ABSTRACT

AN ASSESSMENT OF THE EFFECT OF MULTIMEDIA
ON CRITICAL THINKING OUTCOMES

Terrance L. Cottrell, Ed.D.
Department of Educational Technology, Research and Assessment
Northern Illinois University, 2014
Rhonda Robinson, Director

This research study focused on the critical thinking outcomes of undergraduate business students affected by multimedia classroom resources used in the place of text-based resources during the whole of a 16-week semester. Influenced by models for defining and assessing critical thinking developed through the work of Peter Facione, Diane Halpern, and other researchers, combined with educational multimedia learning theory developed by Richard Mayer, this study investigated the relationship between the development of critical thinking skills thought to be gained through traditional methods of the print era and those expected to be gained through the rapid introduction of multimedia to classroom environments in American higher education. This study employed the use of the Business Critical Thinking Skills Test to assess student (a) inductive reasoning, (b) deductive ability, (c) analytical reasoning, (d) inference ability, and (e) evaluative reasoning contributing to a singular total critical thinking skill score.

Results showed that multimedia used in place of traditional textbook information material led to a significant decrease in overall and select sub-categorical levels of business

critical thinking skills over the course of one semester with gender, ethnicity, and education level not being significant mediating factors.

The results of this study suggest that replacement of textbook material with multimedia equivalents can, in fact, negatively affect critical thinking skill performance. It is recommended that more research into this phenomenon be conducted before replacing printed text-based resources utilized for learning in favor of multimedia presentations of the same information.

NORTHERN ILLINOIS UNIVERSITY
DEKALB, ILLINOIS

MAY 2014

AN ASSESSMENT OF THE EFFECT OF MULTIMEDIA ON CRITICAL THINKING OUTCOMES

BY

TERRANCE L. COTTRELL

A DISSERTATION SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

DOCTOR OF EDUCATION

DEPARTMENT OF EDUCATIONAL TECHNOLOGY,
RESEARCH AND ASSESSMENT

Doctoral Director:
Rhonda Robinson

ACKNOWLEDGMENTS

Much appreciation and gratitude is given first and foremost to my dissertation director, Dr. Rhonda Robinson, for her stalwart support and guidance through my entire doctoral journey.

I also extend deep appreciation to the members of my dissertation committee Dr. Hayley Mayall, and Dr. Thomas Smith, for patiently dealing with my propensity to appear at their offices unannounced, and their generous gifts of time, expertise and keen sense of direction throughout the development of this work.

The ETRA support staff, faculty and administration, under Drs. Lara Luetkehans and Wei-Chen Hung, will always hold my gratitude for their patient attention and genuine desire to see all their students succeed no matter where their research may lead.

Many thanks are given to my doctoral classmates without whom, I believe, I would have become lost in the pursuit.

Endless appreciation is given to the staff, administration, students and faculty at the University of St. Francis in Joliet, IL for cracking open my head.

Special thanks are given to Rebecca Garland, the Sisters of St. Francis of Mary Immaculate, Karen Woodworth-Roman, Drs. Frank Wyrostek, Michael Vinceguerra, Arvid Johson, Frank Pascoe, Gerard Kickul, James Doppke, Constance Bauer, Marcia Marzec, Michael LaRocco, Aaron Krall, Aimee Lanoue, Robert Larson, Wendell Kisner, Marvin Katilius-Boyston, Steven Morrissette, Daniel Hauser, Ed Soldan and Tony Zordan.

Final thanks go to my wife, Michelle, for continuing the clarity and love.

DEDICATION

This work is dedicated to my grandparents, parents, sister, extended family, in-laws and wife for the gift of stability

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CHAPTER 1

INTRODUCTION

Rationale for the Study

The phenomenon of mass multimedia consumption and creation is a global trend affecting the world due to the explosion of internet bandwidth potential, increases in wired and wireless internet access points, and the prevalence of audio and video recorders on almost all mobile communications devices (BBC, 2011; Bernoff, 2005; Castells, 2011; CTIA, 2011). The advent of television brought the concept of mass consumption of moving pictures mixed along with audio into reality (Saettler, 2004). Through television, each home, office, school, and saloon quickly became proving grounds for the installation of screens depicting various combinations of images and audio. Internet protocols are now inevitably swallowing this medium as they provide more ubiquitous access points combined with the ability to engage interactivity beyond textual reading, audio listening or the viewing of images alone (J. Anderson, 2010; Barabash & Kyllo, 2011; Hedges, 2009). Through the internet's ability to quickly deliver enticing multimedia content, today's environment shows that even internet-active children between the ages of zero and five now use the web at least once per week (Gutnick, Robb, Takeuchi, & Kotler, 2011). The eventuality is that internet multimedia engagement, like television of old, is becoming a daily activity for all, leading to the seamless absorption and replacement of television's vast-reaching appeal.

The internet hosts applications that give users the ability to input information, unlike TV's mere static delivery of content, while also receiving responses based on human interaction. It is important to understand, furthermore, that the internet's delivery of multimedia creates an expectation of interactivity above and beyond passive media consumption. When considering multimedia and the internet today, Marshall McLuhan's (1964) assertion that "the medium is the message" denotes that for the user, the message is the combination of video, audio, text, input capability and remote transmission. The internet is increasingly moving away from simple words or images on screens and becoming entirely comprised of multimedia at every click.

The 2013 Horizon Report is a collaborative assessment of current technologies that are shown to have the potential to impact teaching and learning on college campuses. The Report is created annually by the New Media Consortium (NMC) and Educause, "a nonprofit association whose mission is to advance higher education by promoting the intelligent use of information technology" (Educause, 2010, para. 1). The NMC comprises hundreds of for-profit and not-for-profit institutions dedicated to exploring the use of media technologies for learning (The New Media Consortium, 2013). Of the six key trends listed in the 2013 Report, internet-based multimedia is a major component listed in every category for educators seeking to instruct and demonstrate lessons to students. Multimedia's meteoric rise through the internet shakes the foundations of collegiate education from the 14th century onward as ubiquitous video content circumvents the traditions of academia away from the pursuit of a collegiate degree as a symbol of acquiring learning by way of physical face-to-face interaction combined with textual analysis (Brown & Hedges, 2011; Johnson, Levine, Smith, & Stone, 2010; The New Media Consortium, 2013, Waldrop, 2011; Wesch, 2009). People across the globe can now learn much more information than at any time prior to the emergence of the World Wide Web, because of both textual and instructional media content. The processes of free learning and free inquiry have been opened so much wider, because of multimedia's ability to quickly transmit, and repeat, ideas and concepts to the mind of the viewer. Multimedia's unique ability to inspire reflection is due to the medium's combination of images, sounds, and text with the option of instant repetition of, or forwarding to, content. This reflective encouragement, brought on by inherent properties of multimedia learning sources, leads learners toward more opportunities for matching their questions, hypotheses and thoughts to content observed through sight and sound. These cognitive reactions to what is heard and seen combined with reflection, hypothesis generation, and introspection, therefore, can be viewed as a precursor to critical thought.

Critical thinking (CT) is now more of a priority for all educators at every level in today's college environment, because of the need to assess the learning outcomes resulting from student cognitive processing through the increased viewing of course content shown on screens instead of singularly within live classrooms (Halpern, 1999; 2003; Halpern & Riggio, 2003; U.S. Department of Education, 2006). Assessment can be subjective in the form of student journals and/or portfolios aimed specifically at the goal of gauging CT by means of examining student writings and reflections (Marchese & CFAT, 2006). Comprehensive objective and mixed assessment targeting CT has also been seen in instruments like the College Learning Assessment and the Voluntary System of Accountability (Hardison, Vilamovska, & RAND Education, 2009; McPherson & Schapiro, 2008; Miller, 2008). Unfortunately, very recent criticisms of both subjective and objective assessments of student outcomes in the areas of CT, problem solving, and other skills is also on the rise, along with calls for radical changes in curricula and funding for higher education under the auspices that old methods for teaching and learning are neither effective nor worth their soaring costs (Arum & Roska, 2011; Balzer, 2010; Hacker & Dreifus, 2011; Swartz, 2010).

Higher education is at the same time increasingly becoming integrated in the online world of multimedia, because basic multimedia's creation costs have become relatively low; its consumption rate is high; and, its appeal is wide. Multimedia is, therefore, a large force potentially affecting all learning outcomes, including CT, as more and more individuals attempt to learn via images and text combined with sound provided by more and more outlets—some officially sponsored by educational institutions and instructional designers, and some not. Van Gelder (2001) finds that for educational technologists, the core pressure for using technology to aid in CT development is the integration of software tools using multimedia to mediate the development of CT skills from instructors to students in the most realistic way possible. Educational transfer between students and instructors has traditionally been supplemented solely by print materials. Textual materials, however, are not as lifelike and personable to learners as multimedia; yet, they persist as requirements for purchase for most college courses. The aim of this research was to assess CT outcomes in a learning environment where multimedia learning is juxtaposed to traditional text-based learning. This study may help researchers to understand how multimedia learning influences the production of CT outcomes so that greater accountability for this important skill can be achieved through changes in curricula. This study also serves to answer questions regarding CT learner outcomes in a higher educational climate where increasing amounts of multimedia learning sources will be utilized in the future in the place of their print textual counterparts of old.

Purpose of the Study

The purpose of this quasi-experimental, pretest/post design study is to investigate the potential impact of multimedia learning resources compared to equivalent text-based resources on CT outcomes. The rising emergence of quantitative assessment is a key to how colleges are responding to calls for greater accountability, and justification for tuition and student time spent in classes. In the 2011 book, *Academically Adrift: Limited Learning on College Campuses*, Richard Arum and Josipa Roksa note their study of "a large sample of more than 2,300 students, [observed] no statistically significant gains in CT, complex reasoning and writing skills for at least 45 percent of the students in our study" (p. 13). Before the writing of this book, calls for and debate about greater assessment of CT outcomes within higher education contexts were numerous and continue to be anticipated for some time to come (Balzer, 2010; Hacker & Dreifus, 2011; Hardison et al., 2009; Hart & RA, 2008; Heywood, 2000; Jones, Hoffman, & NCES, 1995; Marchese & CFAT, 2006; Paul & Elder, 2005; Perry & Smart, 1997; Sullivan, Rosin, & CFAT, 2008; Swartz, 2010;).

Today, it is rare to find a piece of information stored in one format for very long, before multimedia tools are used to transform the original content into something easily absorbed by alternative ways of transmission and processing. Gardner's Theory of Multiple Intelligences (1985; 1993) remains an often-cited theory for educators seeking justification for the inclusion of multiple information formats within their classes even though this theory does not show the empirical validity of Spearman's (1904; 1927) Theory of General Intelligence—which has led to the high stakes testing seen in many educational environments today (Sackett, Borneman, & Connelly, 2008). The benefits and popularity of presenting ideas in varied combinations of text, video, audio, and images are reflected in the large scale of multimedia pieces created, accessed, and served on the internet each day (YouTube, 2011). Through the internet and multimedia technology, everyone is potentially a user and producer of content for both learning and leisure (Yue-ting, 2005). The mass generation of these materials signals a cultural belief that personal, immersive engagement by a multiplicity of the senses is practical, enjoyable, and relevant. This being said, education and educational resources residing in multimedia formats coincides with Januszewski and Molenda's (2008) presentation of thirteen primary concepts within AECT's newest definition for Educational Technology. Current concerns in the field are the appropriate selection and use of technologies (like multimedia) for learning, the practical management of these technologies, and how these technologies affect outcomes like CT in higher education learners. Many educators find themselves now directly in contact with multimedia resources as aids for learning. Assessing the impact of these resources in place of standard, legacy text-based resources is key to understanding how they may be best strategically utilized instead of adopted because of popular trends.

Problem Statement

Whether the learning environment is face-to-face, or fully or partially online, multimedia as an information source is threatening to completely replace all three of the following learning methods (a) asynchronous chat, (b) textual readings, and (c) lectures (Kurzweil, 2005; Masten & Plowman, 2003; Thompson, 2011; Talbert, 2013; Vinge, 1993).

Multimedia provides many advantages, including "the liberty to proceed or recede allow[ing] self-pacing [and] an immeasurable interconnectivity to information in a variety of possible combinations, sequences, and mixture of resources which shape . . . higher-order thinking" (Teoh & Neo, 2007, p. 28). Multimedia is also a very attractive information paradigm when compared to asynchronous chat, textual readings, and lecture, because it provides a combination of movement and sound that many find as a superior source of entertainment. Entertainment methods and educational methods, however, are not always in parallel in their ability to demonstrate high outputs of happiness on par with high learning outcomes on measures like CT. The problem is that there is not enough good data on the impact of multimedia on CT skills in higher education to warrant replacing these older information formats. Furthermore, while higher education is unified in its call for more CT skill development, it is not in agreement on proper CT assessment methods. It is understood that higher education desires an overall increase in CT. No generally agreed upon assessment for CT exists, however, and this situation combined with the fact that there is not enough data on the impact of replacing older information formats (viz., text, imagery, chat) with multimedia shows a potentially dangerous convergence implying interactions yet to be maturely assessed.

