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Technology in the Classroom: The Affordances of Web 2.0 Applications to Enhance Social Connections in STEM Courses

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Education

by

Michael Leo

Dissertation Committee:
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DEDICATION

I would like to dedicate this dissertation to my loving parents whose encouragement and support constantly uplifted me. Thank you Mom and Dad for always being there for me. I would also like to thank my amazing advisor Penelope Collins for her profound guidance throughout my entire graduate journey. Your invaluable patience and mentorship has led me to this point.

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ABSTRACT OF THE DISSERTATION

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STEM skills such as scientific literacy are essential to being a good citizen who is well informed in the modern informational, technological era. However, most students show little growth in their scientific knowledge throughout their college education. This dissertation aims to examine how STEM education can be improved by applying motivation theory, with an emphasis on the social component, and web 2.0 technologies. Through three studies, different technology applications are implemented across different modes of instruction from face-to-face to online to examine the efficacy of these tools for enhancing student engagement and motivation. Study one integrated Google Documents with collaborative problem based learning in an university science course. Students writing and collaboration techniques were examined with computational linguistic and discourse software and results revealed that the equality of contributions between students were linked to greater science vocabulary use and analytical thinking. Study two applied a voluntary social media application, Facebook Messenger, to a general education science course with weekly text prompts from the instructor. Students reported enjoyment of this supplemental

communications tool and engaged with it extensively. Student's type of engagement, social interactions, within the application was predictive of course achievement. Finally, the third study utilized Google Hangouts as a voluntary resource for students in an online science course. Students demonstrated lower engagement with this application and reported using other social media tools. Both students' sense of belongingness and their use of an additional social media application were predictive of self-efficacy in the course, which served as a mediator for course achievement. The affordances and implications of the addition of these different web 2.0 applications and how they can best be leveraged in the STEM classroom are discussed further in this dissertation.

CHAPTER 1

Introduction

Science, technology, engineering, and mathematics (STEM) occupations are projected to grow 9% annually through 2024 (Noonan, 2017). STEM knowledge is increasingly essential for students in the information age, as STEM degree holders earn a 12% premium compared to non-STEM degree holders (Noonan, 2017). Furthermore, studies have shown that STEM graduates have a distinct advantage in securing full-time employment (Y. Xu, 2015; Y. J. Xu, 2013). In addition to employment benefits, STEM skills such as scientific literacy are essential to being a good citizen who is well informed in the modern informational, technological era (Rodríguez Espinosa, 2005). Scientific literacy skills are necessary to critically analyze and understand science content found in the media and everyday life (Miller, 2010). However, most adults learn the majority of their scientific knowledge after they complete their formal schooling (Miller, 2010). This is concerning since general education science courses focused on scientific literacy have been shown to be an effective educational source for students (Hobson, 2008). Thus, there should be a greater focus on enhancing science knowledge through general education STEM courses.

Despite the importance of scientific knowledge, students lack the necessary proficiency in this area both in the K-12 school system and at the post-secondary level. According to the NAEP, over 60% of fourth and eighth-grade students scored below proficient in science, which increased to over 70% of twelfth-grade students. The NAEP results revealed that science scores for fourth and eighth-graders have marginally increased from 2009 to 2015, while there were no improvements for twelfth-grade students.

This trend of poor science performance continues beyond K-12 at the university level as well. First-year college students tend to enter college with a limited understanding of science's nature, showing high levels of belief in pseudoscience (Impey, Buxner, Antonellis,

Johnson & King, 2011). Approximately 18% of students graduate with a STEM degree and non-STEM majors only exposure to science is through the few general education classes they are required to take (NCES, 2019). Thus, the majority of undergraduates show little growth in crucial areas, including critical thinking skills and scientific literacy during their academic journey (Arum & Roksa, 2011; Impey, 2013).

For most undergraduate students, who are not STEM majors, the limited growth in scientific literacy is coupled with negative attitudes and beliefs regarding the value of science (Lytle & Shin, 2020; Uzpen, Houseal, Slater, & Nuhfer, 2019). These negative values are important to address as they can impact student motivation. According to the expectancy-value theory, how much students value learning a topic is a significant predictor of whether they will study it and perform in that subject area (Wigfield & Eccles, 2000). Thus, students with negative attitudes about STEM are less likely to apply scientific knowledge and reasoning in their day-to-day lives. Similarly, the expectancy-value theory posits that factors such as social connectedness can impact student motivation (M. Te Wang & Eccles, 2012). That is, students who develop rapport and social ties with their instructors and peers are more likely to be motivated to engage with coursework. Web 2.0 tools such as social media and Google docs have shown promise in improving students' social connectedness (Ractham, Kaewkitipong, & Firpo, 2012; D. Wang, Olson, Zhang, Nguyen, & Olson, 2015b).

STEM learning is essential for both career prospects as well as being a well-prepared citizen. Given the importance of scientific knowledge and the lack of student proficiency in the area, it is critical to address approaches to enhance student learning for STEM majors and non-STEM majors taking general education courses. Given the importance of STEM, this dissertation aims to examine how STEM education can be improved by applying motivation theory and the use of technology.

Motivation in STEM

There is a large body of research on instructional interventions focused on the cognition and learning science approach. However, student engagement is a critical component to consider as well in their development. Student engagement has been shown to be influenced by motivational factors (Murphy, MacDonald, Wang, & Danaia, 2019). The main motivational theory this dissertation will focus on is the Eccles expectancy-value theory, which comprises three components: psychological, biological, and socialization (Wigfield & Eccles, 2000). The psychological component encompasses competency beliefs, goals, interests, and values regarding the task. The biological component covers genetic and hormonal influences on the psychological components. The socialization component includes social, cultural, and contextual influences on self-beliefs and values. This dissertation will focus on the psychological and social components within the theory. Competency beliefs will be operationalized through self-efficacy and value measures while the social influences components will be measured through collaboration and sense of belongingness.

Extant research has shown that motivational beliefs as measured by value and self-efficacy predicted STEM achievement which in turn predicted future STEM and college outcomes (Fong & Kremer, 2020). Furthermore, these motivational measures were also predictive of STEM persistence (Andersen & Ward, 2014). Social connections are important for increasing students' motivational beliefs and engagement as well (Master, Cheryan, & Meltzoff, 2017). A person's sense of belonging within a group or field can create socially shared goals around a task and lead to higher achievement motivation (Walton, Cohen, Cwir, & Spencer, 2012).

Social Connections

Considering the importance of motivation to STEM engagement among students and the role that social components play in motivation, this study focused on fostering social connections among students. Social connections between peers and faculty in STEM are vital, considering that in a retrospective study, students reported the leading cause for STEM attrition was a sense of social isolation and loneliness (Heilbronner, 2011). Furthermore, students reported feelings of hostility and an unwelcoming environment in the STEM fields (Correll, Seymour, & Hewitt, 1997). These negative feelings have consequences. Research has found links between the strength of student connections with their instructor and their academic outcomes and their sense of self-efficacy within the course (Micari & Pazos, 2012). Thus, placing a greater focus on developing nurturing and positive relationships between faculty and students is important to enhancing STEM retention and learning outcomes for students (Christe, 2013).

The importance of social connectedness includes factors such as a sense of belongingness, which were important for persistence in STEM among first-generation students (Dika & D'Amico, 2016). More specifically, students' sense of belongingness within their STEM classes was strongly associated with positive emotional engagement in STEM courses. Furthermore, a sense of belongingness was found to work in conjunction with self-efficacy to contribute to engagement in STEM (D. Wilson et al., 2015). This is supported by other research highlighting the importance of social relationships in the classroom that contribute to higher self-efficacy in STEM (Starobin, Smith, & Santos Laanan, 2016). This sense of belongingness is particularly important for retaining women in STEM (Hilts, Part, & Bernacki, 2018). Contact with classmates also impacted self-efficacy and further supports the importance of socialization within the STEM classroom. Social activities such as mentorship, student organization participation, and peer support have been linked to higher perseverance rates in STEM for underrepresented minorities (Lancaster & Xu, 2017). Interventions

focused on enhancing social relationships in courses have been shown to be effective at improving STEM persistence (Turetsky, Purdie-Greenaway, Cook, Curley, & Cohen, 2020). Thus, the literature supports that students' social connections and sense of belongingness promote STEM achievement and persistence.

Much of the research has focused on increasing student connectedness in face-to-face contexts (Christe, 2013; Correll et al., 1997; Heilbronner, 2011; Micari & Pazos, 2012). However, with the rise of online courses, it is more important than ever to examine effective approaches to increasing social connectedness since the lack of interaction further alienates students (Jaggars & Xu, 2016). This is evident because students who attend online courses are more likely to drop out, citing social isolation as a primary factor (Ali & T Smith, 2015). Studies have also found that merely living off-campus can increase social isolation and decrease students' social connectedness (Irani, 2014). Considering that most distance learners are off-campus, they are likely to have a lower social connectedness. This sense of social isolation may be overcome through various approaches, such as increasing the frequency of online discussion forums (Breitenbach, 2019). Although students cannot rely on non-verbal cues to socialize online, they still rely on their socialization processes by attempting to be personable by revealing personal details even without direction (Lebie, Rhoades, & Mcgrath, 1995; Richardson & Swan, 2003). Furthermore, when instructors encourage social connections with pedagogical approaches such as group work, students can form social groups and assign roles effectively, increasing their social connectedness (Heinze & Procter, 2006). Thus, enhancing students' social connectedness is important. A powerful tool for connecting students online is through various Web 2.0 technologies, including collaborative and social media applications.

Utilizing Technology To Increase Social Connections

Undergraduate students utilize various technological tools that differ based on the audience they are contacting (Palmer & Boniek, 2014). Technological tools can be leveraged to create a sense of community within the academic realm as well. Web 2.0 tools such as Google docs, Twitter, blogs, and wikis have been utilized to generate more social connections within a classroom (Abdelmalak, 2015). The adoption of social media within academia as a supplemental communication and learning resource has been growing (C. D. Wilson, 2013). Integrating social media into the classroom has been shown to enhance student motivation and support greater problem-solving amongst students (Mondahl & Razmerita, 2014; Yunus, Salehi, & Chenzi, 2012). Social media applications such as Facebook have enhanced the undergraduate experience by increasing their sense of belongingness (McGuckin & Mareesealey, 2013). Additionally, interventions have been developed to utilize social applications such as Twitter to create an online community in class to develop a greater sense of belongingness among students (Friess & Lam, 2018). Furthermore, Twitter use in a medical school neuroanatomy course boosted student morale and provided a support network for students (Hennessy, Kirkpatrick, Smith, & Border, 2016). The benefits of academic Facebook use among students, such as increased interaction and communication with students, improved social relationships, and increased participation, lead to higher student motivation (Lam, 2012). In addition to enhancing students' motivation and social connections, social media tools can effectively improve academic outcomes when integrated into the classroom (Guo, Shen, & Li, 2018).

Another approach to enhancing social connections involves collaborative activities. Collaboration through Google Docs as an online database has been documented to promote a complex variety of dimensions of social interactions that range from externalization, rapid consensus, integrative consensus, initiative, and consensus through conflict. Furthermore,

Google docs helps facilitate more peer-to-peer and peer-to-instructor interactions and leads to enhanced collaboration (Ishtaiwa & Aburezeq, 2015). Additionally, integrating technology such as Google docs is helpful for knowledge co-construction and leads to greater motivation, enjoyment of learning, and learning outcomes (Liu & Lan, 2016). Google docs carries other affordances as well, that include increasing students' writing quality, enabling students to collect their thoughts when working with peers, working directly with peers, or working independently on a section while others worked together (Blau & Caspi, 2009; Jung, Lim, & Kim, 2017). There is a variety of ways to leverage Web 2.0 technologies to enhance social connections and student learning. This dissertation aims to enhance the existing knowledge base around STEM education by examining the utility of technology-based tools for enhancing social connections.

Dissertation Goals

This dissertation will examine the integration of Web 2.0 technologies to enhance student motivation by increasing social connectedness. Because a sense of social isolation was a significant factor leading to STEM attrition (Heilbronner, 2011), a greater emphasis on social connections was placed in all three studies.

Study 1. The first study, *Science Writing in Groups: A Quantitative Study of Student Collaboration and Learning*, examined the features of science writing by undergraduate upper-division students who are science majors working in a collaborative environment using Google Docs. The study occurred in a face-to-face course and utilized problem-based learning in conjunction with Google Docs as a collaborative technological element. Students were assigned into groups and given six problem based essay assignments based on various diseases taught throughout the quarter. Each group worked collaboratively on their essays through Google docs. Three computational tools were used to analyze each writing sample, the Linguistic Inquiry and Word Count (LIWC2015; Pennebaker, Boyd, Jordan, &

Blackburn, 2015), Coh-Metrix 3.0 (Graesser, McNamara, & Kulikowich, 2011; McNamara, Graesser, McCarthy, & Cai, 2014) and Docuviz (D. Wang, Olson, Zhang, Nguyen, & Olson, 2015a). Measures of writing volume, writing quality, and collaboration were derived. The following measures were derived using the Linguistic Inquiry and Word Count (LIWC2015; Pennebaker, Boyd, Jordan, & Blackburn, 2015) and Coh-Metrix 3.0 software. Our research questions and findings were as follows:

1. What are the most common strategies of collaboration used among undergraduate biology students in their writing? Students employed a parallel construction approach and divided the work amongst members to form a finalized product.
2. How do students' writing change as they progress through the academic term? Students' use of science vocabulary content and complex grammatical structures grew over the course of the term, while their writing volume and use of formal language did not.
3. Are strategies of collaboration predictive of writing content (science vocabulary, word concreteness, analytical thinking, etc.)? The equality of contributions among group members predicted their use of science vocabulary and analytical thinking in their essays.

This study demonstrated that increasing social connectedness through improving collaboration could lead to enhanced scientific literacy. In addition to Google docs, supplementary social media communications tools were studied because they offered a means of providing students a forum to socially engage with each other and the instructor (Dougherty & Andercheck, 2014; Isaacson, 2013).

Study 2. The second study, *Facebook Messenger: An Environment for Enhancing Student Socialization and Interaction within a University STEM Course,* examined an undergraduate general education science course utilizing Facebook Messenger as a

supplemental communications resource. This study occurred in a blended learning environment and revealed the utility of social media applications to fostering an online social community. Students voluntarily joined a Facebook Messenger group that the instructor created for the course. The instructor sent three content related texts out of class time per week starting the second week of class until the final week. Students were free to interact with each other as well as pose questions to the instructor. All other aspects occurred with a business as usual format.

Our research questions and findings were as follows:

1. What are the students' experiences regarding the intervention (i.e., did they find it useful, enjoyable, change their views)? We found that students generally enjoyed using Facebook Messenger, felt a greater sense of belonging from using the app, and felt increased motivation for the course.
2. For those who engaged with Facebook Messenger, did it affect their achievement? Enrollment in the intervention or frequency of posting did not alter student achievement in the course.
3. How does the type of interaction within Facebook Messenger influence outcomes (grades) and student experiences? Student interactions were analyzed and results revealed that the frequency of social posts on Facebook messenger were predictive of course achievement. Other types of posts discussing deadlines, logistics, and even course content did not predict outcomes. This study emphasized the association between socialization and achievement.

Study 3. *Integrating Google Hangouts in an Online Science Course*, the third study sought to measure student motivation, engagement, and social connections directly. It examined an undergraduate general education science course utilizing Google Hangouts as a supplemental communications resource. It explored the effects of utilizing Google Hangouts

on student achievement, self-efficacy, sense of belonging, and value of STEM. This study was conducted during the emergency transition to online-only instruction during Covid-19. Similar to the Facebook messenger study, students voluntarily joined a Google Hangouts group that the instructor created for the course. The instructor sent students a total of three course content related messages per week for 9 weeks in the course to stimulate discussions. Students were free to interact with each other as well as pose questions to the instructor. All other aspects occurred with a business as usual format and this was the same course as that from the Facebook Messenger study but during a different academic year.

Our research questions and findings were as follows:

1: In addition to Canvas, do students engage with the course through social media applications, and how? We specifically examined the instructor-led Google Hangouts app and any student-led social media applications that developed organically. Results differed greatly from the Facebook Messenger study with much lower rates of participation. Google Hangouts had a 67% enrollment rate compared to the 82% enrollment rate in the Facebook Messenger study. 49% of the students reported interacting with Google Hangouts or another social media application during the course. Additionally, 25% of all students made at least one post in the Google Hangouts group.

2: Does engaging with social media apps contribute to students' efficacy, sense of belonging, value of STEM, and achievement? Post frequency and type of posts were unassociated with course outcomes. Results revealed that students' self-efficacy were predictive of course achievement while values did not. Additionally, students' sense of belongingness and whether they used an additional social messaging app, which may not have been Google Hangouts, was predictive of their self-efficacy in the course. This study

demonstrated that the affordances of the type of technologies used are important to consider in order to effectively promote social connections and student motivation.

Structure of the Dissertation

Each study within this dissertation will be presented as a separate manuscript in turn. The three studies have study-specific literature reviews, research questions, methods, discussions, and conclusions. I will end the dissertation by discussing the overarching conclusion that summarizes and includes the significance of the three studies and implications for future research.

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CHAPTER 2

Study 1.

Science Writing in Groups: A Quantitative Study of Student Collaboration and Learning

Introduction

Science, technology, engineering, and mathematics (STEM) occupations are projected to grow 9% annually through 2024 (Noonan, 2017). STEM knowledge is increasingly important for students in the information age as STEM degree holders earn a 12% premium compared to non-STEM degree holders (Noonan, 2017). According to the National Center for Educational Statistics (NCES), 48% of students in a four-year university and 69% of community college students who began as STEM majors had left the field due to switching to a non-STEM major or leaving college altogether (X. Chen, 2014). Despite these high numbers, attrition rates were similar between STEM and non-STEM majors. The strongest factors predicting STEM attrition were overall performance in classes and performance in STEM courses (X. Chen, 2014). Thus, it is imperative that students improve their competency in science in order to improve rates of graduation among STEM students.

Literature review

Why Writing in STEM Matters

Writing may play a central role in students' development of academic language, critical thinking, and reasoning in STEM. Indeed, the alignment of the Next Generation Science Standards (NGSS) with the Common Core literacy standards emphasizes the importance of students developing skills in creating coherent arguments in STEM and communicating them effectively. The NGSS aims to promote educating students in the skills

and practices of scientific and engineering work, which includes composing and refining various types of scientific writing for a variety of audiences and purposes (*Next Gener. Sci. Stand. States, By States*, 2013). However, the importance of including writing in STEM curriculum is not just for college success (Applebee, 2011), but also for employment and promotion (Lapp, Fisher & Frey, 2014). Writing's importance as a job requirement has been growing; labor increasingly involves transforming knowledge into a useable, shareable form (Lapp et al., 2014). Many American adults, including those in STEM fields, spend half or more of their workday writing digitally (Brandt, 2015). Thus, students need to develop skills to write and communicate scientific knowledge.

