Lindenwood University
Digital Commons@Lindenwood University

Dissertations Theses & Dissertations

Fall 12-2020

Exploring the Relationship Between Student Online Discussion-Board Activity and Student Grades

Frank Robert Talbott
Lindenwood University

Follow this and additional works at: https://digitalcommons.lindenwood.edu/dissertations

Part of the Educational Assessment, Evaluation, and Research Commons

Recommended Citation
Talbott, Frank Robert, "Exploring the Relationship Between Student Online Discussion-Board Activity and Student Grades" (2020). *Dissertations*. 73.
https://digitalcommons.lindenwood.edu/dissertations/73

This Dissertation is brought to you for free and open access by the Theses & Dissertations at Digital Commons@Lindenwood University. It has been accepted for inclusion in Dissertations by an authorized administrator of Digital Commons@Lindenwood University. For more information, please contact phuffman@lindenwood.edu.

Exploring the Relationship Between

Student Online Discussion-Board Activity

and Student Grades

by:

Frank Robert Talbott

A Dissertation submitted to the Education Faculty of Lindenwood University

in partial fulfillment of the requirements for the

degree of

Doctor of Education

School of Education

Exploring the Relationship Between

Student Online Discussion-Board Activity

and Student Grades

by:

Frank Robert Talbott

This dissertation has been approved in partial fulfillment of the requirements for the

degree of

Doctor of Education

at Lindenwood University by the School of Education

	12/11/2020
Dr. Kevin Winslow, Dissertation Chair	Date
	12/11/20
Dr. Robyne Elder, Committee Member	Date
Roger "Mitch" Nasser Jr	12/06/2020
Dr. Roger “Mitch” Nasser, Committee Member	Date

Declaration of Originality

I do hereby declare and attest to the fact that this is an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

Full Legal Name: Frank Robert Talbott

Signature: Frank Robert Talbott Date: 12/7/2020

Acknowledgements

For their help and support, I wish to express *heartfelt* gratitude to my dissertation dream team: Dr. Kevin Winslow, Dr. Roger “Mitch” Nasser, and Dr. Robyne Elder. Additionally, I wish to thank all of my family. I thank God for each of you!

Abstract

As students, instructors, and higher-education administrators delve further into cyberspace, scholarly literature and practice require further insights into the dynamics of online learning. This study examined the relationship between online student discussion-board activity and student grades and, consequently, addressed a dearth in the literature about this relationship. Student Involvement Theory provided the theoretical foundation of this research. This study's sample consisted of 200 online undergraduate students in online business-analytics courses. Regression-analyses findings supported the relationship between student postings of certain mathematical-symbol references (e.g., for equalities, inequalities, addition, subtraction, multiplication, and division) and student grades. Therefore, administrators, faculty, and course designers should consider the use of text-based discussions for all courses, online, traditional, and hybrid.

Table of Contents

Chapter One: Introduction

Over the past few decades, online higher-education classes increased in prominence. In examining trends in online education, Allen and Seaman (2013) stated, “Online enrollments have increased at rates far in excess of those of overall higher education. . . . The number of students taking at least one online course increased by over 570,000 to a new total of 6.7 million” (p. 4). Mulvaney (2020) acknowledged a dramatic increase in online education over the past 20 years (p. 88). Additionally, regarding the overall increase in number of online degree and course offerings, Mills, Knight, Kraiger, Mayer, and LaFontana (2011) reported that not only have colleges been offering an increased number of online courses, but colleges are also offering an increased number of online degree programs (p. 31). Accompanying the increase in enrollments and demand for online education is the need for research in the related areas. Notably, the online discussion board is a viable and, arguably, a vital component of online courses. Hence, the research of this study addresses the relationship between student discussion-board posting in online courses and student course grades.

The theoretical foundation for this research is Astin’s (1999) Student Involvement Theory (SIT), with the unit of analysis being the relationship between student input (i.e., in the form of discussion-board activity) and student output (i.e., student grades). According to SIT, greater student input leads to greater output. In the case of online discussions, this research posited that greater student discussion-board involvement leads to greater student performance.

In this study, mathematical symbols and Microsoft Excel references served as measures for discussion-board involvement. The specific mathematical symbols examined in this study were addition (+), subtraction (-), multiplication (x), division

(/, ÷), equality (=), and inequality (<, >, ≤, ≥). Additionally, if words replaced the mathematical symbols, then the word-symbol reference counted as mathematical-symbol usage. For example, if a student wrote the following, “five plus three equals eight,” then a single addition-sign reference counted and an equals-sign reference counted in the data analysis. However, if the student wrote, “love plus liberty equals true freedom,” then no mathematical-symbol reference counted because the word-symbol references were not in a mathematical context. These mathematical-symbol and Microsoft Excel references were predictor variables in this study’s regression analysis.

Any reference to Microsoft Excel functions counted as a separate data entity from that of mathematical symbols. For example, if a student typed a reference to Excel’s averaging function, then that reference counted as an Excel-function reference, not as a mathematical-symbol usage. These Excel-function references are predictor variables in this study’s regression analysis.

This study operationalized SIT inputs and outputs and analyzed the relationship between them, using quantitative statistical analysis. Regression analysis, the examination of Pearson’s Product-Moment Correlation Coefficient, and the examination of the Coefficient of Determination served as the statistical-analysis tools. The regression independent variables and dependent variables consisted of ratio data, with the independent variables measured as frequency counts and the dependent variables measured as a grade percentage (i.e., midterm exam score, final exam score, and course grade percentage). More specifically, the independent variables were as follows: number of mathematical symbols posted, number of references to Excel formulas, references to mathematical functions, and references to mathematical formulas. Thus, student discussion-board activity, operationalized by counting math-symbol and Excel references, measured student involvement.

For this study, student grades served as a measure of student performance in academic achievement. For this study's regression analyses, student grades were the dependent variable, with student-grades examined as percentages, not as letter grades. Moreover, the key focus of this study examined the *relationship* between each independent variable (i.e., mathematical references, and Excel-function references) and the dependent variable (i.e., midterm exam score, final exam score, and course grade as a percentage).

Although research seems warranted in examining discussion-board content for any course that uses online discussions, this research focused upon the discussion-board posting of purely online classes. Neither traditional face-to-face courses, nor hybrid courses (i.e., partly face-to-face and partly online) served as the focus of this study. Furthermore, this research examined discussion-board content postings within the direct environment of online classes. For example, the online courses in this research used Canvas as the Learning Management System (LMS), and this study focused upon the text-based postings made within the Canvas discussion boards. This study excluded all other discussions (e.g., Facebook posts, email messages, phone-text messages, online chatroom discussions, and face-to-face discussions, etc.) from the unit of analysis.

Background of the Problem

Online education is in its infancy, when compared to the backdrop of hundreds of years of higher education. Kentnor (2015) stated that distance education dates back to the 1700's (p. 22). In contrast, the Internet and the World Wide Web (i.e., the platform technologies for online education) date back to the 1960's and 1990's, respectively.

Given this relative newness and importance of online learning, educators need insights into this online learning environment. A number of vital questions demand answers to improve and to help ensure the efficacy of online learning. What is the most efficient and effective means of teaching in online environments? Should instructors teach online classes in the same manner as those of traditional classes? Should online instructors teach classes in a different manner, perhaps even drastically so? Are online students a substantively different type of learner than those who take traditional courses? Thus, questions about online learning environments abound and can branch and sprawl in infinite combinations. Yet, though infinite, these questions unite at the point of learning, and thus, this study focused on an important point of learning for online classes: student online discussion-board activity and its relationship to student performance. Moreover, this study examined mathematically relevant content of online discussions vis-à-vis student grades.

Purpose of the Dissertation

The purpose of this project was to examine the relationship (or lack thereof) between student involvement in online discussion boards and student performance. The researcher examined *anonymized* student posts in online discussion boards (from concluded courses), counted the number of references to mathematical symbols or Excel functions, and compared those counts with student scores (i.e., grades). Anonymization protected student identities throughout this study. All anonymized student data from all classes was bundled together before counting the number of mathematical references. Finally, the researcher conducted regression analyses to compare the number of mathematical references to the anonymized student grades. All tests were conducted at the $\alpha = .10$ level of significance.

This research project contributes not only to research, but also to practice. Namely, this research contributes to the scholarly literature by providing further empirical support for Astin's (1999) Student Involvement Theory. Even in those cases of non-significant statistical findings of relationships, the knowledge of Student Involvement Theory is advanced. However, this study found a relationship between student discussion-board posting and student grades.

The findings from this study provide practical insights into the classroom and teaching methods. Through the insights of this research, online course designs might include a forum for online discussion, with the understanding that including online discussion provides an enhanced learning environment. Instructors could receive forewarning of student academic distress by examining lack-of-mathematical-involvement in online discussion boards. For instance, if an instructor notices a lack of mathematically substantive student posting early in a term, then that lack is an instructor's harbinger to potential student distress.

A number of researchers have acknowledged issues surrounding the technological and globalization impacts of the online developments in education. Patterson, Carrillo, and Salinas (2012) acknowledged technological changes, happening to education on a global scale, and the associated impacts on the classroom. Yang and Liu (2007) acknowledged the impacts of web-based virtual classrooms, which apply to global environments. Budevici-Puiu (2020) reported that globalization and new technologies cause substantial organizational change and have significant impacts upon higher education (pp. 350-351). Farber (2020) pointed out an important problem with globalization and higher education: "Globalization does not inevitably progress over time." (p. 410). In discussing the impacts of globalization upon education and culture, Korotkova et al. (2020) stated, one of the results of globalism is “the spread of mass culture beyond national borders” (p. 245). Thus, considering the impacts of technological change and globalization upon higher education, research and practice benefit from insights into online programs and online classes. Moreover, this study sheds light on the importance of the content of online discussion boards in math-based business courses. Furthermore, the findings might prove valuable for all math-based courses.

Hypotheses

The researcher examined the potential relationship between student input in online discussion boards (i.e., discussion content in the form of mathematical or Excel references) and student output (i.e., measured by student scores). The following are the research hypotheses:

H_1: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their midterm exam scores.

H_2: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their final exam scores.

H_3: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their course grade percentage.

H_4: There is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores.

H_5: There is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their final exam scores.

H_6: There is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage.

H_7: There is a positive relationship between the number of math functions that students reference in their online discussion-board posts and their midterm exam scores.

H_8: There is a positive relationship between the number of math functions that students reference in their online discussion-board posts and their final exam scores.

H_9: There is a positive relationship between the number of math functions that students reference in their online discussion-board posts and their course grade percentage.

H_{10}: There is a relationship between the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores.

H_{11}: There is a relationship between the number of Excel functions that students reference in their online discussion-board posts and their final exam scores.

H_{12}: There is a relationship between the number of Excel functions that students reference in their online discussion-board posts and their course grade percentage.

H_{13}: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores.

H_{14}: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their final exam scores.

H_{15}: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage.

H_{16}: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores.

H_{17}: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts and their final exam scores.

H_{18}: There is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts and their course grade percentage.

Limitations

The limitations of this study consisted of the use of a convenience sample, specific mathematical references, specific Microsoft Excel references, and student grades as a proxy for student performance. The use of a convenience sample was a limiting factor because this study examined data from one specific location, which included students selected from courses at a single private university in the Midwest. Furthermore, the sample consisted primarily of students from the researcher's own previously-taught courses, with two exceptions: two courses were taught by adjunct professors from the same university. Additionally, the cross-sectional research design precluded the establishment of causality. Yet, the cross-sectional data still provided key insights; some of the data revealed statistical relational significance. Thus, this study's key insights and the use of regression analyses warrant the use of cross-sectional data.

As another limitation, this research focused on a single aspect of discussion-board posts. Namely, this research directly examined specific (and limited) mathematical and Excel relevant content. Thus, this study was not exhaustive in its examination of math or Excel content in the discussion boards. For example, this study neither examined student attitudes toward math nor Excel. Thus, this study examined focused mathematical and Microsoft Excel aspects of the discussion-board content and was not an exhaustive examination.

Finally, student grades served to measure student performance. Arguably, in some cases, grades are an inadequate measure of student performance. For example, in the event that a student exercised academic dishonesty as a means of completing the course, then that student exhibited poor performance but might have received a good grade for the course if the student's dishonesty went undiscovered by the instructor.

However, this study neither focused on academic dishonesty, nor was academic dishonesty a controlling variable. Thus, academic dishonesty was beyond the scope of this study. A separate study is required to determine the potential dishonesty factors in online courses. For this study, the researcher assumed that academic dishonesty factors were similar to those of other online courses. Thus, this study focused on the examination of potential relationships between discussion-board posts and student grades, which were examined within the context of an online course, irrespective of extraneous factors.

Definition of Terms

- *Excel Functions* are formulas encapsulated into a grouped set of calculations that are called by a specific and unique name reference. For example, the following are Excel functions:
    - =AVERAGE()
    - =MEDIAN()
    - =SUM()
- *Math Functions* are encapsulated mathematical processes that take one or more inputs and have a single output.
- *Math Symbols* are symbols representing the basic mathematical operations of addition, subtraction, multiplication, division, and the use of exponents, as represented by the following symbols: +,-,x,/,^.
- *Online Course* is a course:
    - "that uses Lindenwood's Learning Management System to deliver instruction to students who are separated from the instructor and to

support regular and substantive interaction between the students and the instructor" (Lindenwood University, 2016, p. 2).

  - "in which all student work and other academic activities can be completed online" (Lindenwood University, 2016, p. 2).

- *Online Degree Program* is a "degree program in which 100% of the required courses may be taken as online courses" (Lindenwood University, 2016, p. 2).
- *Online Discussion Board:* For the purposes of this study, an online discussion board is defined as a text-based communication medium that occurs in an online course.
- *Online Post:* For the purpose of this study, an *online post* is defined as text or numbers typed into an online discussion board.
- *Online Posting:* For the purpose of this study, *online posting* is defined as the activity of creating an online post.
- *Student Involvement and Student Involvement Theory:* Astin (1999) defined student involvement as the "amount of physical and psychological energy that the student devotes to the academic experience" (p. 518). Further, Astin (1999) stated *how* a student behaves and *what* the student does "defines and identifies involvement" (p. 519).
- *Student Online Discussion-Board Content (SODBC):* For the purpose of this study, SODBC consists of the words or symbol references in a post.

Conclusion

Despite having a lengthy history, distance education is missing key insights in its scholarly literature for online learning environments. More specifically, the current literature lacks insights for certain content (i.e., mathematical or Excel content) for student online discussion-board posting vis-à-vis student performance. This study addressed that gap in the literature by building upon Astin's (1999) Student Involvement Theory, which posits a significant relationship exists between student input and student output.

This study presented 18 hypotheses directed at the unit of analysis (i.e., the relationship between student input and student output) and examined those hypotheses by using statistical relational-analyses tools. For H_1, H_2, H_3, H_4, H_5, H_6, H_{10}, H_{11}, and H_{12}, the researcher conducted (when applicable) simple linear regression analyses, in addition to examining the Pearson Product Moment Correlation Coefficients (r) and the Coefficients of Determination (r^2). For H_{13}, H_{14}, H_{15}, H_{16}, H_{17}, and H_{18}, the researcher conducted (when applicable) multiple regression analyses, in addition to examining the pairwise Pearson Product Moment Correlation Coefficients (r) and the Multiple Coefficients of Determination (r^2). Additionally, this study acknowledged the research limitations and presented definitions relevant to the aforementioned hypotheses.

Chapter Two: The Literature Review

One potentially significant component of online classrooms is online discussions. Yet, in searching the literature, one might soon notice a dearth in the literature for quantitative research of online discussions of mathematical- or Excel-referencing content vis-à-vis student performance. The following literature review discloses and analyzes the current state of research relevant to this study. Furthermore, this literature review discusses the following: the research associated with the online learning environment (e.g., distance education, online learning, online courses, online discussions, synchronous and asynchronous communications, etc.), the usage of mathematical symbols, Microsoft Excel references, self-efficacy and motivation, faculty training issues, demographic and academic background, and some concluding thoughts.

In this literature review, the researcher searched the vast array of educational journals, online journals, business journals, engineering journals, math and science journals using premier research databases (e.g., EBSCO, ProQuest, JStore, etc.). However, the current literature lacks student involvement (i.e., relevant to mathematical or Excel content) versus student performance in text-based online discussions. Furthermore, the literature, per se, acknowledged some of the shortcomings of research associated with online learning environments.

The Online Learning Environment

Online learning has increased its presence in academia at a brisk pace. In a report of online learning in the United States, Allen and Seaman (2013) stated that “for every year of this report series online enrollments have increased at rates far in excess of those of overall higher education” (p. 4). Considering Allen and Seaman’s report covered a ten-year period, the rate increases of online learning demand research attention.

Additionally, in some cases, online discussions might even replace or supplement traditional face-to-face classroom discussions. Extant research touts the viability of online discussions as an effective teaching tool (Baglione & Nastanski, 2007; Camus, Hurt, Larson, & Prevost, 2016; Dixon, 2014; Hamann, Pollock, & Wilson, 2012; Krentler & Willis-Flurry, 2005). Furthermore, the current literature examines various dimensions of online learning, number of discussion-board posts, asynchronous versus synchronous discussions, etc. Hence, the literature acknowledges the current state of online learning as growing and vital for higher education. Yet, the roots of online learning reach back centuries, beginning with distance education.

Distance-Education Background

The historical connections associated with online discussion boards link directly to the traditional classroom and to distance education. For centuries, traditional classroom discussions were a real-world phenomenon for the exchange of ideas. This exchange of ideas is critical to higher education, and the importance of this exchange is undiminished in the world of distance learning. Online programs stem from distance education, and for those online programs, discussion boards can replace the traditional classroom discussion, providing a venue for the exchange of ideas. The following discussion reveals links between discussion boards and the traditional classroom and distance education.

Online learning is a form of distance learning, spanning hundreds of years. The earliest form of distance learning, also known as distance education, consisted of mail correspondence, with students and instructors communicating solely through the mail. Early instructors created distance education based on the need for education to bridge distances, and the roots of distance education “can be traced back to as early as the 18th century" (Kentnor, 2015, p. 22). Students, who were remotely located, might not have had access to higher education. Thus, distance education provided the means for those students to be educated from remote locations. In the current age, distance learning covers the globe, with a vast number of courses taken via the Internet.