Problem Detail

CT is a set of skills whose growing influence has entered the minds and emotional consciousness of faculty at degree-granting institutions ever since the publication of the Final Report (i.e., Spellings Report) of the Secretary of Education's Commission on the Future of Higher Education (U.S. Department of Education, 2006). A major problem, however, is that researchers, educators, and administrators face the often-controversial reality that CT is difficult to define, and therefore effectively study (Abrami et al., 2008). For collegiate business programs, the direct inclusion of CT as a requirement for international accreditation by The Association to Advance Collegiate Schools of Business (AACSB) is particularly notable. This accrediting body is the most rigorous and desired accreditation honor to be held by college business programs to date. Section 2 of the AACSB Standards (Association to Advance Collegiate Schools of Business, 2012) states that in order to "assure" proper learning is emerging from accredited institutional business programs, graduates are to "demonstrate knowledge and ability through testing in specific content areas such as . . . critical thinking ability, or specific content knowledge" (p. 65). Little (1980) says that all minds thinking clearly, regardless of discipline, are not only goals in and of themselves, but they also have a practical value, as working members of society have to write plans and processes for strategic decisions, tutelage, and basic communication aimed at the facilitation of peaceful coexistence and shared meaning. Productive members of society are often expected to be seen as people who "serve their communities effectively on councils … geared to resolving social problems. In every case, familiarity with the fundamental[s] of critical thinking … [are] essential" (p. vii). Particularly in the U.S., "a national survey of employers, policymakers, and educators found consensus that the dispositional as well as the skills dimension of critical thinking should be considered an essential outcome of a college education" (Tsui, 2002, pp. 740–741).

The Association of American Colleges and Universities (AAC&U) remarks (2006) on the "Spellings Report" that writing, CT, problem solving, mathematical, and scientific literacy are all mentioned as areas where American students fall short, yet little guidance is given on how to improve outcomes in each of these crucial arenas. In an American Association of

University Professors' (AAUP) response to the Spellings Report, Gerald Graff and Cathy Birkenstein (2008) suggest that institutions of higher learning whose students significantly lack basic CT skills should be held to task on their missions and very existence in society. This is where assessment has become one way to help institutions of higher learning determine if their efforts in the areas outlined by the Spelling Report are successful or in need of retooling and revision.

Educause also provides a response in terms of assessment of higher learning outcomes to the Spellings Report. The 2008 document, written by Michael McPherson and Morton Owen Schapiro, presidents of The Spencer Foundation and Williams College, respectively, and co-chairs of the Ford Policy Forum, assert that Congress is continuing to pressure higher learning institutions to prove, rather than merely assert, their effectiveness and worthiness of receiving government funding along with favorable tax status. Their 2008 report goes on to mention that even with calls disparaging standardized tests for cognitive outcomes, "pressure at the state level will lead to outcomes assessment regardless of whether institutions want it or not . . . the [result is] widespread embrace of standardized tests by the academy—from the AP to the SAT to the GMAT" (p. 5). Not embracing standardized testing of cognitive learning outcomes presents an a priori hypocrisy on the part of institutions of higher learning. Institutions that elect to not use standardized tests for cognitive outcomes will be asked why they insist, then, on ACT scores for admission. Some instrument (objective, subjective or blended) must be used to test what students know and how they can apply what they have learned in college to surmount critical situations. Otherwise, colleges have decreased creditability in claiming they prepare learners for the future—just as similar entrance exams give colleges the power to denote who may and may not enter their doors based on achievement scores that are said to determine students' future achievement in coursework.

The advent of instruction utilizing multimedia has brought further pressure to research this medium as it relates to cognitive outcomes like CT, because more and more multimedia is provided to users online, and online resources are exponentially increasing for learning as they are increasingly seen as more economically sensible for distribution (Chrzastowski, 2011). To date, written (or more specifically, typed) text still prevails as the most popular means of human-to-human communication of ideas in electronic classroom settings (Dinov, Sanchez & Christou, 2008; Garrison, 2000). While students continue to communicate textually in the educational environment, it is this same environment that holds the potential for many learning elements of multimedia for delivery of educational content. Teaching with multimedia first appeared slowly in the educational ecosphere as educators began to use images, then audio combined with text, and then video (Saettler, 2004). With internet connectivity, multimedia now has the potential to affect all learners in higher education as it is no longer exclusively created and implemented for in-classroom settings. Mezirow's (1990; 1991) writings on learning explain that CT in higher education is the "becoming aware of why we perceive, think, feel or act as we do" (1991, p. 108). Students of a variety of ages are excited about the potential that multimedia and internet technologies can add to their program of study partially because of the promise of easy-to-create and consume multimedia information (Dinov et al., 2008). Over 20% of all higher education students are taking at least one online course today (Ho & Swan, 2007, Swan et al., 2008). While in the past, online education was not dependent on multimedia, today's higher education instructors are finding it difficult to use text alone as a means of instruction (Ho, 2012). Images combined with text, in static and video form, are a common component of online learning, building a close bridge between the two previously separate educational mediums. Growth rates of higher education online multimedia worldwide exceed 35% per year (Sun, Tsai, Finger, Chen, & Yeh 2008). These numbers add to the imperative that assessment of multimedia's impact on CT still be sought after in the field of higher education.

The form and function of CT and how it is assessed by different institutions can have a large effect on strategy and pedagogical planning because of the influence of multimedia content delivered online or onsite, and from pressures from the federal government. Institutions ask questions regarding the essence of CT itself. They seek a unified and universally accepted definition for the concept. They then move to find ways in which they may assess CT as a learning outcome. The Voluntary System of Accountability (VSA) was developed as an answer to calls for greater assessment of learning outcomes in the areas identified in the Spellings Report. Developed by 80 higher education leaders broken into focus groups charged with targeting measurement areas for reporting to the public, the VSA currently has over 250 member colleges and universities. Feeling that it would be in the best interest of higher education diversity to devise its own reporting measures (viz., price, student characteristics, graduation rates, learning outcomes, student experiences and perceptions, degree offerings, living arrangements, transfer rates, and post-graduate plans), VSA founders worked preemptively to stave off government-imposed standardization and regulation (Miller, 2008). CT is one of the most important parts of the mix of pre-determined learning outcomes to be reported to the public under VSA guidelines. A standardized test was selected by the member colleges and universities—the ETS Proficiency Profile—which lists CT as first among four core skill areas to be assessed; reading, writing, and mathematics are listed afterward (Educational Testing Service, 2010).

Significance of the Study

It is understood that learning outcomes born through multiple modes of learning are of interest to the field of education. Ever since the great influence of Edgar Dale's Cone of Experience (1946; 1954; 1969), educators have felt the large-scale challenge to think about mediated learning experiences as a means of improving teaching. The Cone itself was not intended to advocate one particular mode of learning experience over another, but the sheer volume of adaptations of Dale's visual metaphor demonstrates its importance towards multiple methods of teaching today (Molenda, 2003). Assessment of learning outcomes for CT skills is more important now than ever for higher education institutions. In the past, the major emphasis on learning has come through providing text-based learning combined with lectures. On the whole, multimedia learning sources have increased in use across the higher education learning spectrum, yet not much research exists on the use of audio and video communication used as multimedia learning resources juxtaposed directly against traditional textual communication sources in the context of the crucial learning outcomes like CT (Bagarukayo, Weide, Mbarika, & Kim, 2012). In fact, many studies show that adding multimedia (in the form of audio and/or video) to existing textual resources (different from creating learning content directly in the form of multimedia from the start) actually hampers learning by providing too much information to learners under the guidelines of cognitive load theory (Barron & Atkins, 1994; Beccue, Vila, & Whitely, 2001; Hede, 2002; Kalyuga, 2000; Kalyuga, Chandler, & Sweller, 1999; Kalyuga, Chandler, & Sweller, 2001; Mousavi, Low, & Sweller, 1995). The problem seen in today's educational climate is that traditional text is rapidly disappearing despite evidence of the need to keep it as part of good pedagogy. A reasoned, and empirically demonstrated, superiority of multimedia sources over traditional text in a variety of educational settings used with care for the complex way in which humans process information is not the cause for multimedia's rapid dissemination (Hede, 2002; Young, 2010). The combination of cost concerns with advances in the ease-of-use and production of multimedia technologies is the reason why this method of learning is becoming more and more popular each day.

Like the concept of "critical thinking" skills, the words "educational technology" and "instructional technology" bear different connotations to students, faculty, users and practitioners alike. The name of the field of Educational Technology (ET) has varied in order to flex and bend with the underlying concepts associated therein (Reiser, 2007). Januszewski and Molenda (2008), in an edited text created by the AECT Definitions and Terminology Committee, note the elasticity of the concepts, by saying the terms have "been evolving as long as the field has . . . Today's conception is . . . a snapshot in time" (p. 1). From this definition, Januszewski and Molenda break the concept into 13 major segments: "1) Study, 2) Ethical Practice, 3) Facilitating, 4) Learning, 5) Improving, 6) Performance, 7) Creating, 8) Using, 9) Managing, 10) Appropriate, 11) Technological, 12) Processes, 13) Resources" (pp. 1-12). The Association for Educational Communications and Technology (AECT) sponsored the work producing the definition segments edited by Januszewki and Molenda. It is from these segments that the author of this study crafts a definition for the term "educational technology" going forward. The author of this study sees educational technology to be defined as the study of the ethical practices of facilitating and improving learning performance by creating, using, and managing appropriate technological processes and resources. From this definition, the assessment of CT affected by multimedia is specifically related to educational technology's study of learning performance through an instructor's use of, and a learner's interaction with, computerized technological resources.

Early definitions of Instructional Technology (IT) directly equated the concept with the use of media in instruction (Reiser, 2007). As time progressed, variations of the definition for IT came closer to what is seen from AECT with its definition of ET today. IT can now be defined as the design, analysis, implementation, and management of learning and performance problems, instructional processes and learning resources in a variety of settings (Reiser & Dempsey, 2007). The author's research endorses this definition for the term "instructional technology." Within the context of the aforementioned two definitions of ET and IT, commonalities can be found emphasizing core elements of the essence of both CT and multimedia learning. The aforementioned definitions call for (a) analysis, (b) procedural development, (c) design toward effective learning, and (d) improvement of education all through the use of a multiplicity of technologies. Herein we find the connection between ET, IT, CT, and multimedia learning. The prevalence of the seemingly unstoppable creation and use of multimedia sources in classrooms combined with recent calls for assessment of CT outcomes from higher education students draws the need for continued research to help build better understanding of the effects of the decline of text as a primary learning tool against the rise of multimedia brought forth by both a rapid increase in ET and IT.

Research Questions

Given that CT assessment is a priority for both educational leaders and the U.S. Government, and given that the integration of multimedia learning resources continues to be a strong reality in higher learning settings, research needs combining these areas continue to persist. The purpose of this study is to investigate the potential impact of multimedia learning resources compared to equivalent text-based resources on CT outcomes. This research seeks to answer the following questions:

1. Does the use of multimedia versus text-based information sources in a higher education classroom affect student CT outcomes?
2. Do the demographic characteristics of gender, ethnicity, or education level moderate the effect of multimedia on CT outcomes?

Definitions

Throughout this study, the following terms and definitions are employed:

<u>Multimedia source(s):</u> Any single item or set of items combining text with audio, video, or images for the purpose of conveying information leading to meaning in the mind of a learner.

<u>Traditional source(s):</u> Any single item or set of items only relying upon text for the conveyance of information leading to meaning in the mind of the learner.

<u>Critical thinking:</u> A skill which allows an individual to (a) solve problems using thought which is inductive, purposeful, reasoned, and goal-directed, (b) make deductions and

decisions appropriately in a variety of contexts, (c) analyze and calculate likelihoods without prompting, and (d) formulate inferences with conscious intent, and (e) evaluate and reason effectively through various scenarios and problems (P.A. Facione, 1992; 2004; 2010; Facione & Facione, 2007; Freely & Steinberg, 2009; Halpern, 1984, 1999).

Schema: Organized collections of information containing understanding of how each individual piece in the collection relates to one another.

Mental model: Active and dynamic representations of knowledge that visualize the invisible, creating analogies between what is known and not known.

Assumptions

It is assumed that students in both sections of the course may discuss the different treatment given to each, because the size of the research setting is very small (under 350 resident students), and because teaching a face-to-face course without a required text-based resource is still controversial (Weir, 2007). The students will know one another personally, but this personal knowledge should have little bearing on the taking of the CT test. It is also assumed that since grades are tied to the course as a whole (but not the particular tests of this study), and that each course will be filled with higher-level business students, no risk of test sabotage will be experienced. The author's fifteen years of experience at the institution of study is the primary support for these assumptions. Overall, the aforementioned factors, combined with the test utilized for the study being short in length (35 multiple choice items), mediate threats to internal validity from students not being motivated to participate fully in the exercise. The next sections of this report comprehensively review related literature, detail methods for research, present analysis of collected data and finally discuss the results and implications of findings.

CHAPTER 2

REVIEW OF THE LITERATURE

The independent topics of critical thinking and multimedia learning are not new research areas within the field of instructional technology or education as a whole. The progression of multimedia resources supplanting text continues to be investigated and pondered as the advance of digital media eclipses currently available text, and gives rise to the overall textual creation slow-down. The goal of this literature review is to show that the progression of investigation into each of these subjects separately reveals an intersection that is far from being maturely assessed. Each topic's separate research genesis leads to the need for further research as education continues to call for increased focus on CT while also witnessing, experiencing, and calling on increases in the use of multimedia resources.

The Beginnings of Science to the Foundations of Successful Civilization

Galileo's critical eye gave birth to scientific inquiry, the need to question, assess, test, and reflect on findings connected to human understanding of truth and existence (Hawking, 2009; Weidhorn, 2005). Soon after Galileo, Rene Descartes (1637) began a new epistemological movement on the connection between thinking, knowing, and being through his essays and his assertion of "Cogito Ergo Sum" ("I think, therefore I am") (IV, para. 1). From doubt of the senses and ontological questioning found in this and other works of the 17^{th} and 18^{th} centuries in Western Europe, the Enlightenment was partially spawned, giving rise to the scientific method (Cordasco, 1976). From the standpoint of both humility and openness in inquiry, today J. Michael Spector (2008) continues to echo Galileo and Descartes' sense of wonderment by saying, "We stand on the shoulders of giants. The problem is deciding whose shoulder to use for [meaning and a clear gauge] over the landscape . . . Surely it would be a remarkable coincidence if the limits of . . . imagination happened to coincide with the limits of reality" (p. 26). Organ (1965) connected CT to the beginnings of science, reason, and the improvement of the human race as a recognition that excellence in thought can come from a variety of places. We only need to research and look to find it. As a result, Organ acknowledges the difficulties found in pinpointing a single definition for the theory of CT. He asserts that CT usually only occurs when a problem or deep desire for inquiry arises in the mind. How we formulate hypotheses from, and eventual solutions to, problems is how CT manifests itself showing that by "critically thinking man has risen from savagery to civilization" (pp. xii-xiii).