Learning goes beyond the simple acquisition of knowledge, as it involves the construction of meaning and understanding through social interactions (Vygotsky, 1978). Tasks that require students to elaborate on their understanding of concepts, hypothesize, interpret, synthesize, debate, and reprocess concepts maximize learning (Rivard, 1994). Writing assignments can be designed to maximize learning through externalizing the organization of understanding an individual has through the use of mental processes such as planning, translating, and reviewing that are managed by a metacognitive monitoring ability (Hayes, 1980). The benefits of writing exercises are threefold. It improves written communication skills (i.e., grammar, syntax, style, etc.) while also improving critical thinking skills (Applebee, 2008) and a deeper understanding of the subject (writing to learn). Thus, writing activities can provide students with additional practice in writing as well as teaching them subject-specific content.

Writing tasks can also be leveraged to enhance learning outcomes as well. A recent meta-analysis by Graham, Kiuhara, and MacKay (in press) has found that writing enhances student learning of academic content in general (ES = 0.30), and in science (ES = 0.31), even when teachers do not provide explicit instruction in writing to students (ES = 0.32). The

effects were enhanced if the treatment length was prolonged and included writing prompts that were metacognitive in nature (Bangert-Drowns, Hurley, & Wilkinson, 2004; Graham et al., in press). Student learning outcomes can be further enhanced through collaborative writing, particularly as co-writers make requests for clarification from one another (Y. C. Chen, Hand, & Mcdowell, 2013). While collaborative writing tasks improved learning outcomes for all students, there were additional positive effects for female, low SES, gifted, and special education students (Y. C. Chen et al., 2013).

Writing to learn activities have been demonstrated to be an effective educational tool in the sciences as well. A writing intervention for undergraduate biology students revealed that writing activities improved students' critical thinking skills, such as their ability to analyze and make inferences about biology (Quitadamo & Kurtz, 2007). Writing to learn activities have also been effective in improving content learning in other scientific subject areas, such as chemistry and physics for students of various ages (Y. C. Chen et al., 2013; Hand, Yang, & Bruxvoort, 2007). In addition to improved content knowledge, students who underwent the writing activities also expressed improved confidence in their knowledge and understanding of concepts (Hand et al., 2007). Overall, writing to learn activities have been shown to improve student learning and enhance critical thinking. This is accomplished by challenging students to understand technical concepts, translate their knowledge for specific audiences, utilize skills such as providing evidence to support claims, and using multimodal representations within texts to further enhance their learning.

Importance of Science Vocabulary

A critical element of effective science writing is developing a mastery of science vocabulary. Numerous terms in STEM content areas are used to define and develop the concepts within the field. Thus, vocabulary knowledge is an essential element in comprehending STEM concepts (Flanigan, Templeton, & Hayes, 2012). Students need to

have a clear understanding of science vocabulary in order to navigate the science content and retain their interest in the field. Careful analysis of higher education science textbooks has revealed that up to thirty percent of a text can consist of technical vocabulary (Chung & Nation, 2004). With nearly one-third of the words within a book being highly technical and discipline-specific, learning scientific vocabulary is critical for comprehending scientific texts and learning scientific concepts and processes. Indeed, science vocabulary knowledge is an important contributor to students' comprehension of scientific texts (Taboada, 2012).

Because of the close connection between scientific vocabulary and scientific concepts, students' science vocabulary knowledge may be a marker of their science content knowledge (Woodward-Kron, 2008). Students' performance on vocabulary-matching probes is predictive of their performance and progress in learning science content among secondary students (Borsuk, 2010; Espin et al., 2013). Vocabulary knowledge is highly associated with discipline-specific content knowledge (Woodward-Kron, 2008). Students who have a greater command of the technical vocabulary in STEM are better equipped to understand lectures and readings in class. Further, the ability to use appropriate, content-specific vocabulary through writing is the main way to demonstrate affiliation with an academic community (Piller & Ivanic, 1999). Thus, the successful application of science vocabulary during writing could reflect both greater scientific thinking and content learning.

Challenges of STEM writing

There are numerous challenges to writing in STEM courses. The language of science is often confusing to students and offers numerous unique challenges. First, unlike everyday language, scientific writing is focused on parsing specialized knowledge and theorems that contain a multitude of distinguishing features. Second, scientific writing often includes greater informational density than other disciplines, which is reflected by greater lexical density (Fang, 2005). That is, scientific texts contain disproportionately more content words

and noun phrases than text in other disciplines. The heavier reliance on nouns enables scientists to communicate rich information concisely, letting fewer words convey more concepts. The lexical density in part reflects that scientific writing uses many nominalizations, or verbs that have been transformed into nouns (e.g., using the noun, "analysis" rather than the verb, "analyze"). One result of nominalizing verbs is that previously clear concepts can become abstract. Because nominalization makes verbs the subjects of sentences and allows for more concise, informationally-dense language, information that was previously clear could become more ambiguous or even hidden through the writing process. Third, science writing further complicates comprehension by incorporating technical vocabulary that is often complex to categorize and construct concepts. Rather than presenting new terms for familiar concepts, scientific texts often contain vocabulary that represents concepts in which readers have no prior knowledge. Words such as *catalyst, anabolic, Borealis effect*, and *acids* are often new vocabulary terms that are conceptually unfamiliar so that readers have learned new terms and concepts before they can comprehend the text. Finally, scientific writing seeks to carry an authoritative nature by distancing the writer from the text, including technical vocabulary, and using declarative sentences to present the author as a knowledgeable expert (Fang, 2005). This distinct style of writing is different from the directness and greater simplicity of everyday speech and can be challenging for students. Thus, the complexity and unique features of scientific writing require more advanced writing skills for students to be successful.

Writing from sources

In college classes, students are expected to learn from independent readings and interpret, critically analyze, and integrate the readings in their writing. Thus, the skill of writing using source documents is an essential academic skill. It is a core component of disciplinary writing in every scholarly discipline, considering its importance in the peer-

reviewed publication process. Learning to write from sources effectively is a fundamental academic skill acquired during secondary and higher education. Thus, it is often considered to be an important learning outcome in higher education studies of writing (Haswell, 2000). Students often struggle with this difficult task; however, prior subject knowledge influences their ability to write from sources (Cumming, Lai, & Cho, 2016). Furthermore, task conditions and types of text impact students' writing from sources (Cumming et al., 2016). An analysis of college students' writing from source texts revealed that they preferred to paraphrase, copy, or patchwrite (making small edits to the copied source material) from individual sentences as opposed to summarizing text (Howard, Serviss, & Rodrigue, 2010). Students may inappropriately cite their works and patchwrite despite understanding university policies (Li & Casanave, 2012). This suggests that students may need specific instruction regarding writing from source texts. Furthermore, students differed in how and when they used their source texts to aid their writing with the stronger readers electing to plan more than the weaker readers during the post-reading and prewriting phases (Kennedy, 1985).

Students may utilize either low or high investment strategies in their research and composition (Nelson & Hayes, 1988). The low investment strategy involves simply reproducing source text for examination while the high investment strategy engages with the source text to develop original conclusions. In addition, novice and advanced writers also utilize different approaches to search for source content. Some novice writers would rely on a content-driven approach that focuses on finding resources related to their topic and build an outline from those sources. An example of a content-driven approach by a writer could include searching for articles associated with Latin American history and piecing bits of each article together to form an essay.

In contrast, more advanced writers would take an issue-driven approach that involved searching for content in support of a position (Nelson & Hayes, 1988). For example, a writer utilizing an issue driven approach could begin a broader search regarding a topic and look for trends and patterns to formulate a thesis around before embedding their analysis into the broader framework of the argument. A writer's reading level was determined to be associated with their reading, postreading, prewriting, and composing strategies (Kennedy, 1985). Students' writing performance and engagement with the source text can be influenced by educators through instructional approaches such as getting students to being the writing process earlier, focusing on high level goals, providing intermediate feedback, and including an audience other than the teacher (Nelson & Hayes, 1988).

Writing with Multiple Sources

Despite the challenges of learning to write from single sources, it is even more challenging to use and integrate information from multiple sources. Multiple document processing involves the ability to read, comprehend, and integrate information from multiple sources (Britt, Perfetti, Sandak & Rouet, 1999). Furthermore, there is a great need for college students to form connections between multiple sources as more primary and secondary sources of information are presented to them. However, most students have little experience and instruction in learning from multiple texts.

Although most of the research examining writing using multiple texts as sources has been done in the field of history (Stahl, Hynd, Britton, McNish, & Bosquet, 1996; Wiley, Steffens, Britt, & Griffin, 2014; Wiley & Voss, 1999), the use of multiple textual sources in STEM is quite common and is an area that needs more research. The construction-integration theoretical model explains the value of multiple texts for improving comprehension (Kintsch, 1988). Kintsch's model focuses on constructing a situation model by integrating information from a single text, prior knowledge, and other source materials. Researchers have argued that

multiple text comprehension involves a deep understanding of an event or topic (Rouet, Mason, Perfetti, & Britt, 1996; Wineburg, 1998). For example, Rouet proposed that a single argument model, or representation of the content of multiple texts, develops after learning from multiple texts and results from the interaction of the models, or representations, of each text (Rouet et al., 1996). Thus, by integrating multiple texts, students can construct a deep understanding of a topic.

When using multiple documents as sources for their writing, writers face unique challenges and opportunities in their writing. Using multiples sources is more cognitively demanding for writers, requiring writers to move their attention across numerous documents frequently. To cope with these demands, writers may adopt strategies such as annotating the source documents as they formulate their plans and thoughts (O'Hara, Taylor, Newman, & Sellen, 2002). Furthermore, this movement of attention leads writers to organize the spatial layout of their documents to facilitate this task with greater ease (O'Hara et al., 2002). When undergraduate students used sources with conflicting information as to their sources for an essay, they displayed behaviors in identifying, monitoring, and evaluating information they read (Anmarkrud, Bråten, & Strømsø, 2014). For example, they used strategies such as evaluating the trustworthiness of their sources and cross-document linking. These particular strategies were positively associated with explicit source citations in their writing and argumentative reasoning about what they read (Anmarkrud et al., 2014).

Collaborative Writing To Maximize the Benefits of STEM Writing

One way to manage the challenges of multiple source writing is to use collaborative writing techniques. Collaborative writing is the joint production of a text where writers all contribute to its authorship (Storch, 2005). Developing collaborative writing skills is an important aspect of academic and science education. Teamwork and coauthorship in research and industry are becoming more and more common. Collaboration enhances task efficiency

and productivity (Jones, 2007). Further, collaborative writing has been found to improve both the accuracy and quality of student writing (Biria & Jafari, 2013; McDonough, De Vleeschauwer, & Crawford, 2018). Thus, many educators have incorporated collaborative group work into their curriculum (Bunch, Kibler, & Pimentel, 2012; C. C. Johnson, Peters-Burton, & Moore, 2015).

Strategies student use in collaborative writing

Strategies for collaborative writing can be separated into distinct styles, including parallel writing (cooperative text writing by authors working in a side by side fashion), sequential writing (co-construction of texts between authors with frequent collaboration), and single-author writing with peer feedback (Noël & Robert, 2004). Students have been observed to utilize a diverse set of strategies during their collaborative writing process that includes parallel construction-puzzle and cut and paste, sequential construction-summative and integration, and integration construction (Onrubia & Engel, 2009). Parallel construction-cut and paste involves dividing the complete task into multiple sections, with each member contributing their portion to create a final product that is an amalgam of the individual components without any editing or modification from the other co-authors. Parallel construction-puzzle involves the formation of a written product from the extracted portions of the initial contributions from each group member. The sequential construction-summative strategy involves one group member taking the lead and creating an initial document that partially or completely answers the task with other members subsequently contributing to the document without altering what was written by the other co-authors and accepting their contributions. Sequential integration construction involves one group member taking the lead and creating an initial document that partially or completely answers the task while other group members contribute and debate modifications to each writing contribution. Finally

integrating construction involves synchronous discussion with multiple revisions in which all authors are engaged in making modifications and changes to the text.

Incorporating Technology with Collaboration

Google docs is a well-known tool for collaborative writing, and students have overwhelmingly expressed positive attitudes in regards to using it collaboratively as a writing platform (Hocutt & Brown, 2016). Students valued the flexibility, convenience, and the fact that comments and revisions could be completed on the same document using Google docs. Furthermore, the collaborative use of Google docs has been linked to improved motivation to learn, a more positive perception of the learning experience, and enhanced learning outcomes among students with varying levels of proficiency in English (Liu & Lan, 2016; Yim, Warschauer, & Zheng, 2016). Also, assigning students to provide anonymous feedback in Google docs can lead to equalized participation rates among students of varying English proficiency levels (P Woodrich & Fan, 2017). Students have been observed to have increased productivity in writing and spend more time revising when using Google docs (Yim, Warschauer, & Zheng, 2016).

Furthermore, Google docs use during writing enhanced agency and authorship and enhanced collaborative accountability due to the recording of edits (Yim et al., 2016). The enhanced collaborative accountability could lead to balanced rates of participation among writers which results in essays with higher qualities of content and more text (Yim, Wang, Olson, Vu, & Warschauer, 2017). Student groups who employed a divide and conquer strategy and evenly shared the workload while using Google docs produced higher qualities of text compared to groups which relied heavily on a single writer (Yim et al., 2017).

Theoretical Framework

This study is grounded in sociocultural theory considering the prevalence and importance of collaborative activities in science courses. Social interactions mediate the co-

construction of knowledge building (Vygotsky, 1978). The process of learning occurs through the interactions between the individual, the activity, and the setting (Lave, 1988). Thus, it is possible for each member in a group to learn different concepts while providing contributions to their combined work. Furthermore, students enter the classroom with different cultural backgrounds, home environments, and languages that allow them to interact with and develop their understanding of concepts (O'loughlin, 1992). Thus, they are able to contribute in different ways during group activities and are able to process their interactions and the subject matter differently as well. Applying sociocultural theories to our studies of collaborative writing tasks can help to explain differences in students' writing and science development.

Science as any other discipline requires the use of a specific discourse different from casual speech (Shanahan & Shanahan, 2012). Science discourse similar to scientific literacy has much greater informational density, lexical complexity, and technicality (Fang, 2005). Students must engage in scientific small group activities uniquely because of its distinct language. Thus, students may decide to utilize specific strategies to navigate the complexity of completing collaborative science writing tasks.

Research Questions

We currently understand the importance and challenges of writing in STEM among K-12 students. We also are aware of some of the strategies students employ in collaborative writing settings. However, we lack information regarding postsecondary collaborative science writing using multiple sources and how collaborative writing impacts the use of specific linguistic factors such as vocabulary, analytical thinking, and content knowledge. Furthermore, we know little in regards to the mechanics of collaboration between students in terms of their use of peer-editing, equality of contribution, and overall group activity in

regards to group STEM writing. This study aims to address that gap by examining collaborative science writing in an upper-division university-level biology course for majors that focuses on producing text from multiple sources. This study is guided by three research questions.

1. What are the most common strategies of collaboration used among undergraduate biology students in their writing?
2. How do students' writing change as they progress through the academic term?
3. Are strategies of collaboration predictive of writing content (science vocabulary, syntactic simplicity, and analytical thinking)?

Methods

Study Setting

This study was performed at a large research institution in the Western United States. Participants were undergraduate students enrolled in a 10-week upper-division biology course that was designed for biology majors. We studied these students for the entirety of the 10-week term.

Participants

The study included a total of 54 biology major students in the upper-division course. There was a total of 20 males and 34 females in the class. Because this was an upper-division or advanced class, there were seven junior (or third-year) students and 47 senior (or fourth-year) students.

Writing Prompts

For each of the six essays, students were given an open-ended writing prompt requiring each group to write 1,500-word papers. The prompts required students to use multiple sources in their research and as evidence to support their arguments about diseases

such as cholera, ebola, coronavirus, HIV, malaria, tuberculosis, and influenza. Because the features of text vary as a function of genre (Schleppegrell, 2004), groups completed essays in four different genres over the course of the term. These genres included a neutral and informed press article, a mini-review for a peer-reviewed research journal, a sensationalized magazine article, and a mini-review article for a medical journal. The genre for each essay was determined by the roll of a die. Groups were encouraged to write a paper for each genre throughout the course. Groups were also encouraged to include real-world examples in their essays. An example of the prompt is available in the Appendix.

Measures

Three computational tools were used to analyze each writing sample, the Linguistic Inquiry and Word Count (LIWC2015; Pennebaker, Boyd, Jordan, & Blackburn, 2015), Coh-Metrix 3.0 (Graesser, McNamara, & Kulikowich, 2011; McNamara, Graesser, McCarthy, & Cai, 2014) and Docuviz (D. Wang et al., 2015a). We derived measures of writing volume, writing quality, and collaboration. The following measures were derived using the Linguistic Inquiry and Word Count (LIWC2015; Pennebaker, Boyd, Jordan, & Blackburn, 2015) and Coh-Metrix 3.0 software.

Variables Associated With Writing Volume

Word Count reflects the total number of words in each student's essay. *Word count* was derived using LIWC2015 (2015; Pennebaker et al., 2015)

Variables Associated With Writing Quality

Writing quality was operationalized in a variety of ways, including word usage, syntactic complexity, and formality of the writing style.

Word concreteness was used to operationalize the complexity of vocabulary usage. *Word concreteness* refers to the degree in which the words in a text are tangible and readily evoke mental images, making the text easier to process and understand. In contrast, texts that have low word concreteness scores contain more abstract words that tend to refer to concepts and are more difficult to understand. *Word concreteness* percentile was derived using Coh-Metrix (McNamara et al., 2014).

Science vocabulary refers to the degree to which scientific words were included in the text. We created a dictionary of science vocabulary using the biology and chemistry lists from the Secondary Vocabulary Lists (Green & Lambert, 2018). *Science vocabulary*, or the number of science words in each essay, was derived using LIWC2015 with the science vocabulary dictionary (Pennebaker, 2015).

Syntactic simplicity refers to the complexity of grammar usage. *Syntactic simplicity* was derived using Coh-Metrix (McNamara et al., 2014). This variable is based on a z-score, with higher scores reflecting shorter, simpler sentence structures and lower, negative scores reflecting greater use of complex syntactic structures.

Connectivity refers to the degree to which the texts contain transitional words or phrases to relate sentences and paragraphs. Examples include additive connectives such as "further" or "similarly," adversative connectives such as "in contrast," causal connectives such as "therefore," and sequential connectives such as "first" or "second." *Connectivity* was derived using Coh-Metrix (McNamara et al., 2014).

Analytical thinking refers to the degree in which the uses words that suggest analytical, formal, or hierarchical thinking. High *analytical thinking* scores would reflect greater adherence to scientific and academic writing conventions, while low scores would reflect more informal language use. *Analytical thinking* was derived using LIWC (2015; Pennebaker, Boyd, Jordan, & Blackburn, 2015).