With the advent of the Internet, instructors discovered computer networking as a viable means of distance education, with universities and colleges "experimenting in online courses in the early to mid-1990's" (Kentnor, 2015, p. 28). Stadtlander (1998) acknowledged the increasing adoption of online learning by universities in the 1990's (p. 146). Also, during the 1990's, Banas and Emory (1998) noted the increase in online programs and aptly stated that the number of online students was "expected to soar" before the year 2000 (p. 365). Hence, institutions of higher education began offering online programs, as a form of distance learning. Consequently, online programs also offered discussion boards as part of some online courses, and online discussion boards are a potential replacement for traditional classrooms.

Online Learning

Online learning is a form of distance learning and consists of learning that occurs via the Internet. Although distance learning might preclude on-campus classrooms, online learning can occur on the campus that is administering the online program. Yet, online learning is a subfield of distance learning. Online learning is of such importance that numerous scholarly journals focus upon it. The following list is a sampling of the scholarly journals of online learning: *Online Learning Journal, ,The Journal of Interactive Online Learning, Learning, Journal of Educators Online, Online Journal of Distance Learning Administration, The Turkish Online Journal of Distance Education, Innovate, e-mentor, Internet and Higher Education, International Journal of Distance*

Education Technologies, International Journal of Web-Based Learning and Teaching Technologies, Journal of Interactive Online Learning, International Journal of Virtual and Personal Learning Environments, and *Proceedings of the International Conference on e-Learning.*

Recent research, as well as research from the early days of online learning, touted the effectiveness of online learning. Banas and Emory (1998) stated that research found no significant quality difference between distance and traditional learning (p. 368). Tanis (2020) reported effectiveness of online learning in a carefully designed online learning environment (p. 1). Tanis (2020) investigated and reported key success factors for online classrooms: "Students need an online instructor who is organized and communicative in the online classroom, and faculty need a solidly designed online classroom, with engaged students who are timely in their work" (p. 1). Although Tanis did not cite Astin's Student Involvement Theory, the presence of the theory is evident in Tanis' mentioning the importance of "engaged students who are timely in their work." (p. 1).

Thus, this study examined a significant swath of scholarly journals of online learning, in addition to examining scholarly journals in other fields: education, business, math, science, communications, etc. Despite the large presence of online-learning journals, extant literature revealed a paucity of research on the SIT relationships examined in this study. This study addresses the literature gap.

Online Courses

The literature proclaimed a growing demand for online-course offerings and services (Allen & Seaman, 2013; Mills et al., 2011). Wyman-Blackburn (2018) indicated that math instruction "continues to move further into digital territory" (p. 66). One educational-information-resources website stated, "Students have also begun to expect colleges and universities to provide more online services similar to those offered by other industries (such as banking and retail)" ("Current issues," n.d., "Student expectations for technology support and services," para. 1). As online programs and online discussions increase in depth and breadth, the enormity of the scope and impact of legal issues also grows. The implications reach far, and institutions of higher education must learn the legal issues associated with online discussions. As Boyer (1990) aptly stated, "Good teaching means that faculty, as scholars, are also learners" (p. 24). Thus, as the online learning grows, the implications of research and practice also grow.

Online environments present special options that might not exist in the traditional classroom. One study examined the usage of conventional static testing versus dynamic testing and found that "training with graduated prompts is effective in increasing the likelihood that children can solve series" (Touw, Vogelaar, Bakker, & Resing, 2019, p. 443). The study examined 164 children, using pre-tests and post-tests. Additionally, the researchers found that "training with graduated prompts is effective in increasing the likelihood that children can solve series completion problems accurately" (Touw et al., 2019, p. 443).

Online Discussion Boards and Content

An online discussion is similar to a discussion conducted in the classroom, at least in terms of content, although the methods of discussion differ. In a traditional classroom, an instructor speaks to the students, and the students speak either to the instructor or to other students. However, usually the dialogue is one-dimensional, with one conversation occurring at a time. That is, the instructor speaks and a student responds, or one student speaks to another. In a traditional classroom, parallel discussions (i.e., multiple conversations simultaneously occurring) can be noisy, chaotic, and unwieldy, unless students are broken into groups. However, with online discussion boards conversations can occur in parallel. The extant research covers various areas of discussion-board content.

Online discussions can occur in various media. Additionally, the literature reflects the existence of discussions in various media. According to Martínez-Cerdá, Torrent-Sellens, and González-González (2018), “The development of collaborative skills by online university students can be supported through several advanced tools for [information communication technology]-supported pedagogical practices” (p. 1067). Thus, the researchers found benefits to various approaches to online discussions. Therefore, the findings of this dissertation, though limited to text-based online discussions, might prove generalizable to online discussions via other media.

Another study examined the focus of online discussions of potentially sensitive material. Littlefield and Bertera (2004) examined the use of online discussions for courses related to social work and stated that “online discussion may be especially useful for sensitive or controversial subject matter such as oppression and diversity” (p. 132). Further, online discussion boards provide a convenient opportunity for anonymous discussions. Therefore, students may conduct sensitive discussions in confidence. In asynchronous online discussion boards, students can take time to consider, carefully, how they might want to share their thoughts, with less concern of making accidental or inconsiderate slips of the tongue. Thus, online discussion forums provide the opportunity for course-design considerations for the allowance of in-depth discussions of sensitive topics.

Online discussions exist in various platforms, not just within a proprietary learning management system. One set of researchers, Camus et al. (2016) researched the use of Facebook as an online discussion tool and examined effects on student participation, learning, and overall course performance. Camus et al. (2016) found that different types of discussion forums seem to effect “classroom dynamics and student learning in different ways” (p. 84). Namely, Facebook seems to be a good environment for students to connect and to participate; however, engagement in Facebook seems to be somewhat superficial, at least in some instances. Camus et al. (2016) stated that “the University-sponsored LMS [i.e., learning management system] may be a more effective tool for encouraging students to develop coherent argument and apply course content in other contexts” (p. 83).

Another group of researchers acknowledged Facebook, Twitter, and YouTube as a means to learn mathematics. António Moreira, Santana, and Bengoechea (2019) examined the use of YouTube as a supplemental means to learn mathematics. The researchers referred to social networking outlets as “digital education network[s] … open and non-formal, in the vicinity of a connected pedagogy, with free access to content and shared knowledge on the network, promoting ubiquitous learning in cyberspace” (António Moreira, Santana, & Bengoechea, 2019, p. 128). In the case of YouTube videos, the online mathematical discussions occur in the YouTube comments section, with the video creator “inviting interaction and / or responding to the comments sent for each content” (António Moreira et al., 2019, p. 122). Thus, although the main medium of YouTube is video, learning still occurs through the interactive discussion tools in YouTube (e.g., text-based comments or chats).

Some research delved into the social and online-presence aspects of content analysis of online learning. Henrikson (2020) examined the use of online lectures to promote student engagement. Henrikson examined the “relationships between teaching presence, social presence, and cognitive presence in online learning environments" (p. 17). The participants of the study consisted of twenty graduate students. The study analyzed content within the contexts of screencasts and discussion forums. The researcher acknowledged the importance of "social presence through participation and collaboration amongst participants" (Henrikson, 2020, p. 27). Furthermore, Henrikson recognized the interplay between "the self-directed nature of online learners and stages of cognitive presence that may change according to different learners' experiences" (p. 29). The researcher also acknowledged "the interdependence between cognitive, social, and teaching presence" (Henrikson, 2020, p. 21). An important conclusion specified that any "online learning structure should have many opportunities for students to maximize their engagement and learning. This interplay may be evident through learning opportunities such as presentations, group work, discussion forums, and other collaborative assignment" (p. 21). Henrikson's study underscores the importance of student engagement. The researcher concluded that it "is essential for online instructors to understand how to facilitate a learner centered online environment that increases engagement and cognitive presence by aligning practice with the theories of adult learning" (Henrikson, 2020, p. 28).

One study examined the potential of online discussion-board usage to improve the learning experience. Krentler and Willis-Flurry (2005) reported that "the incorporation of technology in the classroom does enhance actual student learning and that this relationship is moderated by student characteristics" (p. 316). The research constructs consisted of use-of-technology, student-learning, and individual differences, as a moderating variable. The specific moderators were Major, Class Status, Hours per Week on the Internet, and Term Type. The sample consisted of 549 students from six sections of principles of marketing. Online discussions were the learning-enhancing technology, and the researchers reported statistical significance, with $F(72.578, 38) = 3.48$, $p < 0.001$. The coefficient of determination yielded “24.6% of the variance in student learning was explained by the hypothesized model” (Krentler & Willis-Flurry, 2005, p. 318).

Krentler and Willis-Flurry’s research supports this dissertation, due to its direct link of student learning to an improved learning experience. The statistically significant findings provide empirical support for this dissertation. However, the research does not examine mathematical content of the discussion boards, which seems to be a dearth in the literature. Consequently, this dissertation is an extension of the research of Krentler and Willis-Flurry.

For another area of contrast, Krentler and Willis-Flurry used a single independent variable, moderators, and one dependent variable. Thus, the Krentler and Willis-Flurry study differed from this dissertation because this dissertation used multiple linear regression, in addition to simple linear regression, in exploring the relationship between student involvement and student grades. However, this dissertation did not contain moderators because they were beyond the scope of this dissertation’s goals.

Another set of researchers examined the use of video as a means to increase classroom-text discussion quality. One set of researchers concluded that teacher-video lessons “can provide a rich context for learning through coaching” because it is a means of capturing some of the complexities of traditional classrooms (Matsumura et al., 2019, p. 73). Video lessons can work as a “springboard for collaborative and reflective conversations” in online settings (Matsumura et al., 2019, p. 65). Hence, the video lessons serve as an anchor for the online text-based discussions.

Online Student Involvement

Student involvement theory is a prominent theory in academic literature. According to Astin (1999), student involvement theory relates student input to student output. Online student involvement is student involvement theory applied to online learning. Although much research supports Student Involvement Theory, relatively little research supports SIT relevant to online learning in higher education, especially as it relates to mathematical- or Excel-relevant content versus student grades.

Davies and Graff (2005) examined student involvement in terms of online participation and interactions. They examined 122 undergraduate students and analyzed student participation in online Blackboard communication and group-access versus student grades. The study examined overall online participation as a predictor of grade performance. The data spanned a one-year period, and Davies and Graff analyzed the data using a Kruskal-Wallis test to compare differences between online participation and grades. However, they did not find a significant link between online participation and type of letter grade. Yet, they reported a stark contrast between online participation and student pass or fail status. Although Davies and Graff (2005) shed light on participation versus student performance, the study did not provide insights on the content-type or quality of the participation versus student performance. Thus, their lack of findings for content-relevant student involvement in online discussions further justifies the need for the findings of this dissertation.

In the medical field, Wexler et al. (2020) examined women's use of online discussions to learn about maternal health, baby-related topics, and people/relationships (p. 1). Wexler et al. acknowledged that "90% of pregnant women utilize digital sources to supplement their maternal healthcare" (p. 1). The researchers found that pregnant women are not simply turning to online discussion groups for emotional support; rather, "pregnant women turn to online forums to discuss their health (e.g., labor, miscarriage, etc.) (Wexler et al., 2020, p. 2). The online members referred to the online discussion groups as birth-club forums. While the nature of Wexler et al.'s research is not within higher education, the findings tie directly to learning experiences. Furthermore, the findings suggest that online discussions in higher education might support learning in multiple dimensions.

Other health researchers examined online discussion forum content for issues related to bariatric surgery. The researchers' observational qualitative study aimed to "describe shared values, feelings, and thoughts among visitors to a web-based forum for those undergoing bariatric surgery" (Willmer & Salzmann-Erikson, 2018, p. 1). The content analysis yielded four themes of discussions from 498 posts: 1) a new life, 2) negotiating the system and playing the waiting game, 3) a means to an end, and 4) managing the attitudes of others (Willmer & Salzmann-Erikson, 2018, p. 1). Willmer and Salzmann-Erikson's study demonstrates the dynamic uses of text-based online discussion board. Thus, not only can text-based online discussions serve to transfer data and information, but they can also serve other purposes (e.g., moral support or strategizing).

Synchronous and Asynchronous Communication

Research has identified some strengths associated with synchronous versus asynchronous approaches to online discussions, which might call for course adjustments (Molnar & Kearney, 2017; Sage, 2013; Vess, 2005). Yet, each approach has its strength and weaknesses. Synchronous communication offers the benefit of rapid response. Asynchronous communication offers the benefit of convenience in communication and the opportunity to carefully formulate thoughts. Online discussions can benefit from the appropriate use of synchronous or asynchronous communication.

What is the difference between synchronous and asynchronous communication? Synchronous communications occur in in *real-time*. Real-time communications refer to communications linked to a single point in time, such that one point of communication *immediately* interacts with another point of communication. For example, real-time communications occur during phone conversations because the interactions call for immediate responses. In other words, one point of communication *synchronizes* with another point of communication.

Asynchronous communications do not require immediate responses -- time lapses may occur in asynchronous communications. For example, email communications and text messages occur asynchronously. Molnar and Kearney (2017) stated that “asynchronous discussion occurs with no set day or time, while synchronous decision occurs in real time” (pp. 14-15). In other words, one point of communication does not actively synchronize with another point of communication.

The literature revealed, on one instance, a strength of synchronous communication. Molnar and Kearney (2017) examined communication between two groups of students for a single online class and examined each group’s cognitive presence. The researchers defined cognitive presence as “the extent to which the participants in a community of inquiry are able to construct meaning through sustained communication” (Molnar & Kearney, 2017, p. 15). Both student groups addressed online discussion questions, with one set of students communicating synchronously (i.e., via video web conferencing) and the other communicating asynchronously (i.e., via online discussion board). The study reported a higher level of cognitive presence for the synchronous communication group. Additionally, higher levels of cognitive presence seemed linked to a higher level of critical thinking.

In another study, the researchers noted a positive experience with teacher's use of synchronous discussions. Cook, Dickerson, Annetta, and Minogue, (2011) researched in-service teachers' perceptions of online learning environments and found online discussions effective. However, "post-hoc analyses indicate that teachers participating in synchronous text chats perceive their online learning experiences more reflective, interactive, and supportive" (Cook et al., 2011, p. 73). Thus, synchronous discussion boards might be an effective option as part of an online course design. However, Dixon (2014) acknowledged the widespread use of online discussion, while also acknowledging the lack of online discussion *models* (p. 6). Thus, the literature, per se, acknowledged online-discussion research gaps. Therefore, course designers must be cognizant of the potential impacts of online discussion boards to their courses. Again, these gaps in the literature justify the need for the findings of this dissertation and for further research.

Online Student Experiences

Some students seem to learn better in some environments than in other environments. Some students might prefer an online environment, while other students might prefer traditional classrooms. The following discussion reveals some of the research findings of the strengths and weaknesses of online student experiences.

Several researchers reported positive findings regarding the usage of online discussions. Kayler and Weller (2007), in examining online discussion groups, found that "online communities of practice offer much to the learner in terms of cognitive and affective development and opportunities for growth as independent learners" (p. 144). To reiterate (i.e., relevant to the online student *experience*), Krentler and Willis-Flurry

(2005) examined the use of online discussion boards for enhanced student learning and found that "the incorporation of technology in the classroom does enhance actual student learning and that this relationship is moderated by student characteristics" (p. 316). Dengler (2008) found that online discussion forums increased the opportunities for student participation and "enhances the participation of students who may feel more inhibited to engage in discussions in a traditional classroom setting" (p. 481). Another set of researchers examined the online experience versus a traditional classroom for College Algebra and found that "there is statistical evidence that the mean of online section classes is higher than the mean of traditional section classes" (Graham & Lazari, 2018, p. 5). Furthermore, Graham and Lazari (2018) reported that "there was no statistically significant difference in [student] retention rate" (p. 1).

Some researchers found that online discussions are stronger than discussions held in traditional classrooms. Baglione and Nastanski (2007) stated that online discussions are superior to the traditional classroom in a few ways. Namely, students are able to "discuss complex subjects online. . . . [and have] increased time to research and reflect on ideas and have physical anonymity that may decrease inhibitions and foster broad participation" (p. 139). Thus, Baglione and Nastanski (2007) made the case that a higher degree of the availability for *thoughtfulness* that is present in the online discussion groups that is, likely, absent from the traditional classroom. Thus, an organizational concern, at least in terms of course design, is that introverted students might be more in favor of courses that contain an online discussion component. Additionally, advisers might apprise introverted students of the option of taking courses that have an online discussion component. Consequently, the online discussion provides an opportunity to students that might not exist in a traditional classroom, which further begs for additional research in online discussion boards.

The literature acknowledged mixed findings about the effectiveness of online discussions (Hajra & Das, 2015; Wick, Yeh, & Gajewski, 2017). While some students benefited from online discussions, others did not. Additionally, some students found difficulty in explaining mathematical terms online, while others did not.

Hajra and Das (2015) examined a mathematics course and examined online discussions for that course. Hajra and Das examined student perceptions against three learning strategies: collaborative activity, group-quiz, and online discussion. The researchers found that mathematically adept students found the online discussion workable, with "few express[ing] concerns about explaining mathematical problems in writing in an online platform" (Hajra & Das, 2015, p. 615). However, non-math majors found difficulty in expressing their ideas in the online environment; yet, the researchers reported that students perceived online discussions to be beneficial. Yet, the Hajra and Das study merely examined a single class, consisting of 25 students. Thus, the small sample size limits the generalizability of their study. In other words, the Hajra and Das data might suffer from the small-sample size dilemma: skewed data.

Wick et al. (2017) reported mixed results in comparing online learning experiences with those of face-to-face learning experiences. Wick et al. acknowledged the benefits (i.e., bridging physical distances) of online learning in rural settings. However, they also acknowledged that "empirical evidence on the equivalence of distance education and traditional face-to-face (F2F) instruction . . . is mixed" (p. 137). The grade distributions for online versus face-to-face instruction were similar; however, the researchers acknowledged barriers to the online environment (e.g., student frustration with software, lack of immediate online feedback, etc.).