Theoretical Framework/Constructs

Behaviorism and the theories of B.F. Skinner (1968) greatly influenced educational practice until Cognitivism and Cognitive Psychology emerged in the 1970s. Skinner emphasized teachers being trained to teach better through positive reinforcement of desired outcomes. Chomsky (1959) and Neisser (1967) served to advance a refutation of Skinner by encouraging the theory that thought occurs in the human mind through a series of processes that can be tracked and gauged. In the field of cognitive psychology, the following factors are identified as essential components of the aforementioned processes: attitude, motivation, thinking, memory, the mind, and reflection. Variables for assessing the information-processing abilities of the human mind are circumscribed by what is gathered through our senses, stored in our memory, retained, forgotten, and ultimately accessed through a person's will or outside of human desire (Alessi & Trollip, 2001). When looking at multimedia's effects on aspects of cognitive processing—such as CT—some of the most important variables to consider are (a) comprehension, (b) locus of control, (c) metacognition, (d) transfer, and (e) comprehensive understanding (J.R. Anderson, 1980,1981; R.C. Anderson, 1977; Berger, Pezdek, & Banks, 1986; Bower & Hilgard, 1981; Gagne, Yekovich, & Yekovich, 1993; Kozma, 1987). Many of these elements from decades past coincide with commonly accepted principles and theories of CT today.

Cognitive Theory of Multimedia Learning

The cognitive theory of multimedia includes visual and verbal channels for information processing and knowledge acquisition combined with the fact that these two channels are not unlimited in their abilities to gauge phenomena (Mayer & Moreno, 1998b). This theory also includes three types of memory stores: (a) sensory memory, (b) working (sometimes called short-term) memory, and (c) long-term memory, along with five cognitive processes. Sensory memory captures the text and visuals in their most exact form, as well as auditory sounds, for a very limited amount of time. Working memory takes the sensory memory and allows for manipulation where the raw material from the sensory memory can be made into a model that includes spatial representations. For example, if a person hears the word "cat" they tend to immediately imagine a picture of one instead of an image of a bird. Long-term memory is deep storage where retrieval into working memory is problematic and unreliable at times for a variety of reasons (Mayer, 2005a). The three cognitive processes at play here are (a) selecting and organizing images, (b) selecting and organizing words, and (c) integrating all of the aforementioned into the three types of memory stores (Mayer & Moreno, 1998a). The first four cognitive processes (selecting and organizing images and words) all deal with working memory's ability to create models from the words and images selected and then arrange them into meaningful pictorial and verbal forms. The final process, integrating, works with long-term memory and working memory using schema mixed with priory knowledge to create new knowledge (Mayer, 2005a). Multimedia learning theory is consistent with multimedia design theories like cognitive load theory (Sweller, 1999), and the integrated model of text and picture comprehension presented by Schnotz and Bannert (2003). Schnotz and Bannert's (2003) model leads to their structure mapping hypothesis which states that in order for visual materials like multimedia to aid in learning they must be integrated well with corresponding textual information where it has been found that "interactions of . . . graphics, and text seem to be the key determinant of comprehension and performance in learning from [multimedia]" (Rinck, 2008, p. 186). Each of these theories lead to the sense that multiple channels (e.g., visual, verbal) working in concert together play a key role affecting memory and information processing in the minds of learners (Mayer, 2005a).

Schema Theory and Mental Models

Concepts on schema became influential in the field of cognitive psychology in the 1970s, and inspired research in picture and text processing, and in the world of television (Seel, 2008). Schemas encompass organized collections of information with how pieces of information relate to one another. Schema Theory works under the understanding that human knowledge is collected in the human mind under such schema. Schemas can be modified, reassembled, and then integrated with other schema containing new and different pieces of knowledge (Alessi & Trollip, 2001). Mental models are dynamic and active representations of knowledge that serve to make what is invisible visible, help to create analogies between what is known and not known, or integrate pieces of coherence with unexplained phenomena (Seel, 2008). Mental models can be created in the minds of learners by the use of schema and other elements. These models can be helped by text, pictures, and video—combinations of which are what is now known as multimedia (Clark & Feldon, 2005; Hegarty & Just, 1993; Sharp et al., 1995; Shrock, 1994). Images alone have the vast ability to help students make sense of things they have not witnessed first-hand. Combine images with text for simulation or other forms of multimedia, and instructors find the job of transmitting knowledge much more enhanced (Schwartz & Heiser, 2006).

The application of schema and their accompanying schemata allows the brain to map what the senses perceive in a mental model. Images in the schema and spatial relations that structure the images are mapped to semantic understanding. This means that mapping is a process that aids in mental model development from images, text, and other media sources, and also helps an individual evaluate the model that was in his or her mind before interacting with the media itself (Rouet, Lowe, & Schnotz, 2008). Mapping is part of the process of critically segregating information for better understanding and eventual decision making desired with the development of CT skills.

Theories of Critical Thinking

For over 100 years in America, the ideas of thought, thinking, cognition, and higher order assimilation have been foremost in educators' minds (Astleitner, 2002; Dewey, 1933; Reed, 1998; Sawyer, 2009). John Dewey (1897), Matthew Lipman (1991), and many others, have reminded us of the importance of higher-level thinking in education as a product of critical communities of inquiry constructed from individuals' existing knowledge and understandings. Dewey (1909) called CT "reflective thinking." Edward Glaser's (1941) foundational work defines CT as: (a) an attitude that allows one to use their experiences to give thoughtful consideration toward problems and issues which come their way, (b) retention and retrieval of a variety of methods of logical reasoning and inquiry, and (c) the ability to utilize the aforementioned methods in a variety of applications. Ennis (1987) asserts that CT is focused on action (e.g., what to do) and belief (e.g., how to feel or trust) where individuals use reflective thinking and reason to decide on these matters. Dauer (1989) adds that CT is the practice of the art of assessing what is true and what is not according to accepted and unaccepted principles. CT gives the power of discernment toward specific goals. Gilster (1997) contextualizes CT within a multimedia world by suggesting that now CT is chief among skills to be had because so much information is moving online where the nature of content therein is easily replicable, forgeable, and removable at any time. Peter Facione (1992; 2004; 2010) defines CT through a framework of the individual as thinker. He gives the following characteristics for this theory, saying critical thinkers have "inquisitiveness . . . concern to . . . remain well-informed, . . .trust in . . . processes . . . inquiry, self-confidence in . . . reason . . ., flexibility in considering alternatives . . .honesty in facing . . . biases . . . prudence in . . .

making . . . judgments, [and] willingness to . . . revise views" (p. 10). CT is therefore made manifest through individual contemplation and individual assessment of situations and scenarios counterbalanced against existing understandings and previous experiences.

Diane Halpern and Critical Thinking's Continuing Impact of Importance

Both the American Philosophical Association and the American Psychological Association have taken a keen interest in CT over the last 25 years. In 1990, the American Philosophical Association convened 46 professors of Psychology and Philosophy to discuss, define and explore the subject of CT. Reporting for their efforts (the Delphi Report), Peter Facione (1990) explains that research shows over 80 percent of college faculty say CT is an important skill to be acquired by students while only nine percent of the same faculty said they had a concrete definition for the concept. The American Psychological Association, through the work of past-president Diane Halpern (1984; 1997; 1998; 1999; 2003) and others, also tackle the subject of CT, drawing links between a need for clear thinking and an increasingly complex world. Parallels between CT and its foundation in the theories of cognitive psychology can be seen when Halpern gives the factors of: (a) memory retention, (b) language, (c) deductive reason, (d) argumentation, (e) hypothesis, (f) prediction, (g) decision making, and (h) problem solving skill to support research in many different contexts where CT increases and demonstrations are desired (1997). Ironically, Halpern eventually collaborated with Neisser et al. (1996) on a special taskforce study sponsored by the American Psychological Association to specifically tackle the ideas of intelligence and thought testing in the wake of the popular book *The Bell Curve* by Herrnstein and Murray (1994). In that 1996 study, the taskforce outlined the sensitivity of such testing and helped to inspire others who wish to test thinking levels and conduct studies on outcomes related to all aspects of cognition.

Halpern on Critical Thinking and General Assessment

In today's higher educational environment, it is difficult to find multimedia content separate from the World Wide Web, and likewise it is difficult to find multimedia (of any type) completely absent from online, blended and face-to-face college courses. It is also difficult to find the concept of CT missing from the stated learning objectives of most major colleges and universities. The goal of this author's exploration is to find literature that helps support research on the effects of multimedia on the CT outcomes of higher education learners. Diane Halpern's foundational article (1998) on CT transfer for college learners proposes a four-part model for instructors to incorporate in their instructional design. The model encourages the development of "a) a dispositional or attitudinal component, (b) instruction in and practice with CT skills, (c) structure-training activities designed to facilitate transfer across contexts, and (d) a metacognitive component used to direct and assess thinking" (p. 451). In order to best facilitate CT in their classes, instructors must both believe that CT can be learned and have a working definition for the concept itself. Halpern explains there are many different types of evidence (both quantitative and qualitative) that show appropriate instruction can improve student CT in certain situations. She also provides a definitive definition for critical thinkers as students who possess a

> (a) willingness to engage in and persist at a complex task, (b) habitual use of plans and the suppression of impulse activity, (c) flexibility or open-mindedness, (d) willingness to abandon nonproductive strategies in an attempt to self-correct, (e) an awareness of

> the social realities that need to be overcome (such as the need to seek consensus or compromise) so that thoughts can become actions. (Halpern, 1998, p. 452)

Halpern's definition of critically thinking learners, and subsequent model for CT curricular direction, both serve as substantial contributions to the field due to her past presidency of the American Psychological Association. Her research methods provide a strong comprehensive exploration of fifteen years of research and assessment in the psychology behind CT. Halpern's research finds that CT affected by instruction is rooted in two assumptions: "(a) that there are clearly identifiable . . . thinking skills that students can be taught to recognize . . . (b) if these thinking skills are recognized . . . students will be more effective thinkers" (p. 452). By recognizing and focusing on specific CT skills, instructors begin the process of improving them in their learners. Halpern recognizes CT skill development to be the core of instruction itself, and that these skills are to be tested through cognitive problems and exercises in metacognition. Halpern gives credit to metacognition, saying it "is the executive or 'boss' function that guides how adults use different learning strategies and make decisions about the allocation of limited cognitive resources" (p. 454). Through metacognition (stimulated by text, audiovisual and/or multimedia information resources), Halpern finds students employ more reflection, and therefore, complete the circle of CT when focusing on their lessons. The proof of student CT development and progress can be seen, she says, through the qualitative evidence given by learners in research reports she has reviewed, and in the data given from quantitative assessments (Halpern, 1998).

Facione: Specifically Assessing Critical Thinking Skills

Peter Facione (1990) finds that CT has been an increased focus in the overall field of education, and a key component of the specific call for higher levels of educational accountability, since the 1980s. His efforts to bring scholars (from both the American Philosophical and American Psychological Associations) together from a variety of colleges and universities with the singular charge to provide a usable methodology for defining and assessing of CT led to the "Delphi Report" and the establishment of the California Critical Thinking Skills Test (CCTST) Family—which includes the Business Critical Thinking Skills Test (BCTST). From his beginning work with viewing CT as the basic "development and evaluation of arguments" (1984, p. 259), to his most current work linking CT to decision making and reasoning, Facione finds a common underlying thread for CT where individuals seek a concrete definition for the concept, and then desire a validated tool for skill assessment. H. C. Facione (2012) says CT skills can be assessed through (a) portfolio reviews, (b) validated tests and inventories, and/or (c) rubrics and rating tools. Regardless of the tool used, assessment and measurement aids in both the teaching and further development of CT skills as they help to instruct and show individuals how they may maximize opportunities, avoid unnecessary risk, and match the requirements of the definitions provided by Halpern and the American Psychological Association, the Delphi Report, and many other researchers and philosophers since the 19th century.

Clark and Kozma On Media Impacting Learning

Richard Clark (1994) makes the assertion that media does not affect CT skill, problem-solving abilities or other types of learning goals set in schools at any level. Clark states that the true essence of all "media research question[s] is [that they are part of many] similarly confounded questions in educational research" (p. 27). In Clark's mind, media research is subordinate to instructional design research, because it is the design of instruction that influences learning regardless of media used. The media does not matter, and if replicable media produce similar learning results, then the best choice for instructors is the cheapest and most-easily-acquired form of media available. Robert Kozma (1994a) responds by reframing the concern of media influencing learning from a design science (R. Glaser, 1976; Simon, 1996) perspective rather than from a natural science point of view that seeks to explain human cognitive interaction with the world not created by humans. Kozma explains that educational technology is a design science deserving critique and analysis observed from relationships between human-created tools and other humans completely separate from the natural world. He offers a response to Clark that asserts that both instructional methods and media "influence learning and they frequently do it by influencing each other . . . methods take advantage of a medium's capabilities in well-designed instruction . . . One cannot simply replace one medium with another in a design and hold everything else constant, as Clark . . . suggests" (1994b, p. 11). Professor Anthony Grafton of Princeton University echoes Kozma's sentiment by explaining all aspects of any medium's elements, including art and binding (as with plain text sources), create an environment that affects knowledge consumption and cognitive processing abilities (Prpick, Redel, & Grafton, 2011). Both Clark and Kozma provide a review of the literature to support their claims about multimedia. Kozma, however, provides a quantitative data analysis from a study using his 4M:Chem software that allows students to see the results of their chemistry-related course activities. Kozma's research shows that both the instructional methods used and the multimedia outlet affected overall student learning outcomes. He then asks how this phenomenon is possible.