Narrativity reflects the degree to which texts reflect language use that adheres to the conventions of narratives, or stories, rather than the formal exposition of scientific writing. Higher scores reflect texts that are less formal and more like oral conversation, while lower scores would reflect greater formality. *Narrativity* was derived using Coh-Metrix (McNamara et al., 2014).

Referential Cohesion refers to the degree that words and concepts overlap in a text that creates connections in the explicit text. Referential cohesion may be achieved through the use of pronouns (*e.g.*, replacing "the bacterium" with "it"), repetition of words, or nominalizations (*e.g..*, following the verb "measure" with the noun "measurement"). *Referential cohesion* was derived using Coh-Metrix (McNamara et al., 2014).

Deep Cohesion The degree to which a text contains causal and other types of connectives (*e.g.*, "because" or "consequently") that help the reader form a coherent and deeper understanding of the text. *Deep cohesion* was derived using Coh-Metrix (McNamara et al., 2014).

Variable Associated With Time

Because each group completed six writing assignments, we coded when each paper was completed using the ***time*** variable. Each assignment in the term was assigned a time point starting with one for the first assignment and ending with six for the sixth assignment. This variable was a measure for the progression of assignments and time throughout the academic term.

Variables Associated With Collaboration

We operationalized collaborative writing in three ways – the degree to which collaborations reflected contributions by all group members (equality of contributions), the overall degree of activity (group activity), and the degree to which students interacted with

group member's writing (peer-editing). These three variables were developed following practices informed by (Yim et al., 2017).

The equality of contributions is a measure of how equitable the contributions to the final essay was for each group essay. This variable provides information regarding the contribution of ideas and writing for each assignment. It is calculated through one minus the variance of proportions of contribution for each essay obtained through Docuviz times 100 (to make the scores readable). Higher scores indicate greater balance in written participation. Participation only refers to the quantity of writing from each group member.

Group activity is a measure for the total edits and writing completed by the group. It is useful to determine how much total writing was performed without regard to what remained in the final submitted essay. The data is obtained through summing the total edits of every individual for each essay, as provided by Docuviz.

The peer-editing variable provides information regarding how much editing students were performing on the contributions of other students. It is derived as the sum of the edit of other variable from all contributing members for each essay, as analyzed by Docuviz.

Additionally, visualizations from Docuviz were qualitatively examined for distinct styles and patterns of group activity.

Procedure

At the start of the 10-week term, students were randomly assigned to one of eight groups that each consisted of seven members. Each group completed six collaborative essay assignments during the term, for a total of 56 essays. The first essay was completed by students on week 3, the second was completed on week 4, the third was completed on week 5, the fourth was completed on week 6, the fifth was completed on week 8, and the sixth completed on week 9.

Treatment of Data

The essays from the first group in the dataset were not written using google docs. We were unable to track any collaboration data and did not include any essays from that group for analysis. Thus, the total sample size of this study was 7 groups with 6 essays per group. Mixed-effects regression utilizing STATA 14 software was employed to analyze the impact of various linguistic and collaboration factors on student writing.

Results

RQ1: What are the most common strategies of collaboration used among undergraduate biology students in their writing?

Descriptive data regarding the means and standard deviations of all variables concerning word use, syntax, formality, and collaboration are shown in Table 1. The seven groups are relatively similar, as shown through the descriptive data in terms of many variables such as science vocabulary, equality of contributions, analytical thinking, and more. In general, students adhered to the recommended word length for their essays, with a mean essay length of 1932 words (s.d. = 672). Both the low word concreteness scores (mean = 35.04, s.d. = 14.84) and the moderate science vocabulary use (mean = 7.84, s.d. = 2.88) suggested the writing was complex and resembled scientific writing from experts. The essays tended to be structurally complex, as shown by the high deep cohesion scores (mean = 79.37, s.d. = 12.95). Further, all groups used formal language in their essays, as shown by the high analytic scores (mean = 92.78, s.d. = 3.98) and low narrativity scores (mean = 19.70, s.d. = 10.42). Finally, all groups used a highly collaborative approach to writing, as their equality of contribution scores were very high (mean = 97.77, s.d. = 4.98).

Table 1. ***Writing Features of Students Essays***

	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	All Groups
Word Use Word Count	2334 (1466)	2087 (597)	1747 (391)	1697 (281)	1870 (453)	1752 (451)	2070 (421)	1932 (672)
Word Concreteness	24.5 (9.1)	37.67 (21.91)	35.82 (11.50)	31.30 (16.42)	37.60 (11.98)	39.87 (18.64)	38.53 (11.29)	35.04 (14.84)
Science Vocabulary	8.52 (1.49)	8.52 (1.72)	8.56 (0.97)	8.93 (1.31)	9.01 (2.47)	7.62 (1.65)	9.42 (1.67)	7.84 (2.88)
Syntax Synctactic Simplicity	58.58 (10.64)	60.82 (9.56)	57.11 (11.50)	42.74 (10.35)	56.89 (12.34)	71.97 (6.36)	66.05 (14.96)	59.16 (13.31)
Connectivity	4.82 (3.48)	3.58 (2.87)	2.04 (2.08)	3.59 (2.67)	3.76 (3.83)	6.59 (7.21)	3.52 (3.94)	3.99 (3.95)
Formality Analytic Thinking	92.90 (3.08)	93.98 (2.46)	92.98 (7.51)	91.63 (3.90)	93.90 (3.38)	92.53 (4.27)	91.58 (2.57)	92.78 (3.98)
Narrativity	20.26 (8.90)	12.87 (9.14)	20.72 (11.28)	24.82 (9.50)	19.15 (11.38)	20.48 (16.25)	19.62 (5.19)	19.7 (10.42)
Referential Cohesion	22.33 (9.47)	14.81 (7.38)	43.13 (17.62)	38.27 (17.01)	29.75 (12.13)	22.21 (12.61)	33.03 (13.63)	28.64 (15.16)
Deep Cohesion	82.33 (8.58)	66.31 (17.62)	89.45 (5.72)	91.04 (4.73)	75.24 (7.97)	70.20 (10.49)	83.09 (11.75)	79.37 (12.95)
Collaboration Equality of Contributions*	97.49 (1.39)	99.34 (0.38)	98.48 (0.50)	99.19 (0.42)	93.86 (13.00)	97.54 (1.79)	98.50 (1.92)	97.77 (4.98)
Peer Edits	9814.17 (3095.71)	4871.17 (2341.94)	2117.33 (1320.29)	3346.67 (2602.58)	4394.50 (4445.12)	3834.50 (2541.13)	3917.00 (3871.89)	4613.62 (3630.82)
Contribution	16703.00 (9327.43)	15395.17 (3798.42)	12281.67 (2333.21)	12868.50 (2097.39)	12548.50 (3691.13)	10728.50 (2791.03)	15276.67 (2831.56)	13686 (4598.33)

Means are shown for each variable with standard deviations in parentheses. *Equality of contributions is measured from a scale of 0-100 with 100 representing exactly equal contributions among all group members.

Table 2 shows the correlations matrix for the writing and collaboration variables. Both science vocabulary r=.408 and six-letter words r=. 486 were correlated with syntactic simplicity and negatively correlated with narrativity r=-.364 and r=-.841. The texts with more complex vocabulary tended to have simpler writing structures that were more likely definitive or analytical rather than narrative in nature. Peer edits were negatively correlated with equivalent contributions r=-.363. This suggests that an uneven distribution of peer edits are made by a select few group members while the majority tend to perform few or no peer edits at all. Furthermore, peer edits were negatively correlated with word concreteness r=-.32 and referential cohesion r=-.322. This suggests that most of the peer edits were involved with

the removal or replacement of simple words without linking the edited content with the nearby text. The equivalent contributions variable was positively correlated with science vocabulary use r=.416. This suggests that groups with more equal contributions tend to utilize greater science vocabulary in their writing.

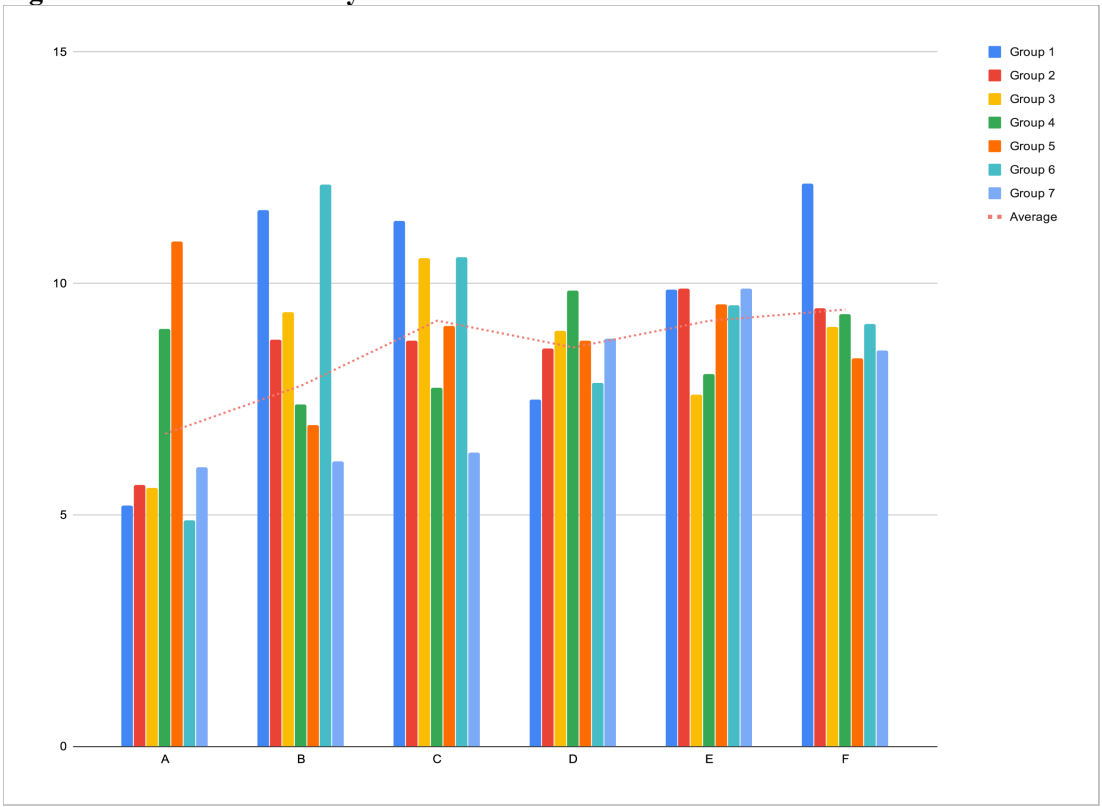
Table 2. ***Correlations Among Writing Variables Among Source Based Writing***

*=p<.05

	Word Count	Science Vocabulary	Analytical thinking	Narrativity	Syntactic Simplicity	Word Concreteness	Referential Cohesion	Deep Cohesion	Connectivity	Equality of Contributions	Peer edits
Word Count	X										
Science Vocabulary	0.162	X									
Analytical thinking	0.031	0.273	X								
Narrativity	-0.149	-0.364*	-0.771*	X							
Syntactic Simplicity	0.285*	0.408*	0.357*	-0.585*	X						
Word Concreteness	-0.231	-0.402*	-0.002	0.053	-0.044	X					
Referential Cohesion	-0.067	-0.127	-0.004	0.238	-0.443*	0.076	X				
Deep Cohesion	-0.071	-0.120	-0.266	0.336*	-0.351*	-0.126	0.442*	X			
Connectivity	0.075	-0.281	0.111	0.116	-0.068	-0.109	-0.071	-0.155	X		
Equality of Contributions	0.072	0.416*	-0.108	0.057	0.085	-0.137	0.143	-0.045	-0.268	X	
Peer edits	0.144	0.054	0.043	0.035	0.052	-0.32*	-0.322*	0.089	0.055	-0.363*	X
Time	-0.039	0.347*	0.386	-0.0002	0.038	-0.162	-0.081	0.00	-0.390	0.253	-0.03

Through further analysis utilizing Docuviz, the equality of contributions, group activity, and peer-editing variables samples are presented visually for each of the group assignments. A pattern emerges in which the individual who created the document was often among the greatest contributors to overall writing volume. Students gradually join in throughout the essay writing process, with the vast majority of the contributions occurring during the latest stages when the majority of members join in before the assignment's deadline. A few students in each group also tended to take turns in their roles as the primary contributor and document creator. The sequential contribution style amongst group members was highly suggestive that each student was assigned a portion of the overall text during pre-planning. Furthermore, little parallel peer edits were completed amongst members, with often one or two group members making the majority of edits sequentially once all contributions were submitted. It is common for group members to contribute a portion of text to the essay and perform few or no edits of their peers' contributions.

Figure 1. Science vocabulary use over time



A-F represents assignment 1-6.

RQ2: How do students' writing change as they progress through the term?

Figure 1 shows the change over time in each group's use of science vocabulary in their essays, with the dot markers showing the mean science vocabulary use for each timepoint. An upward trend in science vocabulary use is shown in the graph with a decrease in standard deviation among groups as well.

The mixed-effects regression models presented in Table 3 were performed to predict science vocabulary use as a function of collaboration and linguistic variables and time. Model 1, with science vocabulary use as the outcome, was statistically significant ($\chi^2(12) = 84.58$), $p > .05$. Results revealed that science vocabulary use was not predicted by the time variable ($\beta = .07, p > .05$),. Model 3 revealed that the syntactic simplicity of students' essays ($\beta = -,06$

p > .05) did not change as a function of time. Models 2 revealed that the use of analytic thinking, which was very high throughout the term, did not change as a function of time (β = -.05, p < .46) changed over time. Thus, it appears that students' use of science vocabulary content, complex grammatical structures, and analytical thinking were unchanged over the course of the term.

Table 3. ***Mixed Effects Regressions Predicting Writing Volume, Science Vocabulary, Analytical Thinking, Syntactic Simplicity, and Equality of Contributions among essays.***

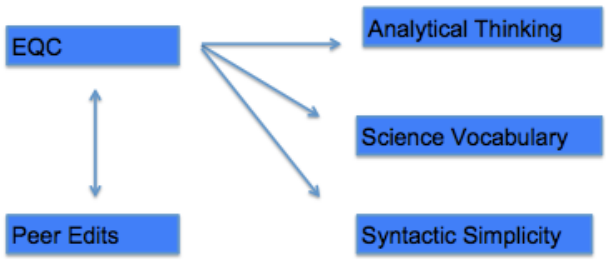
	Science Vocabulary (1)	Analytical Thinking (2)	Syntactic Simplicity (3)
Equality of Contributions	0.48*** (0.12)	-0.03 (0.10)	0.26** (0.09)
Peer Edits	0.27** (0.13)	0.16 (0.10)	0.12 (0.11)
Time	0.07 (0.06)	-0.05 (0.06)	-.06 (0.05)
Word Count	.009 (.09)	-.10 (.08)	.20** (.07)
Narrativity	-0.27** (0.1)	-0.81*** (0.09)	-0.44*** (0.08)
Connectivity	-0.01 (0.11)	0.17* (0.1)	-0.03 (0.09)
Referential Cohesion	-0.14 (0.11)	0.3** (0.1)	-0.38*** (0.09)
Deep Cohesion	-0.08 (0.12)	-0.09 (0.1)	0.1 (0.1)
Word Concreteness	-0.27** (0.10)	0.01 (0.10)	-0.001 (0.08)
Constant	-.30 (.29)	.22 (.22)	.17 (.28)

All coeffecients are standardized. **=p<.05

RQ3: Are strategies of collaboration predictive of writing content (science vocabulary, word count, analytical thinking, and syntactic simplicity) and course performance?

A path model diagram is presented in figure 2. We expected the equality of contributions measure to increase science vocabulary use, analytical thinking, and syntactic simplicity. Additionally, peer edits were expected to increase science vocabulary use, syntactic simplicity, and analytical thinking.

Figure 2. Path model diagram of collaboration measures



EQC=equality of contributions

The mixed-effects regression model presented in Table 3 displays the effect of collaboration on writing content. Only two models suggested more collaborative writing strategies led to a better demonstration of content knowledge and stronger mastery of written language. Model 1 shows that the equality of contribution measure was predictive of science vocabulary use ($\beta = .48, p < .001$) along with the peer edits measure ($\beta = .27, p < .05$). That is, groups that shared the workload more equally tended to incorporate greater use of science vocabulary in their essays. Additionally, those groups that performed more edits amongst each other also incorporated more science vocabulary. Model 3 shows that equality of contribution predicted syntactic simplicity ($\beta = .26, p < .05$). The peer edits measure did not

show a suggestive trend in predicting syntactic simplicity ($\beta = .12, p < .27$). In contrast, neither the equality of contributions nor peer edits were significantly predictive of analytical thinking.

Additional student-level mixed-effects regressions were conducted, as shown in Table 4, to examine if student collaboration measures were associated with course outcomes. Results revealed no significant predictors for final course grades. Student level analysis also revealed that peer edits were predictive of writing volume ($\beta = .761, p < .01$). This suggests that those students who were performing more peer edits were also likely contributing more personal text as well.

Table 4. Student Level Analysis: ***Regressions Predicting Course Grades and Contributions.***

	Course Grade (1)	Contribution (2)
Peer Edits	0	.761**
Contribution	0	
Class Standing	.189	-211.52
Course Grade		922.95

The impact of other writing measures on predicting word use.

In addition to collaboration measures, science vocabulary was negatively associated with word concreteness ($\beta = -.27, p < .05$),, and significantly associated with narrativity ($\beta = -.27, p < .05$). Other linguistic writing were not predictive of science vocabulary use. Analytical thinking was associated with referential cohesion ($\beta = .30, p < .05$), and text narrativity ($\beta = -.81, p < .001$).

In terms of linguistic measures predicting syntactic simplicity, word count ($\beta = .20, p < .005$), referential cohesion ($\beta = -.38, p < .001$), and narrativity ($\beta = -.44, p < .005$) were significant.

Discussion

Incorporating writing assignments in STEM classes can be an effective way not just to promote writing skills, but also to enhance student learning in STEM courses. The literature has found that writing can benefit students by engaging their critical thinking skills and conceptual understanding to encourage them to engage with course content more deeply than through rote memorization (Applebee, 2008; Quitadamo & Kurtz, 2007). The current study closely examined how students engaged with their STEM writing content in the context of multiple collaborative writing assignments.

We first examined how students wrote collaboratively, and changed their writing across the term. We found that all groups had a high equality of contributions score (93-99) that suggests an equally distributed writing load among group members. These results support findings from prior studies regarding collaborative group writing (Yim et al., 2017). However, the majority of peer edits were completed by a few members suggesting a parallel-construction cut and paste style in which each group member completed his or her own portion of the essay and added it to the final document with one or two people organizing it all together. The results from this study revealed an upward trend of science vocabulary use throughout the six assignments as the term progressed. Total writing volume and level of analytical thinking remained consistent throughout the academic term.

