hung out. We studied together, but it was also fun at the same time. A connection. It felt like a group since all [were] interested in the same things. We all had different interests, but hanging out with people in [STEM] clubs and stuff – that was a lot of fun. And it made me feel like it was cool to do that.

Using an "Us against the world" framing, she explained that the STEM-related connections that she had with her peers fostered a sense of teamwork that made any struggles they encountered seem much less daunting and more manageable.

At the same time, for some participants, engaging with STEM meant having experiences with external factors that sometimes posed a challenge to their sense of "fitting in" within STEM. For example, *Katie,* an Engineering major, reported having had exposure to robotics at a young age, but also sharing that, initially, she was unsure that she could participate in the field due to her gender. Despite her uncertainty, she ultimately was not deterred, explaining:

> I've always been such a hands-on learner, and the ability to now study something that gets me excited is wonderful. I was always told that girls couldn't do that, but, they can, obviously; I mean I'm here. Studying this field is teaching me that I can do it.

Janice also reported being hesitant at first, due to not having seen women in positions of science teachers prior to coming to the university. In her opinion, she explained, "It was a total boys'

club, and we were allowed to be [women] students [in the classes], of course, but I wasn't sure we could find support to study it on our own, y'know?" For *Katie* and *Janice*, as well as several other respondents, experiences at an early age (culminating with a lack of visible representation of women in positions of leadership in the field of robotics) caused uncertainty within themselves as to whether they belonged and would be welcomed in STEM at all. However, as both *Katie* and *Janice* reported, pursuing a degree in STEM has given them the confidence that they, in fact, do belong in STEM.

Finally, *Zelda*, a dual Natural Sciences and Mathematics major, indicated that while STEM represented a bridge between her interests and skills, science, especially, was always a way for her to interact with the world around her when communicating with others was difficult. As she put it:

> I've always been sort of different…I have to think about what I say way before I say it so I'm usually pretty quiet. I'm smart, but with people it's hard. But with science, I've loved it since I was young because you can observe and you can measure, take your time [in reporting results]…For me, I've loved science for a long time; I feel at home here.

In this way, *Zelda's* identity in STEM provides her with a sense of competence and comfort when she might not ordinarily encounter it in a non-STEM setting, especially as it related to interacting with her peers.

In examining the narratives provided by these participants, then, it is possible to identify how STEM experiences (both positive and negative) helped to shape their identities. The manifestation of these identities did not arise in a vacuum, however. As respondents explained, it was often the interactions they had with others which helped to solidify their self-recognized

identities in the context of STEM. In this way, for many of the participants in this study, STEM served as the vehicle through which confidence and a sense of belonging could evolve, but it was the networks and interactions with others that provided the pathway on which they could first form.

Seeking Identities in STEM

When prompted, some respondents indicated that identities they *desired* to have in STEM originated from factors definitively set apart from and external to their personal views of and experiences with STEM. For example, over half of the participants reported wanting to be part of STEM in order to earn money to either satisfy their own needs or the needs of their immediate families, though they did not explicitly express a long-term vision of what that might mean for them beyond that immediate scope. *Saman* viewed his pursuit of a Computer and Information Sciences degree as "a way to bring honor to my family because I can bring money home but also because I will be carrying on tradition of my family." Additionally, a majority of participants (20 of 23) also expressed a desire to have an identity in STEM that originated with their desire to achieve certain personal milestones, such as securing constant employment and/or a career in a chosen field, entry into graduate school, or a pathway to permanent residency within the United States.

In addition to personal financial and academic advancement, participants' desired identities also associated with their interactions with broader audiences as well as others' perceptions of them because of their involvement in STEM. For example, several respondents specified that their drive to participate in a STEM program was due not only to internal attraction to the topics, but also to influences of societal and environmental messaging and family practice.

Similar to *Katie's* experiences, *Marie* indicated that the lack of representation of women in the classroom had a large influence on why she decided to study mathematics as she grew up:

> I grew up where I knew I was interested in math, but I didn't have female role models in math. I didn't have anyone saying, 'Yeah, math! Here's a bunch of mathematicians!' So, I really took that to heart, but in the other way. Instead of me saying, 'Oh, I can't do that,' I was like, 'Why not me? Who says I can't?' So I really want to be that woman professor in front of the class who is like, 'Yes, you can do this.'

In *Marie's* case, then, the early challenging experiences she encountered in STEM sparked a desire to be seen as someone who can make space for and bring others into STEM fields.

Similarly, *Penny*, a Natural Sciences major, noted that she gravitated toward STEM because she seeks external validation, veracity, and authority on a topic that a degree in her field would confer to her. As she described it:

> I've always been interested in the environment – and science in general – since I would say my childhood. I was always out exploring and such; I just thought it was all so neat. And in my previous job, I got to go out with the people and sit and take in nature around us. But I know that not everyone gets to enjoy environmental justice – or even access to nature in general – so I want to [after graduation] write about that. To write about it, and to make a difference, I need to have the credentials, the degree. Obviously I need to understand it…So that's why I'm here studying STEM.

This, she believed, would allow her to share information about environmental science with others, ultimately benefitting people well beyond her own person.

Ronald, also a Natural Sciences major, sought an identity in STEM that would enhance his ability to share information with others, too. In his opinion, the ability for him to explain complicated scientific information with the public was a way for him to contribute back to a network of people that raised and supported him. As he explained, a lack of general understanding of basic scientific concepts poses a risk: "Science is great, but if you can't understand it, then you won't understand why it's so great. You won't understand if you're in danger. So, I'd like to try to bring it [science] back to my community, or help to." Similar to *Marie's* sought-after identity, to *Ronald*, being referred to as a "Scientist" would carry a lot of clout and yield an identity he could envision himself using to encourage other generations to follow in his footsteps by, in his words, "following their own wonder."

Finally, for *Ranjan*, a Computer and Information Sciences major, his desired identity in STEM is one of representing both his home country as and a new life in the United States. For him:

> India is home to me and it always will be. This is my first semester actually taking courses on campus. I am hoping that when I am done, it will be a way for me to be seen in my family as a success but also help them out financially and also with information. When I was growing up, I learned that it was important to look out for one's family and neighbor, and me deciding to study what I do, well, that is why I want to.

In this way, and similar to *Ronald's* vision of his own future role in his community, *Ranjan's* identity is inextricably linked to not only how others view him, but also how he can contribute to his communities both back home in India as well as in his immediate surroundings.

In summary, whether found *or* sought-after, participants' experienced identities in STEM strongly connect to three key factors. First, their early involvement in STEM, whether formal or informal, helped to influence their comfort levels with STEM material. When given opportunities to participate in STEM-related activities, they generally found them to be helpful and encouraging experiences. In turn, this granted them a heightened sense of confidence, resulting in a positive feedback loop, which ultimately set the stage for more involvement in STEM.

Next, participants' experiences with and recognition of their role(s) within STEM as it relates to the interactions between themselves and others greatly contribute to their own identity development. Whether the "others" in question comprised their peer groups or members of their immediate family, the interactions that the participants had with them helped shape their identities as future STEM professionals well before they ever set foot in a classroom.

Finally, larger societal messaging (explicit or implicit) surrounding both who is/is not "part" of STEM and the public's broad-scale understanding of STEM-related topics cannot be ignored. On the contrary, this factor contributed to an overwhelming majority of responses to questions relating to why students developed a desire to study STEM at the post-secondary level.

Finding STEM at LLU

To understand the multi-dimensional factors contributing to participants' experiences with their online STEM courses, it is beneficial to first investigate how and why participants chose to enroll in STEM programs at LLU. As a result, this section first highlights the experiences students had when selecting their institution of higher education. As will be shown, participants' decisions to enroll in STEM academic programs specifically at LLU were largely

influenced by impressions resulting from experiences with STEM faculty and students before they enrolled. From here, the section pivots to results focused on participants' expectations regarding STEM courses. The section concludes with a discussion of their actual, lived experiences in their online STEM courses as well as the behaviors that they and their course faculty engaged in that contributed to said experiences.

Experiences Affecting Enrollment Decision: Professor Sets the Tone

As is common with many students, multiple factors contributed to participants' selection of a university in which to enroll. As expected, external elements such as messaging/reputation of institution, marketing and advertisement, affordability of attending, and proximity to home were quoted often as a factor contributing to one's selection of institution. However, the majority of participants reported specific personal experiences which directly affected their decision to enroll in their STEM program. For these respondents, observations of future faculty members' demeanor and teaching styles yielded impressions that they would be supported in their studies by a more-than-willing partner in their learning. However, the learning environment fostered by professors through the inclusion of peer-to-peer interactions also contributed to impressions that led students to enroll at the institution.

Professor-as-learning-partner

For some participants, such as *Saman*, being able to sit in on a class and observe the faculty and teaching assistance interact with other students provided a sense of comfort in knowing that help would be available to students as needed. As he explained, "Both the professor and teaching assistant were walking around asking if anyone needed help. I liked that a lot. Possible to succeed when there is help." *Mei*, too, came to view a future faculty member as

an ally in learning because of the welcoming environment fostered by a small class size and the fact that she and the professor spoke the same language: “It made me feel at home. I thought maybe this was a good place for me. I also really liked that the professors got to work in small classes with only few students.”

Bruce, a non-traditional-aged Computer and Information Systems major**,** also reflected on the importance of his would-be professors accommodating his desire to finish his degree in a timely manner:

> I was looking to get done with a degree quickly; I’m an old geezer compared to these kids, y’know? Don’t want to be here forever. But the professor I spoke with, they showed me how I could get done, even a semester early was good news for me. So, they were helpful and I appreciated that a lot.

For *Bruce*, and other participants like him, experiencing interactions with faculty receptive to students’ needs and wants relating to their learning pathway provided the final push to enroll at LLU.

Learning Environment Also Influenced Experiences

Other impressions contributing to their decisions to enroll at LLU stemmed from the environment and atmospheric tone they experienced while observing classes themselves prior to enrollment. *Sam*, a Natural Sciences major, was impressed with his future faculty’s enthusiasm and verbal interplay with his students during a site visit. He recalled a professor who, giving a tour of the department facilities, discussed high-tech laser beams and how they were used on campus: “At that point, I hadn’t even taken a class with them to ask about the lasers, but the professor was so enthusiastic about it. It was really cool and just unexpected, so it caught my

attention for sure." This professor's outward energy, well beyond the simple whiz-bang of the lasers themselves, provided *Sam* with an experience that, he recalled, made him feel more curious about his eventual program of study and heightened his own sense of excitement at becoming part of the department full-time.