Kozma claims that learning is assessed not so much by the instructor or through the methods used, but by looking at learning "as it happens and [collecting] data on the ways students interact with the system as they learn" (1994b, p. 12). In order to find answers, Kozma conducts a separate study and describes how five students from the first experiment participate in a second experiment where they demonstrate how they learned from 4M:Chem. The students show significant abilities to form inferences about particular chemical events through viewing video sequences in the software. This is the combination of media/medium and instructional method affecting learning outcomes consistent with CT themes of inference and deduction which Kozma desires to see. He concludes, refuting Clark's 'replaceability challenge' by stating, "If two [media] treatments yield a similar outcome it does not mean that they resulted from the same cause . . . [and the outcome] does not identify what that cause is . . . if you want to know what causes learning, you have to look at it as it occurs" (1994b, p. 13).

Mayer and Moreno on Multimedia and Cognitive Load

Mayer and Moreno (2003) propose that learners process pictorial and verbal information differently in their mind, thereby establishing multimedia's effect on the mind as something separate from text-based materials. After starting with their initial proposition, the researchers develop their theory by explaining that there are limits to what people can mentally process when learning. The problem of cognitive overload can stifle learning, they explain, as more information can be presented through multimedia than can be presented through text-based materials. Herein lies the need for their exploratory study eventually leading to nine suggestions for reducing the load that media can place on learners' minds. Mayer and Moreno (2003) provide definitions for their core concepts. They explain that they define multimedia learning as "learning from words and pictures, and . . . 'multimedia instruction' as presenting words and pictures that are intended to foster learning" (p. 43). After providing these definitions, the researchers begin to link them directly to CT.

Since multimedia is generally developed to facilitate more learning in a more efficient manner, Mayer and Moreno (2003) provide ways to mediate the damage that can be done by overload of information through multimedia. The researchers use familiar terms when they argue that they define "meaningful learning" as deep "understanding of . . . material, which includes attending to important aspects . . , mentally organizing . . . into a coherent cognitive structure, and integrating . . .with relevant existing knowledge" (p. 43). This is where the clear connection to the investigators' research and CT can be found. They expand their connection between the mind and multimedia processing by explaining that there are three channels for processing in the mind when it encounters images, text, and sound together as an information resource. Mayer and Moreno (2003) identify a

> [1)] Dual channel [where] humans possess separate information processing channels for verbal and visual material, [2)] Limited capacity [where] there is only a limited amount of processing capacity available in the verbal and visual channels, [and 3)] Active processing [where] learning requires substantial cognitive processing in the verbal and visual channels. (p. 44)

These aforementioned channels provide a framework for the identification of five major ways in which overload can block learning objectives like CT. The scenarios include periods when only the visual or audio channel are taxed individually, times when both are overloaded, times when one or both channels are overloaded by essential and non-essential information, periods when one or both channels are overloaded by information that is presented in a poor manner, and finally times when the learner holds the wrong information in one channel and not the other. Each of these scenarios is given one of nine particular remedies based on an integrative literature review of the researchers' own and others' research.

Multimedia Versus Text

Much debate on multimedia replacing text-based information resources is found in the literature. Little experimental or quasi-experimental, research exists, however, comparing the cognitive effects of multimedia use over text in the specific arena of CT. Comparisons of multimedia's effects on general learning outcomes can be generalizable towards CT only to a certain degree. Of the extant studies available to-date, most carry mixed results of the basic learning effects of multimedia over text.

Cavalier and Weber (2002) explored the effect of multimedia on moral decision-making (a similarly obtuse subject as CT) through the use of a one-factor three-level experiment where students were surveyed after one group studied the case of burn victim Dax Cowart with only text materials, one group with only a 1-hour documentary, and a third group only with an interactive multimedia program created by a third-party vendor. The study was replicated the following year with three different sets of students as participants and using new graders different from the first study. The groups in both years ranged in sample sizes of 21 up to 38 undergraduate philosophy students. The students enrolled in the courses as a requirement for their major. The results of the experiment showed that performance in (a) understanding the complex perspectives and positions of the case, and (b) analyzing the case with respect to its morally relevant details was higher in the groups who were affected only by the interactive multimedia program during the first year of testing. Statistically significant differences were not observed, however, in the study's second year. Aside from mixed results in both study periods, other problems with this study arise when considering the quality of the learning materials given to participants, and the fact that the materials were produced by three distinctly different creators.

Redsell, Collier, Garrud, Evans, and Cawood (2003) conducted a stratified cluster randomized controlled trial of bedwetting children (n=270) undergoing psychological treatment at 15 different nurse-led clinics for their condition. The students viewed and compared bedwetting mediation information in multimedia format with text that was mirrored word-for-word in content. The multimedia learning materials contained an interactive assessment component not present in the text. The researchers' study showed no significant difference between the two information sources' ability to impact the learning outcomes (e.g., time to dry and remaining dry) of medical information for a specific condition post completion of the study and six months after completion.

Barlett and Strough (2003) conducted a 3-semester-long study where samples (25 min/61 max) of undergraduates in seven different Social Psychology courses taught by six different instructors each term were given one of three different methods of instruction: (a) traditional lecture, (b) traditional lecture with course guide, and (c) multimedia with course guide. While the multimedia in this study was, in fact, created by the same instructor in some of the courses, the products were not the same due to the inclusion of so many different instructors used in the study. Final grades in the course were the primary measure used to gauge the impact and effectiveness of the instructional method and information source used in each case. The final results showed that it was the course guide, not the delivery of traditional lecture or multimedia, which improved final grades. The researchers note that redesigning their study so that "a comparison of traditional and multimedia formats when neither is accompanied by a course guide would be useful in understanding the unique contribution of multimedia formats" (p. 337).

Kingsley and Boone (2008) conducted a quasi-experimental, pretest/posttest design study on the effects of multimedia as an augmentation to the existing text and lecture content of a middle school American history class. The researchers compared pre and posttest scores for the students in control and experimental groups using a two-tailed *t*-test (unequal variance), because single-tailed *t*-tests are not as sensitive to unknown changes in the direction of mean test scores. Like the Barlett and Strough (2003) study, Kingsley and Boone (2008) used multiple sections of classes taught by multiple instructors (four, all female in total) for a total of 184 participants (93 aggregate in the experimental treatment group, 91 aggregate for control groups). The researchers in this case, however, conducted their research by pulling participants from three different schools. They also used multimedia created by a different vendor from the text material used in the subject course sections. Gender, age, and experience level of the instructors studied were noted in descriptions of this experiment, but not studied in-depth. The results of the study showed a significant difference between the control and experimental groups with the experimental displaying 12.2% higher scores on the posttest assessment of their knowledge of American history subjects. In this particular study, the addition of multimedia improved students' ability to meet the requirements of a standardized assessment based on NCLB guidelines for middle school student knowledge about American history. Whether or not the multimedia provided more, better or clearer information as compared to the traditional instruction experienced by the control group was not discussed or studied by the researchers. The multimedia was added to traditional instruction, in this case, not set up as a substitution for traditional instruction or instructional course materials like texts or print articles.

Xu, Oh, and Teo (2009) conducted a one-factorial experiment with randomly assigned participants in two groups at a 1:1 gender ratio. The study tested the differential effects of text and multimedia advertising on mobile consumers' perception and behavior. Forty-one males and 41 females were recruited from a large university to received simulated advertisements on their mobile devices in text or multimedia format depending on their vicinity to a particular vendor in a simulated mall. The researchers found that multimedia advertising information improved a viewer's attitude toward a product and significantly increased the intention to buy vs. text-based advertising. Their study also showed that multimedia was more of an irritation, but provided more information and entertainment value over text.

Using the most limited interpretation of the concept of multimedia (viz., still images combined with text), Serra and Dunlosky (2010) conducted a study on undergraduate students at Kent State University. Two groups (n=40 for each) were initially studied with a third later added at the end of the research. The study participants either read 500 words (computer displayed) on how storms develop, or they viewed similar, decreased amounts of text with images added to explicate the same content. The third group in the study examined showed no significant change in learning using text only versus multimedia, while the original two groups did. All three groups also believed they would learn more through the use of multimedia. The researchers provide commentary cautioning the overuse of multimedia as this heuristic did not always show improved learning, even if learners come to believe it is always a superior learning information source over text. They cite this as a reason for future research linking learning belief with learning format and outcomes performance.

Starbek, Erjavec, and Peklaj (2010) conducted a quasi-experimental pretest/posttest study on 3rd and 4th grade students to gauge overall content acquisition in a course module centered on genetics. The researchers used four comparable groups where the first group (n=112) received instruction only via lecture, the second (n=124) only by reading a text, the third group (n=115) only through two short computer animations, and the fourth (n=117) only through images combined with text. Their study showed evidence that multimedia was a better instructional tool over text for the specific material to be acquired—the understanding of a single dynamic process. The researchers call for additional research to be performed due to the type of understanding the students were required to learn. The researchers say their study is ultimately not indicative of multimedia's learning effects toward learning facts, data or other types of knowledge.

Chuang and Ku (2011) conducted a study comparing Chinese-language learning materials in combined text and image form against the same material presented only in images combined with audio narration. Their study resulted in mixed findings where the control group of undergraduate students (text with images, n=33) did not significantly differ from the experimental group (n=33) of undergraduate students in terms of posttest and delayed posttest performance on language learning assessment. There was a significant difference, however, found between the two individual test occasions. The overall results directly contradict

Mayer's (2001) modality principle which suggests that text combined with images on the screen is a superior form of information acquisition over images combined with narration, because the mind working on both the visual and nonvisual channel (in tandem) devotes less time to each, thereby reducing learning potential.

Recently, Kayaoglu, Dag Akbas, and Ozturk (2011) used an achievement test to assess the impact of multimedia animation versus text in two undergraduate English-language learning courses. Pretests were given to the control (n=22) and experimental (n=17) groups showing equivalent abilities before the introduction of the two different forms of learning materials. Both material types were created by the researchers. The results of the study showed increased assessment scores on the posttest for the experimental group given only multimedia animation as a means for learning English. Anecdotal opinion on learning via animation versus text was also collected from the participants and teachers, indicating that they were more excited to learn language via animations. The researchers caution, however, that excitement and statistically significantly higher posttest scores are not a justification to replace text with multimedia completely in all cases, because there was ultimately no difference between the groups in terms of overall increase in achievement. The students in both groups increased their performance on English language assessment at the end of the testing phase. In the end, both text and multimedia each work to increase overall language performance.

Critical Thinking Assessed Through Multimedia Treatment

No true, large-scale meta-analysis of the effects of multimedia on CT alone exists to date. The combination of these subjects creates an environment needing much more research and in-depth study as the advance of multimedia engagement enlarges within all of education and the goal of increased CT becomes more prevalent. When reviewing both of the subjects CT and multimedia research together, however, it can be seen that some studies begin to draw connections relating CT outcomes directly to the effects of multimedia. These analyses show a need for more focused research specifically on the interaction between CT and multimedia, because many of the studies merely link CT to many other learning outcomes rather than treat the subject as its own distinct topic worthy of focused detail.

Jonassen, Carr, and Yueh (1998) identified early forms of web-based multimedia under a term they call "mindtools" describing how multimedia computer applications challenge outcomes skills like CT by requiring students to think deeply about what they are seeing and hearing on a screen instead of merely accepting the premise that absorption is the primary educational goal. In their descriptive meta-analysis of different multimedia tools, the researchers connect these various forms of multimedia to CT by means of the aforementioned core elements presented by Dewey (1897; 1909; 1916; 1933), Ennis (1987), Ellis (2011), P. A. Facione (1984; 1990; 1992; 2004; 2010), P.A. Facione & N. C. Facione (1997; 2007), E. Glaser (1941), and Halpern (1984; 1997; 1998; 1999; 2003): (a) interpretation, (b) inferences, (c) manipulation, (d) semantic organization, (e) linguistic evaluation, (f) visualization, (g) prediction, (h) elimination, and (i) inference. They ask, "Why do Mindtools work, that is, why do they engage learners in critical, higher-order thinking about content?" (Jonassen et al., 1998, p. 12)

What the researchers assert is that, in fact, individuals who are challenged in their learning environments (classroom location, materials, access to information/date, etc.) through any sort of combinations of input other than one (e.g., visual alone or audio alone) are the individuals who wind up thinking the most about the content contained therein. If this maxim is true, multimedia where individuals can both see and hear, or read and hear, or even see, hear, read, speak, and manipulate will engage CT more than their counterparts using traditional learning tools (like text alone) and techniques (e.g., lecture). Jonassen et al. (1998) also determine that individuals using "mindtools" as early forms of multimedia are capable of more critical thought through ideas that would not be present without the actual use of the tool first. This coincides with the basic idea of learning-tool scaffolding as the genesis for all human innovation: The development of electricity, for example, leads humans toward critical inquiry into the powering of all sorts of tools, like radios, which leads humans to the idea of mass communication over long distances which eventually begins the CT behind the creation of the idea of the internet.