Finally, we considered how patterns in student collaboration contributed to the linguistic characteristics of their essays. We found that collaboration factors such as the equality of contribution of group members within texts were linked to greater science vocabulary usage and greater syntactic simplicity. Additionally peer edits were associated with increased vocabulary usage as well. Increased collaboration may have decreased the overall cognitive load of the assignment by allowing each individual member to focus on a section of the assignment prior to compiling the entire work leading to greater science

learning and a more appropriate writing style. Other variables did not predict analytic writing content because of the nature of the class studied in which students select from a variety of writing formats for their assignments such as magazine articles, peer-reviewed journal or news article. Furthermore, this may suggest that collaborative Google document writing does not impact all aspects of writing.

The students collaborated on Google docs from start to finish, and drafting requires a large amount of deletion as well as modification. Additionally, factors such as total edits predicted equality of contributions, which demonstrates that more text writing overall results in more equal contributions. However, the final contribution was not predictive of equality of contributions considering that much of the writing was ultimately deleted. No links between collaboration measures and final course grades were found. These results are consistent with past research regarding collaborative group writing, which also determined that balanced participation and a divide and conquer strategy to writing was associated with higher quality texts (Yim et al., 2017). A possible explanation for the impact of equality of contributions to science vocabulary usage and greater syntactic complexity could be associated with shared mental models. Mental models are internal representations of an individual's externalization of a situation. Thus, having shared mental models can result in the improved delegation of tasks, deciding on strategies, effective communication, monitoring of progress, and deciding on goals. Research has shown that shared mental models between group members were a significant contributor to team effectiveness (Fransen, Kirschner, & Erkens, 2011). Thus, teams that have equal contributions between members may have developed shared mental models to accomplish the task more efficiently.

Challenges of Incorporating Writing in STEM Education

Some of the major obstacles to the inclusion of more writing to learn activities in STEM courses include a lack of a community of faculty committed to applying the necessary

pedagogical research (Reynolds, Thaiss, Katkin, & Thompson, 2012). Although educators view writing in science as a great learning and assessment tool, teachers often felt unqualified to develop rubrics to assess if students learned specific content as opposed to traditional methods of assessment (Hand & Prain, 2002). Research has shown that writing to learn exercises require a shift in pedagogy through changes in scaffolding, design of assessments, and even the role of the teacher (Hand & Prain, 2002). Furthermore, many STEM instructors have large classes upwards of 100+ students making grading and provision of feedback on essays a laborious task. These different demands are often quite daunting and may deter many teachers from utilizing these beneficial activities in a college setting.

The use of collaborative writing activities may be a possible solution to some of these obstacles for the implementation of writing in STEM courses. Collaborative writing significantly reduces the grading and feedback load for instructors. Furthermore, collaborative subject-specific writing activities teach writers to operationalize their thoughts and act as disciplinary writers as experts in their field would while teaching them invaluable teambuilding and organizational skills. Finally, our study has shown that collaborative writing can improve aspects of writing among students by increasing syntactic complexity and science vocabulary use over time.

Limitations and Future Directions

This was an exploratory study with some limitations. First, the analytic writing results may have been impacted by choice of assignments, which allowed students to select from a variety of writing styles that ranged from a sensationalized magazine article for public audiences to research articles for scholars. Past research has demonstrated that writing prompts can impact the compositional fluency of writers (Hudson, Lane, & Mercer, 2005).

Second, because this study was a secondary analysis of students' collaborative writing, our data sources were limited to essays written in Google docs. We were unable to

gather data about whether the groups pre-planned or met in person before or during their time writing in Google docs. Thus, having a more qualitative aspect in which students could be observed in their collaborative interactions and interviewed about their understanding of the collaborative process could provide additional information in regards to their collaboration strategies.

Finally, a possible reason why collaborative writing strategies were not predictive of students' final grades may be that the range of student course grades was extremely limited, with the majority of students receiving A's. However, we did find the use of science vocabulary, a possible indicator of scientific conceptual knowledge, increased as the term progressed. Thus, while we found evidence of growth using a proximal indicator of content knowledge, future research would benefit from using more sensitive distal measures of content knowledge.

Conclusion

This exploratory research suggests that collaborative elements increase science vocabulary use in texts. Furthermore, this study reveals that, when left without particular instructions, students tended to divide the work equally into sections with each member contributing to an overall final product reminiscent of a parallel-construction cut and paste style of collaboration. More balanced participation led to text with more science vocabulary, greater referential cohesion, and simpler overall syntax. The findings regarding how students freely engage with collaborative writing can be used to inform instruction through balancing contributions as a way to increase students' science vocabulary usage and likely understanding of that vocabulary. Finally, this research could be used to inform future interventions intending to utilize STEM and collaborative writing.

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Appendix

Group weekly written assignment instructions:

Article type: (roll a die until you hit a number 1-4 to determine the format for your publication). In the event that you roll the same number multiple times - try to be sure that your group has a chance to write for each type article format at least once. Articles should be approximately 1500 words – use real world examples to guide you.

1. A neutral and informative press article for a well-respected newspaper written for a general audience.
2. A mini review publication for a peer-reviewed research journal written for an informed scientific community.
3. A sensationalized magazine article geared toward providing an overview of the outbreak while grabbing the attention of the general public.
4. A mini review publication for a medical journal written for clinicians and the greater medical community.

CHAPTER 3

Study 2. Facebook Messenger: An Environment for Enhancing Student Socialization and Interaction within an University STEM Course

1. Introduction

1.1 The State of STEM General Education

Every higher education institution is required by its accrediting body to provide some general education requirements to ensure a breadth of knowledge among students. It serves as the foundation of an undergraduate degree. General education requirements can cover as much as a third to a half of all degree units earned by students and comprise a large part of their curriculum. Most curricula require courses from the humanities/arts, social/behavioral sciences, and natural science/mathematics (SOACS, 2002). It comes as no surprise that students ranked the values associated with general education as the least important part of their college experience (Humphreys & Davenport, 2005). When asked, the vast majority of non-STEM students choose to enroll in STEM general education courses because of the course time, their advisor's suggestion, or to fulfill a specific requirement. Few students enrolled to gain exposure to the STEM field or gain a greater understanding of the field (Enderson & Ritz, 2016).

Despite its importance, first-year college students tend to enter college with a limited understanding of science's nature, showing high levels of belief in pseudoscience (Impey, Buxner, Antonellis, Johnson & King, 2011). With only 18% of the bachelor's degrees awarded in 2015-16 in STEM fields (NCES, 2020), the overwhelming majority of college graduates are not required to take more than one or two science courses to fulfill general education requirements. This is concerning, as non-STEM majors have been found to show

no growth in their understanding of science's nature during their college careers and remain no less susceptible to pseudoscience upon graduation (Impey et al., 2011; Moore & Rubbo, 2012). Additionally, non-STEM majors hold more negative attitudes and beliefs about the value of science and show less engagement with their STEM courses (Lytle & Shin, 2020; Uzpen et al., 2019). Through careful curriculum development, required general education STEM courses can be leveraged as an opportunity to improve non-STEM majors' attitudes and understanding of science.

Students' attitudes and beliefs about STEM are important, as they influence their choices and engagement with STEM courses (Eccles, 2009). According to the expectancy-value theory of motivation, students who have high expectations of succeeding in STEM courses and believe STEM is valuable are more likely to pursue STEM courses and majors (Eccles, 2009). Student attitudes such as self-concept of ability (a student's beliefs regarding his/her ability to perform a task), task value (how important the task is to the student), and expectations (how well the student expects to perform on the task) are strong predictors of academic achievement in STEM courses (Else-Quest, Mineo, & Higgins, 2013). For example, student motivation in STEM courses is highly correlated with achievement for both STEM majors and non-STEM majors (Fong & Kremer, 2020; León et al., 2014; Rosenzweig & Wigfield, 2016; Starr et al., 2020).

Several factors inform students' expectancies of success, their value of STEM, and their motivation and achievement in STEM classes. One such factor is social engagement. Interactions with classmates can influence students' perceptions of their competence in STEM and have been found to be especially important for underrepresented students (Hilts et al., 2018). Additionally, other social factors, such as feelings of relatedness (social support from peers, instructors, and others around them), were associated with pursuing more STEM learning (Hilts et al., 2018). Furthermore, socialization experiences are directly associated

with student motivation (Wentzel & Wigfield, 1998). Thus, interventions that promote social interactions and relatedness may have positive effects on both achievement and motivation.

With the massive shift toward online instruction, there is a growing need to engage with students virtually beyond the use of classic online course websites as students are likely to receive much less social interactions than an in-person course. Student socialization is an essential aspect of their educational experience and affects their motivation and achievement. Although discussion forums in online classes provide a venue for group work and involve social features, more contemporary supplements can be utilized as a supplement to keep students engaged and strengthen social connectedness. Many elements are absent in the current learning management systems, such as synchronous collaboration elements, push notifications for users, and a more advanced user interface. It is challenging to enable social interactions in an online classroom, and supplementation can be beneficial. Both Facebook and SMS text messaging have been effectively utilized to enhance and support student learning in undergraduate contexts (Cavus & Ibrahim, 2009; Dougherty & Andercheck, 2014). Through these programs, students can engage in peer-to-peer and student-to-faculty interactions to supplement their standard classroom tools. The addition of socially focused applications such as Facebook Messenger could improve student engagement and learning outcomes in STEM courses by increasing student interactions and sense of belonging.

1.2 The Current Study

We currently understand the importance and challenges of succeeding in STEM among undergraduate students. We also are aware of some of the strategies that may benefit student performance in their coursework. However, we lack information regarding how instructors can easily develop a platform for students to socialize and supplement their virtual instruction. We developed an intervention that required lower levels of instructor effort to be more easily added and implemented in curricula. Approximately 16% of undergraduates have

used Facebook in an academic setting in previous classes (Magro, Ryan, Sharp, & Ryan, 2013). A study utilizing the Delphi method revealed that undergraduate students viewed Facebook as an excellent communication tool between groups and information transfer. Students indicated that they wanted to use Facebook to collaborate among peers and post course-specific information, such as test reviews and instructor announcements (Magro et al., 2013). A previous study utilizing a light-touch intervention that reinforces spacing of studying has been shown to be effective (Rodriguez, Rivas, Matsumura, Warschauer, & Sato, 2018). We have developed an intervention utilizing Facebook Messenger to periodically deliver course-related content to students and create a forum for collaboration among students to support and guide student learning. The basis of this intervention relies on creating an open environment where students may feel freer to interact with each other because of the low-stakes and more socially inclined environment. Furthermore, the periodic texts serve as a mechanism to encourage students to space their studying of course-related content. We elected to utilize this format because of the efficacy and utility of spacing techniques for improving student performance in courses (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). A single instructor could also easily manage to facilitate the Facebook Messenger group, even for a large class. This study aims to facilitate student learning and socialization by utilizing the Facebook Messenger application. Three research questions guide this study.

4. What are the students' experiences regarding the intervention (i.e., did they find it useful, enjoyable, change their views)?
5. For those who engaged with Facebook Messenger, did it affect their achievement?
6. How does the type of interaction within Facebook Messenger influence outcomes (grades) and student experiences?

2. Literature Review

2.1 Mobile Technology in Education

Technology has been utilized in various forms to enhance student engagement, motivation, and learning. Wireless technology, such as short messaging service (SMS) texts, have been used to supplement English vocabulary learning with great effect by improving student posttest scores significantly (Cavus & Ibrahim, 2009). Furthermore, students reported that they enjoyed using the tool because of their flexibility to learn anytime and anywhere. Students generally had positive perceptions of using mobile phones to support their learning (Cavus & Ibrahim, 2009; M. Gasaymeh & M. Aldalalah, 2013). Incorporating these optional learning tools into the curriculum increases the flexibility and convenience of learning and could add to student engagement and motivation. The ability to access these mobile learning tools from any location and allow the user to feel free to learn at their own pace encourages motivation and engagement (Kerawalla et al. 2007; Livingstone, 2007).

Researchers have also attempted to utilize mobile learning (m-learning) software to stimulate student learning through self-assessment content. The mobile-learning results were mixed, with mobile-learning being more effective for younger 14-15 years old students and showing non-significant effects for older high school seniors and 2nd-3rd year university students (De-Marcos et al., 2010). Furthermore, older secondary and university students did not feel that the material was helpful to their learning and did not find increased motivation to engage with the software. The likely cause behind these findings was that the self-assessments were designed to reinforce previously learned content and not provide new knowledge. Thus, providing tools for knowledge acquisition may prove to be more effective for university students, which is why we elected to present new facts in our study rather than utilize self-assessment content.

Technology that uses computers or programs to alter behaviors and attitudes has been utilized in education with good effect (Fogg, 2003). Researchers have used mobile phones to

deliver literacy-related content to motivate parents and pre-school children through persuasive SMS and audio messages delivered through sesame street characters (Revelle, Reardon, Mays Green, Betancourt, & Kotler, 2007). Furthermore, most participants felt that mobile phone technology made incorporating literacy activities into daily life easier and facilitated their children's literacy learning. Persuasive SMS interventions have been shown to be effective in improving college students' self-regulated learning and improved course outcomes for them (Goh et al., 2012), particularly when used to provide assignment reminders encouragement to show up to lectures, workshops, and tutorials. Furthermore, URM students benefitted the most from this type of intervention (Goh, Seet, & Chen, 2012). In addition to encouraging student engagement and productive learning behaviors, push media such as short emails and text messages have been effectively used to promote content area learning by creating a spacing effect, the phenomenon in which long-term memory is improved when studying is spaced apart rather than all at once, for students (Vlach & Sandhofer, 2012). They encourage studying course content at regular intervals among EFL students (Thornton & Houser, 2001). The variety of available approaches through mobile technology creates more options for students to engage with the course content based on their preferred learning style. Considering that learners' motivation can change based on the medium and style of the content's presentation, these additional mobile learning interventions that target different learning styles can add to student motivation and engagement.

2.2 Using Web 2.0 and Social Media in Education

A growing space for mobile learning is social media. Social media is pervasive among youth today, with 68% of American adults using Facebook (Pew 2018). With the shift towards online education, social interactions are hard to come by, and it is more important than ever to retain student motivation and academic success. Social media usage for the

purpose of socialization has been linked to an increased sense of belonging (Pang, 2020). Social media has already been leveraged in educational settings to complement traditional teaching techniques with varying degrees of success. Integrating social media into the classroom has been shown to enhance student motivation and support greater problem-solving amongst students (Mondahl & Razmerita, 2014; Yunus et al., 2012). University students who participated in a course-specific Facebook group used it to collaborate and communicate course concepts and exam-related material. These students received better grades in that course than those who chose not to participate (Bowman & Akcaoglu, 2014). Researchers have also used Facebook as a tool to engage learners in large university classroom settings through the facilitation of a Facebook group. Participants reported a stronger sense of belonging in the course while interacting with other members (Dougherty & Andercheck, 2014). Although these findings are encouraging, they may result from the self-selection bias, in that students who are already more motivated in the course may choose to engage with classmates about the course through social media.

More rigorous designs have been used to examine social media's effects on STEM learning in higher education. In one randomized control study, Facebook was used as an additional communication tool for treatment students. Facebook was thought to simplify the instructor's communication with students, as treatment students showed better course performance than their peers in the business-as-usual condition (Guo et al., 2018). Besides being used as a communication tool, the Facebook platform can be employed in other approaches to influence the instructor and student relationship to improve student motivational factors. For example, the inclusion of Facebook disclosures, where students could see the instructor's profile, helped boost student motivation (Aubry, 2013).

There has been some success with utilizing Facebook as an information-sharing platform among students for courses with students expressing approval and positive feedback

(Omar et al., 2014). More researchers have begun incorporating Facebook into their course content to stimulate discussion and collaboration among students (Ractham et al., 2012). The benefits of academic Facebook use among students, such as increased interaction and communication with students, improved social relationships, and increased participation, lead to higher student motivation (Lam, 2012). When utilized properly, social media-supported learning programs have been demonstrated to increase student motivation and academic outcomes on par with face-to-face learning and blended learning programs (Akgündüz & Akinoglu, 2017). Additionally, interventions have been developed to utilize social applications such as Twitter to create an online community in class to develop a greater sense of belongingness among students (Friess & Lam, 2018). These impacts on students' sense of belonging, motivation, and achievement could increase students' valuations of science in everyday life.

There are some risks associated with Facebook. Overall, Facebook usage has been linked with lower GPAs (Reynol Junco, 2012). However, the type of Facebook use was a moderating factor based on whether it was used to gather and share information or for social purposes. Thus, it is imperative to create a nurturing environment when using social media that focuses on learning rather than solely socialization. Incorporating Facebook into the classroom carry many pedagogical risks as well. Some students may choose to opt-out of required Facebook use in courses and later feel that they received unfair treatment due to the lack of access to pedagogical insights posted on the site.

Furthermore, because of the social nature of the platform, students may post inappropriate comments that may lead to additional complications for instructors (Mendez, Le, & Cruz, 2014). Because students have expressed caution towards incorporating Facebook as a formal learning tool but instead show greater enthusiasm for its use as a social tool, we elected to utilize a more informal format. Facebook has also been used successfully to create

an online learning community among university students who spent their time engaging in effective communication, problem-solving, and social support (Whittaker, Howarth, & Lymn, 2014). It has also been used to effectively foster student collaborations, as evidenced through improved essay revisions linked to posting the essays and receiving peer feedback from the website (Wichadee, 2013). The potential benefits of incorporating social media into the curriculum to support students' sense of belonging, motivation, engagement, and achievement are strong. These potential benefits may be enhanced due to the lack of face-to-face interactions in university classrooms. Thus, incorporating these elements can foster a more inclusive learning environment that could alleviate some of the social isolation associated with online learning.

3. Methods

3.1 Study Setting

This study took place in a large, general education biology course taught at a large research institution in the western United States. We implemented the intervention in one year and compared student achievement to that of students who took the same course with the same instructor the previous year. The participants were 228 undergraduate students in the intervention year, and 288 undergraduate students served as the control group, having taken that course the previous year. Forty students chose not to use the Facebook Messenger platform in the intervention year, leaving 188 students in the intervention group.

3.2 Procedure

The instructor for both cohorts of students was experienced and had taught this course multiple times before the current study. The instructor taught both cohorts of students the same content and used the same pedagogy and assessments, except for the Facebook

intervention. Class instruction included PowerPoint lectures and group discussions. Students were assessed using 13 in-class assignments, two multiple-choice midterms with short written questions, and a final exam with the same format as the midterm. All 13 in-class assignments were included and were graded on a complete/incomplete basis.

In the intervention year, the instruction was delivered in the same way as the previous year, except for adding the Facebook Messenger intervention. Students were invited to join the class's Facebook Messenger group during the first class session. The Facebook Messenger intervention was utilized to deliver additional practice questions and reinforce concepts taught during class by the instructor. These messages were crafted to produce a spacing effect in learning and promote gradual study habits instead of cramming at the end of the course for the exams. Students who joined the Messenger group received texts three times per week, beginning the second week of class, for a total of 27 texts. The texts from the instructor specifically focused on course content and included practice questions. Additional course administrative texts were also provided, such as the time and location of the exam. Students were free to interact and collaborate through the Messenger group.