A few researchers examined online discussions specifically in relation to student perceptions. Žuvic-Butorac, Roncevic, Nemcanin, and Nebic (2011) acknowledged the importance of student perceptions of e-learning in developing and implementing a successful e-earning environment. Online discussion boards are a form of e-learning. Syllogistically speaking, student perceptions of online discussion boards might be important to the success of their effectiveness. Additionally, Hamann et al. (2012) researched student perceptions of the benefits of discussions in small-group, large-class, and in online learning contexts and reported mixed findings regarding the benefits of online discussions. Overall, students were less satisfied with the online component. However, Haman et al. (2012) also acknowledged:

> It is possible that the class design is at fault here: for one, students signed up for a face-to-face rather than an online class, and some anecdotal evidence suggests that students in face-to-face courses are less likely to be satisfied with online class components than those students enrolling in classes that are officially designated as being partially or entirely conducted online. (p. 72)

Thus, students should probably be made aware that their pre-conceived perceptions might impact their satisfaction with online-discussion courses. Furthermore, students should probably be apprised of the use of online discussion boards in traditional courses (i.e., historically, non-online courses). Again, the literature requires further research for online discussions in such matters.

At one southeastern AACSB accredited university, Weldy (2018) examined student preferences of three delivery formats: traditional, online, or blended. The study consisted of surveying 165 students. The study found that despite "the increasing enrolment in blended and online courses, the results indicate preference for [a] more positive experience in traditional courses" (Weldy, 2018, p. 55). The researcher also noted that "students consider podcasts and videos over course content more effective for learning than threaded discussions or forums" (Weldy, 2018, p. 55).

In another study, Yu (2009) examined online discussion impacts on face-to-face discussions and academic achievement. Yu (2009) found that "online intervention increased student's rate of participation and comfort level in [face-to-face] discussions, but it did not produce any quantitatively measured increase in academic achievement" (p. 4). Thus, even a traditional course, which contains an online-discussion supplement, might yield interpersonal changes for the traditional classroom.

Interestingly, one researcher discovered a strength in human interactions in the online discussions. Vess (2015) examined asynchronous discussion communication patterns in online and hybrid history courses, finding that student-to-student interactions were more predominant in the online classes than in the traditional courses. In other words, traditional courses usually have a greater number of student-teacher interactions, more so than student-to-student interactions. In the traditional classroom, if the teacher is speaking, then there is less opportunity (i.e., as compared to text-based online discussions) for students to share ideas. However, in an online discussion, multiple people can speak simultaneously, which provides greater opportunity for student-to-student interaction.

The literature suggests that the way instructors provide feedback to online students might impact the student learning experience. Crisp and Bonk (2018) examined the learner-feedback experience across six dimensions: "timeliness, frequency, distribution, source, individualization, and content" (p. 585). The researchers suggest that analysis of student feedback experiences might be a "better proxy for measuring the quality in postsecondary online learning than grades, satisfaction, or regular and substantive contact" (Crisp & Bonk, 2018, p. 585).

Although Crisp and Bonk (2018) examined student feedback experiences along six dimensions related to temporal, distribution, source, individual, and content measures, another set of research to a closer look at the type of feedback. McGuire, Tu, Logue, Mason, and Ostrow (2017) examined "(1) text-based feedback; (2) image-based feedback; and (3) correctness only feedback" (p. 231). The student examined sixth grade mathematics students "within a web-based online learning platform" (McGuire et al., 2017, p. 231). According to McGuire et al. (2017), there was no statistically significant difference found between the uses of the different feedback types (p. 231).

Usher and Barak (2018) examined student-peer feedback for online courses. They examined the quality of peer feedback and the grading accuracy in a project-based course (Usher & Barak, 2018, p. 745). The study examined 339 participants for science and engineering courses taken in three different modes: an on-campus course, a small private online course (SPOC), and a massive open online course (MOOC), with n = 77, n = 110, and n = 152, respectively (Usher & Barak, 2018, p. 748). The four types of feedback categories consisted of "reinforcement, statement, verification and elaboration" (Usher & Barak, 2018, p. 745). The findings "indicated that the MOOC participants provided more feedback comment and volunteered to assess more projects that their counterparts" (Usher & Barak, 2018, p. 745). Yet, the on-campus students produced higher quality feedback; additionally, for the on-campus students, statistical analysis revealed a higher correlation between the peer-grading and teacher-assigned grades for the course (Usher & Barak, 2018, p. 745). Peer grading consisted of students evaluating "each other's work by considering the value, worth and quality of peers' learning outcomes" (Usher & Barak, 2018, p. 746).

Other research also specifically examines MOOCs. Moreno-Marcos et al. (2018) examined the predictive power of grades in a MOOC. The researchers analyzed "how different course scores can be predicted, what elements or variables affect the predictions and how much and in which way it is possible to anticipate scores" (Moreno-Marcos et al., 2018, p. 1021). The performance indicator variables consisted of those related "to the forum, exercises, videos and previous grades" (Moreno-Marcos et al., 2018, p. 1033). Thus, past student performance could provide possible insights into present and future performance.

Social media is a viable option for online discussions in courses. Hickerson and Kothari (2017) researched instructors' use of online discussions via social media, by examining how "journalism faculty (n = 125) and students (n = 323) . . . learn how each assess the challenges and opportunities of using social media in journalism coursework" (p. 397). The research exposed issues of privacy concerns and revealed that "faculty were also concerned about the legal consequences of students making mistakes publicly online" (Hickerson & Kothari, 2017, p. 397). Furthermore, if a student commits a faux pas in social media, then that misstep "could follow students into their careers" (Hickerson & Kothari, 2017, p. 397). Consequently, some learning environments are not necessarily open-discussion safe-zones.

Hickerson and Kothari (2017) examined social media as an online discussion tool. The participants consisted of journalism faculty (n = 125) and journalism students (n = 323). Consequently, Hickeson and Kothari unearthed privacy concerns with online environments, especially online learning environments in public social media. Journalism faculty expressed concerns over student comments in social media. For example, if a student made a negative comment about another person or a company, the liability issues arose. Is a student's future at a company jeopardized by negative comments made by that student? Additionally, a person could file a libel suit against a student for negative comments. Thus, Hickeson and Kothari's (2017) research presents some important risks regarding online discussion content. Namely, the student experience in online discussions also involves privacy concerns. While privacy concerns are not the focus of the data analyses of this dissertation, the Hickeson and Kothari reveals, even further, the significant gaps in the literature.

Kayler and Weller (2007) examined online discussions as a supplement to the traditional, on-ground, classroom. The online discussions provided an environment of support, reflection, and self-assessment, within the context of professional development. The researchers asked, "how can we develop self-monitoring and acceptance of online discussions so that students become independent learners?" (Kayler & Weller, 2007, p. 136). The research yielded three dominant themes of the discussions: Community of Practice, Independent Learners, Self-Assessment Informs Understanding of Self and Discussion-Group Dynamics. Kayler and Weller (2007) reported positive findings associated with the themes. Namely, Community of Practice supported student professional learning. Kayler and Weller (2007) found that placing "students at the center of their learning affords learners with a new paradigm that can support their development as independent learners" (p. 145). Additionally, the positive results of their self-assessment indicated that self-assessment should be included with online discussions.

Edwards, Rule, and Boody, (2017) examined the differences of online classroom grades with those of face-to-face classroom grades. The study examined the mathematical knowledge retention of 38 middle-school students on "ten mathematical topics they had learned in sixth grade during either online or face-to-face conditions" (Edwards, Rule, & Boody, 2017, p. 1). The students' knowledge assessment spanned a two-year period. The researchers used a quasi-experimental design, with the independent variable being instruction type (i.e., online versus face-to-face) and the dependent variable being academic retention (Edwards, Rule, & Boody, 2017, p. 4). According to the researchers, "Scores for long-term gain scores showed no significant differences between online or face-to-face learning conditions" (Edwards et al., 2017, p. 1). The study used *t*-tests to identify group differences, but the online versus face-to-face groups "showed no significant difference for any topic [i.e., any of the ten mathematics topics]" (Edwards et al., 2017, p. 8). Thus, in Edwards et al.'s study, the efficacy of the online learning experience matched that of the traditional classroom.

Online Student Involvement

Student involvement is vital in mathematics-based courses. Clark, Kaw, and Delgado (2018) stated, the "use of active learning over traditional lecturing indicated an increase of 0.47 standard deviations on exams and concept inventories" (p. 2). Fung, Yuen, and Yuen (2018), in their study on the differences between average versus mathematically talented students, acknowledged that for "students operating in this Internet world, it is highly beneficial if they are motivated" (p. 111). Furthermore, the researchers acknowledged the importance of student involvement (i.e., relative to student self-regulation), by stating, “Learning involves a student taking full control of all processes involved in learning” (Fung et al., 2018, p. 111).

Kearny and Garfield (2019) examined student and teacher perceptions associated with student involvement and mathematics. Kearny and Garfield examined 964 students and 93 mathematics teachers and found two factors of student achievement in mathematics at the middle-school level: “teacher perceptions of student readiness to learn and student perceptions of teacher effectiveness” (p. 9). Student reediness to learn ties directly to student involvement. The researchers found that the two factors “made a significant contribution to the variance in middle grades mathematics achievement” (Kearney, Garfield, 2019, p. 1).

Nyet Moi Siew, Geofrey, and Bih Ni Lee (2016) examined the use of online gaming as a learning tool and discovered positive findings in immersive experiences for students. More specifically, they examined students’ algebraic thinking and attitudes towards algebra in a gaming environment” (Nyet Moi Siew et al., 2016, p. 1). They found that the gaming environment “provided interactive learning and gave students the opportunity to respond and repeat situations in a meaningful context. Thus, it enabled students to engage in the game cognitively, physically and emotionally” (Nyet Moi Siew et al., 2016, p. 8). The operative word is “engaged.” The researchers found that students were engaged, which ties to involvement. Wyman-Blackburn (2018) declared that schools are choosing “online curricula because they can provide more engaging ways for students to learn – from playing games and watching instructional videos to creating graphs and drawing shapes digitally” (p. 66). Thus, the research suggests that immersion and engagement are effective components of student involvement.

Atherton et al. (2017) examined the use of analytics in assessing student engagement via academic outcomes. The study found “a correlation between student access to online learning materials and a positive impact on grades in science courses” (Atherton et al., 2017, p. 119). The study examined student assessment scores and exam results across two campuses.

Dixon (2014) examined online teaching methods and mentioned the dearth of online discussion models. Thus, the researcher studied three elements of discussion (i.e., experience, engagement, and evaluation) and integrated those three elements into one model. The researcher found that the three elements of discussion could be effective in an online learning environment. Experience addresses the development of the online learning environment. Engagement addresses the active-learning component. Evaluation addresses the student’s “clarity and comfort with the process of online discussion while finding the objectives measured fairly and accurately by the instructor” (Dixon, 2014, p. 5). Dixon’s research elucidates online student involvement on a few different levels. Especially important is the construct of engagement, which ties directly to the theoretical foundation of this dissertation: Student Involvement Theory. Dixon underscored the importance of student immersion into the process of online learning, which ties to SIT.

Online discussion boards have also affected the group dynamic. Delaney, Kummer, and Singh, (2019) evaluated the impact of online discussions on student engagement and student learning performance in group work. The researchers noted, “Students’ attitude to the online discussion board improved through the semester” (Delaney et al., 2019, p. 902). Yet, the researchers noticed a difference in classroom group dynamics among international versus domestic students. More specifically, the “online assessment task did not encourage domestic students to be more engaged in group-based activities" (Delaney et al., 2019, p. 902). However, Delaney et al. (2019) found that "international students were more encouraged to participate in group-based activities at the end of the semester" (p. 902).

The literature revealed a different experience for certain subgroups of online students. More specifically, Jabli's (2020) research found that Saudi Arabian international students' experience seemed more difficult than the average online student. The researcher qualitatively analyzed five Saudi Arabian international students' online experience at Norther Illinois University (i.e., the host university). Jabli (2020) stated, "Saudi international students have difficulty struggling through the educational system of the host" (p. 39). The researcher observed negative impacts of the online experience with the students' motivation, which further affected "grades and scores as well as retention and completion rates" (Jabli, 2020, p. 59). During the interview process, the researcher identified three important elements the respondents identified as important to success in online courses: adaptation (i.e., adjusting to the online experience from a traditional setting), self-discipline, and dedication (Jabli, 2020, p. 57). Of the three elements, the researcher stated that adaptation is the "most important factor influencing participation and attitudes of online learning" (Jablie, 2020, p. 57).

Halabi and Larkins (2016) indicated that online discussion board usage affected student overall performance and used multiple regression analysis and found "a positive benefit in terms of greater marks for students who post on the discussion board compared to those who do not post, even after controlling for academic ability" (p. 337). However, student usage of the discussion board was voluntary. Thus, the voluntary element might also be a contributing factor (e.g., self-selection) toward student performance.

Rich, Duhon, and Reynolds (2017) examined the efficacy of computer usage with 57 children learning mathematics. The study found that the sole use of the computer as a means to teach basic mathematics did not “generalize to paper-pencil format” (Rich, Duhon, & Reynolds, 2017, p. 123). Rather, the study found that learning improved with a “mix of computer and paper-pencil practice” (Rich et al., 2017, p. 123). Thus, the study reveals additional levels of student involvement from multiple learning sources (i.e., computer and pencil-and-paper). Although the study focused on children, it still supports student involvement theory. Furthermore, although the study did not use online learning, the study examined the use of computers in learning, which is akin to online learning.

Immersion and Gaming

Hong, Hwang, Tai, and Lin (2019) examined impacts of practice time in an online learning environment experienced with a gaming application, which known as “Quickgame.” According to Hong, Hwang, Tai, and Lin (2019), the “participants were 4th grade students of Southeast Asian heritage who were learning Chinese as” a second language and found that, as gaming practice times increased, student performance increased (p. 597). Thus, the literature reveals more support for increase student involvement yielding greater student performance.

Gaming seems to be an acknowledged form of immersive learning in the literature. Garneli, Giannakos, and Chorianopoulos (2017) examined “games as a malleable learning medium” (p. 842). The researchers examined the direct impact of the gaming upon student performance. Within the context of the study, the researchers viewed gaming tools as serious learning instruments of pedagogy, stating “Serious games should also be considered as an alternative pedagogical medium for attracting students with different needs and expectations" (Garneli et al., 2017, p. 842). The study examined eighty middle-school students, dividing the students into four groups of twenty, which included a control group that used paper-and-pencil (Garneli et al., 2017, p. 842). The researchers' found video-game-play a feasible approach to learning (Garneli et al., 2017, p. 842).

Navigation

Computer-mouse clicking patterns of online students might also present insights into student performance. Researchers have used a number of tools (e.g., Amazon Web Services, built-in learning management systems utilities, etc.) to track student activity (Naranjo, Prieto, Moltó, & Calatrava, 2019; Tellakat, Boyd, & Pennebaker, 2019). Tellakat, Boyd, and Pennebaker (2019) examined the clicking patterns of online students navigating the websites of two large courses (N = 1384 and N = 671) (p. 1). The researchers observed 1) a consistent correlation between studying course content outside of class and student grades, 2) a strong correlation between student grades and study any time anytime except late at night or early in the morning, 3) a strong correlation between grades and students with higher Scholastic Aptitude Test scores (Tellakat et al., 2019, p. 1). The researchers used multiple regression analyses and found that "predicting grades using just SATs and click rates accounted for almost 43 and 36 percent of the grade variance" (Tellakat et al., 2019, p. 1). Student final course grade served as the dependent variable and was a measure of the "average scores of his or her benchmark exams and writing assignments together" (Tellakat et al., 2019, p. 6). Interestingly, the researchers declared, "Studying as measured through out-of-class clicks is a reliable and predictive measure of class outcomes" (Tellakat et al., 2019, p. 14).

Online Homework Managers

As a component of online learning management systems, online homework managers are tools used by some online instructors. One pair of researchers, Türel and Furr (2020), found that students' involvement with online homework (i.e., via online homework management tools) "regularly scored significantly higher on final exams" (p. 130). Furthermore, the study noted higher student course-satisfactions scores (Türel & Furr, 2020, p. 130). The participations consisted of 288 university accounting students from four different accounting classes (i.e., cost accounting, managerial accounting, auditing, and financial accounting). Instructors used online homework managers in each course.

Mathematical Symbols

Mathematics is well known for its use of symbols. Some researchers have examined the relationship between mathematical symbols vs mathematical prowess. Capraro and Joffrion (2006) examined middle-school students' ability to, meaningfully, translate words into mathematical symbols for algebraic equations. The researchers examined 668 students in 25 middle-school classrooms and found that the "relative success students achieved on these items may be attributed to more conceptual understanding" (p. 162). Thus, Capraro and Joffrion's finding support the research of this study. Student involvement, in mathematics courses, aligns with a greater conceptual understanding. Students must be involved to gain a greater conceptual understanding. Capraro and Joffrion (2006) added, "Vocabulary plays an important role in mathematics conceptualization . . . [w]ithout conceptual understanding, procedures mean almost nothing" (p. 162). Thus, students should not simply copy procedures to gain understanding. Instead, students must engage (i.e., *involve*) their minds.

Eyers, Bragg, and Reich (2020) examined the language of mathematics (i.e., numbers, symbols, and operations) as predictors of student arithmetic success. To further define mathematical language, Eyers, Bragg, and Reich (2020) stated that mathematical language has a structure and code and includes notations with symbolic representations (p. 9). In examining predictors of student arithmetic success, Lyons et al., (2014), examined a large sample (N = 1391) of young mathematics students (i.e., grades 1-6) and found that “basic symbolic number processing accounts for the majority of unique variance in children’s arithmetic ability” (p. 723). The mathematically engaged students outperformed the less engaged.