Jonassen et al. (1998) contend that ultimately multimedia-type tools are direct descendants of constructivist thinking about learning and education derived from earlier CT pioneers like John Dewey (1897; 1909; 1916; 1933). The researchers note that multimedia extends the capability of computers to move beyond simple presentation by "engaging learners in reflective, critical thinking about the ideas they are studying" (Jonassen et al., 1998, p. 15). Under this model, computer multimedia information is another powerful partner in the learning process. It is not a merely upgraded and advanced way of storing information for reading and memorization, or for reference.

Liao (1999) conducted a comprehensive meta-analysis of over 45 studies conducted between 1986 and 1998 investigating the role of hypermedia on student achievement in many areas, including CT. The vast majority of multimedia research was found to be focused more heavily on subject-specific areas (e.g., historical facts, practical mathematics, language assimilation) instead of more over-arching concerns like ethics, intelligence, emotional response, or CT. What was found was the extant research on multimedia's influence into student achievement shows mixed results. If no instructor intervenes (via live instruction, video, chat, etc.), multimedia provides a larger effect on student outcomes. With the introduction of instructor interaction, however, text and other forms of traditional information sources become more effective at positively impacting outcomes.

Stoney and Oliver (1999) found that CT can be enhanced, and more strategically focused upon, by adding multimedia to learning environments. The researchers tested their hypothesis by means of one instructional unit inserted into one collegiate finance course focused on accounting. The design of the study called for the replacement of one of the traditional face-to-face instruction days with an equivalent multimedia unit accessed by students during a time of their own choosing. The subject of the intervening treatment was a simple stock price valuation simulation where students had to decide how to pick stocks to increase the profits of a simulated portfolio. Eight students were separated into four groups for analysis of their discussions produced during and after engagement with the multimedia treatment. The researchers analyzed and coded student activity looking for evidence of time spent utilizing the multimedia content juxtaposed against time spent engaged in discussion rooted in the aforementioned core elements of CT. The cognitive activities of the students were grouped into two sub-groups: low-order activity and high-order CT activity. Low-order activity was defined by the researchers as discussion requiring little to no decision-making, cognitive engagement, or problem-solving effort (Stoney & Oliver, 1998; Stoney & Oliver, 1999). High-order, CT activities were described as being any combination of discussion related to: prediction, strategy, contemplation of new and pre-existing knowledge, consideration of belief and evidence, eliminating falsities, and deducing uncertainties.

The findings of the study showed marked increases in overall CT due to interaction with the multimedia unit. All students were required to discuss and make decisions based on the content of the multimedia content regardless of how much time was actually spent with the treatment. The evidence related to CT was shown through analysis revealing that the more time students spent with the multimedia, the more students exhibited higher-order CT skills. Higher overall profits by those groups exhibiting higher levels of CT were also observed, even though profit motivation in decision-making was not explored by researchers. The particular media used in this study was not created by the course instructor or by anyone at the same university. The treatment materials were created by an outside firm specializing in the particular subject field of business finance and accounting.

Thomas, Coppola, and Thomas (2001) questioned whether elements found in e-classrooms (including multimedia) had a demonstrable effect on CT. Their study was wide-ranging, mostly including the effect of learning management system (LMS) integration on CT outcomes. Included in their study was a measure for multimedia's effect by way of on-demand video of course content. The study used the CCTST in a pre and posttest design method on three different sections (three different instructors) of the same master's degree-level information systems course. The ages of the participants were between 20 and 29. The instructor was not the creator of all of the content for any of the courses. One class was conducted in a traditional face-to-face class format, one was conducted totally online via an LMS (Blackboard©), and one was conducted face-to-face with electronic treatments including on-demand video. The researchers define the third type of treatment of electronic classroom as "an interactive multimedia electronic classroom networked to the Internet and housing a video/ audio/ keyboard/ mouse broadcast-on-demand system" (Coppola & Thomas, 2000, para. 45). 20 to 40 students per course served as participants for the study.

This investigation found that the third multimedia treatment section of the MBA course did show increased mean scores improving (11.00 pretest to 14.28 posttest) on the CCTST over the Blackboard course. Posttest CCTST scores from the Blackboard course were actually lower (11.28 to 10.32) pretest to posttest. Final grades, however, were highest for the traditional face-to-face course. No analysis of teaching style was conducted during this study. A perceptions questionnaire was given at the end of the study asking participants to rate how they felt their method of instruction helped with their acquisition of CT skills. As with the final grade reports, the students in the face-to-face class were the most likely to report that they perceived their CT skills had improved most without technological assistance of any kind. At the end of the study, the researchers mention the need to extend their research to cover the same course taught by the same instructor to better control for pedagogical methods concerns.

Kumta, Tsang, and Hung (2003) used 163 final-year medical students in a study aimed at directly gauging the effects of multimedia instructional materials on CT in an orthopedic surgery context. The study was randomized using a control and experimental group. The researchers begin their narrative with a fundamental problem of education and CT where the observable world is filled with so many information sources. This fact makes it difficult to distinguish between what sources will help solve problems and which will not. The researchers say lecture-based curricula are too commonplace, antiquated, and conventional, and therefore "not well-designed to develop . . . analytical thinking and problem-solving skills" (para. 1), because of inundation of information. Multimedia sources, the researchers attest, can mediate this problem. The stakes are higher with medical students, because lack of proper CT skills can mean patient harm. The researchers find that their small study with web-based tutorial sources "led students through a thinking pathway that facilitated the development of higher cognitive skills such as analysis, application, and evaluation" (para. 18). Applying this pathway accomplishes the goal of establishing a marked way toward CT along with more efficient and effective patient care.

The researchers split their participants into 11 groups of 15 students who all attended a 3-week module on orthopedics throughout the span of their final year in medical school. Next, the researchers randomly assigned each group to a Study or Control group. A multiple choice pretest was given to all participants before the experiment began. The Study group was exposed to a web-based clinical case simulation (CCS) program designed by the researchers, but tested by existing orthopedic surgeons, to foster logical thinking abilities in the students. They were not given any other lecture-based or web-based teaching materials. The Control group was given a standard lecture-based curriculum supported by text materials and optional tutoring. At the end of 3-week module, both sets of students were tested on their knowledge and CT abilities in the arena of orthopedics. The researchers note there was no significant difference between the results of the Control and Study group on the pretest. There was a statistically significant difference on the final test at the end of the 3-week module with the Study group scoring higher than the Control. The researchers note that their study was small and limited. But they give commentary to their findings by suggesting their research demonstrates that "well-designed web-based tutorials stimulate students to think and . . . complement . . . teaching resources . . .foster[ing] better clinical and CT skills in medical students, without subjecting them to an information overload" (para. 23).

Sheldon and DeNardo (2005) sought further explanation on the difference between how multimedia video affected CT skills in prospective freshman and upper-level preservice music education majors. The researchers study design included two groups (n = 116 prospective freshmen) and (n =130 upper-level) music education majors. Each participant was shown a video of a particular musical interaction from two earlier studies (Sheldon & DeNardo, 2004). Standley and Madsen (1991) describe the 20-minute multimedia treatment as

> The . . . examples consisted of music in special education interactions . . . with mainstreamed groups and people who were mentally retarded, had cerebral palsy, were hearing-impaired, learning disabled, geriatric, abandoned, or were juvenile delinquents; music education interactions . . . with general, instrumental, or choral groups at the elementary, middle school, and high school levels; and professional, formal music performances . . . that included a piano concerto with both full orchestra and soloist shown and a violin solo accompanied by piano with only the violinist shown. (p. 7)

Each of the aforementioned segments in the treatment was displayed for one minute followed by two seconds of blank screen. The participants were required to watch the presentation, not speak to one another, and simply write down as many observations as they could describing each segment. Assessment by the researchers was made according to two criteria: factual and inferential content of the participants' written observations.

The final results were, like other studies, somewhat mixed. It was hypothesized that the upper-level student would score higher as their experience level would correlate more to what they saw through the multimedia treatment. While this was most often the case, it was not always the case. In some instances, the prospective freshmen demonstrated more CT about the segments they saw on screen. One-way ANOVA was used to compare scores. Post hoc analysis on certain demographic data connected to each participant (viz., GPA, class rank and ACT score) did show consistent correlations. Higher values in these measures equated to higher levels of CT regardless of student status.

Gerjets, Scheiter, and Schuh (2008) experimented with two different methods for attempting to positively affect problem-solving and CT in learners. These two experiments embraced earlier discussed concepts of cognitive load introduced by Mayer and other researchers. Gerjets et al. base their research on the theories of multimedia learning and cognitive processing through examples. The researchers explain that multiple examples accompanying multimedia presentation can be confusing to students. They say their experimental findings support their development of "two instructional devices . . . intended to stimulate learners' processing of single examples per problem category" (p. 80). Problems seen as complex tasks, and the ability to persist and solve them, are one of the cores of Halpern (1997) and P.A. Facione's (1990) explanation of CT. The connection between the research of Gerjets et al. and CT can be more clearly seen under this classification.

In their first experiment, Gerjets et al. (2008) worked with 80 (48 female, 32 male) undergraduate students at a traditional German university. These students were presented with three complex world problems to be solved in an online multimedia environment. A navigation bar was always present with the problems to be solved. The navigation bar contained links with information related to solving the problem at hand. Students had the ability to self-select how many links, and which links, they wanted to use to help solve the problem. They could not look at the information contained in the links while attempting to solve the problem. Students could only use this aspect of the hypermedia environment before attempting a solution. An added value question was included with each "tip" given via the hyperlinks that asked the students if they felt the information they received was helpful. The researchers say the dependent variables for their study were "problem-solving performance for the three . . . problems, time spent on studying example pages, and mean time spent per example retrieved [from the hyperlinks]" (p. 82). The results of this experiment interestingly found a significant difference in solution performance between genders, but not between how many tips were used via the hypermedia links. The only other significant factor found was with students who reported low prior knowledge of the problem material before interacting with the hyperlinks. As hypothesized by the researchers, the experiment suggests that hyperlink prompting for "cognitive processing might result in a better problem-solving performance, particularly for learners with low prior knowledge" (p. 83).

For their second experiment, the researchers used 31 German high school students (14 female, 17 male) in the ninth grade. The students worked in a computer mediated course (CMC) environment where they worked on algebra problems. Each student was given an 11-item pretest that gauged their prior understanding of algebra concepts before beginning work on the main problems. The concept of "pre-knowledge" in the work of Gerjets et al. (2008) is an essential component for the overall understanding of deep-thinking toward problem solving. The ninth grade students in this study were first given examples of algebraic concepts in scenarios typically not emphasizing mathematics, viz., biology, chemistry, and politics. They were required to simply read and study the concepts in this first phase of the experiment. They were allowed use their web browser's forward and backward buttons to help guide their cognitive processing of the material during this phase. It was the second phase of the experiment that required the students to solve 21 algebraic problems. The researchers note they were interested in differential effectiveness and therefore "a second independent variable was manipulated within the transfer distance of the 21 test problems that learners had to solve subsequent to the learning phase" (p. 86). The actual learner's solution performance on the 21 questions in the test phase was the dependent measure for the study. Ultimately, the researchers find that the ability to use multimedia to view and interact with seemingly unrelated content in the same context of an intended problem (viz., algebraic equation problem solving) will positively affect a learner's ability to solve targeted related problems. The researchers find interactive comparison tools "help learners to abstract . . . [and] compare examples that share the same cover stories across problem categories facilitat[ing] later problem-solving performance" (p. 87).

In a more recent study, Serin (2011) studied the effects of multimedia on the more singular component of CT related to student ability to use information to make inferences and solve particular problems. The researcher's method included 26 fifth grade students in a control group and 26 in an experimental group from a single school. In the study, the participants learned about general information on the Earth, the Sun and the Moon. Serin (2011) used a mixed design (pre and posttest) study to assess the impact of multimedia created by the researcher and presented to the experimental group students three hours per week for three weeks. The control group did not have the multimedia treatment added to their lessons for the three weeks during the study. The results of the study showed a statistically significant increase in problem-solving outcomes for learners receiving multimedia treatment.

Serin, Bulut Serin, and Sayg (2010) used a self-created tool for the assessment of problem solving skills, and a general content-based assessment on the subject matter of the "Earth, Sun and Moon" to collect data from the participants in the study. Cronbach's (1951) Alpha for the self-created tool was reported at .85 with a KR-20 reliability level at .72. The contents of the multimedia were also created by the researcher, and included some level of interactivity beyond simply watching, listening or reading in combination on a screen. The results of this study showed mean scores on the self-created tool to be significantly higher for the experimental group. Equivalencies of the groups were assessed by way of initial *t*-tests. Kolmogorov-Simirnov Z was used to determine normal distribution of the scores. The efficacy of the process of the experiment was assessed using ANCOVA. The researcher concludes with a general call for similar studies in different disciplines (and at different education levels) to be carried out using the same pre/posttest design with multimedia content used as an experimental treatment.

Summary and Synthesis

Both CT and multimedia continue to be pressing issues for educators seeking strategies to improve the educational experiences of students. The need for increased accountability in education as the core conduit for the learning of CT shows no sign of abating. As multimedia takes over as the dominant form of classroom information source, assessment of its impact deserves attention. Challenges persist in linking CT outcomes to the influence of multimedia in the classroom as higher education advances through the remainder of the century. Historically, literacy—a goal achieved through engagement with the reading and creation of text—has been one of the chief concerns of education. As literacy has become more of a virtual guarantee (Central Intelligence Agency, 2012) for students in developed nations like the United States, more focused learning outcomes like CT take center stage. Learners can read and write text, but what can they do with what they have learned and how do they explain what they deduce, feel, believe, and know? Multimedia will impact these outcomes as it presents information to and interacts with the cognitive ability of all learners. Finding how well the interaction is accomplishing educational outcome targets is now the necessary research goal.