A voluntary post-intervention survey was given during the final week of class. The survey asked students about biology knowledge learned from the course and their Facebook Messenger experiences. Students were awarded one extra point of extra credit for completing the survey.

3.3 Measures

3.3.1 Achievement Data. Student achievement was operationalized as both their grades on tests and their completion of class assignments. Students completed two midterms and a final exam, which were each worth 50 points. We used their mean score on the exams as the variable, *test grades*, expressed as a percentage score.

The second measure of student achievement was the completion of the thirteen *class assignments*. To this end, we calculated the percentage of class assignments submitted throughout the course.

3.3.2 Facebook Messenger Interaction. The Facebook Messenger chat group was analyzed to understand the nature of student interactions better. Each post within the chat was coded into three categories of interaction, reflecting different goals and purposes. Overall, this coding system yielded an inter-rater agreement of 98%.

Content segments reflected posts directly related to course material, such as key vocabulary or discussion of biological mechanisms and concepts. An example is, "Does MDMA use reverse reuptake on serotonin?...Yes! MDMA acts on NE and DA but more on 5-HT thus, it is not addictive". The total number of posts related to course content or concepts from the class was used for each student's content segments.

Course administration segments reflected posts that related to the logistics of the course. Examples include queries about the date of the midterm and assignment due dates. We used the total number of posts about course logistics submitted as the course administration score for each student.

Social segments reflected posts that did not address course content or the logistics of the course. These posts included memes, jokes, social pleasantries such as greetings and saying thank you, as well as wishing one another luck on the exams. The total number of social segments posted by each student was tallied.

3.3.3 Survey Instruments

3.3.3.1 Attitudes about Messenger. We adapted Cavus and Ibrahim's measures to assess whether students positively responded to mobile interventions. The survey consisted of two sections, with the first section addressing students' perceptions of the course and the intervention. The second portion consisted of 12 questions and focused on surveying the

modifications or changes students wished to see regarding using the Facebook Messenger system. All 30 items used a 5-point Likert scale, with 5 representing a maximum positive reaction and 1 representing a negative reaction. The survey questions addressed students' enjoyment of Facebook messenger, sense of belonging, overall use of the messenger, changes in study habits, motivation, whether students felt learning through the app was effective, attitudes about the course, and self-efficacy. The full survey is shown in the appendix.

The *Self-efficacy* measure was the mean score of the three following questions: Through this course, I am more capable of defining and understanding basic biology terms and concepts; Through this course, I am able to critically think about the impacts of various drugs on the brain; and I feel confident in applying the concepts from this course in the world. All three questions were surveyed on a 5-point Likert scale, with 5 strongly agreed and 1 strongly disagreeing. The reliability of this scale was .88.

4. Results

4.1 Research Question 1: What are the students' experiences regarding the intervention?

Table 1 presents the survey data, showing students' attitudes about Facebook Messenger in the top half and their beliefs about their efficacy, value, and motivation for the course in the lower half. We found that students generally enjoyed using Facebook Messenger, with a mean score of 4.03 out of 5. A two-way t-test found that students reported significantly higher enjoyment ($M=4.03$, $SD=1.03$) than the neutral rating of 3 $t(164)=12.82$, $p<.001$. Additionally, students felt a greater sense of belonging from using the app ($M=3.66$, $SD=1.26$) than the neutral rating of 3 $t(164)=6.73$, $p<.001$). Additionally, students felt that the app helped them to study more consistently throughout the quarter ($M=3.63$ $SD=1.19$)

t(164)=6.83, p<.001and increased motivation for the course (M=3.54 SD=1.10) t(164)=6.32, p<.001.

Table 1. Descriptive Data for Survey Items

Survey Item	Mean	Median	Standard Deviation
Attitudes about FB Messenger			
Using FB Messenger to learn in this class was enjoyable.	4.03	4	1.03
The FB Messenger group improved my sense of belonging in the course.	3.66	4	1.26
I consistently checked the FB Messenger group chat for course content.	3.61	4	1.29
The FB messages helped me to study throughout the quarter instead of cramming all at once.	3.63	4	1.19
Learning through FB messenger has increased my motivation in this class.	3.54	4	1.10
I found learning new content with the FB system to be very effective.	3.92	4	1.10
Attitudes about the course			
Through this course, I am more capable of defining and understanding basic biology terms and concepts	4.29	4	.77
Through this course, I am able to critically think about the impacts of various drugs on the brain.	4.38	5	.76
I feel confident in applying the concepts from this course in the world.	4.12	4	.86
Through this course, my ideas about taking STEM classes have changed.	3.52	3	1.16

The bivariate correlations for students' self-reported usage, enjoyment, and sense of the effectiveness of FB messenger are presented in Table 2 along with their reported beliefs regarding whether the use of the app improved their motivation, sense of belongingness, study habits, and whether the course improved their self-efficacy in regards to biology and if the course changed their ideas regarding STEM courses. Students reported enjoyment of Facebook messenger (rs=.19-.76), whether the use of the app improved their motivation (rs=.26-.71), sense of belonging (rs=.22-.73), and improved study habits (rs=.27-.75) were correlated with every other measure. Whether the course changed students' ideas regarding STEM courses was correlated with every measure except their reported beliefs regarding FB Messenger's effectiveness for learning (rs=.18-.57). Moderate to strong correlations were present between students' frequency of use of the app (rs=.18-.67) and all variables except self-efficacy in the course.

Table 2: Bivariate Correlations of Survey Measures

*=p<.05

	Enjoy FB	Change Ideas about STEM	Motivation	FB Usage	Sense of belonging	Study Habits	Self-Efficacy
Enjoy FB	N/A						
Change Ideas about STEM	0.205* (.008)	N/A					
Motivation	.74* (.000)	0.35* (0.00)	N/A				
FB usage	.667* (.000)	.184* (0.018)	0.656* (0.00)	N/A			
Sense of belonging	.69* (.00)	.278* (0.00)	0.702* (0.00)	.632* (0.00)	N/A		
Study Habits	.732* (.00)	.347* (0.00)	0.727* (0.00)	.697* (0.00)	.735* (0.00)	N/A	
Self-Efficacy	.197* (.011)	.57* (0.00)	0.265* (0.000)	.135 (0.085)	.228* (0.003)	.272* (0.00)	N/A
Effective Learning	.756* (.00)	.146 (0.061)	0.716* (0.00)	.648* (0.00)	.738* (0.00)	.751* (0.00)	.185* (0.017)

We calculated a regression model to examine predictors of students' self-reported enjoyment of FB Messenger. Predictor variables included students' beliefs if using FB Messenger increased their motivation and sense of belonging, and their frequency in using the app, whether the course changed their ideas of STEM, whether the app changed students'

study habits by spacing out their study sessions, gender referenced on males, and their sense of efficacy as the independent measures. The regression model is presented in Table 3, which revealed that student enjoyment of FB Messenger was predicted by gender (referenced level was males demonstrating that females enjoyed the app more) ($\beta = .10, p < .05$), motivation($\beta = .29, p < .01$), beliefs regarding the effectiveness of the app for learning($\beta = .22, p < .01$), and improvement in study habits variables ($\beta = .20, p < .05$).

We next sought to determine how students' attitudes about Facebook Messenger contributed to their beliefs about their efficacy, values, and motivation for the course. We calculated a regression to explore the factors that predicted student motivation, shown in Table 3. Students' enjoyment of using FB Messenger, frequency of checking FB, sense of belonging, whether they felt the course changed their ideas regarding STEM, and the app's overall effectiveness to their learning positively contributed to their motivation.

Additionally, we wanted to examine student perceptions of the FB Messenger platform's effectiveness to assist their learning and calculated a regression, with its results shown in Table 3. Students' perceptions of the app's effectiveness to learn new content were positively predicted by their enjoyment, sense of belonging, motivation, improvement of study habits, and negatively by their beliefs that the course changed their perceptions of STEM courses in general. Finally, to assess the link between students' feelings of sense of belongingness in the class and their Facebook usage, a two-way t-test found that students' self-reported sense of belongingness did not differ from their reported frequency of checking FB messenger $t(164)=.57, p<.57$).

Table 3: Mixed Effects Regressions Predicting FB enjoyment, FB effectiveness, and Student Motivation

	Enjoy FB (1)	Effective Learning (2)	Motivation (3)
Enjoy FB	N/A	0.20** (0.08)	0.28*** (0.08)
Change Ideas about STEM	-0.05 (.05)	-0.16** (.05)	0.15** (0.56)
Motivation	.29*** (.08)	0.21** (0.08)	N/A
FB usage	.13* (.06)	0.05 (0.06)	0.136** (0.059)
Sense of belonging	.10 (.07)	0.21** (0.07)	0.19** (0.07)
Study Habits	.20** (.08)	.31*** (0.08)	0.04 (0.08)
Self-Efficacy	.03 (.03)	0.05 (0.03)	0.008* (0.03)
Gender	.10** (.11)	0.08* (0.11)	-0.04 (0.12)
Effective Learning	.22** (.08)	N/A	0.23** (0.08)
Constant	.70 (.33)	.47 (.33)	-.24 (.35)
R^2	.69	.72	.69

All coeffecients are standardized. Standard errors are in parenthesis. *=p<.10,**=p<.05, ***=p<.01

4.2 Research Question 2: For those who engaged with Facebook Messenger, did it affect their achievement?

Before examining the effects of the Facebook Messenger intervention on student achievement, we explored the frequency with which students engaged with Facebook Messenger. Descriptive data regarding the means and standard deviations of all variables concerning student test scores and Facebook Messenger usage are shown in Table 4. We see that 119 out of 188 students, or approximately 63% of those enrolled, contributed to the

Facebook Messenger platform with at least one post, and 28.72% of those enrolled contributed three or more posts.

Table 4: Descriptive Data of FB Messenger Usage

# of Posts in FB Messenger	# of Enrolled Students	% of enrolled students
0	69	36.70
1	40	21.28
2	25	13.30
3+	54	28.72

We first tested the effectiveness of FB Messenger for improving student grades by comparing the treatment class to the control class. Table 5 shows the descriptive data between the two groups. A two-sample t-test revealed that the FB Messenger intervention class (M=73.64 SD=13.3) had significantly higher test scores than the control class (M=70.85 SD=14.59), $t(515)= -2.24$, $p<.05$, yet students in both classes completed the same proportion of in-class assignments, $t(515) = -1.6584$, $p<.098$. Thus, the FB Messenger texts may have helped students by reinforcing important course concepts specific to exams. However, a regression analysis in table 6 revealed that enrollment in the treatment class did not predict students' test scores ($\beta = .066$, $p < .10$) once we controlled for the proportion of classwork completed.

Table 5: Achievement Data Between Intervention Groups

Variables	2017 Class	2018 Class	
		Enrolled	Not Enrolled
In class assignments (percent completed)	85.04 (20.8)	88.33 (16.72)	86.09 (20.58)
Test grade	70.85 (14.59)	73.77 (12.43)	73.13 (17.09)

Standard deviations are in parenthesis.

We further examined the relationship between the FB Messenger Group and students' achievement in the Facebook Messenger intervention class. More specifically, we calculated regressions predicting test performance, with enrollment in the Messenger group, testing if

enrollment in the Messenger group predicted test performance. Upon closer examination, enrollment into the Facebook Messenger group within the intervention group and whether they contributed a post to the Messenger group were not predictive of student test grades, as shown in Table 6. This suggests that being enrolled in the intervention or posting did not alter student achievement in the course. Students from the intervention class who enrolled in FB Messenger did not differ significantly from their classmates who did not enroll in FB Messenger class in classwork completed $t(226)=-0.74$, $p>.46$.

Table 6: Mixed-effects Regressions Predicting Test Scores between Classes and Test Scores Within the Intervention Group

Variables	Model 1	Model 2	Model 3
Intervention Group	.098** (.088)	.066 (.079)	N/A
Classwork		.447*** (.039)	.468*** (.06)
Enroll			-0.105 (.16)
Contribution			.068 (.12)
Gender			-0.014 (.12)
Constant	-.088 (.059)	(-.058 (.053)	.25 (.16)
R^2	.0097	.208	.227

All coeffecients are standardized. Standard errors are in parenthesis. *=p<.10,**=p<.05, ***=p<.01

4.3 Research Question 3: How does the type of interaction within Facebook Messenger influence achievement (grades) and student experiences?

To further examine the types of interactions within FB Messenger, we looked at the nature of post segments. Student interactions within FB Messenger were coded into three types of posts: content, administrative, and social and are presented in Table 7. Out of the188 students from the intervention class who enrolled in FB Messenger, 32% made at least one post or more regarding content, 30% associated with course administration, and 46% associated with

socialization between peers. Out of the total 556 posts, nearly half, 227, was associated with socialization, followed by course content, 184, and course administrative discussions, 145.

Table 7: Descriptive Data of the Types of Interactions in Facebook Messenger

Type of Post in FB Messenger	Total Posts	% of enrolled students with 1+ posts
Content	184	32.09
Administrative	145	30.65
Social	227	46.52

To examine the types of interactions students engaged with and the relationship with student performance, we regressed the three types of posts, content, administrative, and social, over students' overall test scores. The hierarchical regression presented in Table 8 shows that social segment contributions predicted test scores ($\beta = .193$, $p < .05$) and accounted for a .24 change in variance for the overall model. This suggests that students who were socializing more in the class were also performing better on the exams, possibly due to social learning factors. Both content and course administrative segments were not significant in predicting student test scores.

Table 8: Hierarchical Regression Predicting Test Scores with Types of FB posts

Variables	Model 1	Model 2	Model 3	Model 4
Classwork Completed	.477*** (.07)	.475*** (.07)	.475*** (.07)	.470*** (.07)
Content Segment		-.029 (.05)	-.018 (.07)	-.029 (.07)
Course Administration Segment			-.016 (.07)	-.154 (.09)
Social Segment				.193** (.08)
Constant	.07 (.06)	.068 (.06)	.067 (.06)	.064 (.06)
R^2	.217	.216	.216	.240

All coeffecients are standardized. Standard errors are in parenthesis. *=p<.10,**=p<.05, ***=p<.01

5. Discussion and Conclusions

Our research aimed to examine the effects of incorporating a low effort intervention delivered through Facebook messenger as a supplemental resource in a general education biology course. Students were invited to enroll in a class wide Facebook messenger group that allowed them to collaborate and socialize while receiving periodic informative texts from the instructor. We found that students generally enjoyed adding a social media application to their learning experience and found it a useful supplemental learning tool to improve their study habits and sense of belongingness. Students reported that they enjoyed collaborating with their peers, feeling like they could have their questions answered ASAP, the freedom to engage with the course material outside of regular class times, the additional practice questions to test their knowledge, and greater accessibility to peers and the instructor. All these factors contributed to an improved quality of life for students while requiring little effort for the instructor to implement. Additionally, female students who felt that using Facebook messenger improved their study habits, motivation, and sense of belongingness were more likely to find using the tool enjoyable. Furthermore, students' self-reported rate of using the application was linked to an increased sense of belongingness.

In examining the intervention's impact on student test scores, we found initial differences between our control and intervention classes but no significant impacts once in-class work completion rates were factored in. This suggests that being enrolled in the study alone was insufficient to improve student course performance. However, linking Facebook messenger interactions to student outcomes revealed that students' social engagement with peers in the Facebook Messenger app predicted increased test scores. This falls in line with social constructivist theory and suggests that regular socialization can lead to enhanced achievement and content learning (Okita, Bailenson, & Schwartz, 2008; Zhang, Allon, & Van Mieghem, 2017). The finding that social posts were linked to improved student test

performance may be due to these social interactions reducing students' test anxiety as other studies have found the effectiveness of social media support (Hyseni Duraku & Hoxha, 2018; Warshawski, Bar-Lev, & Barnoy, 2019).

Our study adds to the existing literature on mobile technology's use to enhance classroom instruction in STEM courses by applying a simple and low maintenance intervention. Our research extends the literature on social media applications' utility for enhancing student performance (Cuesta, Eklund, Rydin, & Witt, 2016; R. Junco, Heiberger, & Loken, 2011; Ractham & Firpo, 2011). We see the value of socialization and its predictive potential for student test scores for non-STEM majors in a general education biology course through this intervention. Although we cannot isolate whether increased socialization leads to higher scores or if higher achieving students are more likely to be social, previous literature has demonstrated the value of social connectedness for student retention at the undergraduate level (J. Allen, Robbins, Casillas, & Oh, 2008). Furthermore, an enhanced sense of belongingness is associated with improved academic performance, student motivation, and engagement (K. Allen, Kern, Vella-Brodrick, Hattie, & Waters, 2018; Eccles, 2013; Juvonen, 2015; Neel & Fuligni, 2013). Thus, the increased sense of belongingness through socialization in our intervention may have potential academic benefits and could be enhanced through future interventions targeting this measure.

However, the use of Facebook may better facilitate social interactions at the cost of academic engagement (Wise, Skues, & Williams, 2011). This may explain the greater number of social posts in our study compared to academic and administrative posts. This may be a phenomenon specific to Facebook, and the potential of switching platforms may alter the ratio of social posts to the other types. Further research could examine other social media applications' effectiveness for targeting student learning by increasing engagement with course content-specific posts. Facebook has discontinued its Messenger platform for large

groups(100+); students use other applications such as Instagram, Discord, Wechat, and other applications to supplement their collaborative and social engagement activities. These apps have different features than Facebook Messenger, and understanding each platform's affordances and limitations may provide greater insight into how social media apps may enhance student engagement.

Our intervention was delivered in combination with regular in-person classes and served as an extra venue for students to engage and socialize with each other. With the shift to a fully online model, this intervention's impacts may differ as students have fewer opportunities to socialize in person and rely more on technology to reach each other and the instructor. Another alternative would be that the burnout from the online learning environment may lead to decreased participation rates within the intervention. Although no differences were found between the enrolled and control groups within the intervention class, we did not check for cross-condition contamination. Students may have possibly shared details and information from Facebook Messenger with their other classmates through other means. Further, we built an increased sense of belonging by enabling students to engage in more social interactions outside of class. Future directions can be leveraged to build programs more focused on social connections. This study shows how social media can be leveraged to enhance non-majors' engagement with required STEM classes by increasing social connectedness. This program can be adapted with ease to fit numerous courses and requires minimal instructor input while serving as an enjoyable and useful supplement to improving students' socialization in school.