To *Eve*, a current Mathematics major, while website presentation of departmental faculty information was impressive, personal interviews and site visits provided her with invaluable information and insights as to the dedication of her future faculty members. She also recalled seeing the exchanges between the faculty member and the students in the class she visited as overwhelmingly positive: "Everyone looked like they were having so much fun – yes, in a math class – and that sealed it [decision to enroll at LLU] for me." While she was on her tour of the department, she witnessed other students working in groups to solve problems and engaging in conversation with one another. "Without the teacher just blabbing away at the front of the class," she explained, this interaction gave her the impression that learning would be multi-directional.

And still, for others such as *Willie*, the simple freedom for students to obtain information from their professors yielded a positive experience for her. As she shared:

> I'm someone who likes to ask a lot of questions. 'Cause sometimes it takes me a little longer to understand. So, when I visited, I made sure to do it on a day when classes would be in session, to see what it was like. And I saw the students asking all sorts of questions – not just to the professor, but they were also asking each other. And I felt like, if they can do that, I would like to be part of that.

Indeed, the ability to ask questions of both professor and peer alike was a common theme for roughly a third of respondents, aligning with *Eve's* perception that one-way learning did not dovetail with what they were seeking in a learning experience.

Thus, through interactions of their own with professors as well as observing those between professors and other students, participants recounted numerous experiences which ultimately attracted them to the institution. The friendliness/approachability of professors, small class sizes, collaboration between students, and opportunities to conduct research as undergraduates all factored highly in their decision to pursue a STEM degree at this particular institution of higher education.

Seeking and Finding Online STEM Education at LLU

It should be noted that participant experiences discussed to this point were all based on interactions that participants had with others outside of an online course. Still, participants acknowledged that these experiences shaped and influenced their affected their decisions to pursue STEM as an academic program and strongly factored into their decision to enroll at LLU. On a smaller scale, however, they also indicated that these experiences shaped their expectations of their STEM classes, as well. As instructional delivery modes are, in practice and to a certain extent by definition, different from one another, it is also important to examine the expectations students had of *online* course delivery (that is, what they were "seeking") before exploring the experiences they had in their respective online STEM courses (that is, what they "found"). In this spirit, the first part of this section focuses on the expectations students had prior to enrolling in their online STEM courses at LLU. Here, we explore the connection between previous experiences many students had with online instruction, with particular emphasis placed on both

role of instructor and social interaction on respondents' desired (sought-after) experiences. In the second part of this section, I compare and contrast these expectations with the actual found experiences that participants reported having in their online STEM course(s) at LLU.

Expectations of Online STEM Courses at LLU: Professor and Student Set the Tone

While almost half of respondents indicated that they did not have experience with online learning or instruction prior to enrolling at LLU, several respondents indicated having significant formal experience with this delivery mode. ***Eve*** had taken numerous (12+) online courses at a community college prior to enrolling at LLU, and her experiences with them were overwhelmingly positive, owing, she said, "mainly to the fact that the faculty who taught it really knew their stuff. They kept everything running smoothly, knew the tech, and let us do things at our own pace. It was really self-run."

As a result, *Eve* was one of two participants in this study who reported having a strong inclination toward online learning and expected the experience to be primarily positive, saying "I was hoping for online and asynchronous. I thought there was going to be *no way* that I could take classes online to get a degree like this. Online was my first choice, though. I guess I got lucky?" *Zelda*, too, indicated that she always planned to take a mix of online and in-person classes, although her preference was for synchronous online delivery if given a choice. She explained her reasoning:

> Before coming to LLU, I was 'unschooled,' meaning I was trained at home and stuff. So I relied a lot on online stuff to learn. And people are just so stressful sometimes, so I didn't want to deal with that. 'Cause sometimes I'd get put into a bad work group in [an in-person] class or have a bad lab partner or something like that. So, online synchronous

> is easier if you don't have to deal with that in person but still meet like a class. So, I wanted *some* online and *some* in-person. 'Cause I still like meeting with professors and whatnot. And the professor was the main person in the class who set the guidelines and set up what we studied when, which I appreciated.

For both *Eve* and *Zelda*, their prior experiences with online instruction provided numerous opportunities to become comfortable with the delivery mode and, in turn, raised expectations that their experiences could be positive in their online STEM classes at LLU.

Other participants indicated having experience with online learning, though not in a formal institution-based setting or platform and almost exclusively in an asynchronous delivery mode. For example, *Faisal*, *G*, and *Kanraj*, all Computer and Information Systems majors, first began studying through the online programs offered through Coursera™, Freecore™, and Udemy™ (Massive Open Online Course [MOOC] providers), which allow students to work at their own pace toward a series of milestones and achievements. In these platforms, professors were once again "in charge" of the pace of the course; they pre-recorded lectures and assigned weekly or monthly tasks that were uploaded at a set date and returned/graded within a set time frame. These courses offered limited interaction with other members of the class outside of message/discussion boards.

Still other respondents reporting formal online learning experiences explained that they did so synchronously through their high school or community college and/or asynchronously through YouTube™ videos and instructional tutorials. Interestingly, regardless of whether the courses were delivered asynchronously or synchronously and though these lessons were taken

through different venues, student experiences and day-to-day undertakings associated with their respective delivery modes were fairly similar to those experienced by *Zelda*:

> Well, you know, I'd get up, I'd have breakfast in front of the screen, I'd follow along with the teacher. Then I would do the assignment once they were done talking. I usually worked alone during that break period. I'd have lunch, come back to the class, not really talk with anyone. Many times I would get the work from the teacher and just do it on my own and then we could set up an appointment to meet if I had questions. But mostly it was me looking stuff up online that I was interested in. The class kind of got me started being interested in something, and then I'd go investigate it some more.

That said, their *impressions/opinions* of the course experiences were vastly different. Though none reported dropping out from their courses, their descriptions of their experiences in these non-LLU online courses were those of a one-way, primarily passive, non-interactive relationship between themselves and the online content. In their experiences, the online platform served as a way for them to watch videos (*Asha, G, Mei, Ranjan, Ronald, Zeus*) and turn in assignments (*Marie, Willie*), or "nominally participate" in discussion board assignments (*Eve,* who indicated she "never read anyone else's work, really, but you better believe I put up my assigned stuff to get credit!")

Clearly, of those who had prior experience with online instruction before enrolling at LLU, all acknowledged that the professors/instructors of those courses influenced how they as students experienced the classes and, as a result, shaped their expectations of online instruction at LLU. However, they also recognized that the students contributed to the experiences just as much. As mentioned earlier, while many of the recollections involved a primarily passive receipt

of information, several respondents shared that they were seeking more of an interactive experience. For example, *Sarah*, a Natural Science major, recalled that she was hoping for more opportunities to work with peers:

> I knew that I could read other people's discussion board posts if I had to, but that wasn't what I wanted to do, so I really was hoping for more instances where I could get to know the other people in the class. I really wasn't looking to be alone in a class full of people.

Perhaps unsurprisingly, in total, almost 80 percent of respondents shared *Sarah's* desire for opportunities to interact with their peers if they were enrolled in an online course, suggesting that there was a strong expectation of (and hope for) a peer-based social component in their learning.

When taken altogether, responses suggest that student expectations prior to taking their online STEM courses at LLU had two key influences: professor demeanor and actions, and interactions between students and their peers in the context of their classes. Ultimately, whether rooted in experiences they already had or steeped in hopeful thinking, these expectations set the stage for them as they signed up for their respective online courses. As discussed in the next section, however, participant experiences did not always align with their expectations.

Experiencing STEM in the Online Learning Setting at LLU

To provide context for which experiences relate to different online delivery modes, this section first provides a generalized description of the distribution of online classes taken by participants. Subsequent sub-sections focus on the experiences participants reported having in their online STEM courses centered primarily on descriptions of interactions they had (or did not have) with their instructors and peers. The next two sub-sections focus on specific behaviors and actions undertaken by the participants and the professors that contributed to positive and

negative experiences in participants' online STEM classes. Finally, the section concludes with a summary of respondents' experiences in online STEM learning.

Distribution of Online Classes Taken by Participants

In total and accounting for duplicate/cross-over course identification, responses given by the participants described 11 asynchronous and nine synchronously delivered STEM courses (Table 2.) As displayed, the majority of the participants reported taking at least two online courses at LLU, with a mix of asynchronous and synchronous delivery modes. Though I asked participants which specific classes they took, this information does not appear on the table, to protect the anonymity of the professors who taught them.

Table 2

Distribution of online classes (and respective delivery modes) taken by participants

Participant	Total online classes	Asynchronous	Synchronous
Amanda	3	1	2
Amon	2	0	2
Asha	1	1	0
Bruce	1	1	0
Eve	3	2	1
Faisal	2	2	0
G	3	2	1
Janice	2	1	1
Kanraj	2	2	0
Katie	3	2	1
Marie	3	1	2
Mei	3	1	2
Midi	2	1	1
Penny	3	0	3
Ranjan	3	2	1
Ronald	1	0	1
Sam	1	0	1
Saman	1	1	0
Sarah	1	0	1
Thomas	2	1	1
Willie	2	1	1

Table 2 (continued)

Participant	Total online classes	Asynchronous	Synchronous
Zelda	2	1	1
Zeus	3	2	1

Note. Participant responses to how many online courses they completed at LLU as well as the course delivery modes. Eve, Zelda, and Zeus all reported that they had taken well over 10 online courses at LLU, they were instructed to focus on recalling no more than three distinct classes for the purposes of this study, for brevity's sake.

Interactions with Others: Effects on Learning Experiences

When asked to think specifically about the experiences they had in their online classes, the majority of the respondents indicated that opportunities to do so were limited in scope and duration. Often, these exchanges presented themselves under the duress of time limitations or in situations in which respondents did not experience genuine or meaningful interactions. I discuss two separate forms of interactions below: "Student-professor" and "Peer-to-peer."

Student-professor Interactions Affecting Online Learning Experiences

A common theme pertaining to the interactions between student (participant) and their professor in their online STEM class revolved around professors' lack of timely responses to questions, either asked real-time in synchronous classes or via email for asynchronous classes. Though no participant defined what they meant by "timely" responses, most respondents reported waiting up to a week for a reply, and a handful reported waiting over a month. A handful of participants (e.g., *Mei, Willie,* and *Zeus*) indicated that while interactions with their respective professors did occasionally happen, these interactions were not overwhelmingly positive for them. *Zeus*, for example, recalled feeling "totally out of touch with the professor, who didn't seem to want to be there and really didn't seem like [they] wanted to be teaching online. Miserable for everyone."

Long turn-around times between their asking a question and receiving an answer (via email, assuming there was no time in class) was a common complaint from that subset of participants. Additionally, delayed responses often left students feeling as though they were an afterthought or, in the case of *Mei*, "a burden to the professor."