P. A. Facione (1992; 2004; 2010) and Halpern (1998;1999) provide the underlying theory for this author's research into CT by providing an overall working understanding for the concept despite an acknowledgement that a precise definition is elusive (Abate Bekele, 2009; Brookfield, 1987; Dauer, 1989; Dewey, 1933; Ennis, 1987; P.A. Facione, 1992, 2004, 2010; Freely & Steinberg, 2009; E. Glaser, 1941; King & Kitchener, 1994; Lipman, 1991; Little, 1980; McLean, 2005; Organ, 1965; Paul, 1993; Paul & Elder, 2005). This author uses P.A. Facione (1990) and Halpern's (1997) definition of CT as the basis for operationalization of the concept. Discussion between Clark (1994) and Kozma (1994a) provides one of the main drivers for the need for research on the issue at hand. It is fundamentally the belief of the researcher that Kozma's refutation of Clark's replaceability challenge is the superior argument, because all media are not equal, and therefore, reaction and observed learning outcomes will never be equal across seemingly replaceable media types. In fact, it is the opinion of this author that multimedia types are all distinctive and will produce unique learning outcomes if students under their influence can demonstrate what they assimilate as they learn. Mayer's (2001; 2005a, 2005) research into media and cognitive load give caution to instructors to assess effectiveness of media instead of adopting a "more is best" approach to the inundation of student minds with as many types of media as possible.

Media objects, specifically as multimedia for learning, are increasing rapidly in development and deployment in higher educational environments, because of their perceived benefits and efforts to conserve time. Importantly for research considerations, however, is that multimedia research shows many mixed results on the impact of this popular and popularly easy to use and create medium on critical learning outcomes like CT. Azevedo, Moos, Greene, Winters, and Cromley's (2008) research shows how the increase of availability of multimedia and hypermedia sources can potentially hinder CT and learning, because of information overload in the cognitive abilities of students. This is why this author selects Mayer and Moreno's (2003) solutions to cognitive load as a key research source for design method and overall influence of future research scope.

The research of Kumta et al. (2003) most closely provides equitable and practical design methods for this researcher's question of interest. The environment used in their study was higher educational in nature, but limited to a segment of a particular course. The researchers used pre and posttest analysis. Gerjets et al. (2008) experiment in a similar fashion to Kumta et al. (2003), but provide a deeper study that involves an entire college course in its entirety. Gerjets et al. (2008) test two different sets of students in two different courses, thereby aggregating the results of two different environments entirely. This author initially intends to model a study based off both Kumta et al. (2003) and Gerjets et al. (2008) where the research questions are driven by a need to

- Modify one class entirely with multimedia treatment, while keeping an equivalent class (in subject matter) controlled without the treatment, and
- Use quasi-experimental design to provide statistically significant evidence of the effects on CT outcomes impacted by the treatment of multimedia,

Stoney and Oliver's (1999) work sets a tone for this author's research, because it involves a non-probability convenience sample taken from a small institution within a similar subject field. This particular study, however, needs expansion covering an entire course in the business field. Also, this previous work involved coding discussion activity rather than utilizing a validated instrument employing standardized, objective testing for data collection. Thomas et al. (2001) call directly for an extension of their empirical inquiry to include the examination of at least two different sections of the same course taught by the same instructor to assess electronic information sources like multimedia's impact on CT.

The overall research designs of Starbek et al. (2010), Kayaoglu et al. (2011), Serin (2011), and Sullivan-Mann, Perron, and Fellner (2009) give direction on how to conduct a multimedia versus text impact assessment study on the outcome of critical thinking for the important area of undergraduate business education. Deeply examining many of the methods of the aforementioned studies provides this author with an unmet need in the research. Numerous studies on adolescent students (be they on the impact of multimedia alone, juxtaposed against text or some other form of information presentation, combined or separated from investigation into CT skills) are not as indicative toward traditional undergraduates as studies specifically targeting these groups. Research specifically focused on assessing business CT skills (at any level) impacted by multimedia has not been found in the literature. Finally, studies not accounting for the instructor-as-developer of all aspects of the test classroom environment (multimedia and text) also give cause for this author's inquiry.

Combining what exists in the literature leaves the following conclusion: What is not found are many (a) studies investigating the impact of multimedia on CT, any studies (b) investigating the impact of multimedia on the very popular field of business combined with a distinct focus on business-specific CT skills, and (c) studies conducted on the same course using the same instructor who is also the sole creator of the text and multimedia material. The paucity of empirical research focused on business critical thinking skills is strange considering the sheer number of American business graduates. Each year, there are thousands more students in the United States studying business fields than there are students studying humanities subjects and/or most of the social sciences. The NCES (2011) reports twice as many business graduates than social sciences and history, and over three times as many business graduates versus education. Most college graduates (regardless of major), moreover, work and practice their education in the open market where business CT skills are much more in demand. For this reason, examinations of business CT skills are necessary from vantage points of a variety of different disciplines. This research study will contribute to the field of Educational Technology's body of work experimenting on aspects of its products' (viz., multimedia learning tools) impact on areas of cognitive theory (viz., critical thinking) within the highly-demanded field of business.

CHAPTER 3

METHODOLOGY

Given the context provided by cognitive theories surrounding human psychology, learning, multimedia, and assessment for CT outcomes, a framework for research can be formulated. The framework of this study combines the theories of Peter Facione, Halpern and Mayer, and the aforementioned research found in a review of the literature, with other core sources into a five-phase model for analyzing CT skills in collegiate learners affected by multimedia (a) acquiring and comparing of information to determine objectives for problem solving, (b) hypothesis generation and modification of proposed syntheses for appropriate questioning, (c) processing, exploration, and analysis of inconsistencies among ideas before and during practice, or "play", on confirmed hypotheses, (d) negotiation of meanings based off reviewing findings and likelihoods of replication of results, and (e) reasoning and agreement with application of newly constructed meaning seeking further review and assessment for future retrieval (Bishop & Cates, 2001; Duron, Limbach, &Waugh, 2006; Lowe & Anderson, 1997; Samaras, Giouvanakis, Bousiou, & Tarabanis, 2006; Vygotsky, 1978).

Equal weight is given to each of the five elements of the framework at this time. The framework is designed to be utilized in more than one particular environment in collegiate settings. Each of the elements of the framework can also be made manifest in a variety of different manners as well. Problem solving can come in the form of case study analysis or isolated, objective questioning as in the Kumta et al. (2003) study. The notion of appropriate questioning is consistent with Kozma's (1994a) theory against Clark's (1994) idea of "replaceability" in the sense that each medium is unique and will elicit an appropriate and separate set of questions in the minds of learners. Analyzing inconsistencies within complex problems can be seen in the two-project research approach in Gerjets et al. (2008). Closely reviewing meanings that are found in particular multimedia sources is intimately linked to their impact on the mind as expressed by Mayer and Moreno (2003). Finally, P. A. Facione (1992; 2004; 2010) and Halpern (1998; 1999) note that reasoning can be observed and manifested verbally or in a written fashion or both, and therefore the display of CT skills and assessment of CT outcomes foils itself well against a backdrop of learner engagement with multimedia sources.

Study Design

The author performed a quasi-experimental, pretest/posttest quantitative study (Figure 1) to investigate the potential effects multimedia resources substituted for traditional sources within a higher education course would have on business CT skill outcomes. This study used the Business Critical Thinking Skills Test (BCTST)--An adaptation of the California Critical Thinking Skills Test (CCTST) for Employers and Business Educators and Professionals produced by Insight Assessment—as the pretest and posttest tool for measuring the CT abilities of the study participants. Sample test items and score sheet are provided in Appendix A. In this popular design for quasi-experiments, all groups took the pre and posttest with only the treatment group receiving the treatment (Creswell, 2009). Diffusion of treatment and maturation threats to internal validity concerns are evident, but are well-mediated by control of

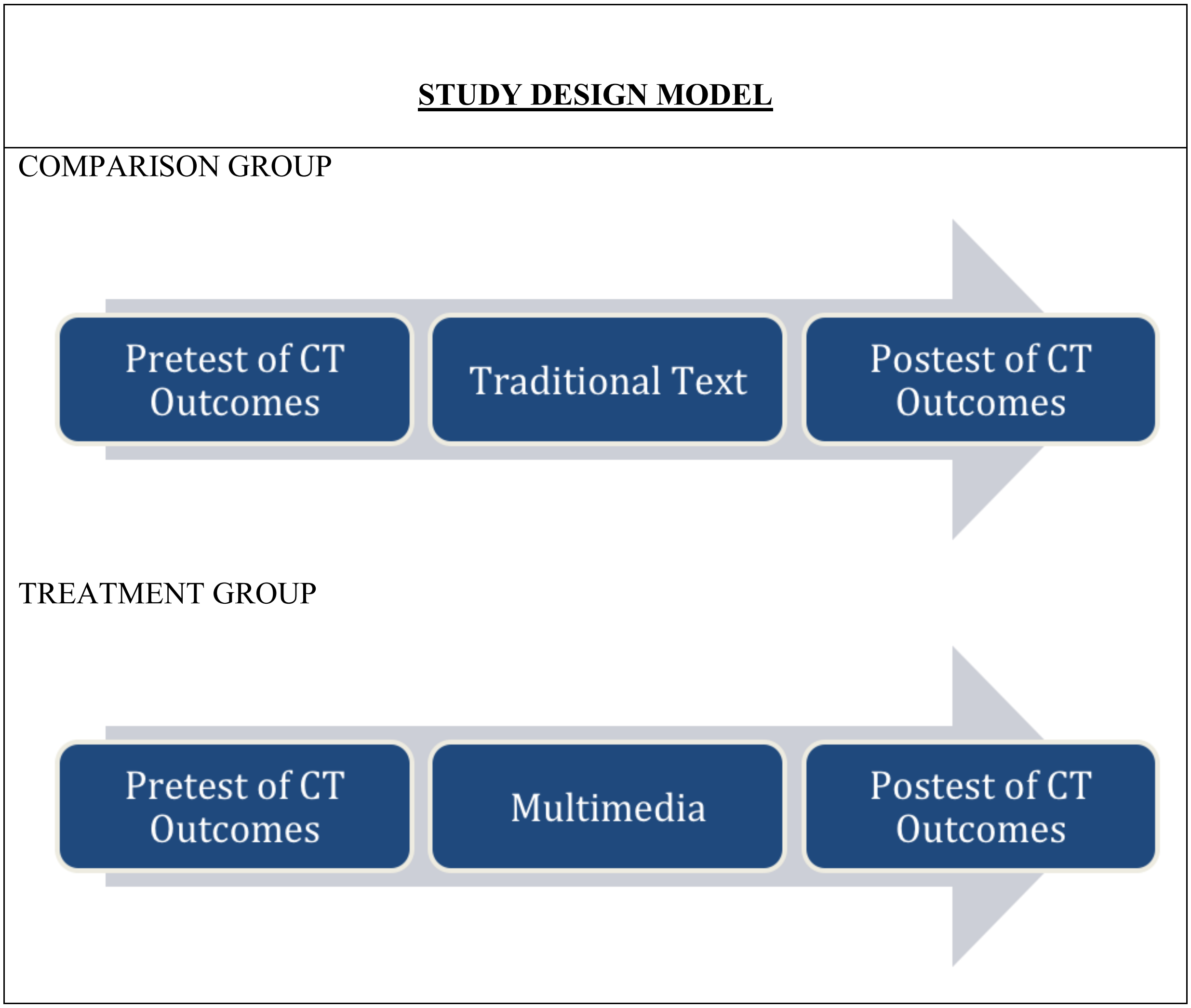


Figure 1: Basic pretest/posttest design model using comparison group with traditional text, and treatment group with multimedia substitution.

the instructor of the courses to be studied, and the selection of higher-education level (upperclass) students rather than lower-education level (underclass) students (Creswell, 2009). Threats to external validity can be seen in the experimenter/researcher effect, if the researcher is also the instructor of one or both sections of the course (Gay & Airasian, 2000). This was not the case, however, with this study. Other threats to external validity come from not enough participation by potential research subjects with the option of refusal. This effect was mediated by (a) the research setting only offering one section per semester of the course, (b) the course being required for all business majors, thereby guaranteeing a predictable stream of students each semester, and (c) the author and course instructor working closely to achieve a high response-rate through integration of the experiment fully into the design of the face-to-face course through pen and paper administration of the measurement instrument instead of online administration (Campbell & Stanley, 1963).

The treatment used in this study was the replacement of the traditional textbook for the only section of a general business management capstone course offered at the research setting with equivalent multimedia—both of which were produced by the same instructor. The textbook for the comparison group consisted of 10 chapters. Equivalent sections of multimedia appeared for the students in the treatment group within the Canvas© LMS. The course schedule was 16 weeks in length. The pretest was administered on the second Wednesday of both of the courses (Fall 2012 and Spring 2013), because it was determined by the experience of the instructor that this particular day would begin the most static time period for enrollment after add/drop opportunities were taken advantage of by students wishing to either enroll or drop out from the course. Posttests were administered on the Wednesday of week 15 as week 16 was the regularly scheduled final exam week.

From each of the four testing collection periods, data from the BCTST were gathered and sent to Insight Assessment for scoring using a standard scoring return sheet (Appendix B). All scoring results were given to the author by Insight Assessment per their written agreement (Appendix C). No scoring of the BCTST was conducted by the author, the cooperating faculty member, or any members of the research setting. Repeated measures (RM) multivariate analysis of variance (MANOVA) was performed to test for differences in CT outcomes for the between-subjects factor (group: text and multimedia) and the within-subjects factor (time: pretest and posttest).