Lyons et al. (2018) tied the early development of symbolic number skills to those of non-symbolic number skills in kindergarteners. The study examined 539 kindergarteners. According to Lyons et al. (2018), “Once one acquires a basic grasp of exact number symbols, it is this understanding of exact number (and perhaps repeated practice therewith) that facilitates growth in the [approximate magnitude system]” (p. 440). In the case of Lyons et al. (2018), the symbols consisted of numeric representations. The researchers demonstrated that strength in number-symbol understanding assisted in other areas of mathematics (e.g., understanding approximation). Although Lyons et al. (2018) focused on kindergartners and numeric symbols, Lyons et al.’s research still demonstrated the importance of mastering basic symbols and demonstrated how that understanding leads to strength in subsequent mathematical concepts.

Powell and Fuchs (2010) examined third-grade student difficulties associated with the equal sign (=). The study, conducted by Powell and Fuchs (2010), addressed the problem of students attempting to use the equal sign as a mathematical operator.

Additionally, an earlier study, by Sáenz-Ludlow and Walgamuth (1998), also found third-grade students incorrectly attempting to use equality symbols as mathematical operators. The researchers identified a flaw in mathematical-concept understanding, which “word-problem tutoring plus equal-sign instruction (combined) tutoring” remedied (Powell & Fuchs, 2010, p. 381). This research finding underscores the importance of student mastery of the basic concepts of mathematical symbols, operations, and relationships. Furthermore, the equal signs is “arguably the most fundamental symbol in all of mathematics and science” (McNeil & Alibali, 2005, p. 286). Thus, the equal sign warrants special consideration for research, just as it did in this dissertation (i.e., H_1, H_2, and H_3).

Research identified the progression of understanding of the equal sign. (McNeil and Alibali (2005) stated that elementary school students “interpreted the equal sign as an operational symbol” (p. 285). However, McNeil and Alibali also noted that “understanding of the equal sign changes as a function of experience in mathematics and variations in context” (p. 285). Seventh grade students began seeing the relational aspects of the equal sign “in the equivalence contexts,” beyond simply seeing the equal sign as an operational symbol “in the alone and addition contexts” (McNeil & Alibali, 2005, p. 285). Graduate and undergraduate students “viewed it as a relational symbol of equivalence in all contexts” (McNeil & Alibali, 2005, p. 285). Thus, a student’s view of the equal sign might provide insights into their level of understanding mathematics. However, an important caveat exists: In the context of computer science, the equal sign routinely equates to operation.

Mathematics anxiety associated with mathematical symbols might be a significant barrier to learning. Rule and Harrell (2006) stated that mathematics anxiety is a “rampant career-limiting psychological complex" (p. 243). Thus, a significant concern to teachers of mathematics is this barrier to learning, which might explain the many mathematical struggles of students. Furthermore, Rule and Harrell stated that teachers' mathematical anxieties could transfer to students. Rule and Harrell used mathematical drawing activities to exchange negative subconscious feelings associated with mathematics to positive feelings. The drawing activities "helped students connect with their previously unconscious images of mathematics and focused the class on affective aspects of mathematics teaching and learning" (Rule & Harrell, 2006, p. 255). Seah and Beencke (2019) also stated the importance of using visual tools in developing mathematical skills: "Students who can interpret a situation and produce accurate visual images are almost six times more likely to solve a word problem correctly" (p. 5). Thus, math instructors must be aware of such barriers. This dissertation's findings might assist practice by early-indicators (e.g., student lack-of-use of math symbols) that students might have these barriers.

Student difficulties in mathematics might stem from more than simple mental blocks. More specifically, some concepts might be inherently more complicated. Solares and Kieran (2013) examined student difficulties with understanding higher-order mathematical equations and functions. Their results "corroborate[d] the importance of the gradual study of these relations and differences" between the syntactic perspective and the numeric perspective (Solares & Kieran, 2013, p. 143).

Ambrus, Filler, and Vancsó, (2018) found that higher-levels of complexity in abstract thinking interfered with students learning of mathematical functional concepts (Ambrus, Filler, & Vancsó, 2018). The researchers determined that the "generalizations regarding the concept of functions in school mathematics (set-theoretic foundation, functions as mappings between arbitrary sets) turned out to work on an abstraction level that was too high for the vast majority of students" (Ambrus, Filler, & Vancsó, 2018, p. 443). Thus, Ambrus, Filler, & Vancsó's research suggested the importance of understanding the basics before attempting more-advanced mathematical concepts.

Microsoft Excel References

The current literature is vacuous for material related to Microsoft Excel references, online discussions, student involvement and student grades. The researcher searched scholarly reference databases (e.g., EBSCOhost, ProQuest, ABI/INFORM, JStore, etc.) but found no relevant search results vis-à-vis Microsoft Excel references, online discussions, student involvement and student grades. Yet, Zverev and Sergeeva (2020) wrote a theoretical paper that was, slightly, tangential to this study by presenting recommendations for training gifted children using Office 365 (p. 291). However, the authors did not conduct a research study and, hence, provided no research findings. Thus, the researcher identified a gap in the literature.

Self-Efficacy and Motivation

Fortunately, the literature provides some findings of experimental research methods. A study conducted at Illinois State University examined the effects of online discussion groups in various delivery formats upon student self-efficacy perceptions (Mulvaney, 2020, p. 88). Mulvaney examined 213 students in an online setting for four undergraduate courses and found that the usage of discussion groups improved student self-efficacy. However, a negative effect emerged when content delivery method spanned multiple formats (e.g., audio, video, presentations, discussion boards, etc.). According to Mulvaney (2020), "when multiple formats were added, participants displayed significantly lower levels of performance appraisal self-efficacy" (p. 99). The researcher considered that the “lack of support for multiple formats in online environments may center on the issue of multimedia overload” (Mulvaney, 2020, p. 99).

The research suggests that student motivation and student personality impact their academic performance in online and blended learning environments (Alkış & Temizel, 2018). In a study consisting of 316 students, Alkış and Temizel (2018) examined academic performance for each learning environment and found that “personality is a predictor of academic performance in both online and blended course settings. A significant positive relation was found between the conscientiousness trait and course grades in both settings” (p. 43). Additionally, the researchers found that self-efficacy was a factor of course grades in the online setting (Alkış & Temizel, 2018, p. 43).

Training Research

In some instances, faculty might be a barrier to student development in online discussions. Lockyer, Sargeant, Curran, and Fleet (2006) stated that faculty who transition from traditional classrooms to online classrooms faced two challenges: “the technical aspects associated with the medium and the skills of facilitating in a different environment” (p. 625). El Mansour and Mupinga (2007) also acknowledged the need to train faculty (p. 242). Thus, this study assists in filling the gap in the literature and contributes to practice (e.g., revealing insights needed for training) by showing that the evidence suggests that a relationship exists between student involvement and student performance in online discussions for a math-based course.

Brancaccio et al. (2019) stated that online-availability of training materials and of support resources could assist teachers of online courses. Such availability seems quite fitting, for instructors of online courses. According to Brancaccio et al. (2019), the “presence of an online course for teacher training has been recognized to be useful by its users" (p. 136). Furthermore, Brancaccio et al. (2019) touted a special value of online resources is that they are permanently available (p. 136).

Rigor

Michel, Campbell, and Dilsizian, (2018) examined rigor and cognitively-responsive teaching in soft-discipline classes versus hard-discipline classes (p. 28). The researchers examined "459 courses across nine colleges and universities" and found that scores were higher in the soft-disciplines versus the hard-disciplines (Michel et al., 2018, p. 28). One of their objects of study was the modality of the course (i.e., online versus traditional). However, the number of online classes were approximately 4.4% of the total number of classes (Michel et al., 2018, p. 37). Thus, the researchers did not consider the findings for the online classes to be generalizable (Michel et al., 2018, p. 37).

Demographic and Academic Background

One study by Park, Martin, and Lambert (2019) identified predictors of student success in a large undergraduate hybrid course (p. 11). The study used quantitative analysis, and the study's participants consisted of 260 undergraduate students. The researchers found that demographic and academic background are predictors of student grades. The study mentioned that "participation in online and in-class act ivies have significant predictive values towards their final grades" (Park et al., 2019, p. 11). Thus, Park et al.'s study provides further support for SIT, by showing statistical support for student participation vis-à-vis student grades.

Conclusion

Online learning is still in its infancy, relatively speaking. Thus, research opportunities abound and further research is necessary in this online-learning world impacted by new technologies. Higher Education practices stand to gain much from the insights of the numerous facets of online learning, especially those insights related to text-based online discussion content. This literature review demonstrated the gap in the literature, relevant to online student involvement versus student performance. More specifically, no research exists that examines the relationship between student discussion-board content (i.e., measured as mathematical symbol or Excel references) and student scores (i.e., midterm exam, final exam, and course-grade percentage).

Chapter Three: Methodology

The following sections present the methodology of this research project. The sections consist of the methodology conceptual framework, the participants and environment, the population and sample information, the data collection methods, and the data analysis methods. Additionally, this study's methodology included strict security measures for identity protection.

Methodology Conceptual Framework

This research project quantitatively examined the relationship between student involvement and student performance. According to Bluman (2015) and Camm et al. (2019), regression analysis is an appropriate tool to examine relationships between independent variables and dependent variables of ratio data. In this study, all of the variables, independent and dependent, represented ratio data. The independent variables of student-posting activity measured student involvement and were purely mathematical summations of the number of instances of mathematical or Excel references. All dependent variables of student grades were reported as percentages, which represented ratio data. For example, the researcher counted the number of student-posted addition-symbol references as a predictor (i.e., the independent variable) of student grades (i.e., the dependent variable). Then, the researcher compared those counts to student grades in regression analyses.

Multiple authors (Bluman, 2015; Camm et al., 2019) condoned the use of the Coefficient of Determination (r^2) and the Pearson Product-Moment Correlation Coefficient (r), in addition to the comparison of p-values against the level of significance, in statistical relational analyses. Therefore, as a means of triangulating the data, the researcher not only examined the regression-equation parameters, but the researcher also examined the Coefficient of Determination and the Pearson Product-Moment Correlation Coefficient. For the regression-equation parameters, a moderate level of significance ($\alpha = .10$) determined significance and was compared to the *p*-values.

The Population and Sample Data

For this study, the ideal target population was one of online students in math-based courses. However, the practical target population for this study was online *business* students in math-based *business* courses. This study used a convenience sample, which is an acknowledged limiting factor of this study. Despite the usage of a convenience sample, this study's sample consisted of a significant number of actual students (i.e., not a simulation) and, therefore, one can make some degree of inferences for courses of a similar type (e.g., online students in online business analytics courses). Furthermore, business analytics courses are math-based; thus, inferences potentially extend to other math-based business courses. Finally, the large sample size (n=200) aids in the generalizability of the findings.

The participants and environment. The researcher collected data from concluded online courses that the researcher taught or that fell under the researcher's ownership. The subjects in this study consisted of 200 randomly selected students from 16 different sections of business-analytics courses that were taught at a Midwestern university between the fall 2016 and the fall 2018 terms (inclusive). Each course lasted for eight weeks, with each week containing a discussion. Thus, for a single course, there were eight discussions. All 16 courses contained a grand total of 128 discussions. Adjunct instructors taught two of the 16 courses. The researcher taught 14 of the 16 courses. The historical nature of the data eliminated the possibility of participant coercion. The research was not experimental and only examined past data. Hence, the researcher had neither influence over the data nor over the subjects.

The learning management system. Instructors for the sixteen courses delivered the courses via the Canvas Learning Management System (LMS). At the time of this study, Canvas was a popular LMS, with over 30 million users ("Instructure's Company Story," n.d., para. 14). Instructure is the parent company that owns Canvas, and the New York Stock Exchange listed Instructure as a publicly traded company in 2015 ("Instructure's Company Story," n.d., para. 10). According to "Instructure's Company Story" (n.d.), Instructure is a large company with a market capitalization of over 1 billion dollars (para. 12). Thus, Canvas is a premier LMS in online learning and has significant corporate and market support.

The weekly format. In Canvas, students engaged in a weekly discussion for each of the eight weeks of the course. Each weekly discussion included instructions consisting of a high-level chapter question, questions soliciting student experiences with the homework, and an open-ended encouragement for students to discuss anything on their minds.

Each weekly high-level question, provided by the instructor, consisted of a chapter-overview question. For example, the first week of class required students to define the words "Business Analytics" in their own words. Students could respond to other student posts about the overview question.

Additionally, each weekly instruction stated that students are to make posts regarding any difficulty that they might have experienced with the homework. For example, a student might indicate that she or he experienced problems with question #14 of chapter 3. The student might also describe her or his process in arriving at a solution.

Additionally, the weekly instructions explicitly directed students to request help on homework problems or the readings, as needed. If a student made a request for assistance on a homework problem, then the instructor required the class, as a whole, to help resolve the student's problem. Yet, students were not required to post mathematical content, mathematical symbols, mathematical functions, nor Excel material. Rather, the weekly instructions simply indicated that students were to post their difficulties or issues. Some students did not always respond to the weekly instructions, while others carefully adhered to the weekly-discussion requirements.

The weekly instructions also indicated that the discussions were completely open for any type of discussion material, with the exclusion of content that was private in nature. In some cases, students might post information about the weather in their region. In other cases, students might post information about their experiences at work. However, the weekly instructions disallowed the posting of student grade information. Instead, the instructor would only discuss private-natured material via phone or email.

The discussions allowed threaded responses from anybody involved in the discussion. Students could respond directly to the instructor's main weekly prompt, or the students could create their own discussion threads. The instructor required student interactions with other students. Therefore, some discussion threads received numerous responses. However, some student posts received no threaded responses. The instructor, from time to time, would interject or make corrections in the discussion threads, as necessary.

The discussion participation grading. At the end of each week, the instructor assigned a weekly participation grade to each student. The quality (e.g., substance and completeness) and timeliness of the student-posting activity determined the participation grade. Additionally, the syllabus dictated that students were to make from five to seven posts each week. However, students were not limited to seven posts. The instructor encouraged students to be actively engaged in the discussions throughout each week. Although the instructors encouraged students to make substantive posts, neither the instructor nor the weekly instructions dictated that students post mathematical or Excel content. Neither the instructor nor the weekly instructions required the explicit usage of mathematical equations, mathematical symbols, or Excel references.

The determination of students involved. The nature of this study dealt with student involvement. Therefore, this study examined only students who were involved in the online discussions for the mathematical and Excel references in each research hypothesis. Out of the 200 randomly-selected students, 75 made no mathematical or Excel references; however, 125 made mathematical or Excel references. Thus, this study's regression analyses consisted of the data for the 125 students who demonstrated at least one discussion-board post within at least one of the hypothesized categories. For example, if a student posted an addition symbol, which corresponds to H_4, H_5, and H_6, then that student's posting activity was included in the regression analyses of the 125 participatory students. If a student made no mathematical symbol or Excel references in any post, then the regression analyses excluded that student.

In this study, the Learning Management System excluded student demographic data. Fortunately, this exclusion served as an added layer of identity protection. Thus, this study focused on student involvement from a generalized student type. That is, the sole identifier of the type of student in this study is that of the *online* student. Neither gender, gender-identity, age, ethnicity, race, health status, nor employment status prevented any student's inclusion in this study.

Overview of data collection and anonymization. The data collection process consisted of multiple steps conducted in a two-phase process. The researcher designed the collection process with two main goals: 1) anonymize the data and 2) collect random data. The random collection of data aimed to support statistical inference, despite the use of a convenience sample. The anonymization steps aimed to ensure student-identity protection. The data-collection process integrated the randomization and anonymization processes. Phase 1 consisted of randomly collecting data and, then, anonymizing the data. Phase 1 ensured identity protection from all parties, except the researcher. Phase 2 consisted of a second randomization process and a second anonymization process. Phase 2 ensured student-identity protection from the researcher. Thus, Phase 1 and Phase 2 produced randomized data, which included student-identity protection.

The data files. First, the researcher placed a full listing of all students from all sixteen business-analytics courses into an Excel spreadsheet. Second, the researcher randomized the list of students by using Excel's Rand() function. Third, the researcher selected the first 200 contiguous student names from the randomized list. Fourth, the researcher downloaded all of the Canvas discussions for all 200 students, which consisted of approximately 1,500 pages of typewritten material. The researcher stored each student's discussion material for an entire course into a single file, along with student grade information. Each discussion file contained eight weeks' worth of discussions (i.e., one discussion per week of an eight-week course). In total, the discussion files consisted of 200 files, one file per student. Fifth, the researcher named each student-discussion file according to a unique identifier, which was a single number between 1 and 200. Sixth, the researcher removed or redacted all student-identifying information from each discussion file, in keeping with student identity protection.

Identity protection details and the counting. To protect student identities, all student names underwent the 2-phase anonymization process. In Phase 1, the researcher 1) anonymized all student names and 2) removed or redacted any potential discussion-board references (direct or indirect) to the students. In Phase 2, a third party re-anonymized all student identifiers that were anonymized by the researcher in Phase 1, and then, the third party submitted the data to the researcher. Next, using the third-party anonymized data (TPAD), the researcher 1) counted the number of references (according to the hypotheses), 2) stored those counts in a count table, and 3) conducted the regression analyses. Thus, in Phase 1, the researcher hid all student identifiers from the third party. In Phase 2, the third party hid all student identifiers from the researcher.

Phase 1. Phase 1 consisted of the researcher randomly selecting students, anonymizing all student names, and removing all potential student-identification references. For example, if a student's name was "Joe Smith," and he identified himself in a discussion-board post as the chief information officer of an organization, then the researcher removed or redacted the student's name the discussion. In another instance, a student received an honors award for a specific year. The researcher removed the reference to the award from the discussion. Additionally, the researcher removed or redacted any reference to a student's position or company. For example, the researcher redacted or removed the wording of "chief information officer" and the reference to the organization. Additionally, the researcher stored student grade information into the associated student's *anonymized* discussion file. Thus, at the completion of Phase 1, the data were Researcher-Anonymized Data (RAD).