In the case of *Mei* and *Zeus*, especially, these interactions left them feeling that they were wasting the professor's time. In the most extreme case (*Mei*'*s*), all students in a single course were strongly discouraged from asking questions during class time at all due to time constraints but also due to a professor's statement that, "If you have to ask questions, you shouldn't be in the class to begin with." This, *Mei* said, was the same professor she had seen interacting with other students in the in-person class she observed prior to enrolling at the institution. Unfortunately, such experiences were shared by other study participants, as well, though it should be noted that they described similar experiences in completely separate online STEM classes.

As before, however, not all student-professor interactions affected online learning experiences negatively. In fact, some of the interactions between students and professors, especially those which resulted from specially-designed activities meant to boost engagement levels and impart a bit of friendly competition in the class (such as through the use of online Kahoot™ quizzes). As *Amanda* (a Mathematics major) shared:

> The fun parts were when we got to compete against each other. I mean, you had to be paying attention or your team wouldn't get the points, so you were working together to solve a problem or figure out a term or something. It wasn't a major competition, but it did snap us back from our own worlds when we got to do that. We weren't so separated. But I came away from those [instances of competition] having learned a lot. I studied for

them but it was also that we worked together so we learned from each other.

These interactions resulted in many students, like *Eve* and *Amanda*, feeling as though the professor had a vested interest in (1) whether they showed up to class and (2) more important, whether they could work cooperatively with their peers.

Peer-to-peer Interactions

The majority of the respondents indicated that opportunities to interact with their peers during class periods were few and far between, and a few indicated that they had no opportunities to interact with others at all during their courses. Surprisingly, this was often reported by students irrespective of whether their courses were being delivered asynchronously or synchronously, though the use of cameras in "real time" was relegated to synchronous-only courses. *Midi*, who took both a synchronous and asynchronous course, described them both as "A way to get things done fast because you never talked with anyone, so the professor would cover material quickly. Sometimes we ended early but still didn't get to talk."

Of those who did report *some* interactions with peers during class time, those interactions primarily took the form of small group discussions on Zoom™ with the bulk of the class members' cameras turned off. This lack of visual connection or confirmation that others were in the same virtual "room" with them lead to some participants experiencing feelings of being disconnected or otherwise separated from what they had experienced in a previous F2F educational setting. *G*, who described his synchronous class, indicated, that the lack of faces on the camera screen contributed to feeling disconnected from being a college student:

> The way the class was run, it didn't feel like being real school, you know? We were given assignments to do, but we did it on our own, always on our own. And then the

> professor would talk at us for a few minutes but then we would just go off online to find the answer…We couldn't ask questions in real time because there was never any time. It was harder to learn things when I had no one to talk to. Very difficult.

For the most part, participants indicated that they had more positive experiences in their online synchronous class(es) when given the opportunity to meet and collaborate with their peers in the form of small discussions or group work activities. Of note, this was highly dependent on whether their peers had their cameras on at the time of interaction, which the majority of participants reported was not often the case. When cameras *were* on, participants reported that their experience was more like a typical classroom and they also reported feeling more connected to the course material. *Marie* indicated that she felt much more welcomed and had a stronger sense of belonging when cameras were on:

> For me, like, I know I am paying money for a class and the professor is there to teach us. There's this whole vibe that's different when we were using cameras, though. It felt less like we were numbers in a crowd. It felt more humane and human. I felt like I was a part of a class – and really part of the program – when we had cameras on. Otherwise, I'm just a bunch of letters on a screen and I really could be anybody. Any of us could be. But seeing faces felt like we were a real class. And I learn stuff better when I can work through problems with others.

Additionally, harkening back to the "Us against the world" framing that *Asha* provided earlier, many participants also experienced a feeling that they were united with their peers in a common goal of communal learning. Along these lines, *Janice,* a Natural Sciences major, said "Learning is just better when it's something you're not doing alone. If you have a goal you can work

toward together, even struggling together, it's more rewarding." These responses suggest, then, that the ability for students to work in groups and have discussions helped many to solidify their understanding of course-related concepts. In essence, when students were given opportunities to bounce ideas off one another and see other peoples' thought processes, learning was more enjoyable and concepts were less abstract.

On the other hand, participants reported that the lack of face time on the cameras provided two main negative experiences. First, as *Amon* acknowledged, it was very difficult to ensure that their peers were even in the same online room at the same time as them, complicating problem-solving work times:

> When I was put into a breakout room (in Zoom™) and all I would see would be the blank spaces or screens of the other members of my group. They didn't talk, they didn't show up, none of us had our screens [cameras] on, so it was very easy to think, like, maybe they ghosted the class for the day so sometimes it would just be me alone in the breakout room or maybe only one other person if they didn't leave.

Second, others described a phenomenon in which they found themselves getting distracted by everything residing outside the course. The ability to "tune out" the course *while* the class was in session was also compounded by the fact that, as *Thomas* said, "It was really tempting to go off and do work for another course where you knew that your work actually meant something." *Penny*, too, recalled struggling to focus on her synchronous courses sometimes:

> For me, I just have a lot of stuff going on. Plus, like, if it's a nice day outside and if your desk at home just happens to be near a window – well, it's just like regular school, right? You're going to be looking out that window instead. But now it's even harder to stay "in

> the moment" and paying attention to what the class is doing because oh, maybe your neighbors are outside with their dog, or maybe your family is wanting to go to the park or something else. So, I'd definitely say it's harder to keep attention on the class when it is online like that.

It is important to note, also, that these responses did not account for every participants' experiences with their online STEM course in the context of peer-to-peer interactions. On the contrary, for some, their experiences were positive *because of* the lack of such interactions. Both *Zelda* and *Eve* indicated that the lack of interactions with their peers meant their social anxiety was *not* triggered; they could remain completely separated from their peers in the way their courses were delivered. This experience held true for them regardless of whether the course was delivered synchronously or asynchronously for them. It should also be recalled that these two students were those who were initially hoping for if not an outright online-only STEM program of study, then at the very least one with options to take several courses online.

Personal and Professor Behaviors: Effects on Learning Experiences

Participants also provided reflections on behaviors they encountered during their online STEM course(s) and what experiences (positive or negative) resulted from said behaviors. In their reflections, there was no delineation made between synchronous or asynchronous delivery in the prompts or in the replies, but, rather, general themes that emerged from their responses. Ultimately, these were grouped into four themes: "Positive online learning experiences stemming from personal behaviors," "Negative online learning experiences stemming from personal behaviors," "Positive online learning experiences stemming from professor behaviors," and "Negative online learning experiences stemming from professor behaviors."

Positive Online Learning Experiences Stemming from Personal Behaviors. The two most-mentioned behaviors or activities that resulted in a positive learning experience for the participants in their online STEM class(es) related to time and task management. *Amanda* and *Janice,* for example, shared their reflections on the importance of compartmentalizing their school studies from the rest of their lives, explaining that their online learning experiences could quickly grow all-consuming without these separations. *Amanda* described her experience:

> When your classroom is your dining room and you've got people around, it's really hard to concentrate. It's not like you can yell at your kids to quiet down because you're in class, so you have to adjust. But, finding a way to segregate myself from distractions was a big thing for me. Otherwise, the experience would have just had me pulled in too many directions.

Janice, too, recognized how overwhelming her online courses (both synchronous and asynchronous) became early on without a set structure and the ability to unplug from her screen due to academic commitments. Doing so, she said, required that she carve out time in her "real life" for studies too. Setting aside time to focus just on tasks in the course and then adhering to the strict limitation, allowed her to limit screen time and "connect with my people," she explained. Whether these associated behaviors involved attending class regularly at a scheduled time for an online synchronous class or selecting a day (or two) per week devoted to completing online coursework, adhering to a self-set schedule was key to students feeling as though they could handle the workload.

Interestingly, about one half of participants who took online asynchronous STEM classes reported that they took it upon themselves to reach out to other students to form study groups,

despite not explicitly being given the opportunity to do so while in class. This decision to make connections outside of class, as suggested by *Asha*, *Amanda*, *Eve*, *Marie*, *Penny*, and *Sam*, was a way to get to know their classmates but also learn how to troubleshoot problems on their own. For *Sam,* forming a study group provided multiple benefits:

> First, it made me feel like, okay, I wasn't the only one who was lost with the material. Second, it got me to have a set routine, even outside of the class. That was important for me because I struggle with time [management] sometimes, but if I know I'm meeting up with folks from class I'll plan that. It also made me work on the stuff that I might not usually do; like, if I know we're going to be talking about a topic or something, I'll come more prepared. Because with your group, it's different from the class. You *have* to talk in the group, 'cause you're all there together for that one reason, to study.

Additionally, this provided a sense of belonging for students who were not in the same time zone as that in which the course was being delivered (*Faisal*, *G*, and *Kanraj*.) As *Kanraj* described:

> Being from oversees it's not like I could take the class at the same time as the others exactly. So being able to talk with someone who is in the same time zone – and have a professor be aware of the time zone difference – it is very healthy and hopeful for me. So [the professor] would ask us from the different country to meet up online in same time Zone so we would be able to talk on our time.

By successfully engaging in these behaviors, they (and other participants who engaged in them) reported feeling in control of their course tasks, and much more confident in their abilities to succeed in completing the required workload assigned by their professors. However, participants

also recounted feeling more "whole" when they were able to step back from the screen and devote time to other aspects of their lives (such as family, non-school work, etc.)

Negative Online Learning Experiences Stemming from Personal Behaviors. Participants were very forthcoming in identifying the negative experiences of their online STEM courses. Situations in which they found themselves constantly playing "catch-up" with the coursework became overwhelming quickly for some. Lack of professor feedback and/or the inability to interact with peers led to feelings of isolation and inadequacy for others. However, as quick as they were to identify the negative experiences, many were also quick to recognize some of their own behaviors which contributed to the challenges they encountered while taking their online courses.

The vast majority of respondents reported that their STEM courses required they have strong motivation to stay on top of their assignments; when they procrastinated getting their tasks done, it was very difficult to catch back up. For *Zeus*, frequently finding himself behind in action items he was expected to accomplish caused him to persist in a negative headspace:

> Falling down the rabbit hole of missing or forgetting an assignment was due for two weeks in my asynchronous class and then playing behind the eight ball the rest of the month nearly ended me in that course. It was super stressful. I think I lost about a week's worth of sleep. Wasn't fun at all. I felt really low about myself when that happened, 'cause I felt like I had let myself slide backwards.

Others shared his lament, as well, with *Penny* adding, "I always I figured I could go back and watch the video later or something. But then I would forget, and have ten more things to do on top of that. Yeah, that definitely was rough at first." Participants also shed light on a factor

contributing to this near-constant feeling of playing catch-up: Many reported feeling wholly unprepared for the amount of self-pacing they would have to engage in while taking their online classes. *Zeus* brought up that his experiences with time management were unlike any he had prior to postsecondary education, and that he was caught off guard:

> So, the thing that really surprised me about the whole [online course experience] thing was that, it felt like the professor had all these expectations that we'd be on top of the readings and assignments and stuff. That we would manage our time and whatever. And like, yeah, okay, that's the adult thing to do, but where did we learn to do that before coming here? We weren't doing that in high school. I know *I* wasn't. Even when COVID first hit and we went online in high school, we didn't have a class in time management; nobody showed us how to do it. So, these classes [at LLU] were just a wake-up because it was like they [the professors] just assumed everyone knew how to keep a schedule. I had a lot of problems at first 'cause of that. 'Cause how would I know [time management] without being taught how?