The Fall 2012 and Spring 2013 sections of the research setting course contained completely different students and are therefore regarded as independent samples. The significance level (alpha) at which the null hypotheses (H0) are rejected was chosen to be .05. This study used a .05 level of significance as a compromise between committing type I (rejecting H0 when it is true) and type II (failing to reject H0 when it is false) errors (Wuensch,1994).

Research Setting

The research setting for this quantitative study was two separate face-to-face sections of one undergraduate-level, general business management capstone course at a small Midwestern university (FTE enrollment 2150). Total enrollment for each section of the course was between 20 and 30 students. The comparison group for this study was the first section of the course (Fall 2012) where all course material for the class was provided via a textbook produced by the instructor. The treatment group was an identical section of the same course using the same instructor where all course material was provided via multimedia delivered within the Canvas© LMS. The multimedia was created by the same instructor utilized in both comparison and treatment groups of the study. Only one section of the course is offered at the research setting due to the low total FTE (120) of traditional business (accounting, finance, marketing, management) students enrolled at the college. Only one instructor is retained full-time in the finance department at the institution's college of business. This individual was the sole instructor teaching face-to-face sections of the course at the time and has retained this position since 2000.

Sample Participants

There were 43 total participants in the study. The study used nonprobability convenience samples from two separate, individual, consecutive sections of the same undergraduate business administration course. The participants were a sample of the entire full-time equivalent (FTE), traditional, undergraduate business student population of approximately 120. The 43 participants were split into two groups of 22 for the Fall 2012 semester and 21 for the Spring 2013 semester by virtue of their voluntary registration in their respective course sections. Gender, race, and other demographic data stratification were random through the procedure of ordinary course registration. All students were fully admitted to the research setting's business school with their GPAs being between 2.8 and 3.7. Students voluntarily registered for the course used in this study and all participants experienced the same instructor each term. The treatment was not instructor-specific and the sample had no motivation to take one instructor over another in an effort to avoid the study. Unlike the Kingsley and Boone (2008) study which used numerous students, instructors and various creators of both media and text for comparison, this study followed Stake's (2000) assertion of following the heuristic of more intensive learning from an intrinsically unique case study that uses a smaller sample from a singular source.

Ethical Principles/Human Subject Compliance

The author of this study was employed at the research setting as an administrator in an unrelated department. The author holds NIH Office of Human Subjects Research certificate (09/29/2009) number: 1254326492. The author has completed 12 graduate credit hours in educational research at Northern Illinois University (NIU) and has taught social science research methods since 2004. Students enrolled in the course were recruited for participation in the study by the course instructor as a way of integrating the study within the class. Participants in this study were notified of the project via the "Research Participation Invitation" (Appendix D) preloaded into the course LMS prior to the start of the semester and handed to each student the first day of class. Participants were told that the purpose of the tests they were taking was to provide them with insight into their own CT development over the course of the semester and throughout the whole of their studies in general. Cumulative results (with de-identified participants) of the tests were provided to participant students via a freely accessible web site. Access to the full report of the study was also made available to all participants.

Compliance for inclusion in the study was obtained through "Informed Consent" forms for the research setting and NIU (Appendix E) both preloaded into the course LMS, presented to and signed by each student in print before data collection. Each student was provided with a "Notice of Privacy Practices" instilling the understanding that data from their test performance will not be shared with other individuals or agencies (Appendix F). Each student was provided with a signed letter of consent to conduct the research from the cooperating faculty and the Provost of the research setting (Appendix G). All documents for consent, privacy, and a full description of the study were approved by the Institutional Review Boards of the research setting, and NIU.

Benefits/Risks

The results from this research study may be used by faculty and higher education administrators as they seek to understand more about how multimedia is impacting specific CT outcomes as applied to overall learning in students. This understanding may provide for greater accountability for student performance of the important skill of CT achieved through changes in resource planning and pedagogy. The data from this study can provide insight into how to best plan for a future that may (by default rather than by positive evidence from research) include more multimedia and fewer static text resources. Educational technology professionals may find the data generated from this study to be useful in the pinpointing of efforts to create multimedia for instruction for specific CT outcomes, demographic participants, or both combined. Overall, it is expected that this study will help higher education leaders make more informed decisions about the use of multimedia in the classroom by way of an analysis of CT outcomes.

A summary of the findings of this research were provided to all participants as a way to allow them to compare and contrast the results to their own experiences with CT in the curriculum. Insight can be gained guiding the participants' future choices in (a) attending classes that emphasize multimedia over text, or vice versa, and (b) thinking more strategically about supplementing their own individual research efforts with the information source that best impacts their specific CT outcomes. The inadvertent disclosure of participant information was the primary risk in this research. This risk, however, was deemed minimal by the author. Contact information for the Dean of Students, the Dean of the College of Business, the University Human Resources Department, and the Office of Disability Services at the research setting, as well as contact information for the dissertation chair, the author, and the NIU Office of Research Compliance was provided to all students in the event of harm to a subject.

The items on the BCTST are related to core business subjects (accounting, finance, marketing, and management) of the sort that upper-division students have experienced in the past. The design of BCTST was typical and consistent with that of current ACT, SAT, GMAT, and especially, LSAT, and CPA examinations. The BCTST was administered in a secure classroom location monitored by the author and the course instructor. Students were assured by the author and the course instructor that their particpation in the research testing would bear no impact on their formative or summative assessment in the course. The security of the data gathered was ensured by the author collecting all written test answer forms, and then through the immediate transferring of the forms to Insight Assessment for scoring. Participant identity remained confidential, and was not shared with anyone other than the author and the course instructor. Name and contact information for the participants was not associated with the data. Name and contact information for the participants was only used to assess if the participant had completed the BCTST. Before secondary statistical analysis, to assure confidentiality, case numbers were assigned to all data sets masking individual identity in all statistical reports and graphs. Participant tests were stored in a locked facility that is only accessible by the author and the course instructor. Three years after the completion of this study, all tests and any other items containing participant personal information will be destroyed.

No other CT testing for business students is being administered at the research setting at this time. This study benefits the participants in the sense that it is the one of the only structured ways they will gain an enhanced understanding of their own CT outcomes related specifically to their own discipline in light of the existence of numerous books and articles emphasizing the great importance of CT as one of the core reasons to attend college at all. It also gives the participants a first-hand example of how future research they may want to perform themselves can be conducted in a real-world setting. Undergraduate research is highly desired among college administrators. Participation in studies like what is proposed here is argued to be more benefical to a student's development as future researcher above and beyond any minimal risk that may be incurred as a study participant involved in such in research as described in this report.

Textbook for Comparison Group

Students in the first semester's portion of the study (comparison group) purchased a copy of *Principles of Finance* (Wyrostek, 2011) published by Cengage Learning in Mason, Ohio, the sole textbook for the course to be used throughout the semester. All students were required to purchase this text. The text is divided into 10 chapters with one appendix of basic financial tables. Each chapter is briefly described as follows:

Chapter 1 provided an overview of financial management and how it fits with the rest of business reasoning and managerial CT skills. Finance is described in context with a description of businesses in general encouraging students to think about why businesses exist, before thinking about how they make money or what they do with the money they make after they become successful. The chapter is keen to describe the critical differences between long-term and short-term goals of a business. Ethics, whistle blowers, and managerial incentives were discussed in context of the different kinds of jobs one can obtain within a company. Advantages and disadvantages of different business types are explored and juxtaposed with an emphasis on the role of managers and line employees, and how they each objectively reason their positions within an organization.

Chapter 2 presented the time value of money as one of the most important concepts in the study of business. How to calculate present and future values of lump sums was explained in detail as a means of evaluating where companies will be, financially and managerially, in the future. Basic fundamentals of stocks and bonds were explicated including an overview of interest rates. Accounting principles of amortization concluded this chapter coinciding with the CT principle of understanding societal realities affecting all organizations.

Chapter 3 presented fundamental concepts within of the overall subject of management and finance, and the thought involved with relating capital to operations. An introduction to fiscal statements provided students with a view of information they will see for the rest of their careers that will fuel their individual CT about all aspects of a business. Cash flow management, as a core business principle, was also discussed in this chapter, with a final large segment discussing the philosophy and background of taxes as a societal reality with which all companies must comply.

Chapter 4 was entirely dedicated to financial statements and their analysis with a goal of influencing key business reflection and decision-making skills. Ratio analysis, interpretation of the impact of percentage yields, balance sheets and income statements were covered in this chapter, because they serve to sharpen CT analysis skills needed for the practical understanding of effective business communication of operations. Return on Equity (ROE) is introduced in this chapter as the most important managerial control point within a business. The fundamental unpredictability of some aspects of business is also introduced along with a brief overview of benchmarking and trend analysis to connect to the core CT skills of anticipation, flexibility, and persistence.

Interest rates were the primary subject of Chapter 5. How much money costs a business, needs for capital, inflation, securities risk, and liquidity also comprised major sections of this chapter. An introduction to yield curves and how to interpret and analyze their shape was given for students to correlate to the forecasting of future interest rates affecting the thought processes behind running an organization's capital. Encouragement to begin to critically examine potential investment decisions began with this section of the book telling students to consider the combination of risk and reward against leverage and interest potentially owed.

Chapter 6 covered how companies raise money through the issuing of debt (viz., bonds). Differing features of bonds were explored. The text made an effort to influence the students' thoughts away from the assumed complicated nature of bonds and more toward a confidence in knowing the sharp limitations of this particular financial instrument. The CT element of persistence at complex tasks correlated strongly to the focus of this chapter, as it is mentioned that the reason so many students shy away from bonds is because they assume they are difficult to understand in in their totality. How to calculate yields, understand calls, interpret changes in price and determine corporate capital finalized this chapter.

Chapter 7 detailed how risk is decided upon and how rewards are assessed based on rates of return. Each day, businesses weigh risk versus reward, and therefore the text devoted an entire chapter to elements involving this crucial managerial decision point. Financial assets and how they produce cash flow was covered along with real assets and how they impact capital budgeting. Diversification was introduced in this chapter as well as determining failing and succeeding business strategies as consistent with the definition of CT. The concept of investment portfolios was also explained as a way to spread and distribute risk in a strategic and thought-provoking manner.

Chapter 8 was juxtaposed against Chapter 6 through a focus on stock, the equity markets and stock valuations. Legal issues centered on the areas of inductive and deductive reasoning regarding shareholders rights and how to pursue business interests on behalf of others was introduced. Critical thought was encouraged through the use of trusted models for estimating stock values, discounted dividends and corporate valuations. Cost of capital as a mediating factor in thinking about stock valuation and how to increase stock price was explored with an emphasis on critically examining budgets looking for ways to eliminate nonproductive activities of the past. Chapter 8 focuses on stock, but with a more concentrated explanation of the CT skills of inductive reasoning and elimination of falsities by examining stock price in relation to the concept of intrinsic corporate value. Students reading this chapter were exposed to key characteristics of common stock versus preferred stock seeking to find the differing values and how they related to the marketing of a company to prospective new investors. Models for estimating corporate value were shown as a way to interpret future estimations of needed products and/or services to develop to increase value.

Chapter 9 began the section of the text where the previous chapters were to be synthesized into a comprehensive review for approaching the next levels of business study. Weighted average cost of capital (WACC) used in capital budgeting was explained in this chapter as a way to estimate capital components. The CT skills of estimation and elimination were a component of this chapter when students were exposed to the concepts of retained earnings and other types of capital. The key decision-skill to be learned in this chapter was the ability to pick new projects based on understood and practiced financial concepts.

Chapter 10 concluded the book by focusing on capital budgeting—the place where organizations put their critical strategic thinking and planning into final action and implementation. Discussions of scenarios of capital budgeting examples were presented as a way to relate theory to practice. Internal rate of return (IRR), net present value (NPV), payback and other financial concepts designed to influence CT and decisions are defined, explained and demonstrated in cases that were current at the time and easy for students to understand.

Course Instructor and Multimedia Used In Treatment Group

The multimedia used in the research setting course for the treatment group were created by the same instructor who provided the text for the course. Each chapter reviewed above had a corresponding multimedia piece created by the instructor containing his voice, various images, animations, and the instructional information of each chapter. The instructor used Macromedia Breeze© and Adobe Connect© to create multimedia presentations containing video, audio, text, images, and Microsoft Power Point© and Excel© content. The instructor originally created the content to accommodate assumptions related to differing learning styles found among all students. The instructor notes that his particular instructional design activity serves as an alternative way for students to learn the same information contained in his text.

The instructor collaborated closely with the research setting instructional design department for the creation of the multimedia and for the hosting of the content within the LMS.

Figure 2, for example, shows a multimedia screenshot of a unit on financial management which corresponds to Figure 3 showing the same content presented in the course textbook. Figure 4 shows a multimedia screenshot of a unit on balance sheet analysis as a fundamental concept of financial management. This image corresponds to Figure 5 showing the same content presented in the course textbook. Figure 6 shows a multimedia screenshot of a unit on bond yield calculation. This image corresponds to Figure 7 showing the same content presented in the course textbook. Figure 8 is a multimedia screenshot of a unit on stock beta coefficients as an indicator of a stock's propensity to move with the overall rises and falls in the stock market. This image corresponds to Figure 9 showing the same content presented in the course textbook.