Phase 2. In Phase 2, the research provided RAD to a third party via an Excel document. The Excel document contained a table with RAD unique references to each student discussion file. In other words, the Excel file contained a listing of RAD student anonymized identifiers (i.e., 1-200) that linked to each student discussion file. Additionally, the researcher provided explicitly written directions to the third-party anonymizer in the process of data re-anonymization. The third party only saw anonymized student identifiers, not student names. Student name and grade information were inaccessible to the third party. The third party used the Excel file to rename all of the student-discussion files according to a randomly generated number. Excel provided the randomly generated number. Once Excel created the random numbers, the third party used the random numbers to re-name all of the student discussion files. More specifically, the third party used a batch file (i.e., an automated computer script) to rename all of the RAD unique student identifiers into newly-anonymized files. Finally, the third party submitted the newly-anonymized third-party anonymized data (TPAD) to the researcher.

Phase 2: Further detail. The third party followed a written script in the Phase-2 anonymization process. The process required the third party to assign new unique identifiers to each student. The third party replaced the RAD references with newly anonymized and randomized references. For example, the third party replaced references of "RAD1" with a randomly-named identifier (e.g., TPAD1). Thus, the researcher did not directly participate in the third-party anonymization phase because the third-party anonymization phase hid student identifiers from the researcher. At the completion of Phase 2, the third-party processed RAD into third-party anonymized data (TPAD), and consequently, the third party hid student identifiable references from the researcher.

Aggregated security. This study provided an additional layer of security in the form of aggregated data. Specifically, this study grouped data, analyzed the group data, and, finally, reported group data. All single-student datum is masked. Thus, aggregated reporting provided an added later of student-identity protection.

The Final Analyses

Using TPAD, the researcher 1) counted the number of mathematical or Excel references (as per the hypotheses), 2) stored the counts and grades into a table, and then, 3) conducted regression analyses. The researcher only conducted the regression analyses on the TPAD by examining the counts of mathematical references and Excel references against student grades. Hence, the use of TPAD ensured the protection of student identities.

The counting process. Using TPAD, the researcher tallied the counts for each of the types of references, according to the hypotheses. For H_1, H_2, and H_3, the researcher tallied every instance of an equality or inequality reference (i.e., =, <, >, ≤, or ≥) and stored the tally into a count table, along with the student grade. For H_4, H_5, and H_6, the researcher tallied every instance of a mathematical symbol (i.e., +,-,x,/,or ^) that students reference and stored the tally into a count table, along with the student grade. Insufficient data precluded analyses for H_7, H_8, or $H_{9.}$ For H_{10}, H_{11}, and H_{12}, the researcher tallied every instance of an Excel reference (i.e., +,-,x,/,or ^) and stored the tally into a count table, along with the student grade.

The multiple regression hypotheses simply re-used the tallies from the simple linear regression hypotheses. The researcher did not re-tally the instances of references for the multiple regression hypotheses, which consisted of H_{13}, H_{14}, H_{15}, H_{16}, H_{17}, and H_{18}. Thus, although the multiple-regression analyses differ from the simple-regression analyses, the tallying process did not change.

The researcher conducted the tallying process multiple times to ensure accuracy for all tallies. The researcher logged, re-counted, and re-verified any discrepancies. Additionally, the researcher re-verified the accuracy by randomly checking tallies. After the researcher reached a state of data-checking saturation, the researcher aligned the tallies with the anonymized student grades.

The counts and grade alignment. The researcher stored the tallies in an Excel table. The researcher collected the student grades from the anonymized discussions and stored the grades in alignment with the tallies. Consequently, all tallies aligned with the anonymized student grades. After this alignment step, the researcher conducted the regression analyses.

Pearson's Product-Moment Correlation Coefficient (PPMCC). The main tool of analysis of this study was regression analyses. However, prior to the regression analyses, the researcher examined PPMCC's for each pairwise comparison of independent variables to the dependent variables. Even for the multiple regression analyses, the researcher conducted a pairwise examination of PPMCC's. The researcher used Microsoft Excel 2016 to generate all PPMCC's.

The regressions overview. This study examined simple relationships via simple linear regressions and multiple regressions. Thus, the researcher opted to examine not only the base relationships, but also the next layer of complexity. Namely, the researcher conducted simple linear regressions for hypotheses H_1, H_2, H_3, H_4, H_5, H_6, H_{10}, H_{11}, and H_{12}. The lack of data prevented regression analyses for H_7, H_8, and H_9. Finally, the researcher conducted multiple linear regressions for H_{13}, H_{14}, H_{15}, H_{16}, H_{17}, and H_{18}.

The simple regressions. The simple linear regressions consisted of analyzing the tallies for each of the independent variables against the dependent variables of student grades. In the case of H_1, H_2, and H_3, the researcher performed a regression analyses on the tallies of equalities and inequality references against student grades. In the case of H_4, H_5, and H_6, the researcher performed a regression analyses on the tallies of mathematical references against student grades. In the case of H_{10}, H_{11}, and H_{12}, the researcher performed a regression analyses on the tallies of Excel references against student grades. Prior to data collection, the researcher predetermined to test regression parameter significance at α =.10 level of significance.

The multiple regressions. The multiple linear regressions consisted of analyzing the tallies for each of the independent variables against the dependent variables of student grades. In the case of H_{13}, H_{14}, and H_{15}, the researcher performed a regression analyses on the tallies of equalities, inequality, and mathematical symbol references against student grades. In the case of H_{16}, H_{17}, and H_{18}, the researcher performed a regression analyses on the tallies of equalities, inequality, mathematical symbol, and Excel references against student grades. Prior to data collection, the researcher predetermined to test regression parameter significance against at α =.10 level of significance.

The level of significance. This study aimed to examine the relationship between student input versus student output. Consequently, the researcher hoped to identify an effect in that relationship. Thus, the researcher used a less-stringent level of significance (α = .10) to determine the significance of the relationships. The researcher used the same level of significance for all of this study's regressions, both simple and multiple. Although other researchers (e.g., Bluman or Camm et al.) might use different levels of significance (e.g., α =.01 or α =.05) in examining relationships, those levels are unnecessarily more demanding for the nature of this study. The level of significance at α

=.10 is sufficient to detect a relationship in this study, which is the reasoning for selecting $\alpha = .10$.

Future research might warrant requiring a stricter level of significance. Moreover, stricter levels of significance might be a means of teasing out a greater level of accuracy of the predictors of student performance. For example, one might posit that a greater mathematical lexicon leads to higher performance in a math-based course. If a student uses more-advanced mathematical expressions, then that student's performance might exceed those students who exhibit strong, but basic, mathematical prowess.

However, the nature of this study is limited to the basic mathematical and Excel lexicons. Given the nature of the data and the aim to examine the relationship between the independent variables and the dependent variables, a stricter level of significance is unnecessary. Thus, the researcher chose the level of significance in an attempt to find a reasonable significant effect, without creating excessive significance criteria.

***The technical aspects*.** The researcher used Microsoft Excel 2016 for all regression analyses. More specifically, the researcher used Excel's Data Analysis ToolPak, which contains a regression tool, to process all of the mathematical and Excel reference tallies. The regression tool processed the tallies contained in Excel tables. The researcher used the regression report, created by the regression tool, to evaluate the *p*-values, *r*-values, r^2-values, and examine the regression equations.

The researcher repeated the regression analyses multiple times. First, the researcher conducted all of the regressions. Second, the researcher conducted the exact same regressions. Third, the researcher compared the regression reports and their associated values to ensure accuracy of all of the regression values. All final *p*-values, *r*-

values, and r^2-values matched each regression analyses report for both the first and second iterations of the creation of the regression reports.

Conclusion

The researcher chose regression analyses because regression analyses are a standard tool for the assessment of statistical relationship analyses. The data collection methods leveraged the random-sampling on a large sample, while carefully adhering to privacy requirements. The researcher randomly selected 200 students from 16 courses taught by three different instructors. The researcher used a subset of 125 students based upon their involvement in the discussion by their usage of mathematical or Excel references. The researcher repeated the reference-counting process to ensure accuracy. Finally, the researcher used Excel's Data Analysis ToolPak to generate and compare PPMCC's (i.e., *r*-values), conduct the regression analyses, and evaluate the *p*-values, and r^2 values.

Chapter Four: Results

The results consisted of analyses of statistical significance of the regression parameters at the α =.10 level of significance. Additionally, Pearson's Correlation Coefficient (*r*) and the Coefficient of Determination (r^2) provided insights into the relationship between student performance and student grades. The evidence suggests significant support for H_1, H_2, H_3, H_4, H_5, H_6, H_{10}, H_{11}, and H_{12}. The data proved insufficient to conduct analyses for H_7, H_8, and H_9. An extremely large data set might provide insights into H_7, H_8, and H_9; however, this study's student-data yielded too few data points. Consequently, this study conducted no regression analyses for H_7, H_8, or H_9. The results showed insufficient support for H_{13}, and H_{16}. The analyses revealed mixed support for H_{14}, H_{15}, H_{16}, H_{17}, and H_{18}.

For each of the regressions, the researcher examined the residual plots to ensure that the error terms (*e*) of the regressions met the conditions of being both normally distributed and statistically independent. Camm et al. (2019) stated that the examination of scatter plots of the residuals is "an extremely effective method for assessing whether these conditions are violated" (p. 314). In this study, the researcher found no discernable pattern in any of the residual scatter plots. Furthermore, the residuals distributed randomly across the residual-plot horizontal axis for all of the plots. Hence, the residual-plots analyses indicated fulfilled conditions for normally distributed and statistically independent error terms.

The following sections present the details of the statistical findings. The first section presents the findings associated with the simple linear regression hypotheses. The second section presents the findings associated with the multiple-regression hypotheses. The final section integrates the findings and presents some concluding remarks. The following sections integrate the examination of PPMCC's with the regression discussions for both simple and multiple regressions. Additionally, the researcher analyzed all hypotheses with a large samples size of $n = 125$.

Simple Linear Regression Hypotheses

The following sections reveal the findings for this study's simple linear regression analyses. The associated simple-linear regression hypotheses consisted of a single independent variable and dependent variable. For each of the hypotheses (H_1 through H_{12}), the independent variable represented a tally of a number of student references, in the form of a total count of the number of 1) equality or inequality references (i.e., =, <, >, ≤, ≥), 2) basic mathematical operator references (i.e., +,-,x,/,^), 3) mathematical function references, or 4) Excel references. The dependent variable represented student performance, either in the form of 1) student midterm exam score, 2) student final exam score, or 3) student course-grade percentage. The simple regression analyses provided evidence that supports positive significant relationships for H_1, H_2, H_3, H_4, H_5, H_6, H_{10}, H_{11}, and H_{12},

H_1. The first hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their midterm exam scores. The statistical evidence supports H_1, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_1 by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance ($\alpha = .10$), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_1.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .258$. Although the correlation is not extremely strong, it is clearly existent and positive. Thus, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their midterm exam score.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥). The dependent variable is student midterm exam scores.

Testing for significance. The *p*-value fell well below the level of significance ($\alpha = .10$) at $p = .004$ and $t(123) = 2.97$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$). Thus, the evidence supports a positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of equality and inequality symbol references. The dependent variable is student midterm exam score. Hence, the evidence supports a significant and strong positive relationship between the tally of equality and inequality symbol references and student midterm exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary

conditions for a regression's error terms (p. 314). Thus, the regression for H_1 produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 6.7% of the variation in student grade was determined by the usage of equality or inequality symbol references ($r^2 = .067$). The variation of 6.7% is merely slight. Thus, although the variation is significant, the independent variable is only a mild predictor. Equation (1) articulates the relationship between the independent and dependent variables of H_1:

$$y = .010x_1 + .701. \tag{1}$$

In (1), only a small slope exists as the parameter of the independent variable x_1.

H2. The second hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their final exam scores. The statistical evidence supports H_2, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_2 by examining Pearson's Correlation Coefficient (*r*), the *p*-value against the level of significance ($\alpha = .10$), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_2.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .339$. Thus, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their final exam score.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥). The dependent variable is student final exam scores.

Testing for significance. The *p*-value fell well below the level of significance ($\alpha = .10$) at $p < .001$ and $t(123) = 3.99$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$ or $\alpha = .01$). Thus, the evidence supports a significantly strong positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of equality and inequality symbol references. The dependent variable is student final exam score. Hence, the evidence supports a significant and strong positive relationship between the tally of equality and inequality symbol references and student final exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_2 produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 11.5% of the variation in student grade was determined by the usage of equality or inequality symbol references ($r^2 = .115$). Although 11.5% is not a large variation, the variation remains significant and shows that the independent variable is a predictor. Equation (2) articulates the relationship between the independent and dependent variables of H_2:

$$y = .017x_1 + .568. \quad (2)$$

In (2), only a small slope exists as the parameter of the independent variable x_1.

H_3. The third hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their course grade percentage. The statistical evidence supports H_3, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_3 by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance ($\alpha = .10$), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_3.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .362$. Thus, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their course grade percentage.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥). The dependent variable is student course-grade percentage.

Testing for significance. The p-value fell well below the level of significance ($\alpha = .10$) at $p < .001$ and $t(123) = 4.31$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$ or $\alpha = .01$). Thus, the evidence supports a significantly strong positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of equality and inequality symbol references. The dependent variable is student final course grade. Hence, the evidence supports a significant and strong positive relationship between the tally of equality and inequality symbol references and student final course grade.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_3 produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 13.1% of the variation in student grade was determined by the usage of equality or inequality symbol references ($r^2 = .131$). Although 13.1% is not a large variation, the variation remains significant and shows that the independent variable is a predictor. Equation (3) articulates the relationship between the independent and dependent variables of H_3:

$$y = .012x_1 + .687. \quad (3)$$

In (3), only a small slope exists as the parameter of the independent variable x_1.

H_4. The fourth hypothesis states that there is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores. The statistical evidence supports H_4, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_4 by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance ($\alpha = .10$), and finally, the Coefficient of

Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_4.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .248$. Thus, there is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of mathematical symbols (+,-,x,/,^). The dependent variable is student midterm exam score.

Testing for significance. The *p*-value fell well below the level of significance ($\alpha = .10$) at $p = .005$ and $t(123) = 2.84$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$ or $\alpha = .01$). Thus, the evidence supports a significantly positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of the number of mathematical symbols (+,-,x,/,^) that students reference. The dependent variable is student midterm exam score. Hence, the evidence supports a significant and positive relationship between the tally of the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_4 produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 6.2% of the variation in student grade was determined by the usage of between the number of mathematical symbols (+,-,x,/,^) that students reference (r^2 = .062). The variation, at 6.2%, is small. However, the variation remains significant and shows that the independent variable is a predictor. Equation (4) articulates the relationship between the independent and dependent variables of H_4:

$$y = .008x_1 + .704. \quad (4)$$

In (4), only a small slope exists as the parameter of the independent variable x_1.

H_5. The fifth hypothesis states that there is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their final exam scores. The statistical evidence supports H_5, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_5 by examining Pearson's Correlation Coefficient (*r*), the *p*-value against the level of significance (α = .10), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_5.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .392$. Thus, there is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their final exam scores.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of mathematical symbols (+,-,x,/,^). The dependent variable is student final exam score.

Testing for significance. The *p*-value fell well below the level of significance ($\alpha = .10$) at $p < .001$ and $t(123) = 4.72$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$ or $\alpha = .01$). Thus, the evidence supports a significantly positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of the number of mathematical symbols (+,-,x,/,^) that students reference. The dependent variable is student final exam score. Hence, the evidence supports a significant and positive relationship between the tally of the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_5 produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 15.4% of the variation in student grade was determined by the usage of between the number of mathematical symbols (+,-,x,/,^) that students reference (r^2 = .154). The 15.4% variation is not big, but it is also not small. The variation remains significant and shows that the independent variable is a predictor. Equation (5) articulates the relationship between the independent and dependent variables of H_5:

$$y = .016x_1 + .565. \tag{5}$$

In (5), only a small slope exists as the parameter of the independent variable x_1.

H_6. The sixth hypothesis states that there is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage. The statistical evidence supports H_6, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_6 by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance (α = .10), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_6.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .397$. Thus, there is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of mathematical symbols (+,-,x,/,^). The dependent variable is student course-grade percentage.

Testing for significance. The *p*-value fell well below the level of significance ($\alpha = .10$) at $p < .001$ and $t(123) = 4.79$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$ or $\alpha = .01$). Thus, the evidence supports a significantly positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of the number of mathematical symbols (+,-,x,/,^) that students reference. The dependent variable is student course-grade percentage. Hence, the evidence supports a significant and positive relationship between the tally of the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_6 produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 15.7% of the variation in student final-course grade percentage was determined by the usage of the number of mathematical symbols (+,-,x,/,^) that students reference ($r^2 = .157$). The 15.7% variation is positive and sizeable. The variation is significant and shows that the independent variable is a predictor. Equation (6) articulates the relationship between the independent and dependent variables of H_5:

$$y = .010x_1 + .686. \tag{6}$$

In (6), only a small slope exists as the parameter of the independent variable x_1.

H_7. The seventh hypothesis states that there is a positive relationship between the number of math functions that students reference in their online discussion-board posts and their midterm exam scores. However, the data lacked sufficient data points to conduct a regression analysis. Thus, the researcher could not investigate any potential relationship. Although further research might reveal support for (or the lack thereof) a relationship, this study's results yielded insufficient evidence to support or to deny a relationship.

H_8. The eighth hypothesis states that there is a positive relationship between the number of math functions that students reference in their online discussion-board posts and their final exam scores. However, the data lacked sufficient data points to conduct a regression analyses. Thus, the researcher could not investigate any potential relationship. Although further research might reveal support for (or the lack thereof) a relationship, this study's results yielded insufficient evidence to support or to deny a relationship.

H_9. The ninth hypothesis states that there is a positive relationship between the number of math functions that students reference in their online discussion-board posts and their course grade percentage. However, the data lacked sufficient data points to conduct a regression analysis. Thus, the researcher could not investigate any potential relationship. Although further research might reveal support for (or the lack thereof) a relationship, this study's results yielded insufficient evidence to support or to deny a relationship.