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Appendix

1. Through this course, I am more capable of defining and understanding basic biology terms and concepts. *

2. Through this course, I am able to critically think about the impacts of various drugs on the brain. *

3. I feel confident in applying the concepts from this course in the world. *

4. Through this course, my ideas about taking STEM classes have changed. *

5. Using FB Messenger to learn in this class was enjoyable. *

6. I can easily remember the material that I received through FB Messenger. *

7. The content I learned through FB Messenger have increased my understanding of concepts in the course. *

8. I would like a similar system to be used in my other classes. *

9. The material delivered through FB Messenger helped me to correct my understanding of concepts that I misunderstood. *

10. Learning through FB Messenger has increased my motivation in this class. *

11. I felt more confident of my understanding of course content that was covered in the FB group chat. *

12. I consistently checked the FB Messenger group chat for course content *

13. Because I am very occupied during class hours it is more difficult to learn new content.

But I can learn and remember new content easier during my leisure time. *

14. I used the FB Messenger group to collaborate with my peers. *

15. I liked having an additional forum to collaborate with my peers. *

16. The FB Messenger group improved my sense of belonging in the course. *

17. I found the FB Messenger group a useful resource for contacting the professor *

18. The FB messages helped me to study throughout the quarter instead of cramming all at once. *

19. I would like to see the FB Messenger system to be used in next semesters as well. *

20. I found learning new content with the FB system very effective. *

CHAPTER 4

Study 3. Integrating Google Hangouts in an Online Science Course

Introduction

1.1 The State of STEM in General Education

General education science requirements are designed to provide students with a solid foundation and broad understanding of the natural sciences and are necessary for students to pass before graduation. Many students would rather skip general education courses and focus on their major if they were not required by universities (Thompson, Eodice, & Tran, 2015). Research has shown that far too many students lose interest in science, technology, engineering, and mathematics even before attending college (Aschbacher, Li, & Roth, 2010). Additionally, in a survey conducted on behalf of the Association of American Colleges and Universities, employers listed a greater focus on science and technology education in classrooms as one of their top priorities in order to ensure that students will be prepared to participate in the future global economy (Hart, Peter D., Research Associates, 2006). The majority of students point out that their main reason for taking a general education STEM course was their advisors (Enderson & Ritz, 2016). This data further emphasizes the importance of providing a positive experience in general education STEM courses as it is many students first encounter with STEM concepts and ideas and serves as a gateway for them to continue their STEM learning. This, in turn, could potentially help the employability of these students, as employers are increasingly valuing applicant's knowledge of science and technology.

1.2 Impact of Covid-19 on Student Learning in STEM

The transition to mass online instruction during the Covid-19 epidemic has led to decreased student engagement and decreased effectiveness of lectures in general education STEM courses (Perets et al., 2020). However, more independent tasks like research papers and blogging managed to garner greater engagement than lectures. While the shift to online learning did not negatively impact students' self-efficacy and sense of belonging in STEM, it did impact their growth in these areas as students did not demonstrate a notable increase in these factors throughout the semester (Wester, Walsh, Arango-Caro, & Callis-Duehl, 2021). However, students demonstrated a decline in emotional engagement and significantly declined positive attitudes about learning science (Wester et al., 2021). Additionally, students reported decreased motivational fortitude in online STEM courses (Means & Neisler, 2020). Finally, declines in student mental health were observed with increased feelings of anxiety and major depressive disorders (Chirikov, Soria, Horgos, & Org, 2020). The lack of face-to-face interactions contributed to these problems. Thus, to develop a sense of community and create a more informal venue for students to engage with each other and help build their sense of belonging and attitudes towards science, we developed an intervention utilizing Google Hangouts as a social media tool to supplement the standard venues of communication.

2. Literature Review

2.1 Motivation Theory

The Eccles expectancy-value theory argues that an individual's choices, performance, and persistence on a task are explained by their beliefs regarding how much they value the task and how well they believe they will perform (Wigfield & Eccles, 2000). These expectancies and values are in turn influenced by an individual's goals, self-schemata, personal and social identity, and self-concept of abilities. Thus, an individual's beliefs regarding how well they

will perform in a task, influenced by their efficacy beliefs and background, and their subjective task value would determine their choices and performance on that task. Subjective task value can be further influenced by factors such as intrinsic value, attainment value, utility value, and the cost of doing the task. Wherein intrinsic value refers to the interest and enjoyment from doing the task. Attainment value is associated with the importance that an individual holds for a task in relation to their social identity. For example, individuals who view themselves as scientists would strive to do well in science courses, whereas those who view themselves as athletes would not have the same attainment value for the task. Utility value refers to the importance of the task to fulfilling an individual's present and plans, such as how necessary a course is for graduation. Utility value is connected to a person's goals and sense of self. Finally, the cost has three components: effort cost or the perception of effort to complete a task, opportunity cost or the loss of other opportunities from performing this task, and emotional cost or the psychological costs of performing the task (Eccles & Wigfield, 2020). An individual's sense of belonging is directly associated with social support, which can influence the emotional costs of performing a task by alleviating stressors (Friedlander, Reid, Shupak, & Cribbie, 2007; M. Te Wang & Eccles, 2012). Furthermore, their sense of belongingness can influence their social identity, thereby affecting the attainment value for a task (Cameron, 2004).

Social media and web 2.0 contain many features and characteristics that enhance student motivation for learning when applied with appropriate designs. Social media has been demonstrated to improve motivation in students and can be leveraged to enhance students' values regarding a task (Laserna & Miguel, 2018; Oh, Chan, & Kim, 2020). Additionally, social media can affect students' sense of belonging with their environments and be leveraged to enhance this measure positively (Pang, 2020; Vincent, 2016).

2.2 Mobile Technology in Education

Technology has been utilized in various forms to enhance student engagement, motivation, and learning. Wireless technology, such as short messaging service (SMS) texts, has been used to supplement English vocabulary learning with great effect by improving student posttest scores significantly (Cavus & Ibrahim, 2009). Furthermore, students reported that they enjoyed using the tool because of their flexibility to learn anytime and anywhere. Students generally had positive perceptions of using mobile phones to support their learning (Cavus & Ibrahim, 2009; M. Gasaymeh & M. Aldalalah, 2013). Incorporating these optional learning tools into the curriculum increases the flexibility and convenience of learning and could add to student engagement and motivation. The ability to access these mobile learning tools from any location and allow the user to feel free to learn at their own pace encourages motivation and engagement (Kerawalla et al., 2007; Livingstone, 2007).

Researchers have also attempted to utilize mobile learning (m-learning) software to stimulate student learning through self-assessment content. The mobile-learning results were mixed, with mobile-learning being more effective for younger 14-15 years old students and showing non-significant effects for older high school seniors and 2nd-3rd year university students (De-Marcos et al., 2010). Furthermore, older secondary and university students did not feel that the material was helpful to their learning and did not find increased motivation to engage with the software. The likely cause behind these findings was that the self-assessments were designed to reinforce previously learned content and not provide new knowledge. Thus, providing tools for knowledge acquisition may prove to be more effective for university students, which is why we elected to present new facts in our study rather than utilize self-assessment content.

Technology that uses computers or programs to alter behaviors and attitudes has been utilized in education with good effect (Fogg, 2003). Researchers have used mobile phones to deliver literacy-related content to motivate parents and pre-school children through

persuasive SMS and audio messages delivered through sesame street characters (Revelle et al., 2007). Furthermore, most participants felt that mobile phone technology made incorporating literacy activities into daily life easier and facilitated their children's literacy learning. Persuasive SMS interventions have been shown to be effective in improving college students' self-regulated learning and improved course outcomes for them (Goh et al., 2012), particularly when used to provide assignment reminders encouragement to show up to lectures, workshops, and tutorials. Furthermore, underrepresented minority (URM) students benefitted the most from this type of intervention (Goh et al., 2012). In addition to encouraging student engagement and productive learning behaviors, push media such as short emails and text messages have been effectively used to promote content area learning by creating a spacing effect, the phenomenon in which long-term memory is improved when studying is spaced apart rather than all at once, for students (Vlach & Sandhofer, 2012). They encourage studying course content at regular intervals among English foreign language students (Thornton & Houser, 2001). The variety of available approaches through mobile technology creates more options for students to engage with the course content based on their preferred learning style. Considering that learners' motivation can change based on the medium and style of the content's presentation, these additional mobile learning interventions that target different learning styles can add to student motivation and engagement.

2.3 Using Web 2.0 and Social Media in Education

A growing space for mobile learning is social media. Social media is pervasive among youth today, with 72% of American adults using some form of social media (Anderson & Smith, 2018). With the shift toward online education, social interactions are hard to come by, and it is more important than ever to retain student motivation and academic success. Using social media for socializing has been linked to an increased sense of

belonging (Pang, 2020). Social media has already been leveraged in educational settings to complement traditional teaching techniques with varying degrees of success. Integrating social media into the classroom has enhanced student motivation and supported greater student problem-solving (Mondahl & Razmerita, 2014; Yunus et al., 2012). In particular, the Google Hangouts application has demonstrated potential for synchronous learning (Isaacson, 2013). Research has shown that the utilization of Google Hangouts as a delivery medium for problem-based learning exercises was effective (Hashim et al., 2017). Students enjoyed the affordances that Google Hangouts had to offer, such as the ability to record sessions. Google Hangouts did not compromise learning outcomes compared to face-to-face interactions (Hashim et al., 2017). However, students did feel that discussions were inferior in comparison to face-to-face learning. When utilized as a supplemental resource, Google Hangouts was found to be superior to asynchronous communications tools such as discussion boards and emails regarding student satisfaction with online teamwork. Additionally, students reported a greater sense of community using Google Hangouts (He & Huang, 2017). Students have been reported to be highly satisfied with the use of Google Hangouts during online instruction (Almusharraf & Khahro, 2020).

More rigorous designs have been used to examine social media's effects on STEM learning in higher education. In one randomized control study, Facebook was used as an additional communication tool for treatment students. Facebook was thought to simplify the instructor's communication with students, as treatment students showed better course performance than their peers in the business-as-usual condition (Guo et al., 2018). Additionally, interventions have been developed to utilize social applications such as Twitter to create an online community in class to develop a greater sense of belongingness among students (Friess & Lam, 2018). These impacts on students' sense of belonging, motivation, and achievement could increase students' valuations of science in everyday life.

Incorporating Google Hangouts into the classroom carry many pedagogical risks as well. Some students may opt-out of required Google Hangout use in courses and later feel that they received unfair treatment due to the lack of access to pedagogical insights posted on the site. Furthermore, because of the social nature of the platform, students may post inappropriate comments that may lead to additional complications for instructors (Mendez et al., 2014). The potential benefits of incorporating social media into the curriculum to support students' sense of belonging, motivation, engagement, and achievement are substantial. These potential benefits may be enhanced due to the lack of face-to-face interactions in university classrooms. Thus, incorporating these elements can foster a more inclusive learning environment that could alleviate some of the social isolation associated with online learning.

3. The Current Study

We currently understand the importance and challenges of succeeding in STEM courses. We are also aware of the strategies that can be utilized to enhance STEM instruction. However, there is little research on utilizing online communication applications to supplement the current educational tools. Most academics and administrative staff in higher education view Google apps as a positive and useful suite of tools in the workplace and already use them (Al-Emran & Malik, 2016). Additionally, many students already have access to a Gmail account provided by their schools, as in our study. Thus, we developed an intervention requiring minimal instructor input utilizing Google Hangouts as a supplemental tool to engage with students and generate greater collaboration and communication. Google Hangouts was selected because of the access that students had to the app and would require minimal setup for the students and instructor. Our intervention was designed to periodically deliver course-related content to students and create a collaboration forum to support and

guide student learning. The basis of this intervention relies on creating an open environment where students may feel freer to interact with each other because of the low-stakes and more socially inclined environment. Furthermore, the periodic texts serve to encourage students to space their studying of course-related content. We elected to utilize this format because of the efficacy and utility of spacing techniques for improving student performance in courses (Dunlosky et al., 2013). A single instructor could also easily facilitate the Google Hangouts group, even for a large class. This study aims to facilitate student learning and socialization by utilizing the Google Hangouts application during the Covid-19 epidemic. Through providing an additional informal venue, we aim to increase students' motivation to learn science through targeting their sense of belonging, self-efficacy, and values regarding science by increased social interactions between students and the instructor. Two research questions guide this study.

RQ1: In addition to Canvas, do students engage with the course through social media applications, and how? We specifically examined the instructor-led Google Hangouts app and any student-led social media applications that developed organically.

RQ2: Does engaging with social media apps affect course achievement? Additionally, do motivational factors predict students' use of social media apps?

3. Methods

3.1 Study Setting

This study took place in a large, general education biology course taught at a large research institution in the western United States. Enrolment in this class was restricted to students who were not majoring in biology. The participants were 215 undergraduate

students. Seventy students chose not to enroll in the Google Hangouts platform, leaving 145 students in the intervention group.

3.2 Procedure

The instructor for the course was experienced and had taught this course numerous times before the current study. Class instruction included PowerPoint lectures and group discussions. Students were assessed using 13 in-class assignments, two multiple-choice midterms with short written questions, and a final exam with the same format as the midterm. All 13 in-class assignments were graded on a complete/incomplete basis.

The instruction was delivered in the same way as any other year, except for adding the Google Hangouts intervention. Students were invited to join the class's Google Hangouts group during the first class session. The Google Hangouts intervention was utilized to deliver additional practice questions and reinforce concepts taught during class by the instructor. Example text questions: 1. In the peripheral nervous system where are nicotine receptors located? 2. If you wanted to find out the efficacy of a drug which of the following would you want to know? Kd, ED50, LD50, BMAX. These messages were crafted to produce a spacing effect in learning and promote gradual study habits instead of cramming at the end of the course for the exams. Students who joined the Google Hangouts group received messages three times per week, beginning the second week of class, for a total of 27 messages. The messages from the instructor specifically focused on course content and included practice questions. Additional course administrative messages were also provided, such as the time and location of the exam. Students were free to interact and collaborate through the Google Hangouts group.

Voluntary pre and post-intervention surveys were given during the first and final week of class. The survey asked students about their sense of self-efficacy in biology, their

sense of belongingness, value of STEM, and basic demographic information. Students were awarded one extra point of extra credit for completing each survey.

3.3 Measures

3.3.1 Achievement Data. Student achievement was operationalized as their end of quarter grades as percentages for the course.

3.3.2 Google Hangouts Interaction. The Google Hangouts chat group was analyzed to understand the nature of student interactions better. Each post within the chat was coded into three categories of interaction, reflecting different goals and purposes.

Content segments reflected posts directly related to course material, such as key vocabulary or discussion of biological mechanisms and concepts. An example is, "Does MDMA use reverse reuptake on serotonin?...Yes! MDMA acts on NE and DA but more on 5-HT thus, it is not addictive". The total number of posts related to course content or concepts from the class was used for each student's content segments.

Course administration segments reflected posts that related to the logistics of the course. Examples include queries about the date of the midterm and assignment due dates. We used the total number of posts about course logistics submitted as the course administration score for each student.

Social segments reflected posts that did not address course content or the logistics of the course. These posts included memes, jokes, social pleasantries such as greetings and saying thank you, as well as wishing one another luck on the exams. The total number of social segments posted by each student was tallied

3.3.3 Survey Instruments

3.3.3.1 Student Attitudes and Beliefs. We adapted measures to assess students' levels of self-efficacy in regards to biology from ***(Braten et al. 2013)***. Additionally, we

created measures for both sense of belongingness and STEM values in line with the expectancy value theory. All 30 items used a 7-point Likert scale, with 7 representing a maximum positive reaction and 1 representing a negative reaction. The survey questions addressed students' self-efficacy for biology content, their values regarding biology, and their sense of belonging within the campus and within STEM. The full survey is shown in the appendix. One survey was conducted during the first week of class with another at the end of the quarter to measure changes in students' beliefs and values.

The *Self-efficacy* subscale was the mean score of the following questions: 1. It is easy for me to understand biology content, 2. I will probably have problems understanding much of what's in this biology course this quarter (reversed), 3. I am not particularly good at understanding the biology lectures & slides that I read (reversed), 4. I understand what I read in biology well, 5. It is not always easy to understand the biology lectures & slides that I read (reversed), 6. Most of the others in my class are probably better than me at comprehending biology content (reversed), 7. I will not have problems understanding even the most difficult biology content this school year. 8. I feel confident that I can succeed in my biology course. All eight questions were surveyed on a 7-point Likert scale, with 7 strongly agreed and 1 strongly disagreeing. This subscale's reliability had a Cronbach's alpha of .90.

The *biology value* measure was the mean score of the following questions: 1. Even though it can be difficult to understand the content of this biology course, I think it is important to understand it. 2. I really have no use for understanding the concepts in this biology course (reversed). 3. I think it is always important to understand what I read biology. 4. Good reading comprehension is useful in biology. 5. I really like to understand the concepts and terms that I read in biology. 6. Compared to other things that I do at school and

in my free time, understanding biology content is not so important for me (reversed). 7. A strong understanding of biology content is useful to get a good job. 8. To understand a biology lecture & slide is not so important that I work extra to comprehend it (reversed). 9. I do not think it matters if I do not understand what I read in biology (reversed). 10. I have no use for understanding what I read in biology (reversed). 11. It is important to me to be good at biology. All eleven questions were surveyed on a 7-point Likert scale, with 7 strongly agreed and 1 strongly disagreeing. This subscale's reliability had a Cronbach's alpha of.87.

The *sense of belongingness* measure was the mean score of the following questions: 1. The biology department is a place where people care about one another. 2. I feel that I really belong in this class. 3. My instructor really cares about me and my learning. 4. My instructor helps me understand what I need to learn and how to be successful in my studies. 5. I feel like I am an important part of this class. 6. How much do you feel like you belong in STEM or are welcomed in STEM. 7. How well do you feel you are represented in STEM. 8. How well do you feel you are valued or belong in STEM. 9. I feel like I am an important part of UCI. 10. UCI encourages me to explore all sorts of career opportunities for after I graduate. 11. I feel like I have a lot of choices in what and how I learn. 12. I feel supported and respected at UCI and in my classes. All twelve questions were surveyed on a 7-point Likert scale, with 7 strongly agreed and 1 strongly disagreeing. This subscale's reliability had a Cronbach's alpha of.88.

Treatment of data

An additional question regarding whether students used a communications application outside of the standard classroom medium was posed. Seventy students answered they used either Google Hangouts or another application to supplement their communications. In order

to ascertain the effects of the treatment on the treated, we opted to utilize this self-reported app usage measure in our analyses instead of the enrollment data considering that the self-reported measure may be more indicative of student engagement with the app than simply enrolling into the intervention. Furthermore, these students did not differ in achievement or other demographic measures as shown in Table 1.

Results

RQ1: In addition to Canvas, do students engage with the course through social media applications and how?

The course consisted of 122 first generation and 70 non-first generation college students. Table 1 shows the mean scores of student grades, self-efficacy, value, and sense of belongingness both during the beginning and at the end of the course. All survey measures were measured on a Likert scale from one to seven. The mean final grade was 93.55 with a 9.23 standard deviation. The maximum score in the course was 104 due to the extra credit opportunities offered.