Bruce also summed up the experiences of many of the students who had taken such classes:

> We were expected to stay on task, on schedule. If we fell behind, that was on us. But, it was also on us to basically do everything ourselves. We didn't work together, we didn't share any time together. It was basically a one-man show here. Couldn't talk to the professor and they rarely answered their emails. So, yeah, it was just me at the screen doing what I needed to do.

The second most-mentioned behavior (or, in this case, inactivity) contributing to negative experiences that some students engaged in related back to a previously mentioned theme of

interaction. Namely, several students recognized that their decision to not reach out to others in their class was detrimental to their online learning experience. Both *Sarah* and *Mei* acknowledged that their hesitancy to meet up with people probably contributed to their sense of loneliness and isolation. For *Sarah*, "At first I felt too apart and eventually too bored, to reach out. So it became a cycle of feeling left out and then not bothering with anyone else. I guess I tuned out and then stayed that way."

Mei, on the other hand, indicated that while she desired to reach out, she felt too shy to ask for anyone's contact information to talk outside of class time:

> I definitely didn't want to feel like I was bothering anyone. And I'm a shy person who likes to be in a class with people but I know I didn't reach out as I could have. I think that probably made me feel more alone, looking back, though. When you're in a classroom it's different; you are asked to work with someone right then and there. But I didn't have that in my classes. We were all over and doing things at different times. So, yeah, that probably helped me to feel lonely.

Amon related his apathy to his apparent (though not literal) withdrawal from his synchronous classes:

> Even though they're some of my last required classes, I got to a point where I just wanted to get through them. Plus, I had a lot of other life stuff going on, so I just couldn't allow myself to care in the class when no one else would even come to be on their camera. I couldn't force them to participate, and so I figured, why should I?

Janice, too, recounted times when she would allow herself to become distracted, ironically more during the synchronous class. This, she explained, occurred because:

> With the asynchronous class, I could plan things out a bit more, but with the synchronous class, it was forcing me to sit still, not engage with anyone, just sit and listen, but I was home, so it's not like I had to sit there as if I was in a classroom. So I would get up and do other things while I was supposed to be listening. I missed some things that way, for sure. But there was just so much other things to be distracted by.

In all, roughly half of the participants also responded that they found their tendency to isolate and not reach out to their class peers was a personal "failing" that may have caused them to feel more isolated and/or distracted than they would have in a F2F course.

Positive Online Learning Experiences Stemming from Professor Behaviors. As before, participants reported having the most positive experiences in their online courses when they felt confident and comfortable with themselves as learners. Though they recognized that they themselves have the ability to craft/affect positive learning experiences, their responses also suggest that professor behaviors contributed to their positive experiences in the course.

The majority of participants indicated that when the professors shared lectures and assignments ahead of time and gave clear directions, it provided structure and order to an online course, and this was a comfort to most of the respondents. They reported that they were able to pay better attention during the class since they had a preview of what to expect and it prepared them to ask questions, although admittedly many indicated there was not often time for questions in such a class. For synchronous classes, recording lectures and labs as well as providing captions for recordings was seen as especially helpful to allow students to follow along in real time and review as necessary at a later time. All respondents indicated that when they were given the opportunity to ask questions (either in real time or via email) and when they got responses,

they felt more engaged with the material as well as with each other. *Penny* reported feeling "way more likely to 'get it' – to understand the stuff we were supposed to learn about – if I could ask about it. The other students perked up when that happened, too."

Similarly, when faculty were responsive, returning emails and providing feedback in a timely manner, students reported experiencing feelings of worthiness and satisfaction, sometimes resulting in incentive for them to increase their efforts in the class. *Ronald*, for example, recalled feeling "important enough to get an email back from someone who was really busy, so that made me try harder sometimes. And the feedback became like a conversation; I liked that." Additionally, as mentioned before, the occasional introduction of competition in the form of impromptu group contests (such as those provided by the online platform Kahoot!™) was also favorably recalled as a positive learning experience from several students, as it provided them the opportunity to work collectively to score the most points for their team.

Participants also indicated having positive experiences resulting from other specific "engagement activities" which involved components of both types of interaction during synchronous classes. Designed and implemented by the professor, these activities, including in-class quizzes, real-time, small-group discussions, and leaving time for answers provided students with positive experiences when they occurred. *Willie* recalled a time when she got to ask questions in class:

> Okay, I was the only one who did it that day, but for the first time I got to ask a question with enough time for the professor to think about how to answer it and then when I didn't understand they were able to explain it a different way. And it sounds so small, so silly,

> but not having to go online to look it up, getting to talk and ask like normal…that helped me a lot. And I obviously paid attention ‘cause I was asking the question [laughs].

It should be noted that a repeated phrase, “if there was time” was appended on a fairly regular basis to the aforementioned activity of providing students opportunities to ask questions. Respondents often indicated that one experience they kept having was that, with an online synchronous class, the professor was often pressed for time. This time crunch was due to the fact that many of their peers (and sometimes they themselves) encountered technical issues which delayed the start of class, as described by *Amon*:

> Yeah, most times there would be, like, ten minutes of tech issues at the beginning of class. Like someone’s internet was down or they couldn’t log in to the Zoom room. So if it was a day when we got to work together but not everyone was there, then your group would be smaller. Sometimes the professor even had troubles, so it would take longer.

The resulting truncated classes left little time for questions. In fact, many respondents indicated that opportunities for collaboration and interaction between students, their peers, and their professors was something out of the ordinary. Still, the majority of respondents indicated that engagement activities, when they did occur, brought them heightened senses of connection with the material, and that the classes, in the words of *Amanda*, “felt more like the classes I was used to; there was more like there was reason for me to follow along.”

In essence, the findings suggest that the most positive experiences for students came when their professor provided pedagogical tools to help students build a heightened sense of agency over their own learning as well as a connection with other students in the class. Their professors contributed to this by creating opportunities for students to learn at their own pace (as

in the case of recorded lectures), interact with others in friendly competition (as in the case of the quizzes), and invite questions on the material.

Negative Online Learning Experiences Stemming From Professor Behaviors. As mentioned earlier, there were two dominant themes that emerged from answers regarding negative experiences in an online course relate to professor behavior. Ironically, a task that participants reported being used by their professors to foster interaction, the use of discussion board forums, was almost universally met with derision and contempt, leading to very negative learning experiences. Common refrains when asked to describe their experiences with them included, "Those were a waste of time," "They felt like busywork," and "I'm pretty sure no one reads any more on them than they absolutely have to."

An exception to these negative feelings toward discussion board-based assignments was *Zelda*, who indicated that while she acknowledged that they were a cheesy way to get to know her classmates, she was able to think about what she posted before she posted it and read at her own pace:

> For me, I got to know the people in my classes through their words more than through working alongside them. I could sit and read about them and respond to them on my own time so I could think about how I wanted to interact with them without worrying about how I was coming across.

This, she indicated, made her feel less intimidated about interacting with other people. *Amanda*, too, reported that discussion boards could be useful, saying "As long as they are monitored by a professor or teaching assistant (TA), they [the boards] could help people ask questions about the material they may not be comfortable asking about in class."

Still, for the majority of respondents, these discussion board assignments were experienced less as a way to genuinely interact with their peers and more along the lines of arduous tasks. Some respondents, like *Eve*, viewed these tasks as something to "just get through with; don't read more than you have to, just reply to one and be done." According to the participants, entries on such boards were viewed as neither spontaneous nor organic conversations and, since they were often not monitored, they did not promote higher-level (or critical) thinking, they were viewed more as busywork assignments. The same was said about breakout room-based activities in online synchronous courses utilizing Zoom™. *G*'s experience with Zoom™ summed up many other participants' experiences, as well:

> Like, we were given assignments to do, but we did it on our own, always on our own, and then the professor would talk to us for a few minutes and then we would all go off and look at things online to find the answer. We didn't even really talk with each other during lab time, because no one had their cameras on. So who knows what is going on behind the camera at all, you know? I don't even know if they were there.

Another, nearly universal behavior (or, in this case, inactivity) that resulted in negative experiences for online learners was the lack of responses to student questions, especially those sent via email. Of the 23 respondents, only two mentioned attending virtual office hours to ask questions of their professors, but even then, sometimes technical issues or the inability for students to attend office hours at the designated time would preclude those meetings. An experience shared by students who took synchronous and asynchronous online courses alike, an overwhelming number of participants commented that when they sought assistance from their professors, they were often waiting a week or more for a reply, usually yielding negative results.

This delay left students feeling confused and frustrated more often than not, as described by *Saman*, who explained:

> I would ask for help in class but there wouldn't always be time [for answers to be discussed] so I would email, but then I wouldn't get a response. So sometimes I would do a whole problem set one way and I would think it would be correct, but then I would get marked off for it and the answers wouldn't be shared for four or five weeks so I wouldn't know how to fix the mistake.

The final, and most commonly reported, lamentation was the perception that professors, regardless of whether the course was synchronous or asynchronous, provided little-to-no opportunities for students to work together in meaningful ways. This persistent lack of meaningful interaction led to feelings of apathy, disconnect as well as isolation for many students. In general, the experience of learning in the online STEM courses was captured succinctly by both *Faisal* and *Penny*, whose respective word choices were "solo, lonely, lots of screen time" and "disconnected" when asked to choose words to summarize their online courses. For *Faisal*, he felt particularly negative about the lack of response when he would reach out to his instructor for assistance:

> It was like, I had these questions, but we never had time to ask them in class because it was asynchronous, so when I would go and try to do the work, I would get confused, but when I would send emails, I didn't hear back. I tried to set up an appointment for help but the schedule never seemed to match mine. So, I eventually pulled away from the class and I stayed in it, but I didn't care about it as much, anymore.

Penny, meanwhile, shared that the lack of human faces made it particularly difficult:

> I'm a people person, you know? I need to work with people in order to really 'get it.' And so, with my classes, they were synchronous, and I thought maybe – just maybe – I would at least be able to work with other people. But then, when it came time to do that, no one had their cameras on, so it was like, 'Okay, why would I put my camera on if no one else does?' And so, it was just really easy to tune out and not engage. I'd usually end up doing something completely different during class time that had nothing to do with class.