H_{10}. The tenth hypothesis states that there is a relationship between the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores. The statistical evidence supports H_{10}, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of

H_{10} by examining Pearson's Correlation Coefficient (*r*), the *p*-value against the level of significance (α = .10), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_{10}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .186$. Thus, there is a positive correlation between the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of Excel function references. The dependent variable is student midterm exam score.

Testing for significance. The *p*-value fell below the level of significance (α = .10) at $p = .038$ and $t(123) = 2.10$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$). Thus, the evidence supports a significantly positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of the number of Excel functions that students reference. The dependent variable is student midterm exam score. Hence, the evidence supports a significant and positive relationship between the tally of the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_{10} produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 3.5% of the variation in student grade was determined by the usage of the number of Excel functions that students reference ($r^2 = .035$). The variation, at 3.5%, is quite small. However, the variation remains significant and shows that the independent variable is a predictor. Equation (7) articulates the relationship between the independent and dependent variables of H_{10}:

$$y = .009x_1 + .703. \tag{7}$$

In (7), see only a small slope exists as the parameter of the independent variable x_1.

H_{11}. The 11th hypothesis states that there is a relationship between the number of Excel functions that students reference in their online discussion-board posts and their final exam scores. The statistical evidence supports H_{11}, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_{11} by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance ($\alpha = .10$), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_{11}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at $r(123) = .195$. Thus, there is a positive correlation between the number of Excel functions that students reference in their online discussion-board posts and their final exam scores.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of Excel function references. The dependent variable is student final exam score.

Testing for significance. The p-value fell below the level of significance (α = .10) at $p = .029$ and $t(123) = 2.21$. The researcher could have used a stricter level of significance (e.g., $\alpha = .05$). Thus, the evidence supports a significantly positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of the number of Excel functions that students reference. The dependent variable is student final exam score. Hence, the evidence supports a significant and positive relationship between the tally of the number of Excel functions that students reference in their online discussion-board posts and their final exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_{11} produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 3.8% of the variation in student grade was determined by the usage of the number of Excel functions that students reference (r^2 = .038). The variation, at 3.8%, is quite small. However, the variation remains significant and shows that the independent variable is a predictor. Equation (8) articulates the relationship between the independent and dependent variables of H_{11}:

$$y = .012x_1 + .578. \quad (8)$$

In (8), see only a small slope exists as the parameter of the independent variable x_1.

H_{12}. The 12th hypothesis states that there is a relationship between the number of Excel functions that students reference in their online discussion-board posts and their course grade percentage. The statistical evidence supports H_{12}, suggesting that a positive relationship exists. The researcher evaluated the relationship between the variables of H_{12} by examining Pearson's Correlation Coefficient (*r*), the *p*-value against the level of significance (α = .10), and finally, the Coefficient of Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_{12}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlation between the independent and dependent variables. In this study, Pearson's Correlation Coefficient suggested a positive correlation at *r*(123) = .244. Thus, there is a positive correlation between the number of Excel functions that students reference in their online discussion-board posts and their course grade percentage.

The regression components. The components of the regression consist of one independent variable and one dependent variable. The regression's independent variable is the tally of the number of Excel function references. The dependent variable is student course-grade percentage.

Testing for significance. The *p*-value fell below the level of significance (α = .10) at p = .006 and $t(123) = 2.79$. The researcher could have used a stricter level of significance (e.g., α = .05 or α = .01). Thus, the evidence supports a significantly positive relationship between the regression's independent and dependent variables. The regression's independent variable is the tally of the number of Excel functions that students reference. The dependent variable is student course-grade percentage. Hence, the evidence supports a significant and positive relationship between the tally of the number of Excel functions that students reference in their online discussion-board posts and their course grade percentage.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_{12} produced error terms that were both normally distributed and statistically independent.

Coefficient of Determination. Finally, the Coefficient of Determination showed that 5.9% of the variation in student grade was determined by the usage of the number of Excel functions that students reference (r^2 = .059). The variation, at 5.9%, is small. However, the variation remains significant and shows that the independent variable is a predictor. Equation (9) articulates the relationship between the independent and dependent variables of H_{12}:

$$y = .010x_1 + .690. \quad (9)$$

In (9), see only a small slope exists as the parameter of the independent variable x_1.

Multiple Linear Regression Hypotheses

The following sections reveal the findings for this study's multiple linear regression analyses. The multiple regression analyses came in two forms: 2 independent variables or 3 independent variables. For each of the hypotheses (H_{13} through H_{18}), the independent variables represented a tally of a number of student references, in the form of a total count of the number of 1) equality or inequality references (i.e., =, <, >, ≤, ≥), 2) basic mathematical operator references (i.e., +,-,x,/,^), 3) mathematical function references, or 4) Excel references. The dependent variable represents student performance, either in the form of 1) student midterm exam score, 2) student final exam score, or 3) student course-grade percentage. Overall, the multiple regression analyses revealed mixed support, with mathematical-operators parameters providing the sole significant support for most of the hypotheses of the multiple regressions: H_{14}, H_{15}, H_{17}, and H_{18}. The other multiple-regression hypotheses (H_{13} and H_{16}) were unsupported, with their associated parameters all indicating non-significance.

Two Predictors

H_{13}. The 13th hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores. The statistical evidence does not support H_{13}, providing no significant support for a positive relationship. The researcher evaluated the relationship between the variables of H_{13} by examining Pearson's Correlation Coefficients (*r*) for each independent variable against the dependent variable and the *p*-

value against the level of significance ($\alpha = .10$). The following paragraph presents the statistical details of the regression analysis of H_{13}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlations between each independent variable versus the dependent variable. In this study, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their midterm exam scores, at $r(123) = .258$. There is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam scores, at $r(123) = .248$.

The regression components. The components of the regression consist of two independent variables and one dependent variable. The regression's independent variables are the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts. The dependent variable is student midterm exam scores.

Testing for significance. The p-value is above the level of significance ($\alpha = .10$) at $p = .150$ and $t(122) = 1.45$ for the equality and inequality references and $p = .237$ and $t(122) = 1.19$ for the mathematical operators references, each indicating non-significance. Therefore, the evidence does not support a positive relationship between the regression's independent and dependent variables. Hence, although Pearson's Correlation Coefficient indicated a positive relationship, the statistical evidence does not support a significant positive relationship between the number of equation and inequality symbols (=, <, >, ≤,

≥), the number of mathematical symbols (+,-,x,/,^) that students reference, and their midterm exam score.

H_{14}. The 14th hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their final exam scores. The statistical evidence showed mixed support for H_{14}, with one independent variable indicating non-significance and the other independent variable indicating significance. The researcher evaluated the relationship between the variables of H_{14} by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance (α = .10), and finally, the Coefficient of Multiple Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_{14}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlations between each independent variable versus the dependent variable. In this study, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their final exam scores, at $r(123) = .339$. There is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their final exam scores, at $r(123) = .392$.

The regression components. The components of the regression consist of two independent variables and one dependent variable. The regression's independent variables are the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts, x_1 and x_2 respectively. The dependent variable is student final exam scores.

Testing for significance. The *p*-value is above the level of significance ($\alpha = .10$) at $p = .199$ and $t(122) = 1.29$ for the equality and inequality references, but the *p*-value is below the level of significance for the basic mathematical operators references, at $p = 0.008$ and $t(122) = 2.71$. Therefore, the evidence indicates non-significance for equality and inequality references as a predictor of final exam scores. However, the evidence supports a positive relationship for basic mathematical operator references as a predictor of final exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_{14} produced error terms that were both normally distributed and statistically independent.

Coefficient of Multiple Determination. Finally, the Coefficient of Multiple Determination showed that approximately 16.5% of the variation in student final exam scores were determined by the usage of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference ($r^2 = .165$). The variation, at 16.5%, is not large, but it is sizeable. Equation (10) articulates the relationship between the independent and dependent variables of H_{14}:

$$y = .007x_1 + .012x_1 + .558. \tag{10}$$

In (10), only a small slope exists as the parameter of the independent variables.

H_{15}. The 15th hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage. The statistical evidence showed mixed support for H_{15}, with one independent variable indicating non-significance and the other independent variable indicating significance. The researcher evaluated the relationship between the variables of H_{15} by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance ($\alpha = .10$), and finally, the Coefficient of Multiple Determination (r^2). The following paragraph presents the statistical details of the regression analysis of H_{15}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlations between each independent variable versus the dependent variable. In this study, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their course grade percentage, at $r(123) = .362$. There is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage, at $r(123) = .397$.

The regression components. The components of the regression consist of two independent variables and one dependent variable. The regression's independent variables are the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts, x_1 and x_2 respectively. The dependent variable is student course-grade percentage.

Testing for significance. The *p*-value is above the level of significance ($\alpha = .10$) at $p = .105$ and $t(122) = 1.63$ for the equality and inequality references, but the *p*-value is below the level of significance for the basic mathematical operators references, at $p = 0.012$ and $t(122) = 2.55$. Therefore, the evidence indicates non-significance for equality and inequality references as a predictor of final exam scores. However, the evidence supports a positive relationship for basic mathematical operator references as a predictor of final exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary conditions for a regression's error terms (p. 314). Thus, the regression for H_{14} produced error terms that were both normally distributed and statistically independent.

Coefficient of Multiple Determination. Finally, the Coefficient of Multiple Determination showed that 17.5% of the variation in student final exam scores were determined by the usage of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference ($r^2 = .175$). The variation, at 17.5%, is not large, but is still sizeable. Equation (11) articulates the relationship between the independent and dependent variables of H_{15}:

$$y = .006x_1 + .007x_1 + .681. \tag{11}$$

In (11), only a small slope exists as the parameter of the independent variables.

Three Predictors

H_{16}. The 16th hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores. The statistical evidence does not support H_{16}, providing no significant support for a positive relationship. The researcher evaluated the relationship between the variables of H_{16} by examining Pearson's Correlation Coefficient (*r*) and the *p*-value against the level of significance (α = .10). The following paragraph presents the statistical details of the regression analysis of H_{16}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlations between each independent variable versus the dependent variable. In this study, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their midterm exam score, at $r(123) = .258$. There is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm exam score, at $r(123) = .248$. Finally, there is a positive correlation between the number of Excel functions that students reference in their online discussion-board posts and their midterm exam scores, at $r(123) = .186$.

The regression components. The components of the regression consist of three independent variables and one dependent variable. The regression's independent variables are the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts. The dependent variable is student midterm exam scores.

Testing for significance. The *p*-value is above the level of significance ($\alpha = .10$) at $p = .379$ and $t(122) = .88$ for the equality and inequality references, $p = .193$ and $t(122) = 1.31$ for the mathematical operators references, and $p = .283$ and $t(122) = 1.08$ for the number of Excel function references. Thus, each independent variable indicated non-significance. Therefore, the evidence does not support a positive relationship between the regression's independent and dependent variables. Hence, although Pearson's Correlation Coefficient indicated a positive relationship, the statistical evidence does not support a significant positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), the number of Excel functions that students reference, and their midterm exam score.

H_{17}. The 17th hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts and final exam scores. The statistical evidence showed mixed support for H_{17}, with one independent variable indicating significance and the other independent variables indicating non-significance. The researcher evaluated the relationship between the variables of H_{17} by examining the *p*-value against the level of significance ($\alpha = .10$) and the Coefficient of Multiple Determination. The following paragraph presents the statistical details of the regression analysis of H_{17}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (*r*) to examine the correlations between each independent variable versus the dependent variable. In this study, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their final exam score, at $r(123) = .339$. There is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their midterm final score, at $r(123) = .392$. Finally, there is a positive correlation between the number of Excel functions that students reference in their online discussion-board posts and their final exam scores, at $r(123) = .195$.

The regression components. The components of the regression consist of three independent variables and one dependent variable. The regression's independent variables are the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥) the number of mathematical symbols (+,-,x,/,^), the number of Excel functions that students reference in their online discussion-board posts (i.e., x_1, x_2 ,x_3, respectively). The dependent variable is student midterm exam scores.

Testing for significance. The *p*-value is above the level of significance ($\alpha = .10$) at $p = .434$ and $t(122) = .79$ for the equality and inequality references and $p = .339$ and $t(122) = .96$ for the Excel function references. However, the *p*-value is below the level of significance for the basic mathematical operators references, at $p = .006$ and $t(122) = 2.80$. Therefore, the evidence indicates non-significance for equality and inequality references, as well as Excel function references, as predictors of final exam scores. However, the evidence supports a positive relationship for basic mathematical operator references as a predictor of final exam scores.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary

conditions for a regression's error terms (p. 314). Thus, the regression for H_{17} produced error terms that were both normally distributed and statistically independent.

Coefficient of Multiple Determination. Finally, the Coefficient of Multiple Determination showed that approximately 17.1% of the variation in student final exam scores were determined by the usage of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference (r^2 = .171). The variation, at 17.1%, is not large, but it is still sizeable. Equation (12) articulates the relationship between the independent and dependent variables of H_{17}:

$$y = .005x_1 + .013x_2 + .005x_3 + .548. \tag{12}$$

In (12), only a small slope exists as the parameter of the independent variables.

H_{18}. The 18th hypothesis states that there is a positive relationship between the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts and their final exam scores. The statistical evidence showed mixed support for H_{18}, with one independent variable indicating non-significance and the other independent variable indicating significance. The researcher evaluated the relationship between the variables of H_{18} by examining Pearson's Correlation Coefficient (r), the p-value against the level of significance (α = .10), and finally, the Coefficient of Multiple Determination (r^2). The following paragraphs present the statistical details of the regression analysis of H_{18}.

Pearson's Correlation Coefficient. The researcher used Pearson's Correlation Coefficient (r) to examine the correlations between each independent variable versus the dependent variable. In this study, there is a positive correlation between the number of equation and inequality symbols (=, <, >, ≤, ≥) that students reference in their online discussion-board posts and their course grade percentage, at $r(123) = .362$. There is a positive correlation between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their course grade percentage, at $r(123) = .397$. Finally, there is a positive correlation between the number of Excel functions that students reference in their online discussion-board posts and their course grade percentage, at $r(123) = .244$.

The regression components. The components of the regression consist of three independent variables and one dependent variable. The regression's independent variables are the tally of the number of the number of equation and inequality symbols (=, <, >, ≤, ≥), the number of mathematical symbols (+,-,x,/,^), and the number of Excel functions that students reference in their online discussion-board posts (i.e.,x_1, x_2, x_3, respectively). The dependent variable is student final exam scores.

Testing for significance. The *p*-value is above the level of significance ($\alpha = .10$) at $p = .370$ and $t(121) = .90$ for the equality and inequality references and at $p = .145$ and $t(121) = 1.47$ for the Excel function references. However, the *p*-value is below the level of significance for the basic mathematical operators references, at $p = .008$ and $t(121) = 2.72$. Therefore, the evidence indicates non-significance for equality and inequality references, and the Excel function references, as predictors of final exam scores. However, the evidence supports a positive relationship for basic mathematical operator references as a predictor of course grade percentage.

Residuals scatter-plot analysis. The residuals scatter-plot analysis for the regression revealed no discernable pattern in the data and displayed a randomness about the scatter-plot's horizontal axis. According to Camm et al. (2019), the examination of scatter plots of the residuals is "an extremely effective method" in checking the necessary

conditions for a regression's error terms (p. 314). Thus, the regression for H_{18} produced error terms that were both normally distributed and statistically independent.

Coefficient of Multiple Determination. Finally, the Coefficient of Multiple Determination showed that approximately 19% of the variation in student final exam scores were determined by the usage of the number of equation and inequality symbols (=, <, >, ≤, ≥) and the number of mathematical symbols (+,-,x,/,^) that students reference (r^2 = .190). The variation, at 19%, is sizeable. Equation (13) articulates the relationship between the independent and dependent variables of H_{18}:

$$y = .003x_1 + .008x_2 + .005x_3 + .671. \tag{13}$$

In (13), only a small slope exists as the parameter of the independent variables.

Conclusion

Regression analysis for basic mathematical operations suggested a rich, significant relationship between mathematical operations and student scores (i.e., for H_4, H_5, and H_6). For H_4 there was a positive correlation with statistical significance, with α = .10, n = 125, $r(123)$ = .248, $t(123)$ = 2.84 and p =.005. For H_5 there was a positive correlation with statistical significance, with α = .10, n = 125, $r(123)$ = .392, $t(123)$ = 4.72 and p < .001. For H_6 there was a positive correlation with statistical significance, with α = .10, n = 125, $r(123)$ = .397, $t(123)$ = 4.79 and p < .001.

Three of the hypotheses (i.e., H_7, H_8, and H_9) explored a potential relationship between mathematical functions and student grades. However, only one student posted a reference to a mathematical function. Thus, the lack of mathematical function data precluded a regression analysis for the mathematical function hypotheses of H_7, H_8, and H_9.

Regression analysis suggested a significant relationship between Excel functions and student scores (i.e., for H_{10}, H_{11}, and H_{12}). For H_{10} there was a positive correlation with statistical significance, with $\alpha = .10$, n = 125, $r(123) = .186$, $t(123) = 2.10$, and $p = .038$. For H_{11} there was a positive correlation with statistical significance, with $\alpha = .10$, n = 125, $r(123) = .195$, $t(123) = 2.21$, and $p = .029$. For H_{12} there was a positive correlation with statistical significance, with $\alpha = .10$, n = 125, $r(123) = .244$, $t(123) = 2.79$, and $p = .006$.

Chapter Five: Discussion and Conclusion

The purpose of this study was to examine the relationship (or the lack thereof) between student involvement in online discussion boards and student performance. Astin's (1999) Student Involvement Theory (SIT) served as the theoretical foundation for the research. SIT posits that student involvement directly affects student output. In this study, student discussion-board posting measured student involvement, and student scores measured student output. Many of the hypotheses had statistical support, while some hypotheses did not have statistical support. However, the salient finding is there is a positive relationship between the number of mathematical symbols (+,-,x,/,^) that students reference in their online discussion-board posts and their scores (midterm exam, final exam, and final course-grade percentage). The following sections present the most critical findings, a review of the research methodology, a discussion of research limitations and threats to validity, recommendations for future research, and a conclusion.