Table 1. Descriptive Data for Survey Items based on enrollment in Google Hangouts

	Enrolled	Not Enrolled	Overall	Enrolled	Not Enrolled	Overall
Measures						
Self-efficacy	3.90 (1.06)	4.12 (1.15)	3.98 (1.15)	4.16 (1.12)	4.52 (1.07)	4.30 (1.11)
Biology Value	5.41 (.87)	5.40 (.98)	5.38 (.90)	5.42 (.83)	5.44 (.94)	5.43 (.88)
Sense of Belongingness	4.83 (.88)	4.90 (.90)	4.85 (.92)	4.94 (.96)	4.97 (.97)	4.95 (.96)
Grades (percentage)				94.5 (7.74)	92.2 (11.5)	93.55 (9.23)
N						

Instructor led social-media app: A total of 145 students that is approximately 67% of the class enrolled into Google Hangouts section while 114 self-reported using an additional messaging application outside of canvas for the course as shown in table 2. The difference may be due to the fact that some students joined the group but never contributed or checked the Google Hangouts. Among those 145 students, 55 students made at least one post making a combined total of 197 posts during the quarter. Students who enrolled did not differ from those who self-reported usage in terms of first-generation status or achievement measures such as final course grades.

Table 2. Student enrollment and interaction with Google Hangouts

	Enrollment	Contribution
Yes	145 (67.44%)	55 (25.58%)
No	70 (32.56%)	160 (74.42%)

Enrollment refers to joining the GH group. Contribution refers to making at least one post within the GH group.

How students interacted on the app: To examine how students utilized the Google Hangouts platform to enhance their educational experience, we tabulated the participation

rate among students in the study along with the type of participation in Table 3. 25% of all students made at least one post in the Google Hangouts group. The majority of posts, 97 or 49%, were associated with course administration then social interactions, 72 or 36%, and with the least being posts related to content,29 or 15%, in the course. The instructor sent students a total of three course content related messages per week for 9 weeks in the course to stimulate discussions. It appears that students used Google Hangouts for a variety of purposes with a heavier emphasis on administrative goals such as due dates, office hours, and specific assignment requirements. A total of 25 students out of the 55 who posted in the Google Hangouts posted in two or more categories while the remaining thirty consistently posted the same type of posts.

Table 3. Descriptive Data of the Types of Interactions in Google Hangouts

Type of Post in GH	Total Posts	% of enrolled students with 1+ posts in category
Content	29	13.10
Administrative	96	26.90
Social	72	22.07

Student-Led Social Media Apps: To examine students' self-reported usage of messaging applications, Table 4 shows that 51%, (98) of the students did not use an additional app outside of canvas while 12.5%, 24, used Google Hangouts, 30.73%, 59, used something besides Google Hangouts, and 5.73%,11, used both Google Hangouts and another additional application. The students did not differ in their grades, sense of belongingness, self-efficacy, or value. Students utilized a range of other applications, Discord, FB Messenger, Whatsapp, Imessage, campuswire, and slack, with the majority stating that they used discord, 55, then Facebook messenger, 16. When asked why they preferred the other apps a student responded ''It (discord) might be better than Google Hangouts just because it has mini groups for specific questions!'' This suggests that the organizational features of the app may play an important role in student preferences.

Table 4. Student Self-reported application usage

Application	Frequency
No App	98 (51.04%)
GH	24 (12.50%)
Another app other than GH	59 (30.73%)
GH+another app	11 (5.73%)

RQ2: Does engaging with social media apps affect course achievement? Do motivational factors predict students' use of social media apps?

Table 5 categorizes students' grades, value, sense of belonging, and sense of self-efficacy both in the pre and post survey by first generation status and whether they utilized a messaging application. The descriptive data reveal that no significant difference exists between first generation and nonfirst-generation students. Furthermore, students who self reported usage of a messaging application did not differ in any measures from those who reported otherwise. Additionally, no significant changes were made in terms of self-efficacy, value, or sense of belonging between the beginning and end of the quarter.

Table 5. Descriptive Data for Survey Items based on enrollment in a social media app and first gen status

	Pre			Post			
Measures	Self-efficacy	Biology Value	Sense of Belongingness	Self-efficacy	Biology Value	Sense of Belongingness	Grades (percentage)
App+First gen	3.74 (1.08)	5.37 (.87)	4.84 (.81)	3.94 (1.14)	5.38 (.77)	4.90 (.98)	94.2 (7.69)
App+cont gen	4.16 (.98)	5.49 (.89)	4.83 (1)	4.54 (.98)	5.48 (.94)	5.01 (.92)	95.1 (7.88)
No App+firstgen	4.20 (.97)	5.48 (.98)	5.11 (.82)	4.45 (1.09)	5.48 (.94)	5.04 (1.06)	90.6 (10.5)
No App+cont gen	3.97 (1.44)	5.24 (.97)	4.51 (.94)	4.64 (1.04)	5.37 (.95)	4.84 (.79)	95.1 (12.9)

The correlation matrix among first generation status, enrollment into the study, self-reported use of a messaging app, grades, and the pre and post surveys for self-efficacy, value, and sense of belongingness can be found in table 6. Student's self-reported sense of self-efficacy is the only measure significantly correlated with final course grades pre-survey r=.26, post-survey r=.42. Additionally, self-efficacy both pre- and post surveys is correlated with sense of belongingness and value in the pre-survey and post-survey. First generation status, enrollment, and self-reported usage of social media apps were uncorrelated with any of the measures.

Table 6: Bivariate Correlations of Survey Measures
*=p<.05

	Grade	Self-efficacy	Value	Sense of belonging	Self-efficacy post	Value post	Sense of belonging post	First-gen
Grade	1							
Self-efficacy	0.258* (.002)	1						
Value	-.004 (.96)	0.396* (0.00)	1					
Sense of belonging	-.027 (.747)	.381* (0.00)	0.438* (0.00)	1				
Self-effiacy post	.417* (.00)	.626* (0.00)	0.247* (0.003)	.245* (0.003)	1			
Value post	.064 (.45)	.349* (0.00)	0.712* (0.00)	.697* (0.00)	.358* (0.00)	1		
Sense of belonging post	.108 (.201)	.288* (0.001)	0.288* (0.001)	.397* (0.00)	.329* (0.001)	.416* (0.00)	1	
First-gen	-.035 (.68)	-.097 (0.252)	0.004 (0.966)	.091 (0.283)	-.113 (0.184)	.029 (0.737)	.064 (0.452)	1
Otherapp	.104 (.219)	-.099 (.245)	.009 (.911)	-.037 (.664)	-.125 (.141)	.032 (.71)	-.052 (.539)	.003 (.976)

To examine the impact of this intervention on students' sense of self efficacy, sense of belonging, and value of biology among the subsample of students who utilized Google Hangouts, we calculated a 2 (first-gen status) X 2 (sense of belonging) X 2 (used other apps or not) repeated measures ANOVA, with sense of belonging as a repeated measure, revealed that all children showed no significant growth in sense of belonging throughout the quarter, $F(1, 137) < 1.6$, *ns*. There were no significant differences between the first-gen groups, $F(1, 137) < 2.6$, *ns* or the use of other applications with no interactions between first-gen and other app use being significant, $F(1, 137) < 2.6$, *ns*. Additionally, a 2 (first-gen

status) X 2 (self-efficacy) X 2 (used other apps or not) repeated measures ANOVA, with self-efficacy as a repeated measure, revealed that all children showed no significant growth in self-efficacy throughout the quarter, $F(1, 137) < 1$, *ns*. There were no significant differences between the first-gen groups, $F(1, 137) < 1$, *ns* or the use of other applications with no interactions between first-gen and other app use being significant, $F(1, 137) < 2$, *ns.* Finally, a 2 (first-gen status) X 2 (value) X 2(used other apps or not) repeated measures ANOVA, with value as a repeated measure, revealed that all children showed no significant growth in value throughout the quarter, $F(1, 137) < 1$, *ns*. There were no significant differences between the first-gen groups, $F(1, 137) < 1$, *ns* or the use of other applications with no interactions between first-gen and other app use being significant, $F(1, 137) < 2$, *ns*

Additionally, we performed a regression analysis to examine student achievement as a function of their self-efficacy, value, and sense of belonging all at the beginning of the quarter, first gen status, and whether they used a communication app outside of canvas. The regression presented in table 7 shows that self-efficacy predicted final grades in the course ($\beta = .35$, $p < .01$) and accounted for .11 change in r2 for the overall model. The other measures including Google Hangouts enrollment and use did not impact student grades.

Table 7: Multiple Regressions Predicting Grades and Self-efficacy

	Grade (1)	Other Social Media Usage (2)
Pre-Self-effiacy	.36*** (.093)	-.12 (.05)
Pre-Value	-0.09 (.087)	0.06 (.05)
Pre-Sense of belongingness	-.09 (.094)	-0.02 (0.05)
First-gen status	.018 (.162)	-0.007 (0.09)
Other social media app usage	.14* (.16)	N/A
Enroll in GH	.05 (.19)	N/A
Contribution in GH	-.155* (.187)	N/A
Cons	-.315 (.30)	1.62 (.07)
R^2	.128	.013

All coeffecients are standardized. Standard errors are in parenthesis. *=p<.10,**=p<.05, ***=p<.01

To examine the factors that predict students' self-reported use of social media applications, a linear regression was conducted. Results revealed that first-generation status, self-efficacy, value, sense of belongingness at the beginning of the quarter did not predict students' engagement with social media applications.

Discussion

Our study utilized Google Hangouts as a supplemental communications venue for undergraduate students in a general education STEM course during the online instructional

phase of the Covid-19 epidemic. Our key goals were to examine the utility of a supplemental communications application, Google Hangouts, in an online STEM course. We aimed to explore the effects of utilizing Google Hangouts on student achievement, self-efficacy, sense of belonging, and value of STEM. Furthermore, we investigated how students engaged with each other on Google Hangouts in terms of social activity, administrative activity, and course content related activity.

In order to explore our goal of understanding student engagement with online communications tools, we examined, in addition to Canvas, how students engaged with the course through social media applications**.** We found that more than two-thirds of the students voluntarily joined the instructor-formed Google Hangouts chat group. However, only 38% of those who joined the chat group made at least one post. The low participation rate in the current study contrasts with that of He and Huang (2017), who found that students reported that Google Hangouts created a greater sense of community in their classes. Indeed, students' limited engagement in the chats was primarily related to course administration, with some posts being social, and the fewest posts associated with course content. These results corroborate the decreased student engagement and decreased effectiveness of lectures in general education STEM courses during the pandemic (Perets et al., 2020). The low student participation rates may be associated with the decline in emotional engagement and large declines in positive attitudes about learning science that occurred during the pandemic (Wester et al., 2021). Alternately, the Google Hangouts application may not be as well suited for promoting student engagement and social interactions. This is in stark contrast to other studies that have utilized social media applications such as Facebook to increase interaction and communication with students, improve social relationships, increase participation, and enhance student motivation (Dougherty & Andercheck, 2014; Lam, 2012). Our results reveal that the pandemic environment may be prohibitive to increasing student interactions through

social media applications and/or that Google Hangouts was an inefficient platform for our case to engage students in a general education STEM course when applied with minimal instructor input.

Our study also examined if engaging with Google Hangouts contributed to students' efficacy, sense of belonging, value of STEM, and achievement. We found that the Google Hangouts app usage did not significantly improve students' sense of belonging, self-efficacy, or value of biology. While our findings were consistent with other studies that either failed to find growth or found decreases in student motivation, efficacy, or sense of belonging in their fully online STEM classes during the COVID-19 pandemic (Almoayad, Almuwais, Alqabbani, & Benajiba, 2020; Patricia Aguilera-Hermida, 2020; Usher et al., 2021; Wester et al., 2021), they diverged from those involving in-person instruction (Bowman & Akcaoglu, 2014; Doughery & Andercheck, 2014). In contrast, when social media apps such as Facebook were incorporated with in-person instruction, using Facebook to interact with peers was associated with higher grades and a greater sense of belonging in large, undergraduate classes (Bowman & Akcaoglu, 2014; Dougherty & Andercheck, 2014). The online interventions that were successful with in person instruction may not transfer to online instruction. Social media was an additional way for students to connect with in-person instruction. However, providing an additional way of virtually connecting with a class that is already online may not provide the same necessary human connection.

Despite the lack of change throughout the course, students' self-efficacy was predictive of course grades. This is consistent with prior research that has shown both initial self-efficacy and growth in self-efficacy throughout an academic year as predictors of student achievement (DiBenedetto & Bembenutty, 2013; Vogel & Human-Vogel, 2016). Enrollment into Google Hangouts did not increase students' self-efficacy.

To further examine the contributing factors to students' engagement with social media, we determined that students' sense of belonging, their value of biology, and self-efficacy were not predictive of students' social media usage in the course. Thus, these motivational measures appear to be unrelated to social media use in the classroom. This study suggests that implementing text based social media into a classroom may not enhance outcomes for students aside from their enjoyment. Our implementation of Google Hangouts was ineffective at enhancing course outcomes and motivation among students.

The fact that this intervention occurred during the pandemic and the class was solely online may also have impacted student engagement. Students may have experienced a digital burnout from the overuse of computers and smartphones and the multiple forms of online communication from zoom, discussion boards, and recorded lectures to take on an additional communications tool (Mheidly, Fares, & Fares, 2020). The concept of Zoom fatigue has been well documented and was increasingly prevalent during distance learning throughout the pandemic (Islam, Kim, & Kwon, 2020; Nadler, 2020; Peper & Yang, 2021).. Additionally, students were free to join the Google Hangouts group chat and thus some self-selection mechanisms may be at play despite us seeing no differences in baseline measures between those who joined and those who did not.

Limitations and future directions

Digital tools can be used to foster greater collaboration between students but examining the affordances of the platforms and the challenges and limitations of the platforms prior to implementation is essential. Google Hangouts was less effective and less appealing than something like Facebook. In one randomized control study, Facebook was used as an additional communication tool for treatment students. Facebook was thought to simplify the instructor's communication with students, as treatment students showed better course performance than their peers in the business-as-usual condition (Guo et al., 2018).

Many students opted to create their own chat groups on other applications such as discord exemplified the importance of the affordances of the tools used. It is likely that students felt Google Hangouts was not attractive and was a bit too academic because it was associated with their university email accounts. Thus, it turned into a communications tool for administrative tasks instead of a place for social interactions. We conducted a similar study with the same format with the same instructor in the same course before the shift to online instruction utilizing Facebook messenger as the communications tool of choice and found much higher levels of participation among students in terms of posting. Additionally, students mainly used Facebook messenger for social posting and reported high levels of enjoyment of integrating the application into the course. Finally, students' social posts were associated with their course outcomes in that study. Thus, these vastly different results may either be a result of the shift to purely online instruction or an issue with students opting to avoid the Google Hangouts application for social uses. Furthermore, other studies have revealed that Google Hangouts was more useful for improving student satisfaction and than academic outcomes (He & Huang, 2017). If instructors want to use social media such as Google Hangouts in less formal ways then they may want to use platforms students are already engaging in and already using.

Future studies should utilize a randomized control design to incorporate different types of social media applications such as Discord, Facebook Messenger, or Google Hangouts to compare student engagement rates and the efficacy of these tools to enhance student socialization and learning. The body of literature regarding if social media applications could enhance student learning is rather large and has been answered. However, our study supports the notion that examining the affordances of the different types of applications and how they can be leveraged is an important and integral aspect to effective integration within the classroom.

Conclusion

We found that students did not engage heavily with the supplementary addition of Google Hangouts as a communications resource in a university STEM course. Additionally, the use of Google Hangouts did not enhance students' sense of belonging, self-efficacy, or value of biology. Our results reveal the importance of platform selection if instructors wish to add an informal social media application in their classrooms. Previous studies have found Google Hangouts to be effective when used as more than a messaging tool. Additionally, a very similar previous study utilizing Facebook messenger found drastically different results. Thus, both the platform and the approach utilized with the social media tool are important to consider before implementing a supplementary social media resource.

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Appendix

1. It is easy for me to understand biology content.

2. I will probably have problems understanding much of what's in this biology course this quarter.

3. I am not particularly good at understanding the biology lectures & slides that I read.

4. I understand what I read in biology well.

5. It is not always easy to understand the biology lectures & slides that I read

6. Most of the others in my class are probably better than me at comprehending biology content.

7. I will not have problems understanding even the most difficult biology content this school year.

8. I easily lose interest when biology lectures & slides are difficult to understand

9. Even though it can be difficult to understand the content of this biology course, I think it is important to understand it.

10. I really have no use for understanding the concepts in this biology course.

11. I think it is always important to understand what I read biology.

12. Good reading comprehension is useful in biology.

13. I really like to understand the concepts and terms that I read in biology.

14. Compared to other things that I do at school and in my free time, understanding biology content is not so important for me.

15. A strong understanding of biology content is useful to get a good job.

16. To understand a biology lecture & slide is not so important that I work extra to comprehend it.

17. I don't think it matters if I don't understand what I read in biology

18. It is particularly fun to read biology lectures & slides when I understand them well.

19. I have no use for understanding what I read in biology.

20. It is important to me to be good at biology.

21. I feel confident that I can succeed in my biology course.

22. Which of the following best describes your study patterns? I most often space out my study sessions over multiple days/weeks or I most often do my studying right before the test

25. Select the top 3 study strategies you use most regularly. Please select ONLY 3.

Test yourself with questions or practice problems Use flashcardsReread chapters, articles, notes, etc.Underlining or highlighting while reading

Recopy your notes word-for-word Condensing/Summarizing your notes Recopy your notes from memory Make diagrams, charts, or pictures Study with friends

Absorbing lots of information the night before the testWatch/listen to recorded lessons either by instructor or from outside source (Khan Academy, Youtube, etc.). Other

26. The biology department is a place where people care about one another.

27. I feel that I really belong in this class.

28. My instructor really cares about me and my learning.

29. My instructor helps me understand what I need to learn and how to be successful in my studies.

30. I feel like I am an important part of this class. I feel like I am an important part of UCI.

31. UCI encourages me to explore all sorts of career opportunities for after I graduate.

33. I feel like I have a lot of choices in what and how I learn.

34. I feel supported and respected at UCI and in my classes.

35. I enjoy studying biology

36. How much do you feel like you belong in STEM or are welcomed in STEM *

37. How well do you feel you are represented in STEM

38. How well do you feel you are valued or belong in STEM.

39. Are you a first generation college student?

40. Did you join other messaging groups for this course e.g. (FB Messenger, Discord, Whatsapp, Imessage)?

41. If you used another messaging app, which one did you use? Put N/A if you answered no to previous question.

CHAPTER 5

Discussion and Conclusion

Technology and Social Connectedness

This dissertation aimed to examine how technology could be leveraged to enhance undergraduate students' social connections and achievement in science courses. Strong STEM education is vital to keeping America competitive in the modern age. In addition to the increasing surge of jobs within the STEM fields (Langdon, McKittrick, Beede, Khan, & Doms, 2011), STEM education is beneficial even for students who are not STEM majors. Indeed, scientific literacy is an essential and necessary element of being an informed citizen within society (S. Lee & Roth, 2003). In order to tackle the current social and environmental issues facing the world, students must first be able to understand and evaluate scientific knowledge to make informed decisions (Hodson, 2003).