When taken together, the experiences relayed by the participants paint a somewhat bleak picture when it relates to interactions with their professors in their online STEM course. In place of an exchange of information between pupil and instructor, their recounted experiences point to a disconnect between these two entities. Some of this owed, undoubtedly, to differences in technological infrastructure and acumen (potentially true of both parties).

However, the responses also suggest something was possibly amiss regarding the pedagogical delivery method itself, as employed by the course instructors. Namely, the lack of professor-provided opportunities for students to interact in genuine, meaningful, and impactful ways with their peers in the course both in synchronous *and* asynchronous courses. Indeed, when asked to describe their online learning experiences, almost all respondents used the words "lonely," or "alone," while two-thirds indicated it was difficult to stay engaged and/or feel like participating on a regular basis.

Of the students who had taken online synchronous STEM courses at LLU, most indicated that there was a defined structure to the course where they could very occasionally see who else was in the course, and therefore it felt nominally like a F2F course in that regard. However, a

majority of these students also reported a sense of learning in isolation, owing primarily to the fact that they were seldom given opportunities to see, interact with, or work with peers on a regular basis. Finally, with regard to academic rigor, half the participants responded "easy" when asked to provide a word to describe their course; this was primarily due to, in their assessment, a lack of supervision from professors as relating to looking up answers during outside-of-class time. As *G* said, "They weren't watching us and never told us we couldn't, so we would go and look it up. If they didn't care, why would we? So we would look and find the answers. They're out there."

With the exception of *Zelda's* and *Eve's* responses, this study's overall findings suggest that word or phrase choices used to describe the general experiences that these students had in their online STEM courses would not widely be considered "positive." Instead, the experiences that stand out most often reflect an experience of isolation, disconnect, and frustration. One might wonder, then, whether these experiences had any effect on students' decisions to remain in their academic programs of study.

Online Learning Experiences and Students' Decisions to Persist

While participants reported examples of both positive and negative experiences in their online class(es), there were only two who indicated that their decision to persist in (or, in their cases, switch out of) their original STEM major was influenced by what they experienced in their online STEM course(s). All other respondents indicated that they completed their online coursework online either by choice (as in the case of *Eve* and *Zelda*, who both explicitly sought out/hoped for online courses as part of their STEM program) or because they needed it to

continue in their program. In this final section there is a brief discussion of the students who decided to leave their original major (and their reasons for doing so).

Making the Decision to Stay

Despite the challenges and disappointments that many participants recalled having in their online course(s), the vast majority of participants indicated that they did not switch out of their major in favor of another one. The reasons for this were primarily two-fold: First, many participants expressed their views that, while lonely, they didn't want to give up their major altogether, since they had sought a STEM identity for an extended period of time. *Penny* summed up the feelings of many: "Sure it's not ideal, but if it gets me to where I can accomplish what I set out to do, I will survive the [online] courses. I may be bored or sad or lonely, but I'll get through them." Second, for a vast majority, the pursuit of any financial benefits that a STEM degree could provide far outweighed what they considered to be temporary let-downs. As *Kanraj* said, "I am willing to put up with a lot to be able to stay in the country and get a job in the field."

Staying, but With an Important Caveat

As if to emphasize the importance of word-of-mouth, half of the students who indicated they stayed in their major shared that they had either (a) already dissuaded another student from entering into their major, or (b) *would* dissuade someone else from entering into their major as a result of their negative experiences in their online classes. For some, like *Saman*, he could not envision herself telling someone to enroll without feeling "at least a little guilty. I mean, if they were expecting something that was like college, it's not like college." *Saman* explained that, to him, college was meant to include research, but *working together* on research, not engaging in actions like looking up videos online from which to glean information about how to perform

certain calculations. He further indicated that the isolation he experienced caught him very off guard, explaining, “I always thought that college would be friends, friends, friends, and work, but now it’s just me in front of screen.”

Others, like *Mei,* viewed her online experience as alienating enough to dissuade her younger sibling from attending. In her view, “I couldn’t tell her to come here. Not after what I’ve gone through. It was a lonely experience. I tell her she should look somewhere else.” *G* compared his education within his program at LLU as “Something I could find for free online, but it will get me the degree, I guess. Still, I wouldn’t tell others to come here – some of my friends go elsewhere and they do online well.” And *Thomas* echoed the feelings of several others by summarizing his thoughts: “If the professors acted like they cared about online students, maybe, but until then? No, I’d have to tell people to stay [expletive deleted] away from that major.” Clearly, from these students’ perspectives, the apparent disconnect between expectations and experienced traits of their online courses at LLU was not strong enough to force them to leave their majors or STEM, but they clearly did not wish others to follow in their academic footsteps and experience the same things they had.

Making a Decision to Switch

The two students who switched out of their original majors, *Amanda* and *Zeus*, reported that they changed out of their major after taking one and two required online STEM courses (respectively). *Amanda* was originally pursuing a degree in Natural Sciences but is now a Mathematics major, and *Zeus* was originally an Engineering Major and is now pursuing a Natural Science major. They both remain students at LLU and are both still pursuing a STEM degree, albeit in fields that are decidedly different from the ones in which they originally

enrolled. While Zeus's decision was primarily driven by internal factors, *Amanda's* decision to leave her original field of study was influenced by internal and external factors.

Internal Experiences Affecting the Decision to Switch. Amanda cited a growing sense of disconnect from the subject matter as she pursued her initial degree, "Mainly because I was doing most of the work alone. And I know that science is meant to be done with others so for me, it was really hard to be isolated and feel like I belonged in the class." Though her professor was kind, her classmates did not regularly participate in the in-class discussions or lectures, so she felt like she was alone in asking questions. "It got to be a little tiring, trying to liven it up." Eventually, she took it upon herself to create study groups in her classes, but the more she studied the material with classmates she "barely knew," she made the decision to change majors.

Zeus, too, experienced a disconnect from his original field, though he indicated that his disconnect was more due to his lack of confidence in his original course material since so much of it relied on hands-on application and, in his words, "It's hard to put your hand on material and feel it through a screen. It's just not the same." His tactile learning style would serve him well, he figured, in the Natural Sciences, and he noticed that more courses were offered with in-person delivery in his new major when he decided to make the switch.

External Experiences Affecting the Decision to Switch. *Amanda's* recollection of why she switched her major also reflected the influence that her family dynamics and interactions had on her decision. She recounted that her old major required that she value her studies over her time with her family because she constantly found herself trying to play catch-up with material that she was no longer feeling a connection to. As she explained,

> I have no problem being challenged. But, when my family doesn't get to spend time with me – and they're living in the same house as me – because my nose is always in a book or I'm always in front of a screen…and I don't even like what I'm studying anymore? Yeah, at that point it was definitely time to go [from the major].

Of note, regardless of whether they decided to switch their majors or remain in their majors, none of the participants indicated they regretted their decision.

Summary

This chapter described the themes gleaned from interviews with undergraduate students who took online STEM courses as part of their academic major program of study. First focusing on student experiences (both positive and negative), patterns relating to self-identity in STEM emerged and were discussed in the context of both "found" identities and "sought-after" identities relating to experiences they had with STEM prior to enrolling at LLU. I then examined these experiences in the context of what expectations students had for their pursuit of a STEM degree at LLU; what they were ultimately "seeking" from their online courses. In turn, I then compared these expectations with actual "found" experiences students had in their online STEM courses. I discussed behaviors contributing to both positive and negative experiences in the context of sought-vs-found experiences, as well. The chapter culminated with a discussion of whether and how these "found" experiences contributed to students' decisions to remain in their chosen STEM program of study.

Chapter 5: Discussion and Implications

The purpose of this phenomenological study was to gain insight into the experiences of undergraduate STEM students taking major-required, online STEM courses at LLU. This study was guided by a framework based on the sociological theory of social constructivism, focusing heavily on influences that social interactions have on students' learning and knowledge (Dewey, 1925, 1928; Kincheloe, 2001, 2008; Vygotsky, 1978). I asked participants a series of questions about their experiences in required online STEM courses at their university, focusing on the essence of their interactions with and behaviors of other people in their courses. Their impressions of and reflections on their experiences in their online class(es) provided answers to the study's research questions:

1. What practices, occurring in online STEM course delivery, have led to positive and negative experiences for students who have taken the course(s)?

2. How have these specific experiences influenced students' decisions to persist in their academic programs?

In Chapter Two, I reviewed literature on student experiences to STEM education, beginning with a discussion of the background of STEM in the context of higher education in the United States. As the system of American postsecondary education has grown in purpose, scope, and reach, so, too, have STEM academic programs. Despite this expansion, however, the net effect has still resulted in fewer students of historically marginalized identities persisting through to completion due to a lack of equitable systemic support systems for some students and an over-abundance of those same resources for others (Blickenstaff, 2005; Cronin & Roger, 1999; Higher Education Research Institute, 2010; Martinez & Renn, 2002; McGee, 2017; McGee, 2020).

Contributing to the lopsided nature of the support systems (and degree acquisition rates) are the implicit and explicit biases found at institutions of higher education. Unconscious attitudes and stereotypes toward racial, ethnic, ability status, and socioeconomic identities of students can manifest in explicit reactions and interactions in the classroom setting which can impede student success (Blackwell et al., 2009; Boysen & Vogel 2009; Bunk et al., 2015; Clark, 1993; Kirwan Institute 2017; Muenks et al., 2020; Tabata & Johnrud, 2008.) These biases can also affect hiring practices at the postsecondary level, which can, in turn, impart a lack of diversity among staff and administrators in institutions of higher education (Beattie et al., 2013). The resulting microaggressions, macroaggressions, and additional inequities often propagate academic and social inequality in and beyond the classroom (Ambrose et al., 2010; Center for Educational Effectiveness, 2019; Ridgeway, 2014).

On the other hand, research has shown that faculty can also have positive impacts on their students' learning. Through the use of collaborative learning and instruction practices, engaging in inclusive language and actions, engaging multiple learning styles, and centering students' experiences, faculty can foster supportive and nurturing learning environments (Barr & Tagg, 2005; Braxton et al., 2004; Canning et al., 2019; Fairweather, 2008; Henderson et al., 2008; Wilson & Varma-Nelson, 2016). In this way, faculty actions can improve student retention rates within STEM programs (Anft, 2017; De Leo-Winkler et al., 2016; Franchetti, 2010; Hemslee & Klein, 2017; Herbert, 1998; Morton & Parsons, 2018; Najmabadi, 2017). (While it lies beyond the scope of this study, I would be remiss to write of all of this without acknowledging that this puts the onus of change on the professors, while doing little to, as Morton and Nkrumah [2021] point out, significantly change a larger system fundamentally built upon a bedrock of inequity.)