Critical Findings

This study consisted of simple and multiple regression analyses. The following subsections present the critical findings according to regression type. First, the subsections present a review of the hypotheses and their regression components. Second, each subsection presents the most prominent finding. Finally, the last subsection presents one final integrated critical finding of this study, as a whole.

The Simple Linear Regression Hypotheses

The simple-linear regression hypotheses consist of a single independent variable and a dependent variable. For each of the hypotheses (H_1 through H_{12}), the independent variable represented a tally of a number of student references, in the form of a total count of the number of 1) equality or inequality references (i.e., =, <, >, ≤, ≥), 2) basic mathematical operator references (i.e., +,-,x,/,^), 3) mathematical function references, or 4) Excel references. The dependent variable represented student performance, either in the form of 1) student midterm exam score, 2) student final exam score, or 3) student course-grade percentage. The simple regression analyses provided evidence that supports positive significant relationships for H_1, H_2, H_3, H_4, H_5, H_6, H_{10}, H_{11}, and H_{12},

Critical finding #1. The most critical simple-regression finding is that all of the hypotheses found support for each of the independent variables, with the exception of those hypotheses designed to examine mathematical function references (H_7, H_8, and H_9). The lack of data prevented analyses of mathematical function references. Thus, the evidence suggests that there is a positive relationship between equality and inequality symbol references, basic mathematical operator references, and Excel functions that students reference in their online discussion-board posts and their scores (i.e., midterm exam score, final exam score, and final course grade percentage).

The Multiple Linear Regression Hypotheses

The multiple regression analyses revealed mixed support, with mathematical-operators parameters providing the sole significant support for most of the hypotheses of the multiple regressions: H_{14}, H_{15}, H_{17}, and H_{18}. The other multiple-regression hypotheses (H_{13} and H_{16}) were unsupported, with their associated parameters all indicating non-significance. The multiple regression analyses came in two forms: 2 independent variables or 3 independent variables. For each of the hypotheses (H_{13} through H_{18}), the independent variables represented a tally of a number of student references, in the form of a total count of the number of 1) equality or inequality references (i.e., =, <, >, ≤, ≥), 2) basic mathematical operator references (i.e., +, -, x, /, ^), 3) mathematical function references, or 4) Excel references. The dependent variable represented student performance, either in the form of 1) student midterm exam score, 2) student final exam score, or 3) student course-grade percentage.

Critical finding #2. The most critical multiple-regression finding is the prominence of the mathematical-operators parameters providing the sole significant support for most of the hypotheses of the multiple regressions: H_{14}, H_{15}, H_{17}, and H_{18}. Only two of the multiple-regression analyses did not provide support for the mathematical-operator parameters: H_{13} and H_{16}. Thus, the mathematical-operators parameter seems an important factor of the multiple regression, which leads to the most-important critical finding (i.e., critical finding #3).

Multiple and Simple Regressions: Critical Finding #3.

The most critical finding of this entire study is the prominence of the mathematical-operators parameters significance across both the simple and the multiple regression analyses. The mathematical-operators parameter found significance in each of the simple-regression hypotheses in which it was contained: H_4, H_5, and H_6. Moreover, the mathematical-operators parameter provided the sole significant support for most of the hypotheses of the multiple regressions: H_{14}, H_{15}, H_{17}, and H_{18}. Thus, the mathematical-operators parameters are vital predictors. In other words, the culmination of this research project has found that the evidence that suggests there is a positive relationship between the number of mathematical symbols (+, -, x, /, ^) that students reference in their online discussion-board posts and their scores (i.e., midterm exam score, final exam score, and final course grade as a percentage).

Review of Methodology

The researcher counted the number of basic mathematical symbol and Excel function references as a quantitative measure of student involvement. Additionally, student midterm exam, final exam, and final course grade (measured as a percentage) operationalized student output. The researcher examined *anonymized* student posts in online discussion boards (from concluded courses), counted the number of references to mathematical symbols or functions, and compared that count with student scores (i.e., grades).

Anonymization protected student identities, throughout this study. All anonymized student data from all classes was bundled together before counting the number of mathematical references. Finally, the researcher conducted regression analyses to compare the number of mathematical references to the anonymized student grades. All regression tests were conducted at $\alpha = .10$ level of significance.

The researcher triangulated the data by examining Pearson's Product-Moment Correlation Coefficient and conducting regression analyses for each hypothesis. To ensure reliability and accuracy in the results, the researcher conducted the regressions multiple times and conducted comparative analyses of the results. Consequently, the researcher logged any discrepancies and re-examined the data until all data discrepancies were reconciled.

The subjects in this study consisted of 200 randomly-selected students from sixteen different sections of business-analytics courses that were taught at Lindenwood University between the Fall 2016 and the Fall 2018 terms (inclusive). This study examined student involvement; therefore, based upon the usage of a reference to a basic mathematical symbol or Excel function in one or more discussion-board posts, the researcher sub-selected 125 students from the 200 randomly-selected students based upon student use of any single-instance (or more) of the hypothesized references.

Research Limitations and Threats to Validity

The research limitations and threats to validity for this study come in a number of forms. First, only one university served to provide data. Second, the 16 courses that served as a selection pool of students consisted of a single math-based business-topic course: Business Analytics. Third, the researcher taught 14 of the 16 courses. Only two adjunct instructors taught two of the 16 courses. Fourth, although the data are technically longitudinal (i.e., cover an eight-week period), the data analyses are cross-sectional in nature. Fifth, class sizes, in general, did not exceed thirty students, whereas some universities have much larger class sizes. Sixth, the term lengths were limited to an eight-week format. Seventh, the university in this study used only one learning management system (i.e., Canvas) between the fall 2016 and the fall 2018 terms.

Each of the aforementioned limitations are threats to the validity of the statistical inference power of this study. However, the statistical-inferential power is not nullified by the threats, and one can make a reasonable level of inference based upon the current data set. Granted, further research with fewer of the aforementioned limitations could provide stronger inferential power and unearth additional insights. However, some of these limitations are also strengths, providing keen insights to particularized environments. For example, this study is limited to online business analytics courses. Thus, while the results are not necessarily generalizable (i.e., a weakness) across disciplines, the results can provide valuable and focused insights (i.e., a strength) into similar-topic or same-topic courses.

Single-university data source. One significant limitation of this study is its use of a single mid-sized Midwestern university as its sole data source. A series of limitations accompany this single data source. For this single-university data source, the researcher drew data from a limited pool of instructors and students. The faculty and students in this study might have a different culture from those of other universities. Thus, this single-university data source study does not necessarily yield results that are generalizable to other universities. Additionally, other factors might influence the findings of this study in a way that would differ at other universities.

The limitations from stakeholders and environments are limitless. Governing bodies, location, technical environment, faculty teaching philosophies, student learning philosophies, laws, public influence, etc. all tie to this single-university data source and can significantly differ from other universities. Although the students and instructors were in an online environment, the physical location of the main campus of the university was restricted to a single physical location. Thus, the university was bound to a certain set of local, county, and federal laws.

The key governing bodies come in a number of forms. The university is subject to city, county, state, and federal authorities and laws. The university is accredited by the Higher Learning Commission (HLC) and the Accreditation Council for Business Schools and Programs (ACBSP). The university has its own governing administration and board. Thus, each of these governing bodies affects the university and the impact results on students, faculty, staff, and the academic programs might differ from the impacts to other universities. Thus, the findings of this study are subject to these numerous factors in ways that might differ from other universities.

However, this study is not concerned with every possible factor (direct or indirect) influencing student activity in discussion-board activity. Additionally, this study focused on online students, which have no on-campus requirement. Hence, this study simply focused upon posting activity versus student performance, with the researcher regarding those measures *in summa* of all other influences.

Limited selection pool. The 16 courses that served as a selection pool of students consisted of a single math-based business-topic course: Business Analytics. Thus, statistical inference of this study is limited to varying degrees. Business analytics is a business course that is math based. For this study, statistical inference is somewhat limited to online business analytics courses that parallel the characteristics of the university, course, faculty, and students of this study.

However, one can certainly make reasonable extensions to the inferences of this study. For example, especially when one considers the very limited scope of the independent variables (e.g., equality, inequality, basic math operators, Excel functions), we know that those entities can abundantly appear in other math-based business courses. Additionally, non-business courses that are math based can certainly have abundant math and Excel references. Thus, any math-based course is, at least, a potential candidate for applying the statistical-inference findings of this study.

Limited instructors. The researcher taught 14 of the 16 courses. Only two adjunct instructors taught two of the sixteen courses. Thus, the limited pool of instructors was a considered factor in influencing the validity of the findings. However, the instructors made no requirement of the usage of mathematical terminology, mathematical symbols, nor Excel references. Thus, students' usage of the references in the hypothesized categories were entirely autonomous and separate from the influence of the instructors.

Cross sectional nature. Although the data are technically longitudinal (i.e., cover an eight-week period), the data analyses are cross sectional in nature. The aim of this study was to determine the existence (or lack thereof) of a relationship between the independent variables and the dependent variables. Thus, the analyses methods did not require longitudinal data. Furthermore, this study did not aim to establish causality, which requires experimentation. Hence, the researcher did not attempt to retain the longitudinal characteristics of the data. Rather, the research simply tallied the number of reference counts (i.e., the independent variables) and analyzed those references against student scores (i.e., the dependent variables). Thus, the researcher is not stating that the usage of math symbol or Excel function references necessarily *causes* higher scores. Additionally, the researcher is not stating that higher scores necessarily lead to an increase in the number of math symbol or Excel function references. However, the researcher is stating that the salient finding of this study is that the evidence suggests a positive relationship exists between basic math operator references and student scores.

Furthermore, although a natural progression exists for the independent variables and the dependent variables, the natural progression was immaterial to the goals of this study. Additionally, a natural progression is self-evident in the sequencing of the dependent variables (midterm exam, final exam, and final course grade percentage). However, this study did not aim to analyze phenomenon in these natural progressions. Granted, a future study could provide valuable insights by using longitudinal data or experimentation. Thus, although causality is beyond the scope of this study, it is an interesting potential successor topic.

Small class sizes. Class sizes, in general, did not exceed thirty students, whereas some universities have much larger class sizes. Class size might affect online student performance. However, this study did not aim to analyze the influence of class size on student performance. Therefore, even though the examination of class size vis-à-vis scores is beyond the scope of this study, class size is a potential influencing factor for large online classes. The small class sizes of this study threaten statistical inference power for online courses with large classes. Yet, for this study, the limited class size serves, quite nicely, as a control and limiting variable. The researcher excluded class size from the regression analyses, but class size is a possible variable for future examination.

Term lengths. The term lengths were limited to an eight-week format. The eight-week format is not an industry standard. Universities have leeway in the determination of the term lengths. In some cases, an online term might last for fifteen or sixteen weeks. Term length might affect online student performance. However, this study did not aim to analyze the influence of term length on student performance. Therefore, even though the examination of term length vis-à-vis scores is beyond the scope of this study, term length is a potential influencing factor for online classes. The term length of the classes in this study could threaten statistical inference power for online courses with differing term lengths. Yet, for this study, the matching eight-week term lengths serves, quite nicely, as a control and limiting variable. The researcher excluded term length from the regression analyses, but term length is a possible variable for future examination.

Single learning management system. The university in this study used only one learning management system (i.e., Canvas) between the fall 2016 and the fall 2018 terms. Although Canvas is a popular LMS, some universities use other LMS's. The choice of LMS might affect online student performance, especially considering an LMS's learning curve, ease-of-use, familiarity, or technical support. However, this study did not aim to analyze the influence of LMS on student performance. Therefore, even though the examination of LMS length vis-à-vis scores is beyond the scope of this study, LMS type is a potential influencing factor for online classes. The LMS of the classes in this study could threaten statistical inference power for online courses with differing LMS types. Yet, for this study, the LMS serves as a control variable. The researcher excluded LMS type from the regression analyses, but LMS type is a possible variable for future examination.

Recommendations for Future Research

The future-research possibilities extend in numerous ways (e.g., closer examination of mathematical symbol types, inclusion of demographic information, examination of different disciplines of math-based courses, etc.). However, a few recommendations come to the forefront of possibilities. Namely, both globalism and causality are key areas for future research consideration. The following discussion explains the reasoning behind these choice-research directions.

Globalization continues to affect higher education (Budevici-Puiu, 2020; Farber, 2020; Korotkova et al., 2020; Patterson, et al., 2012; Yang & Liu, 2007). Thus, globalization is a key consideration for the continuation and augmentation of this study. For example, globalization introduces multicultural elements into higher education because various people groups interact in online learning environments. In improving the predictive power of the regression variables, future research could incorporate demographic data as an independent variable (or even a moderator or mediator) to the relationship between the independent and dependent regression variables of this study. Greater predictive power, in the form of moderators or mediators, could help to identify student groups from cultures or socio-economic conditions that might be require more instructor attention.

Research examining causality between the variables of this study might provide the most value and greatest insights because identifying the cause in the relationship between the variables carries significant implications for practice. Identifying the cause of student success in relation to the predictor variables might provide a means to increase student mathematical prowess. Unfortunately, the current literature does not address the question of causality in mathematical or Excel relevant discussion-board content vis-à-vis student grades. Yet, action research or experimentation would be particularly useful in identifying causality. For instance, this study found statistical support for a significant relationship between student usage of mathematical operators and student grades (e.g., H_4, H_5, and H_6). However, this study did not determine a causal relationship. A study that can determine causality might provide a definitive path for improved student performance. For example, if a study revealed that increased usage of mathematical operator symbols caused improved grades (possibly indicating improved mathematical skill), then instructors might encourage (or even require) students' increased usage of such symbols in online discussions. Thus, students' increased usage of mathematical operator symbols might lead to improved course performance.

Identifying causality might provide a means to identify and remedy mathematics learning-barriers. Rule and Harrell (2006) identified mathematical anxiety as a barrier to learning. If an instructor required students to increase their use of mathematical symbols, then would such a requirement help students to overcome such mental barriers? Experimental research would address the questions associated with causality. Thus, causality is a key target for future research. The potential findings are intriguing and could prove quite valuable.

Future Implications for Practice

Technology seems to change rapidly. Additionally, online courses seem to be changing rapidly, as related to changes in technology and changes in teaching methods. Thus, higher education must constantly keep abreast of technological changes. However, online discussion boards have been predominantly *text-based*, which is a relatively stable (i.e., unchanging) technology. Thus, future implications for technological changes to online discussion boards should be somewhat limited. However, technological supplements to text-based online discussion boards are available, which adds complexity to simple text-based technology. For example, with some online discussion boards, students can include pictures or videos as part of their online discussion ("How do I," 2018). Furthermore, virtual reality technology allows for audio-video online discussion boards. Thus, organizational concerns for the future consist of potential technological changes.

As Birnbaum (1991) so aptly stated, the "concept that best reflect the ways in which institutions of higher education differ from other organizations is governance" (p. 4). Birnbaum (1991) defined governance as "the structures and processes through which institutional participants interact with and influence each other and communicate with the larger environment" (p. 4). Thus, faculty and administrators should consider the findings of this study when encountering the governance processes associated with online courses, programs, and discussion boards. The following discussion visits possible implications for administration, faculty, students, and staff.

Administration. A number of key concerns exist regarding administration at institutions that use online discussion boards. The key concerns relate to questions of staffing and deployment. How is the organization going to plan, lead, organize, and control online programs that use online discussion boards? For instance, Hülsmann and Shabalala (2016) raised the organizational concern of class size and workload associated with online programs. For large class sizes, teacher availability for one-on-one student contact drops. Thus, for courses that use online discussion boards, what should be the optimal class size? Additionally, some courses might require more teacher attention than others. Hence, should those online classes be smaller so that teachers can give greater attention to the online discussion boards? Additionally, Lockyer et al. (2006) stated that faculty who transition from traditional classrooms to online classrooms faced two challenges: “the technical aspects associated with the medium and the skills of facilitating in a different environment” (p. 625). El Mansour and Mupinga (2007) also acknowledged the need to train faculty (p. 242). Therefore, administrators should consider offering faculty training for the transition to the online environments. Thus, online programs that use discussion board courses require administrative attention.

Faculty. Various research shed light on the organizational concerns regarding faculty and online discussion boards. For example, a teacher might need to change her or his course design based upon the inclusion of online discussions. Furthermore, the content of the classroom discussions might need adjustments based upon the presence of an online forum. As will be seen in the following discussion, curriculum and course designs might need adjustment based upon the findings of extant research.

Students. The impacts of online discussions to students are another key concern. Some students seem to learn better in some environments than in other environments. Some students prefer an online environment, while other students prefer traditional classrooms. Thus, research could provide deeper insights into the impacts of online discussions for students.

Staff. An institution that uses online discussion boards must have staff available to support the technology. Even if an institution chooses to outsource the technology, the institution must have a point of contact between the institution and the student or faculty member. For example, if a student or faculty member experiences technical difficulties with an online discussion board, that student or faculty member needs a point of contact to address the technical difficulty. Furthermore, somebody must be available to *fix* technical problems. Thus, a key organizational concern, relevant to the support of technology associated with online discussion boards, is staffing. An institution must hire information technology personnel to support the technology, or the institution must outsource the work. In each case, staffing is a concern of practice for online discussion boards.

Conclusion

This study examined the relationship between online student discussion-board activity and student grades and, consequently, addressed a dearth in the literature about this relationship. Astin's (1999) Student Involvement Theory provided the theoretical foundation of this research. This study's sample consisted of 200 online undergraduate students in online business-analytics courses. Regression-analyses findings supported the relationship between student postings of certain mathematical-symbol references (e.g., for equalities, inequalities, addition, subtraction, multiplication, and division) and student grades.

This study's regression analyses revealed both significant and non-significant statistical findings for simple linear regressions and multiple regressions for the research hypotheses. Simple linear regression analyses showed significant support for H_1, H_2, H_3, H_4, H_5, H_6, H_{10}, H_{11}, and H_{12}. Thus, the evidence supported equalities and inequalities, basic math operations, and Excel function references as predictors of student grades. Insufficient data prevented regression analyses of H_7, H_8, and H_9. Multiple regression analyses revealed mixed support for H_{13}, H_{14}, H_{15}, H_{16}, H_{17}, and H_{18}. More specifically, the evidence did not support any predictors of H_{13} and H_{16}. However, H_{14}, H_{15}, H_{17}, and H_{18} only supported the basic math-operations references as a significant predictor, with all other predictors being non-significant.