Despite the importance of STEM, there are concerns regarding students' progress in learning in this area. First-year college students tend to enter college with a limited understanding of science's nature, showing high levels of belief in pseudoscience (Impey, Buxner, Antonellis, Johnson & King, 2011). With only 18% of the bachelor's degrees awarded in 2015-16 in STEM fields (NCES, 2020), the overwhelming majority of college graduates are not required to take more than one or two science courses to fulfill general education requirements. This is concerning, as non-STEM majors have been found to show minimal, if any, growth in their understanding of science's nature during their college careers, and they remain no less susceptible to pseudoscience upon graduation (Impey et al., 2011; Moore & Rubbo, 2012).

Given that students, particularly non-STEM majors, tend to show little growth in their scientific literacy, greater attention in the field has focused on how to improve student

learning (Impey, 2013; Moore & Rubbo, 2012). Although numerous factors impact STEM learning, this dissertation focused on the role of motivation, using the expectancy-value theory as the theoretical framework. The expectancy-value theory argues that an individual's choices, performance, and persistence on a task may be explained by their beliefs regarding how much they value the task and how well they believe they will perform (Wigfield & Eccles, 2000). These expectancies and values are in turn influenced by an individual's goals, self-schemata, personal and social identity, and self-concept of abilities. Individuals also evaluate a cost component when performing a task, such as how much time and resources it would take to accomplish it. An individual's sense of belonging is directly associated with social support, which can influence the emotional costs of performing a task by alleviating stressors (Friedlander et al., 2007; M. Te Wang & Eccles, 2012). Furthermore, their sense of belongingness can influence their social identity, thereby affecting the attainment value for a task (Cameron, 2004). Thus, fostering social connections may lead to increased motivation resulting in enhanced learning outcomes for students. This dissertation focused on the social connectedness component of the theory in the first two studies by exploring student collaboration in group assignments and their patterns of use on a social media application. The final study elaborated on the role of social connectedness through technology in relation to the expectancy-value theory.

This dissertation aims to focus on leveraging social elements to improve student development and outcomes in STEM courses. This dissertation utilizes a motivational theory framework that combines the role of social connectedness and self-efficacy to examine and increase student engagement with STEM. A person's sense of belonging within a group or field can create socially shared goals around a task and lead to higher achievement motivation (Walton et al., 2012). Furthermore, motivation is a product of a person's expectations for success and the value of a task (Wigfield & Eccles, 2000). Thus, creating

social connections may impact aspects of self-efficacy, which is contained within expectations for success and the value of a task. Technology is an ideal medium to utilize to increase student motivation and social connections. Mobile technology incorporation has been shown to increase student motivation and social presence (Rau, Gao, & Wu, 2008). The ability to access these mobile learning tools from any location and allow the user to feel free to learn at their own pace encourages motivation and engagement (Kerawalla et al., 2007; Livingstone, 2007). Additionally, social media use has been linked to increasing students' sense of belongingness (Pang, 2020). Thus, many studies have integrated social media into the classroom to enhance student motivation and support greater student problem-solving (Mondahl & Razmerita, 2014; Yunus et al., 2012). By leveraging digital tools, instructors can improve student motivation and social connectedness, ultimately leading to greater learning in their STEM courses.

Collaboration

The social connectedness construct encompasses students' satisfaction with interpersonal relationships and social groups and consists of multiple elements that include a sense of belongingness and integration within a group (Farrell, Jorgenson, Fudge, & Pritchard, 2018). Social connectedness was examined through both a collaborative and social media facilitated perspective. We examined students' integration within groups by operationalizing it as how equal their contributions were and how they shared responsibilities and comingled ideas within a group setting. Collaborative learning has been shown to improve learning and help teams achieve a higher level of thinking than individuals (R. T. Johnson & Johnson, 1994; Loh & Ang, 2020). In addition to the academic benefits, collaborative learning also provides affective, emotional, and social competence lessons (Loh

& Ang, 2020). These are all important elements for student learning in the STEM fields, as collaboration is highly prevalent in the workplace beyond the classroom.

This dissertation examined science writing in groups in a collaborative upper-division science course. Students worked collaboratively through a series of writing assignments using Google documents. Google docs was particularly well-suited for collaborative writing because of its affordances. Google docs is a free online word processor that allows users to share, edit, comment, and work on a single document collaboratively. It provides great flexibility in that it can be used synchronously or asynchronously. Furthermore, the tool allows students to comment and revise each other's writing and includes a historical log of all revisions on the document. These affordances provided a solid rationale to incorporate Google docs as a digital collaborative tool of choice.

This dissertation's collaborative group writing study using Google docus found that students equally distributed their workload without instructor input. Furthermore, the students mainly opted to use a parallel construction approach, in which the writing was divided up into sections for each member to complete. Overall, group writing assignments that showed more balanced collaboration or more equal contributions of individual members were associated with higher quality content and form. The equality of contributions to the essay between group members was predictive of science vocabulary use, syntactic simplicity, and text referential cohesion. That is, as group members' contributions became more balanced, their assignments reflected richer use of scientific vocabulary and greater overall cohesion throughout the text despite the use of a parallel construction approach.

These findings are consistent with other studies utilizing Google docs as a collaborative writing tool. Collaborative writing through Google docs was associated with higher perceptions of writing quality by students that were linked to perceived learning (Blau

& Caspi, 2009). Further, using Google docs for collaborative writing has led to superior writing outcomes than face-to-face collaborative writing (Suwantarathip & Wichadee, 2014).

Google docs may foster greater learning by promoting increased student interactions focused on the task at hand (Ishtaiwa & Aburezeq, 2015). Google docs helps facilitate multimodal leadership among a single group member while allowing non-leaders to contribute collaboratively (Olesen, 2020). Furthermore, Google docs may be more flexible than face-to-face collaborations, as it enables students to collect their thoughts when working with peers, work directly with peers, or work independently on a section while others worked together (Jung et al., 2017). Thus, the literature suggests that students can produce a higher quality written product between the increased student interactions and the collaborative structural enhancements between group members. This was supported by the results from the dissertation's study on collaborative group writing in which groups that worked together equally had greater use of science vocabulary and analytical thinking. Particular group engagement patterns such as greater peer edits were correlated with unequal contributions between group members. This suggested that a minority of the students were making the majority of the changes. Furthermore, the peer edits were mostly replacement or removal of simple words without linking the edited content back to the main text and likely decreasing the quality of the essay. Thus, groups with greater equality of contributions, and likely more organized and greater interactions, had more science vocabulary use and higher levels of analytical thinking in their writing. This phenomenon in which the more balanced contribution groups have more analytical content suggests that greater learning occurred for more students since everyone contributed some element to the final work. Additionally, group members would likely feel more integrated and more satisfied with the group, as each individual's ideas and work were included in the final product, as opposed to having an entire essay comprised of work from only a few key members.

Increasing Social Connectedness through Social Media

Other tools that can be used to facilitate social connectedness between students include social media applications. These social applications have numerous affordances that range from their prevalence, with 68% of American adults using Facebook alone (Pew 2018). Furthermore, social media has been integrated into the classroom as supplemental tools for communication that served as a venue for networking, a safe haven for expression, and learning communities (Rambe, 2012). Social media use has been associated with collaborative learning practices that moderate academic performance for college students in Malaysia (Al-Rahmi, Othman, Yusof, & Musa, 2015). When schools foster environments where students can utilize social media for collaborative purposes, students demonstrate improved academic outcomes. Prior research demonstrated that Twitter usage among students demonstrated a positive correlation with course engagement, as shown through sharing of information and social exchanges (Evans, 2014). Similarly, Twitter use in a medical school neuroanatomy course boosted student morale and provided a support network for students (Hennessy et al., 2016). Twitter as a platform helped foster communication among students who reported reduced anxieties. This supportive communication between students is reminiscent of the trust-building process in a community of practice.

This dissertation has included two studies utilizing two different social media applications, Facebook Messenger and Google Hangouts, and yielded mixed effects on student social connections. Both studies included similar methodology, with the instructor creating a voluntary forum within the social media applications for students to join and interact with each other. Additionally, the instructor periodically posted course content-related questions within the forums to generate discussion and critical thinking. Both studies were conducted in lower-division, general education biology courses and did not alter student grades based on enrollment into the social media applications.

When Facebook Messenger was used as a supplemental communications resource, the nature of interactions between students within Facebook Messenger were predictive of their grades, with social engagement between peers being positively predictive. This study provided insight into how students freely engaged with each other and its relation to their academic outcomes. It showed that the addition of social interactions could lead to enhanced outcomes for students. Social posts on Facebook Messenger were predictive of student performance, while posts that focused on administrative concerns, such as deadlines, or course-specific content, did not. These results demonstrate the value of social engagement among students and align with previous research that suggests that students who could easily make friends in their academic programs had higher grade point averages (Melnick, Kaur, & Yu, 2011).

This study reinforces the notion that student engagement is linked to achievement, as demonstrated by previous studies focused on discussion forums instead of social media (Carceller, Dawson, & Lockyer, 2013). However, we expanded on this research by explicitly identifying that the type of engagement is more relevant than the number of posts, with social engagement being the primary predictor of achievement. These purely social contributions by students on Facebook Messenger had more impact on grades than discussing course content or assignments and deadlines. This particular impact may be due to the enhanced social connectedness that students who socially interacted on the app received, resulting in greater motivation and enjoyment in the course. For example, we found that both Facebook Messenger usage and students' self-reported enjoyment from using the application predicted their motivation in the course. This increased motivation may have contributed to their improved performance in class.

Additional research has shown that social media can be applied effectively in the classroom. When professors uploaded course content and engaged with undergraduate

students on Facebook for educational purposes, students' frequency of use of Facebook positively correlated with their academic performance (Lambić, 2016). Students utilized the Facebook group to expedite gathering academic information, leaving them with more time and energy to engage with the course content. Students could share resources such as links to clarify information, ask and answer each other's comments, and "like" specific questions to indicate that the material was helpful. They also shared their projects with the group in order to receive feedback. Students' perceptions of the usefulness of Facebook greatly impacted their decision to utilize it as a learning tool. Furthermore, general social media use did not impact academic outcomes (Lambić, 2016). Additionally, social media such as Facebook and Twitter have been leveraged in university settings to improve students' sense of belongingness (Dougherty & Andercheck, 2014; Friess & Lam, 2018).

In contrast, the Google Hangouts study found a much lower level of social engagement among students and found that social posts were not associated with course outcomes like in the previous Facebook Messenger study. Instead, we found that Google Hangouts use did not impact students' motivational factors or course outcomes. Furthermore, self-efficacy, value, and sense of belongingness at the beginning of the quarter did not predict social media use at the end of the quarter.

One reason for these discrepant findings may be that this study was conducted during the pandemic, with entirely online instruction. Thus, online social connectedness may function differently when a course is online rather than supplementing an in-person format. Including a supplemental communications tool in an in-person course could enhance relationships already formed in person. The same social bonds may not be found if students never had the opportunity to meet each other and form relationships that the social media applications might augment. This was evident from the lower student participation in the courses' social media for Google Hangouts compared to Facebook Messenger. Google

Hangouts had a 67% enrollment rate compared to the 82% enrollment rate in the Facebook Messenger study. Furthermore, only 38% of the enrolled students posted at least once in Google Hangouts compared to 63% using Facebook Messenger. Alternately, this contrast may reflect the different affordances of Google Hangouts and Facebook Messenger. Google Hangouts, which does not have the option of hosting images or videos, functions as a chat group, whereas Facebook Messenger is a full-spectrum social media platform and may better foster social engagement. Thus, in addition to the online or in-person formats of the courses, the limited features of Google Hangouts may have impacted students' attitudes and engagement.

The divergent results between the Facebook Messenger and Google Hangouts studies show that changes in instructional mode and platform can impact student interactions with the tool. This complements previous research that showed that the benefits of discussion forum participation on student outcomes were more robust in blended learning classes than fully online classes (Carceller et al., 2013). Furthermore, these studies provide insight on the importance of selecting the appropriate digital tools for instruction under specific environments. This study suggests that the online learning environment requires different support structures than blended learning as student engagement differs in quantity and type. Furthermore, the relationships between engagement type and academic achievement shifted between the modes of instruction as well.

Student impressions

Students generally enjoyed both the Facebook Messenger and Google Hangouts resources. They found them useful and added an element of interactivity between the students and the feeling that the instructor was easier to reach. Students reported wanting the FB element in more courses. This is consistent with past research that generally supported the theory that students enjoyed utilizing social media in the classroom (Guo et al., 2018; Omar

et al., 2014). In the GH study, students created separate groups outside of GH via discord, suggesting a possible level of dissatisfaction with the platform. Furthermore, students' sense of belonging did not increase in the Google Hangouts study.

Although the Google docs collaborative science writing study did not include measures of student satisfaction, we did explore student interactions. Unsurprisingly, we found evidence of student frustration when student contributions were uneven. This free-rider effect often occurs when an inequitable contribution of work is a common concern in online collaborations (Chang & Kang, 2016). Thus, greater equality of student contributions not only supported student learning but also promoted student morale.

Pitfalls of Technology

There are some possible disadvantages associated with the utilization of technology presented in this dissertation. The Google docs collaborative element leaves room for inequitable group work and may be seen as unfavorable or unenjoyable by some students. This unequal distribution of labor can lead to decreased motivation (Loh & Ang, 2020). A solution for this issue could be utilizing tools like Author Viz, which makes individual contributions visible to instructors and participants alike. This greater accountability may encourage the less productive students to contribute their fair share.

The Facebook Messenger and Google Hangouts supplemental communications tools may have lower participation and unequal participation among students. More extroverted students would be likely to post more while others may opt-out entirely, creating two separate sections of students, although both studies have shown that enrollment does not impact grades. This is a common problem found in online discussion forums in which a few highly vocal students control the flow of the discourse and monopolize the discussion (Dooley & Wickersham, 2007). However, the loss of possible social interactions through opting out or

lack of access to technology may create a sense of alienation. The social media applications could be an additive resource for those who are already likely active participants in the course, thereby furthering the achievement gap. The results from both studies are correlational, so it could be possible that the students who are already more engaged are the ones enrolling and contributing more while the unmotivated and disengaged students are not. Thus, instructors could use these social media groups as an early indicator of students needing more encouragement and support.

Implications for Practice

The collaborative writing Google Docs study results reveal the value and importance of equally distributed group work in STEM writing. Thus, instructors should focus on implementing mechanisms promoting accountability and shared group work so that contributions are more equal among group members since this factor has been found to lead to greater science vocabulary use, which is a proxy for scientific knowledge. Increased accountability can be achieved through utilizing authorviz or other tracking software among students to monitor contributions. Additionally, creating opportunities and scaffolds for groups to come together during class could potentially result in greater equality of contributions and ultimately greater learning.

In contrast to Google documents use, there are some mixed results regarding whether social media use positively or negatively impacts academic performance. Some studies find no relationship between social media use and student GPA (Alwagait, Shahzad, & Alim, 2015; E. B. Lee, 2015). In contrast, others indicate that social media use and electronic media usage were negatively associated with grades (Jacobsen & Forste, 2011). Research suggests that the time college students spend on social media websites such as Facebook negatively predicted overall GPA (Reynol Junco, 2012). The effect was so large that time spent on

Facebook as a predictor was half as strong as high school GPA, the strongest predictor, in predicting college grades. Certain behaviors such as checking up on friends and sharing links were positively associated with GPA (Reynol Junco, 2012). In search of a possible explanation for this phenomenon, researchers examined how Facebook impacted time spent studying. Time spent on Facebook was negatively and weakly associated with time spent preparing for class, while time spent on Facebook chat was a stronger negative predictor of preparing for classwork (Reynol Junco, 2012). This suggests that there may be another mechanism other than losing studying time from using Facebook that negatively impacts student achievement. Thus, it is clear that social media is not a panacea for increasing student motivation and sense of belongingness. However, social media has also been effectively utilized to enhance student learning (Bowman & Akcaoglu, 2014; Yunus et al., 2012). It is important to note that faculty participation and integration of theoretical models with social media along with requiring participation often leads to enhanced outcomes (Reynol Junco, Elavsky, & Heiberger, 2013).

Thus, if instructors wish to implement social media, they must focus on integrating social media with theoretically driven pedagogy, require participation, and frequently engage with students. Simply, including social media platforms in the classroom as a supplement may lead to mixed results and can be highly dependent on the format of the class as well as the social media platform utilized. Integrating social media elements with collaborative tools in the classroom can result in greater sense of belongingness and enhanced academic outcomes with proper instructor preparation and guidance.

Limitations and Future Directions

All three studies were exploratory in nature and had some limitations. Because of sample size limitations, no true control group was present in the three studies to compare the

effects of the different interventions. The Google docs study could have benefited from a standardized essay format in which all groups were required to write the same essays during the same weeks instead of being allowed to select their format for each assignment as past research randomly has demonstrated that writing prompts can impact the compositional fluency of writers (Hudson et al., 2005). The comparison between the Facebook Messenger study and the Google Hangouts study is complicated due to the timing of global events. The Facebook Messenger study occurred pre-Covid and included in-person instruction, while the Google Hangouts study was solely online. Covid-19 related stress factors may have been present during the Google Hangouts study and confounded the results, as students may have been more preoccupied with caring for family and themselves.

Future studies should utilize a randomized control design to incorporate different types of social media applications such as Discord, Facebook Messenger, or Google Hangouts to compare student engagement rates and the efficacy of these tools to enhance student socialization and learning. Additionally, integrating problem-based learning activities and providing social media forums in conjunction with a digital collaboration tool such as Google docs would amplify the effects of each intervention by providing more mediums for students to interact with each other. The body of literature regarding whether social media applications could enhance student learning is rather large and answered. However, our study supports the notion that examining the affordances of the different types of applications and how they can be leveraged is an important and integral aspect of effective technology integration within the classroom.

Conclusion

Incorporating outlets for increased social connections between students can promote varying outcomes. For example, focusing on the collaborative elements within social

connectedness in conjunction with science writing between students has resulted in writing with greater science vocabulary use, and syntactic simplicity. Thus, focusing on promoting equal contributions among students and providing an environment conducive to collaboration is effective at enhancing student adoption of disciplinary literacy. Student social connectedness is associated with academic outcomes. Furthermore, fostering social communication between students via Facebook Messenger led to enhanced academic outcomes. However, simply adding an outlet for additional online communication in a fully online course may not increase students' sense of belongingness and social connectedness. The appropriate environment must already be present so that students opt to utilize the social apps to enhance their socialization as was shown in the Google Hangouts study which had lower participation rates in comparison to the Facebook study. Practitioners must consider how they implement online technology in their classroom, considering the mode of instruction and the structure it is delivered in to encourage socialization among students appropriately. Following the guidelines set by previous successful studies that have implemented social media effectively in the classroom is important to consider if the goal is to improve student learning along with course satisfaction (Reynol Junco et al., 2013). The three studies presented in this dissertation provide a window for the possible application of various technological tools to increase the quantity and enhance the variety of interactions between students within STEM courses.

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