On a broader scale, it researchers have also shown that professor attitude toward online teaching (and their perceived readiness to do so), can have huge impacts on the delivery of online courses (Bennett & Bennett, 2002; Florence et al., 2019; Lao & Gonzales, 2005). As shared in Chapter Two, then, faculty – and students' interactions with them – have the potential to yield both positive and negative results in relation to affecting students' experiences in their courses. Therefore, I undertook this study to learn what actions and behaviors, specific to online learning, contributed most to their experiences in their respective courses.

In Chapter Three, I described the methodology used for this study. I used a phenomenological research design to investigate the participants' experiences in their respective online STEM courses (Giorgi, 2012; Starks & Trinidad, 2007). All participants were undergraduate STEM majors at Long Lake University, a medium-sized, four-year regional comprehensive university in the Upper Midwestern United States. Participants and I engaged in one-on-one semi-structured interviews lasting approximately one hour each. I developed interview questions to gain understanding of (1) participants' STEM identities (both internally and externally ascribed to them) in and out of the postsecondary classroom environment, (2) their encountered routines relating to their online course(s), (3) opportunities for them to work collaboratively with their peers, and (4) what influences, if any, their experiences in their online course(s) had on their decision to persist in or leave their STEM major. In this study, I followed a six-step framework for collecting and analyzing the data, using methods in accordance with those suggested by Braun & Clarke (2006). That is to say, I familiarized myself with the data, developed initial codes, evaluated codes for themes, reviewed said themes, refined and defined the themes, and eventually wrote up the results (Braun & Clarke, 2006).

In Chapter Four, I described the themes that emerged from my analysis of the data. By taking a macroscale view, I first explored broad, overarching identities and relationships that students described within the context of STEM. To accomplish this, I discussed themes emerging from participant descriptions of what identities they found for themselves by engaging with STEM as well as identities provided to them by external factors such as family members. Subsequently, I broke these themes into "finding" and "seeking" sub-themes, making mesoscale connections between how students' prior experiences with STEM (what they had "found") impacted their expectations of pursuing a STEM degree and how said degree would align with their identities (what they "sought.") Next, bringing the themes to a narrower focus, I discussed their predictions for what a STEM education at LLU would be for them, including the experiences they hoped for and expected; that is, what they were "seeking" from a STEM course. I concluded the chapter with a microscale analysis of participants' reported experiences with their online STEM courses at LLU, again highlighting what their actual "found" experiences were. All told, underlying themes gleaned from the majority of the responses suggest a fundamental disconnect between their perceptions, expectations, and experiences.

In this fifth and final chapter, I will first review the results of my data and re-contextualize them with the literature on social constructivism and several articles relating to the current (recent) state of student experiences with online learning, especially in the context of STEM education. I will then describe implications for future practice at LLU. I will end the chapter by identifying the limitations of the project, using them as a springboard for a discussion of possible future research.

Discussion

Analysis and examination of the data suggests that, for many participants, there was first a fundamental misalignment between their perceptions of what their involvement in STEM signified, their expectations of how online STEM learning would go, and experiences in the courses themselves. Aligning somewhat with existing research relating to best pedagogical practices in STEM and online education, many participants reported feeling comfortable and "at home" in their respective STEM fields prior to taking their online STEM classes but encountered solitary and isolation-inducing experiences in their online classes. Further, where many had previously indicated feeling curious and confident about their field, themes arising from their reported experiences suggested feelings of insecurity surrounding their standing in their classes as well as their understanding of the material. Thus, this study's findings suggest that there was a disconnect between what students' desired and actual experiences were not in the context of STEM itself, but specifically in the context of online delivery of content. Interestingly, while this was especially true of student experiences in asynchronous classes, students who had taken synchronous classes reported many of the same experiences. Still, regardless of delivery mode, main factors owing to these misaligned expectations and realities centered on two key characteristics of their online classes: (1) an unexpected necessity for students to be highly motivated, self-regulated, and disciplined, and (2) deep-seated loneliness stemming from a lack of opportunity to interact with their peers and/or professors during or outside of class time.

Self-Motivation is Key

First, there was an undercurrent of participants' surprise, if not dismay, at the amount of responsibility the students felt they had to bear for their own learning in the courses delivered in

an online format. Almost all respondents who had taken at least one online course provided words “self-taught” and “self-structured” in conjunction with “unprepared.” Participants reported that while there was a nominal structure (their professors set assignments/lectures and collected assignments electronically), there was otherwise little resemblance to a typical F2F course due to their professors’ reliance on students’ self-guided learning. These perceptions align, somewhat, with previous research highlighting the importance of self-motivation to fostering learning and self-efficacy throughout multiple stages of life the world over (Bettinger et al., 2017; Bothma & Monteith, 2004; Cho et al., 2021; Cho et al., 2017; Cho & Shen, 2013; Kuo et al., 2014; Kryshko et al., 2022; Vansteenkiste et al., 2004; Zimmerman & Schunk, 2011). However, there was also an element of surprise; for the unaware or underprepared, the requirements of self-regulation and self-discipline often posed a significant challenge, leading to negative experiences.

Still, two participants, *Zelda* and *Eve* reported that they appreciated how in-depth they themselves went into their course content, albeit also out of necessity. Interestingly, both *Eve* and *Zelda* indicated that their experiences in synchronous classes were nearly identical to those in their asynchronous classes, as both required a large amount of maturity, fortitude, and perseverance to be successful in them, which strongly aligns with previous research. *Zelda* said she enjoyed going on “deep dives down the hole of researching topics because it forced me to learn the material on my own, at my own pace, without having to talk to anyone else about it.” They also acknowledged that their experiences in their online STEM courses could be summed up using the phrase “self-motivated,” as well. *Eve*, in particular, made a connection between her ability to navigate online classes successfully and her prior experience with the online delivery mode, stating that the self-reliance she developed helped her when she got to her program LLU.

In this way, the data suggest that students who had previous experience with online-only instruction may have an advantage over their peers who, it appeared, were not entirely aware of the responsibilities, requirements, or dynamics expected with online delivery modes. These findings, too, align with literature highlighting students' need to be motivated in learning environments to offer the best chances at high levels of self-efficacy, well-being, and satisfaction, ultimately contributing to academic persistence and success (Bandura, 1997; Cordero et al., 2010).

All Alone, Together

The theoretical framework guiding this study was social constructivism; specific to this study, focusing on the influence that social interactions have on building students' knowledge and understanding of course-related concepts. Perhaps one of the most interesting aspects of this study's thematic analysis was the continued realization and confirmation that the vast majority of participants experienced few opportunities to engage in social interactions – breakout rooms, group work sessions, or other collaborative learning activities – with either their peers or their professors during class time. Still, a few students did make a concerted effort to make connections with their peers outside of their respective class times, as in the case of *Asha* and several other students who formed study groups. For them, as *Sam* explained, "Working with others, when I got to do it, helped me to understand the material better. It made me feel more connected to the class, more a part of it."

Thus, while this specific theory did not end up being directly reflected in the participants' *in-class* experiences, such social interactions were apparently important enough for several students to seek out others on their own. This suggests that, while not perfect, there is at least

some alignment between this theory and student learning experiences, at least for some of the participants. Indeed, they appeared to be strongly learning for the connection with others, as *Amanda* put it "on the other end of the screen." Bringing a human aspect to an online course in the form of allowing for peer-to-peer interactions as well as interactions with their professors is highly valuable. "I never felt more connected to a course," *Penny* said, "than when I could see faces. Even tired faces or frustrated faces."

Additionally, while many participants initially reported an overall enthusiasm for building and sharing their knowledge of STEM with others, once in their online course they routinely encountered situations in which their classmates appeared as a series of blank screens. This lack of interpersonal interaction, in turn, often yielded feelings of apathy and disconnectedness. These lamentations of feeling alone due to their inability to interact with other classmates aligns well with recent and current literature. One of the largest contributors to student satisfaction with online learning, research has shown, is students' interactions with peers and instructor (e.g., Bolliger & Martindale, 2004; Juwah, 2006; Kuo et al., 2014), though there is some disagreement as to how much of each type of interaction plays the biggest role in said satisfaction. In this study, it would appear that the lack of interaction with peers and professors weighed equally on the students' views of their experiences. That is to say, respondents referred to the lack of interactions between themselves and their peers as often as they did to their lack of interactions between themselves and their professors. Still, participants' responses suggest they are capable of placing responsibility for their dissatisfaction with the course on their own shoulders, too, these types of recognition and metacognition also align well with research (Puzziferro, 2008; Ross et al., 2006; Song & Hill, 2009).

In summary, participants provided many answers to this study's first research question relating practices in online STEM course delivery leading to positive and negative experiences for students. For the most part, their narratives reflected a period of time in their academic lives where they were undeniably isolated in their courses but certainly not alone in their collective experiences. Still, with respect to the second research question seeking to link experiences with academic persistence, responses indicated that participants' decisions to persist in their academic programs (and STEM) were, at least marginally, unaffected by their experiences in their online course(s). Whether this owed to their desire to maintain their identity in STEM in the short term or satisfy their longer-term goals and desires to, as *Faisal* put it, "Just get through to the end and keep focus on what matters – a job," despite the negative experiences that participants reported, the vast majority did not leave their academic major.

Limitations

This study took place at a medium-sized, four-year public regional comprehensive university, and though its participant pool encompassed several age ranges and included individuals reporting a variety of gender, racial, and ethnic identities, the study's selected sample *was* limited to only undergraduate students pursuing a STEM degree. Additionally, I only asked this study's participants to describe their experiences in online STEM courses; they were purposefully *not* asked to compare them with other classes with a F2F delivery mode, as that lay beyond the scope of this study. The experience of students taking non-STEM classes, with or without an online delivery mode, may very well be vastly different from those identified in the study. So, too, would likely be the experiences of professors teaching F2F versions of the courses or professors teaching non-STEM courses online.

As previously mentioned, in my semi-structured interviews, I did not ask questions that expressly or explicitly asked for students' experiences in the context of specific identities such as gender identity or racial/ethnic identity. I fully acknowledge that their experiences *may* have been influenced by such identities, but none of the participants explicitly stated this was the case. In my

The COVID-19 global pandemic presented a unique catalyst and challenge itself. Halfway through the Spring 2020 semester, all courses at LLU were directed to go online by state-, system-, and institution-level administrators, and many departments required that their course offerings remain online-only for multiple semesters after. Though the experiences students had in their courses during the Spring 2020 semester were purposely omitted from consideration for this study, it cannot be ignored or denied that the experiences students had in their Spring 2020 courses possibly had an influence on their memories of their experiences in subsequent classes, even if unintentionally or subconsciously. Additionally, it must be acknowledged that many faculty members were required to learn to teach in a delivery mode that may have been new or strange to them. It would appear, as *Bruce* said, "The professor was trying, we were trying, but it…we just didn't have a great time in class. It's hard to when everyone is just in survival mode in class, y'know?" Therefore, the student experiences, as shared with me by study participants, must not be interpreted as a catch-all representation of the professors' overall teaching styles.