The findings of this study informs research and practice of the importance of student involvement in online discussions. The evidence of this study suggests that there is a positive relationship between equality and inequality symbol references, basic mathematical operator references, and Excel functions that students reference in their online discussion-board posts and their scores (i.e., midterm exam score, final exam score, and final course grade percentage). The findings of this study support Astin's (1999) Student Involvement Theory vis-à-vis student involvement (via text-based discussion) and student grades. Therefore, administrators, faculty, and course designers should consider the use of online text-based discussions for all math-based courses, online, traditional, and hybrid.

References

Alkış, N., & Temizel, T. T. (2018). The impact of motivation and personality on academic performance in online and blended learning environments. *Journal of Educational Technology & Society*, *21*(3), 35–47.

Allen, I. E., & Seaman, J. (2013). *Changing course: Ten years of tracking online education in the United States.* Retrieved from https://www.onlinelearningsurvey.com/reports/changingcourse.pdf

Ambrus, G., Filler, A., & Vancsó, Ö. (2018). Functional reasoning and working with functions: Functions/mappings in mathematics teaching tradition in Hungary and Germany. *Mathematics Enthusiast*, *15*(3), 429–454.

António Moreira, J., Santana e Santana, C. L., & González Bengoechea, A. (2019). Teaching and learning in digital social networks: The Mathgurl case on Youtube. *Revista de Comunicación de La SEECI*, *50*, 107–126.

Astin, A. W. (1999). Student involvement: A developmental theory for higher education. *Journal of College Student Development*, *40*(5), 518-529.

Atherton, M., Shah, M., Vazquez, J., Griffiths, Z., Jackson, B., & Burgess, C. (2017). Using learning analytics to assess student engagement and academic outcomes in open access enabling programmes. *Open Learning*, *32*(2), 119–136.

Baglione, S. L., & Nastanski, M. (2007). The superiority of online discussion. *Quarterly Review of Distance Education*, *8*(2), 139-150.

Banas, E., & Emory, W. (1998). History and issues of distance learning. *Public Administration Quarterly*, *22*(3), 365-383.

Birnbaum, R. (1991). *How colleges work: The cybernetics of academic organization and leadership*. San Francisco: Jossey-Bass.

Bluman, A. G. (2015). *Elementary statistics: A step-by-step approach*. New York, NY: McGraw-Hill Education.

Boyer, E. L. (1990). *Scholarship reconsidered*. Princeton, NJ: The Carnegie Foundation for the Advancement of Teaching.

Brancaccio, A., Esposito, M., Marchisio, M., Sacchet, M., & Pardini, C. (2019). Open professional development of math teachers through an online Course. *International Conference on E-Learning*, 131–138.

Budevici-Puiu, L. (2020). The necessity of change and development of the higher education institution in the age of globalisation. *Romanian Journal for Multidimensional Education, 12*(1), 350–356.

Camm, J. D., Cochran, J. J., Fry, M. J., Ohlmann, J. W., Anderson, D. R., Sweeney, D. J., & Williams, T. A. (2019). *Business analytics*. Boston, MA, USA: Cengage.

Camus, M., Hurt, N. E., Larson, L. R., & Prevost, L. (2016). Facebook as an online teaching tool: Effects on student participation, learning, and overall course performance. *College Teaching, 64*(2), 84-94.

Capraro, M., & Joffrion, H. (2006). Algebraic equations: Can middle-school students meaningfully translate from words to mathematical symbols? *Reading Psychology*, *27*(2/3), 147–164.

Clark, R. M., Kaw, A., & Delgado, E. (2018). Do adaptive lessons for pre-class experience improve flipped learning? *Proceedings of the ASEE Annual Conference & Exposition*, 1–13.

Cook, M., Dickerson, D. L., Annetta, L. A., & Minogue, J. (2011). In-service teachers' perceptions of online learning environments. *Quarterly Review of Distance Education*, *12*(2), 73-79.

Crisp, E. A., & Bonk, C. J. (2018). Defining the learner feedback experience. *TechTrends: Linking Research & Practice to Improve Learning*, *62*(6), 585–593.

Current issues for higher education information resources management. (n.d.). Retrieved from https://www.educause.edu/ir/library/html/cem/cem97/cem9742.html.

Davies, J., & Graff, M. (2005). Performance in e-learning: online participation and student grades. *British Journal of Educational Technology*, *36*(4), 657-663.

Delaney, D., Kummer, T., & Singh, K. (2019). Evaluating the impact of online discussion boards on student engagement with group work. *British Journal of Educational Technology*, *50*(2), 902–920.

Dengler, M. (2008). Classroom active learning complemented by an online discussion forum to teach sustainability. *Journal of Geography in Higher Education*, *32*(3), 481-494.

Dixon, C. S. (2014). The three e's of online discussion. *Quarterly Review of Distance Education*, *15*(1), 1-8.

Edwards, C. M., Rule, A. C., & Boody, R. M. (2017). Middle school students' mathematics knowledge retention: Online or face-to-face environments. *Journal of Educational Technology & Society*, *20*(4), 1–10.

El Mansour, B., & Mupinga, D. M. (2007). Students' positive and negative experiences in hybrid and online classes. *College Student Journal*, *41*(1), 242-248.

Eyers, A. M., Bragg, L. A., & Reich, M. (2020). Supporting mathematical language through the Frayer Board. *Australian Primary Mathematics Classroom*, *25*(2), 9–13.

Farber, H. (2020). Caught between pedagogy and politics: The challenges of teaching globalization in the Twenty-First Century. *History Teacher*, *53*(3), 409–439.

Fung, J. J. Y., Yuen, M., & Yuen, A. H. K. (2018). Validity evidence for a Chinese version of the online self-regulated learning questionnaire with average students and mathematically talented students. *Measurement & Evaluation in Counseling & Development*, *51*(2), 111–124.

Garneli, V., Giannakos, M., & Chorianopoulos, K. (2017). Serious games as a malleable learning medium: The effects of narrative, gameplay, and making on students' performance and attitudes. *British Journal of Educational Technology*, *48*(3), 842–859.

Graham, V., & Lazari, A. (2018). College algebra - online section versus traditional section. *Georgia Journal of Science*, *76*(2), 1–6.

Hajra, S. G., & Das, U. (2015). Undergraduate students' perceptions of collaborative learning in a differential equations mathematics course. *College Student Journal, 49*(4), 610-618.

Halabi, A. K., & Larkins, J. (2016). The impact of discussion board usage on overall performance in an introductory accounting subject. *Pacific Accounting Review*, *28*(3), 337-358.

Hamann, K., Pollock, P. H., & Wilson, B. M. (2012). Assessing student perceptions of the benefits of discussions in small-group, large-class, and online learning contexts. *College Teaching, 60*(2), 65-75.

Henrikson, R. (2020). Using online lectures to promote engagement: Recognising the self-directed learner as critical for practical inquiry. *Journal of Open, Flexible & Distance Learning*, *24*(1), 17–32.

Hickerson, A., & Kothari, A. (2017). Learning in public: Faculty and student opinions about social media in the classroom. *Journalism & Mass Communication Educator, 72*(4), 397-409.

Hong, J.-C., Hwang, M.-Y., Tai, K.-H., & Lin, P.-H. (2019). Improving cognitive certitude with calibration mediated by cognitive anxiety, online learning self-efficacy and interest in learning Chinese pronunciation. *Educational Technology Research & Development*, *67*(3), 597–615.

How do I embed an image in a discussion reply as a student? (2018, June 25). Retrieved from https://community.canvaslms.com/docs/DOC-10700-4212190965.

Hülsmann, T., & Shabalala, L. (2016). Workload and interaction: Unisa’s signature courses – a design template for transitioning to online DE?. *Distance Education*, *37*(2), 224-236.

Instructure's Company Story. (n.d.). Retrieved June 26, 2020, from https://www.instructure.com/about/our-story.

Jabli, N. M. (2020). The attitudes of Saudi students toward e-learning at Midwest university in USA. *Journal of Education - Sohag University*, *73*(2), 38–63.

Kayler, M., & Weller, K. (2007). Pedagogy, self-assessment, and online discussion groups. *Journal of Educational Technology & Society, 10*(1), 136-147.

Kearney, W. S., & Garfield, T. (2019). Student readiness to learn and teacher effectiveness: Two key factors in middle grades mathematics achievement. *Research in Middle Level Education Online*, *42*(5), 1–12.

Kentnor, H. E. (2015). Distance education and the evolution of online learning in the United States. *Curriculum & Teaching Dialogue, 17*(1/2), 21-34.

Korotkova, Y., Romanyuk, S., Vysochan, L., Shkleda, L., & Kozlova, L. (2020). The phenomenon of the institution of education in the world order of postmodern globalization. *Postmodern Openings*, *11*(3), 244–256

Krentler, K. A., & Willis-Flurry, L. A. (2005). Does technology enhance actual student learning? The case of online discussion boards. *Journal of Education for Business, 80*(6), 316-321.

Littlefield, M. B., & Bertera, E. M. (2004). A discourse analysis of online dialogs in social work diversity courses: topical themes, depth, and tone. *Journal of Teaching in Social Work*, *24*(3/4), 131-146.

Lockyer, J., Sargeant, J., Curran, V., & Fleet, L. (2006). The transition from face-to-face to online CME facilitation. *Medical Teacher*, *28*(7), 625-630.

Lyons, I. M., Price, G. R., Vaessen, A., Blomert, L., & Ansari, D. (2014). Numerical predictors of arithmetic success in grades 1-6. *Developmental Science*, *17*(5), 714–726.

Lyons, I. M., Zheng, S., De Jesus, S., Bugden, S., & Ansari, D. (2018). Symbolic number skills predict growth in nonsymbolic number skills in kindergarteners. *Developmental Psychology*, *54*(3), 440–457.

Martínez-Cerdá, J.-F., Torrent-Sellens, J., & González-González, I. (2018). Promoting collaborative skills in online university: comparing effects of games, mixed reality, social media, and other tools for ICT-supported pedagogical practices. *Behaviour & Information Technology*, *37*(10/11), 1055–1071.

Matsumura, L. C., Zook, H. D., Bickel, D. D., Walsh, M., & Correnti, R. (2019). Harnessing the power of video to increase classroom text discussion quality. *Reading Teacher*, *73*(1), 65–74.

McGuire, P., Tu, S., Logue, M. E., Mason, C. A., & Ostrow, K. (2017). Counterintuitive effects of online feedback in middle school math: Results from a randomized controlled trial in ASSISTments. *Educational Media International*, *54*(3), 231–244.

McNeil, N. M., & Alibali, M. W. (2005). Knowledge change as a function of mathematics experience: All contexts are not created equal. *Journal of Cognition & Development*, *6*(2), 285–306.

Michel, J. O., Campbell, C. M., & Dilsizian, K. (2018). Is STEM too hard? Using Biglan to understand academic rigor and teaching practices across disciplines. *Journal of the Professoriate*, *9*(2), 28–56.

Mills, M. J., Knight, P. A., Kraiger, K., Mayer, W., & LaFontana, K. (2011). Developing and managing i-o online: What's behind the virtual classroom? *TIP: The Industrial-Organizational Psychologist*, *48*(4), 31-37.

Molnar, A. L., & Kearney, R. C. (2017). A comparison of cognitive presence in asynchronous and synchronous discussions in an online dental hygiene course. *Journal of Dental Hygiene*, *91*(3), 14-21.

Moreno-Marcos, P. M., Muñoz-Merino, P. J., Alario-Hoyos, C., Estévez-Ayres, I., & Delgado Kloos, C. (2018). Analysing the predictive power for anticipating assignment grades in a massive open online course. *Behaviour & Information Technology*, *37*(10/11), 1021–1036.

Mulvaney, M. (2020). Discussion groups and multi-formatted content delivery in an online module: Effect on students' self-efficacy. *College Student Journal*, *54*(1), 88–105.

Naranjo, D. M., Prieto, J. R., Moltó, G., & Calatrava, A. (2019). A visual dashboard to track learning analytics for educational cloud computing. *Sensors, (14248220)*, *19*(13), 2952.

Nyet Moi Siew, Geofrey, J., & Bih Ni Lee. (2016). Students' algebraic thinking and attitudes towards algebra: The effects of game-based learning using Dragonbox 12 + app. *Electronic Journal of Mathematics & Technology*, *10*(1), 1–17.

Park, E., Martin, F., & Lambert, R. (2019). Examining predictive factors for student success in a hybrid learning course. *Quarterly Review of Distance Education*, *20*(2), 11–27.

Patterson, L. M., Carrillo, P. B., & Salinas, R. S. (2012). Lessons from a global learning virtual classroom. *Journal of Studies in International Education*, *16*(2), 182-197.

Powell, S. R., & Fuchs, L. S. (2010). Contribution of equal-sign instruction beyond word-problem tutoring for third-grade students with mathematics difficulty. *Journal of Educational Psychology*, *102*(2), 381–394.

Rich, S., Duhon, G., & Reynolds, J. (2017). Improving the generalization of computer-based math fluency building through the use of sufficient stimulus exemplars. *Journal of Behavioral Education*, *26*(2), 123–136

Rule, A. C., & Harrell, M. H. (2006). Symbolic drawings reveal changes in preservice teacher mathematics attitudes after a mathematics methods course. *School Science & Mathematics*, *106*(6), 241–258.

Sáenz-Ludlow, A., & Walgamuth, C. (1998). Third graders' interpretations of equality and the equal symbol. *Educational Studies in Mathematics*, *35*(2), 153–187.

Sage, M. (2013). Distance guest speakers in online synchronous classrooms: Practical and legal considerations. *Journal of Teaching in Social Work, 33*(4/5), 385-392.

Seah, R., & Beencke, A. (2019). Developing critical thinking in the primary years. *Australian Primary Mathematics Classroom*, *24*(3), 3–7.

Solares, A., & Kieran, C. (2013). Articulating syntactic and numeric perspectives on equivalence: the case of rational expressions. *Educational Studies in Mathematics*, *84*(1), 115–148.

Stadtlander, L. M. (1998). Virtual instruction: Teaching on online graduate seminar. *Teaching of Psychology*, *25*(2), 146.

Tanis, C. J. (2020). The seven principles of online learning: Feedback from faculty and alumni on its importance for teaching and learning. *Research in Learning Technology*, *28*.

Tellakat, M., Boyd, R. L., & Pennebaker, J. W. (2019). How do online learners study? The psychometrics of students' clicking patterns in online courses. *PLoS ONE*, *14*(3), 1–17.

Touw, K. W. J., Vogelaar, B., Bakker, M., & Resing, W. C. M. (2019). Using electronic technology in the dynamic testing of young primary school children: predicting school achievement. *Educational Technology Research & Development*, *67*(2), 443–465.

Türel, A., & Furr, D. (2020). A study of online homework managers on student learning and satisfaction in accounting courses. *World of Accounting Science*, *22*, 130–141.

Usher, M., & Barak, M. (2018). Peer assessment in a project-based engineering course: comparing between on-campus and online learning environments. *Assessment & Evaluation in Higher Education*, *43*(5), 745–759.

Vess, D. (2005). Asynchronous discussion and communication patterns in online and hybrid history courses. *Communication Education*, *54*(4), 355-364.

Weldy, T. G. (2018). Traditional, blended, or online: Business student preferences and experience with different course formats. *E-Journal of Business Education & Scholarship of Teaching*, *12*(2), 55–62.

Wexler, A., Davoudi, A., Weissenbacher, D., Choi, R., O'Connor, K., Cummings, H., & Gonzalez-Hernandez, G. (2020). Pregnancy and health in the age of the Internet: A content analysis of online "birth club" forums. *PLoS ONE*, *15*(4), 1–15.

Wick, J. A., Yeh, H.-W., & Gajewski, B. J. (2017). A Bayesian analysis of synchronous distance learning versus matched traditional control in graduate biostatistics courses. *American Statistician*, *71*(2), 137–144.

Willmer, M., & Salzmann-Erikson, M. (2018). 'The only chance of a normal weight life': A qualitative analysis of online forum discussions about bariatric surgery. *PLoS ONE*, *13*(10), 1–14.

Wyman-Blackburn, S. (2018). Math instruction: Digital and physical. *District Administration*, *54*(3), 66–69.

Yang, Z., & Liu, Q. (2007). Research and development of Web-based virtual online classroom. *Computers & Education*, 48, 171–184.

Yu, S. W. (2009). The impact of online discussion on face-to-face discussion and academic achievement. *American Secondary Education*, *37*(2), 4-25.

Žuvic-Butorac, M., Roncevic, N., Nemcanin, D., & Nebic, Z. (2011). Blended e-learning in higher education: Research on students' perspective. *Issues in Informing Science & Information Technology, 8*, 409-429.

Zverev, O., & Sergeeva, T. (2020). Designing a professional training program for working with gifted children using software Office 365. *Mathematics & Informatics*, *63*(3), 291–296.

Vitae

F. Robert Talbott

EDUCATION

Master of Science in Information Systems
University of Missouri – Saint Louis 2012

Master of Business Administration
Lindenwood University 2006

Bachelor of Science
Major: Computer Science
Southern Illinois University at Edwardsville -- School of Engineering 1996

ACADEMIC EMPLOYMENT

Lindenwood University 2007 - Present
Assistant Professor (2007 - Present)
Program Manager of Management Information Systems (2008)
Department Chair of Management Information Systems (2008-2012)

IT PROFESSIONAL EXPERIENCE (1996-2007)

Performed consulting, software engineering, Web development, database, and IT Team-Lead work.

The following is a listing of my client sites and associated consulting companies:

- A.G. Edwards
- Maritz, Inc.
- Peabody Energy Corp.
- StreamSearch.com
- Technology Partners, Inc.
- Ferguson Consulting
- Analysts International Corp. (AiC)
- Computer Sciences Corp.