The participant pool derived from responses to a solicitation email sent out two times through the list-servs of several offices within the School of Computing, Engineering, and Science (SCES). While all were eager to share their information and insights with me, it might

be possible that some would-be participants did not receive either email, and thus missed the opportunity to join the pool. Additionally, while participation in the study was completely voluntary, participants were given an incentive in the form of a $10 gift card if they agreed to have me use their interview in this study and there was a fiscal limit as to how many incentives could be provided. Similarly, there was a temporal limit, as well, since the hour-long interviews and subsequent transcription and thematic analysis thereof were time-consuming. While the use of an incentive is not a limitation itself, the financial and temporal restrictions on the study's data collection and analysis phases did prevent additional students' admittance into the study.

Finally, I also note that while the phenomenological "essence" for many of this study's 23 participants, specifically, was primarily one of a solitary, self-guided learning experience, I would be hard-pressed to argue that this is transferable to every other student taking online STEM courses at LLU. Still, I acknowledge that my own biases regarding this; prior to beginning this study, I viewed online learning and instruction as a challenge rife with isolation and frustration for both student and faculty alike. While I did my best to bracket these impressions, as stated earlier, this study does confirm that students are not monolithic learners. It is possible, if not likely, that additional themes would emerge if I increased the sample size. For example, it would stand to reason that students who had more prior experience with online learning would potentially have different expectations of what their online STEM class(es) might have been and their reported experiences may have different, as well.

Still, despite these limitations, this study's participants did provide responses that can be used as a springboard for reflection on behaviors faculty and students at institutions of higher education approach online STEM courses. Thus, the following section describes some

implications for practice in the context of participants' suggestions for students as well as faculty of these online courses.

Implications for Practice at Institutions Offering Online STEM Classes

It should be noted that while no participant in this study explicitly recalled instances where they felt slighted due to one or more identity(ies) of race, ethnicity, class, ability status, or gender, many still reported feeling unsupported in their respective courses. In contrast, they reported their courses' structures as a source of their feelings of being forgotten, overlooked, or otherwise apart from the course. Still, participant responses provide insights for what professor and student actions may inform course practices and, in turn, make for more positive learning experiences. In *Ready Player One*, the protagonists are hunting for clues, or keys, to unlock hidden treasures throughout the online world (Cline, 2011). Thus, in this section, I will be presenting the thematic suggestions that participants provided as keys to successful online course delivery. In this section, these suggested best practices are broken down into two main categories of suggested action items: "Key Actions for Students" and "Key Actions for Professors."

Key Actions for Students

Participants' most repeated pieces of advice for students yet to take the same online STEM class at LLU related to professor reputation originating from both word-of-mouth and publicly sourced databases that compile opinions and ratings of professors and courses. As *Zeus* said, "I absolutely recommend that someone taking this class check out who's teaching, then look them up on 'Rate My Professor.' If someone awful is teaching it, you want to stay really far away and hope someone else teaches next time." *Marie* agreed, saying "Students talk to other

students, y'know? We know who to take and who to avoid. So, I would recommend talking to someone who's taken the class with the professor before and see what they say."

If given the chance to choose between online asynchronous and online synchronous, the majority of participants also recommended signing up for a synchronous course to maximize the likelihood of being able to interact with other classmates. Interestingly, many of these participants indicated that they themselves only had limited interactions during their online synchronous classes, but, as *Janice* explained, "Even if I didn't always get to see people in *my* class, I would think that you'd have a better chance of seeing someone else if you had to be in the class at the same time."

In this way, these suggestions highlight the importance of students acknowledging the experiences of their peers. This is consistent with prior findings that students feel more autonomy over and connection with their learning when they feel their voices are heard and they can share their insights with others (Fong et al., 2019; Simon et al., 2015; Van Soom & Donche, 2014). This is also consistent with findings that it is in the best interest of institutions to foster environments where student feedback is, among other things, collected, analyzed, and routinely used as a way to factor into course improvement as well as faculty professional development and training (Bull Schaefer & Copeland, 2022; Kumar et al., 2019)

Key Actions for Professors

By far, the most repeated suggestion that participants had when it came to suggestions for how professors can improve upon their online delivery was to be timelier in their responses to students. As before, this suggestion was true regardless of whether participants had taken their course synchronously or asynchronously. This aligns identically with prior research suggesting

timely responses and feedback are key to fostering learning in an online setting (Baker, 2010; Eskey & Schulte, 2010; Grant & Thornton, 2007; Liu et al., 2005; Picciano, 2017). In addition to allowing students to clarify misconceptions with course content, participants indicated that hearing from their professors on a more regular basis made them feel more a part of the class than a nameless, faceless person out in the ether. A not-so-fringe benefit of increased contact, also, is the fact that research suggests that students who receive feedback on their assignments typically exhibit higher academic performance than those who do not (Cuthrell & Lyon, 2007; Espasa & Meneses, 2010; Martin et al., 2020).

Additionally, students recommended that professors seek out feedback from their students while the course is in progress, to assess course reception. *Mei* offered her insight regarding professor practices involving feedback forms, explaining:

> In two of my classes, the professor asked us to fill out a form at the end of the class. It was an online class, so we just filled it out online, but it felt good to be able to get my thoughts down. I don't know if the professor read it, but I hope [they] did. I hope [they] learned from it and they take it to heart and it's better for the next student. But it would be great if they asked us before the end of the semester, too.

Still other responses suggest that the demeanor of the professor can go a long way to influence the tone of the course as well as increase the likelihood of a positive learning experience for the students. As *Amanda* shared, there is much value to professors remembering that they are people, as are the students taking the course. "Please remember that you are not just a voice or a hand on the screen," she explains. "Like, maybe we don't want to be in this situation, but still be human about it." Bringing in a human aspect to the course and maintaining a tone of respect was

important to *Sam* as well, who advised professors to "treat your students with respect and value their time as though it's yours. Treat your students like adults, y'know, and be approachable."

Finally, *Eve* provided a suggestion that highlighted the importance of professors as life-long learners themselves:

> I think my number one suggestion would be for professors who are going to be teaching online to learn how to teach online. I think, for a lot of them, they just think, 'Oh, online is online, and it doesn't matter if it's synch or asynch.' But they're very different. And it's not just putting up slide sets and letting students have at it, you know? You wouldn't do that in a face-to-face class, don't do it for online. Make us *want* to learn from you. And if you don't know how, then you should shadow someone who does. It would be great if this school would pair up the good online teachers with the opposite. Learn from each other. Online [education]'s not going away any time soon.

It is undeniable that the COVID-19 pandemic caught many students and faculty at institutions of higher education by surprise, resulting in many faculty scrambling to adjust their courses to online-only delivery (Brennan, 2021; De & Arguello, 2021; Prince et al., 2020). Still, it should come as no surprise that many of the best practices recommended for decades by STEM Education-focused research would still be applicable to STEM courses delivered online even after the COVID-19 pandemic is no longer directly influencing course delivery mode. This study's participants' learning experiences were inextricably tied to feelings surrounding competency, confidence, and senses of belonging and purpose in their respective courses, just as has been discussed in research carried out in F2F environments for decades (Baker, 2010; Braun et al., 2018; Genet, 2021; Lee & Oh, 2017; Seymour & Hewitt, 1997).

Additionally, while online delivery modes present a unique set of challenges and opportunities for improvement on current practices at LLU, students' desires for increased instructor presence, more avenues for interactions with peers, and providing timely feedback echo the recommendations of researchers spanning all STEM fields. Therefore, it would behoove faculty to become familiar with techniques for online instruction that are effective and pedagogically sound. After all, as *Eve* said, "Online learning isn't going anywhere. Professors might not like it, but it's here to stay."

Finally, the data also suggest that there is a genuine desire among many students to make connections with their peers, regardless of online delivery mode. Obviously, responses from *Amanda*, *Marie*, and others who indicated feeling more confidence in course material *when being able to work with peers* align most directly with the literal theory of social constructivism. However, the responses from others who indicated they felt alone and disengaged when having to stare at blank screens also suggest that learning was harder from them when they were kept separate from their learning peers by way of class organization. Therefore, a strong implication for *both* student and professor action would be for students to avail themselves of opportunities to meaningfully interact with their peers, and for professors to provide such opportunities.

At the institutional level, the implications of findings such as those stemming from this study are two-fold. First, these findings serve as a bellwether, if not outright warning, to LLU, which is currently seeking to expand their online course offerings in STEM. Students who are not satisfied with their experiences may not leave their majors, but there is strong evidence suggesting that they are actively dissuading others from pursuing degrees at that institution. Second, regardless of whether students persist in their major or not, there is also evidence that

many students' expectations of online learning are not currently dovetailing with their real, lived experiences in their courses. Thus, administrators at this particular institution of higher education should be encouraged to think about short-term vs long-term goals and sustainability when it comes to student enrollment and persistence in online courses and academic programs. It is not enough to bring students in through the (virtual) door; students must be welcomed, heard, and, valued as more than seats (or pixels) in a class.

Though it lies beyond the scope of this specific study, these implications suggest that, to promote positive experiences for students, administrators in higher education must first be willing to invest time and resources into effective professional development opportunities for their faculty, who can then model pedagogically sound behavior for their students. In turn, this would ideally promote not only a professor-as-learning-partner relationship, but could also potentially better inform students of expectations and requirements of online learning. Thus, beneficial professional development opportunities should not just focus on new technology (and the use thereof), but also online curriculum/content development, effective and engaging online pedagogy, and purposeful building of communities of learners (Elliot et al., 2015; Santelli et al., 2020; Schmidt et al., 2015; Smith, 2005). Second, it would behoove administrations of such institutions to re-forge connections students have with their classes by getting rid of the conditions leading to unidirectional feedback, such as an end-of-term survey that goes unread or emails that go unanswered throughout the semester (Bols & Wicklow, 2013; McCarthy, 2017; Winstone & Carliss, 2020). Instead, administrations should actively develop tangible, accessible, and meaningful ways of soliciting feedback *from* students while simultaneously highlighting the importance of providing feedback *to* students. Finally, promoting the importance of collaborative

learning and peer interactions in online learning environments would go a long way to not only improve engagement levels but also reduce the feelings of isolation that so many of the participants in this study reported (deJong, 2019; Eberle & Hobrecht, 2021; Misseyanni et al., 2019; Hofer et al., 2021.). While, realistically, there is clearly no one panacea to address or assuage negative experiences that students may have in their online STEM courses, at the very least, not heeding these best practices could potentially exacerbate any negative word-of-mouth that students at LLU are already sharing with friends, family members and others.

Future Research

The results of this study leave open multiple avenues for further examination. First, it would be beneficial to interview faculty members for their perspectives on their online course delivery. It could be interesting to compare and contrast their responses with the responses of their participants, as each would obviously bring a fresh perspective. (Though, to be fair, informal conversations with my colleagues who have been teaching online courses suggest they, too, encounter many of the same challenges their students do, so perhaps there would be more similarities than differences.)

It would also be worthwhile to investigate the perspectives of students within their F2F STEM courses at LLU or a similar campus, and what actions lead to positive and negative learning experiences for them. Though some might argue that this would be comparing to unequal entities, I would argue that many of the experiences students reported from their online courses align well with the literature written about F2F courses, too. Thus, by exploring the levels of confidence with material in in-person F2F courses – as well as what actions contribute

to these confidence levels – would be beneficial to professors to place focus on how their students view how they are / are not being served, regardless of delivery mode.

A longitudinal study of student experiences in online STEM courses taken early on versus later in their time as undergraduates would also be interesting, as this study's data suggests that students who have more experience with online instruction tend to navigate the courses more easily. This is not to say that their comfort levels are all necessarily more positive than others' (clearly, this study's data suggests that is not always the case), but it could be informative to explore lower-level, major-required STEM courses delivered online as compared to upper-division STEM courses delivered the same way.

It would also be interesting to cast a wider net and perhaps conduct a quantitative survey of undergraduates who are majors outside of the SCES at LLU. It could be beneficial to obtain more information about non-STEM online courses and assess responses for similarities and differences therein as well. Due to the number of student enrolled at LLU, employing a quantitative research method would likely yield a much larger participant pool from which to retrieve and analyze data.

Finally, it could be very interesting to widen the participant pool, intentionally, to students who chose to leave their major as a result of their experiences in their online courses. As it so happened, this study had two participants who chose to leave their majors, while the vast majority of them remained. This may imply that the online learning environment has little impact on students' persistence in their academic major, one way or another. On the other hand, it may just imply that the luck-of-the-draw nature of my study's solicitation process needs finessing.

Concluding Thoughts

This phenomenological qualitative study investigated the experiences that undergraduate STEM majors at a RCU in the Upper Midwest had in their online major-required courses. Many participants described experiences of loneliness and frustration, brought about from a lack of interaction between themselves, their peers, and their instructors. Still, few participants reported feeling liberated by the fact that they had limited interactions with others. Participant responses highlighted key themes in online postsecondary education, including (1) the variability of STEM-related identities, (2) the effects that interactions (or lack thereof) have on learning, and (3) behaviors that contribute to both positive and negative online learning experiences.

It is highly improbable that there will ever be a single anecdote that encapsulates a pure essence of online learning. “Ready Pupil One” may have hinted toward a catch-all experience for this study’s participants, but even within the participant pool there were varying degrees of differences. This was, of course, to be expected; as mentioned, learners are not monoliths, and neither are professors. They come to a classroom (virtual or otherwise) with many internal and external factors affecting their roles, identities, and functions. However, further research allowing for additional exploration of more characteristics, conditions, perceptions, and insights would undoubtedly go a long way to provide more insight into the questions surrounding what the online learning – and teaching – experience is. This would go a long way to explore whether postsecondary institutions can provide a virtual educational oasis that keeps its characters – and future generations of characters - interested in engaging in “extended play” modes.

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Appendix A: Recruitment Email

Ready Pupil One: Online Learning Experiences of Undergraduate STEM Majors Recruitment Email

Hello -

You are receiving this e-mail because I am currently seeking volunteers for a research project I am conducting here at Long Lake University. This project will involve face-to-face, one-on-one interviews (either in person or via Zoom) with undergraduate STEM majors who are currently taking or who have already taken STEM-related, program-required *online only* courses at this institution during the following semesters:

Fall 2016 through Spring 2021 (including summers)
Please note: At this time, this study will not include courses delivered during the Spring 2020 semester.

If you are aged 18 or older *and* are interested in sharing your story with me, please complete the following survey (<Survey Link redacted>) by 30 September 2021 to determine your eligibility to participate in this study. Eligibility is met if you are aged 18 or older, are a STEM major, and have taken or are currently taking STEM-related, program-required, online only courses at this institution between Fall 2016 and Spring 2021 (excluding Spring 2020.)

If you are eligible to participate in this study, I will then contact you so you and I can make a time to set up an interview session that is convenient for you.

During the interview, I will ask you questions in order to learn more about what it's like for students to take online STEM courses here. As a "Thank You," if, after our interview has concluded, you agree to have your responses used as part of the study, you will automatically receive a $10 digital gift card to Amazon.com.

Thank you for your time and consideration,
Rachel

Appendix B: Demographic Survey Questions

Ready Pupil One: Online Learning Experiences of Undergraduate STEM Majors

What is your age?
18 – 24 years
25 – 34 years
35 – 44 years
45 – 54 years
55 years or older
Prefer not to answer

What is your gender identity? Please select all which apply to you:
Man
Woman
Non-binary / Agender
Transgender
Prefer to self-describe
Prefer not to answer

What is your self-identified race/ethnicity? Please select all which apply to you:
African American/Black
East Asian
Hispanic or Latino/a
Indigenous/American Indian or Alaskan Native
Multiracial
Native Hawai'ian or other Pacific Islander
South Asian
White
Prefer to self-describe
Prefer not to answer

What is your academic major? Please write in the space provided below:

What is your academic standing?
Freshman
Sophomore
Junior
Senior
Other (please specify)
Prefer not to answer

Have you taken an online course required for your major through this institution between Fall 2016 and Fall 2019 and/or during the Fall 2020 semester? Please select either "Yes" or "No."

Was this course delivered completely online? Please indicate "Yes" or No" in the space provided below.

How many STEM-related, program-required courses have you taken online through this institution? (A program-required course is a core course that is required for your major.)
One
Two or more

For this study, you will be allowed to use a pseudonym (a substitute name.) Please indicate your preferred pseudonym below.

Appendix C: Informed Consent Form

Ready Pupil One: Online Learning Experiences of Undergraduate STEM Majors Consent to Participate

You are invited to participate in a research study about the experiences of undergraduate students majoring in STEM programs at Long Lake University.

As part of the research study, you consent to participating first in an online survey, used to collect demographic information as well as determine your eligibility. Eligibility will be determined solely by whether you are 18 years of age and whether you are a STEM major who has taken an online STEM class required for your major through this institution between Fall 2016 and Spring 2021, excluding Spring 2020. No other demographic information will be considered when assessing eligibility for participation in the study interview. If you are eligible for a study interview, I will contact you so we can arrange a time for you to answer questions relating to your experiences as an undergraduate STEM major who has taken at least one program-specific course through online delivery.

Benefits of the research: Through your answers, you will be sharing your experiences, allowing me to learn more about the experiences of undergraduate online learners in STEM programs at Long Lake University. *Additionally, if, after our interview has concluded, you agree to have your responses used as part of the study, you will automatically receive a $10 digital gift card to Amazon.com.*

Risks and discomforts: Though I anticipate no risks of physical harm resulting from your participation in this study, you may feel discomfort or uneasiness discussing course-specific practices with me, especially if it relates to practices undertaken by another faculty member. While I will do my best to ensure that you do not feel such discomfort, as a participant, you can choose to end the interview at any time.

All collected responses will remain strictly confidential. Your name will not be disclosed, nor will identifiable direct quotes be used. During the interview, you may refuse to answer any questions. After the completion of your interview, you will be given the opportunity to receive your transcribed interview. At this point, if you wish to expand your responses or request omissions, you may.

Participating in this study is completely voluntary. Your decision whether or not to participate will not affect your current or future relations with Long Lake University, or the researcher. If you decide to participate, you are free to withdraw at any time without penalty.

If you have questions about this research study, you may contact Rachel Humphrey at rhumphrey@[redacted.edu] or [phone number redacted]. Results of the study can be requested from the researcher. You may also contact my research advisor, Dr. Rachel Friedensen, at refriedensen@[redacted.edu] for additional questions about the research study.

Your signature indicates that you are at least 18 years of age, you have read the information provided above, and you have consented to participate.

_____ _____

Signature Date

Appendix D: Interview Guide

1. Please tell me a little bit about yourself – how long have you been at this university, what your major is; anything else you would like to share with me about how you define/view yourself.

2. What got you interested in pursuing a degree in STEM?

3. What made/got you interested in pursuing a degree at this university?

4. Prior to coming to college, did you have any experience with online classes?

5. When you were considering coming here, were you expecting to take online classes (was that part of the draw here), or did circumstances change in such a way that you're "going with the flow?"

6. How many online courses have you completed here? What were they?

7. Please tell me a little bit about what your online STEM class(es)-related experiences have been / are like. (General experience; are they synchronous, asynchronous, lecture or lab-based, etc.) *If participant has completed more than one online STEM course at the university, encourage them to compare/contrast.*

8a. What are the first three words that come to mind when you think back to your online course(s)?

8b. Please explain why you chose each word.

9. Please tell me what a typical/normal online class experience is like for you on a given day or in a given week.

10. Can you tell me, specifically, what some positive aspects of your online STEM class(es) are? For example, is there something that you do, or your peers do, or your instructor does that you feel really positively about as a student? *If participant has completed more than one online STEM course at the university, encourage them to compare/contrast.*

11. Can you tell me, specifically, what some of the more challenging aspects of your online course(s) are? For example, is there something that you do, or your peers do, or your instructor does that you feel really is challenging for you as a student? *If participant has completed more than one online STEM course at the university, encourage them to compare/contrast.*

12. If you had any suggestions for students who were about to begin taking online STEM course(s) – the one(s) you took – what would they be?

13. If you had suggestions for instructors who were about to begin teaching online STEM courses – the one(s) you took – what would they be?

14. Before we conclude this interview, is there anything else you would like to share with me?

15. Do you have any questions for me?

Appendix E: IRB Approval

ST. CLOUD STATE UNIVERSITY
EDUCATION FOR LIFE

Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

Name: Rachel Humphrey

Email: rhumphrey@stcloudstate.edu

IRB PROTOCOL DETERMINATION: Exempt Review

Project Title Ready Pupil One: Online Learning Experiences of Undergraduate STEM Majors at a Midwest Regional Comprehensive University

Advisor Rachel Friedensen

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Please note the following important information concerning IRB projects:

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

-Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

IRB Chair:

Dr. Mill Mathew
Chair and Graduate Director
Assistant Professor
Communication Sciences and Disorders

IRB Institutional Official:

María-Claudia Tomany

Dr. Claudia Tomany
Associate Provost for Research
Dean of Graduate Studies

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SCSU IRB#: 2040 - 2651	**Type:** Exempt Review	**Today's Date:** 7/20/2021
1st Year Approval Date: 7/20/2021	**2nd Year Approval Date:**	**3rd Year Approval Date:**
1st Year Expiration Date:	**2nd Year Expiration Date:**	**3rd Year Expiration Date:**