The cooperating instructor for this author's research has been a leader in the movement at the research setting to duplicate textual content in multimedia format in attempts to enhance student learning. The instructor used in this study was one of the first faculty at the research setting to work with instructional designers to create multimedia content. As with the motivation of Carver, Howard, and Lane (1999), and many others after, the cooperating instructor in this study felt that the advent of easily creatable multimedia generation offered great opportunity to provide a variety of differing information formats that could increase student comprehension and performance. Even though Carver et al. (1999), and others, have found their original hypotheses regarding increases in understanding through multimedia learning resulting in mixed cases of evidence, it is important to acknowledge that many students and faculty feel that multimedia enhances learning over text-only information sources

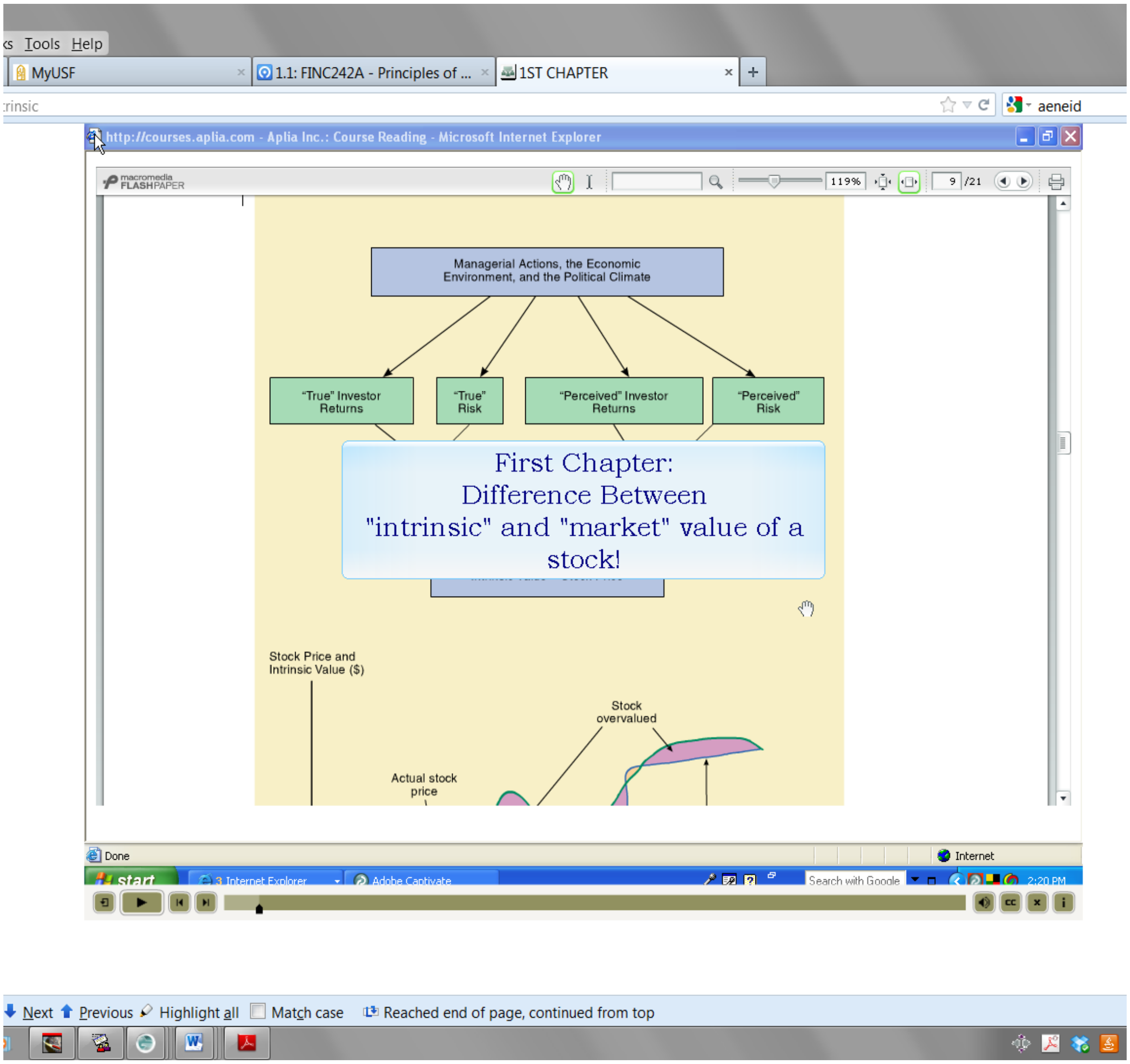
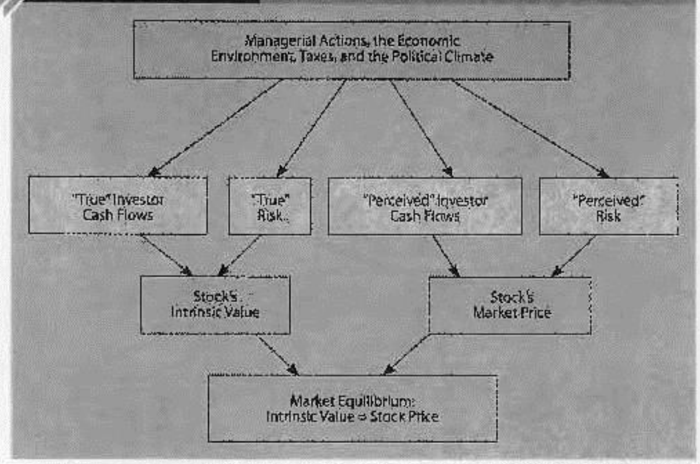


Figure 2: Multimedia presentation screen capture from research setting online streaming class content depicting page 13, Chapter 1: Overview of Financial Management, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

FIGURE 1.2 Determinants of Intrinsic Values and Stock Prices



would enjoy high and rising future profits. They also thought that actual results would be close to the expected levels and hence, that Enron's risk was low. However, true estimates of Enron's profits, which were known by its executives but not the investing public, were much lower; and Enron's true situation was extremely risky.

The third row of boxes shows that each stock has an **intrinsic value**, which is an estimate of the stock's "true" value as calculated by a competent analyst who has the best available data, and a **market price**, which is the actual market price based on perceived but possibly incorrect information as seen by the **marginal investor.**[3] Not all investors agree, so it is the "marginal" investor who determines the actual price.

When a stock's actual market price is equal to its intrinsic value, the stock is in **equilibrium**, which is shown in the bottom box in Figure 1.2; and when equilibrium exists, there is no pressure for a change in the stock's price. Market prices can—and do—differ from intrinsic values; but eventually, as the future unfolds, the two values tend to converge.

Actual stock prices are easy to determine—they can be found on the Internet and are published in newspapers every day. However, intrinsic values are estimates; and different analysts with different data and different views about the future form different estimates of a stock's intrinsic value. *Indeed, estimating intrinsic values is what security analysis is all about and is what distinguishes successful from unsuccessful investors.* Investing would be easy, profitable, and essentially riskless if we knew all stocks' intrinsic values; but, of course, we don't. We can

Intrinsic Value
An estimate of a stock's "true" value based on accurate risk and return data. The intrinsic value can be estimated but not measured precisely.

Market Price
The stock value based on perceived but possibly incorrect information as seen by the marginal investor.

Marginal Investor
An investor whose views determine the actual stock price.

Equilibrium
The situation in which the actual market price equals the intrinsic value, so investors are indifferent between buying or selling a stock.

[3] Investors at the margin are the ones who actually set stock prices. Some stockholders think that a stock at its current price is a good deal, and they would buy more if they had more money. Others think that the stock is priced too high, so they would not buy it unless the price dropped sharply. Still others think that the current stock price is about where it should be; so they would buy more if the price fell slightly, sell it if the price rose slightly, and maintain their current holdings unless something were to change. These are the marginal investors, and it is their view that determines the current stock price. We discuss this point in more depth in Chapter 9, where we discuss the stock market in detail.

Figure 3: Page 13, Chapter 1: Overview of Financial Management, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

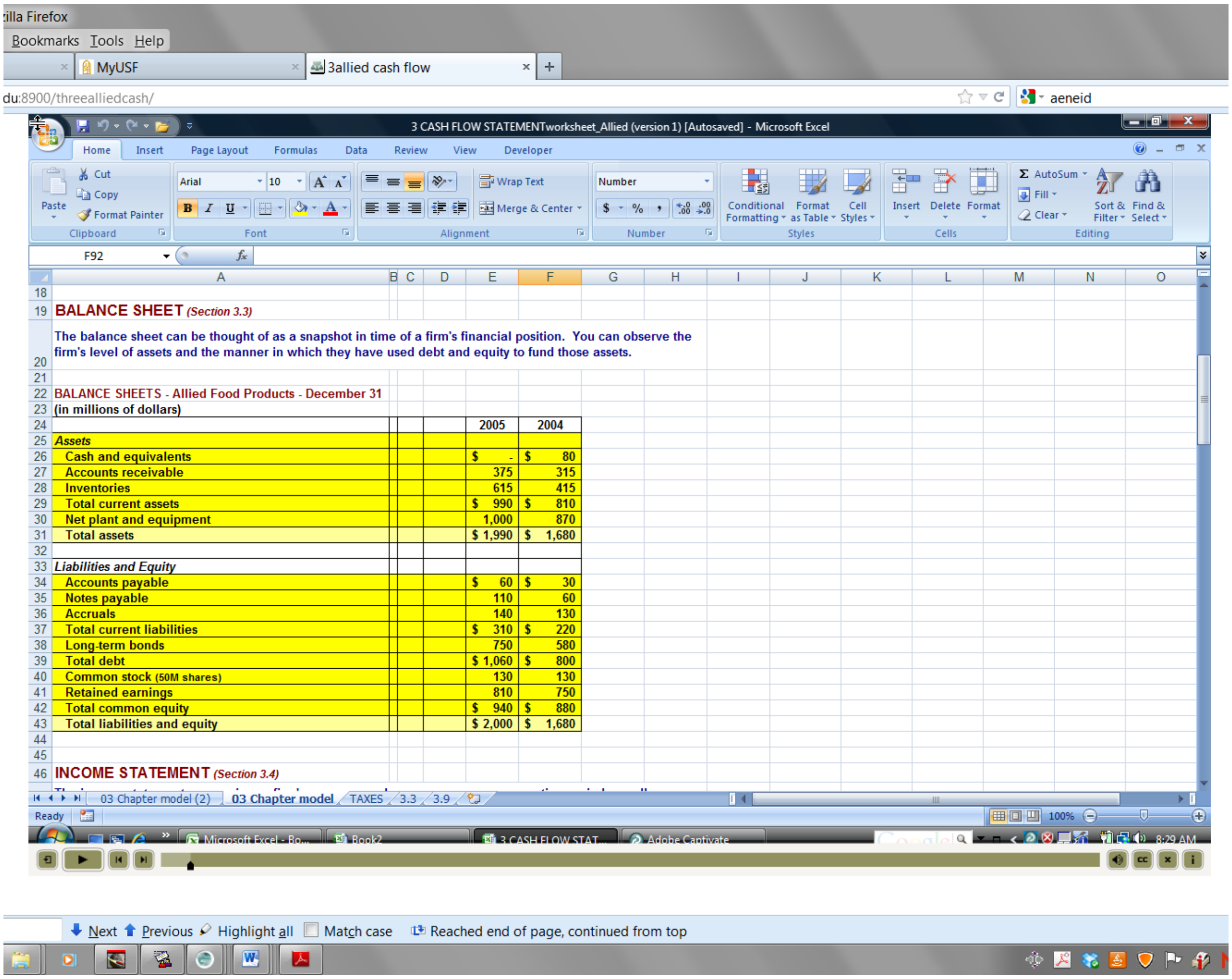


Figure 4: Multimedia presentation screen capture from research setting online streaming class content depicting page 76, Chapter 3: Financial Statements, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

Table 3.1 Allied Food Products: December 31 Balance Sheets (Millions of Dollars)

	2011	2010
Assets		
Current assets:		
Cash and equivalents	$ 10	$ 80
Accounts receivable	375	315
Inventories	615	415
Total current assets	$1,000	$ 810
Net fixed assets:		
Net plant and equipment (cost minus depreciation)	1,000	870
Other assets expected to last more than a year	0	0
Total assets	$2,000	$1,680
Liabilities and Equity		
Current liabilities:		
Accounts payable	$ 60	$ 30
Accruals	140	130
Notes payable	110	60
Total current liabilities	$ 310	$ 220
Long-term bonds	750	580
Total debt	$1,060	$ 800
Common equity:		
Common stock (50,000,000 shares)	$ 130	$ 130
Retained earnings	810	750
Total common equity	$ 940	$ 880
Total liabilities and equity	$2,000	$1,680

Notes:

1. Inventories can be valued by several different methods, and the method chosen can affect both the balance sheet value and the cost of goods sold, and thus net income, as reported on the income statement. Similarly, companies can use different depreciation methods. The methods used must be reported in the notes to the financial statements, and security analysts can make adjustments when they compare companies if they think the differences are material.
2. Book value per share: Total common equity/Shares outstanding = $940/50 = $18.80.
3. A relatively few firms use preferred stock, which we discuss in Chapter 9. Preferred stock can take several different forms, but it is generally like debt because it pays a fixed amount each year. However, it is like common stock because a failure to pay the preferred dividend does not expose the firm to bankruptcy. If a firm does use preferred stock, it is shown on the balance sheet between total debt and common stock. There is no set rule on how preferred stock should be treated when financial ratios are calculated—it could be considered as debt or as equity. Bondholders often think of it as equity, while stockholders think of it as debt because it is a fixed charge. In truth, it is a hybrid, somewhere between debt and common equity.

show the cost of raw materials, work in process, and finished goods. Net fixed assets represent the cost of the buildings and equipment used in operations minus the depreciation that has been taken on these assets. At the end of 2011, Allied has $10 million of cash; hence, it could write checks totaling that amount. The noncash assets should generate cash over time, but they do not represent cash in hand. And the cash they would bring in if they were sold today could be higher or lower than the values reported on the balance sheet.

Figure 5: Page 76, Chapter 3: Financial Statements, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

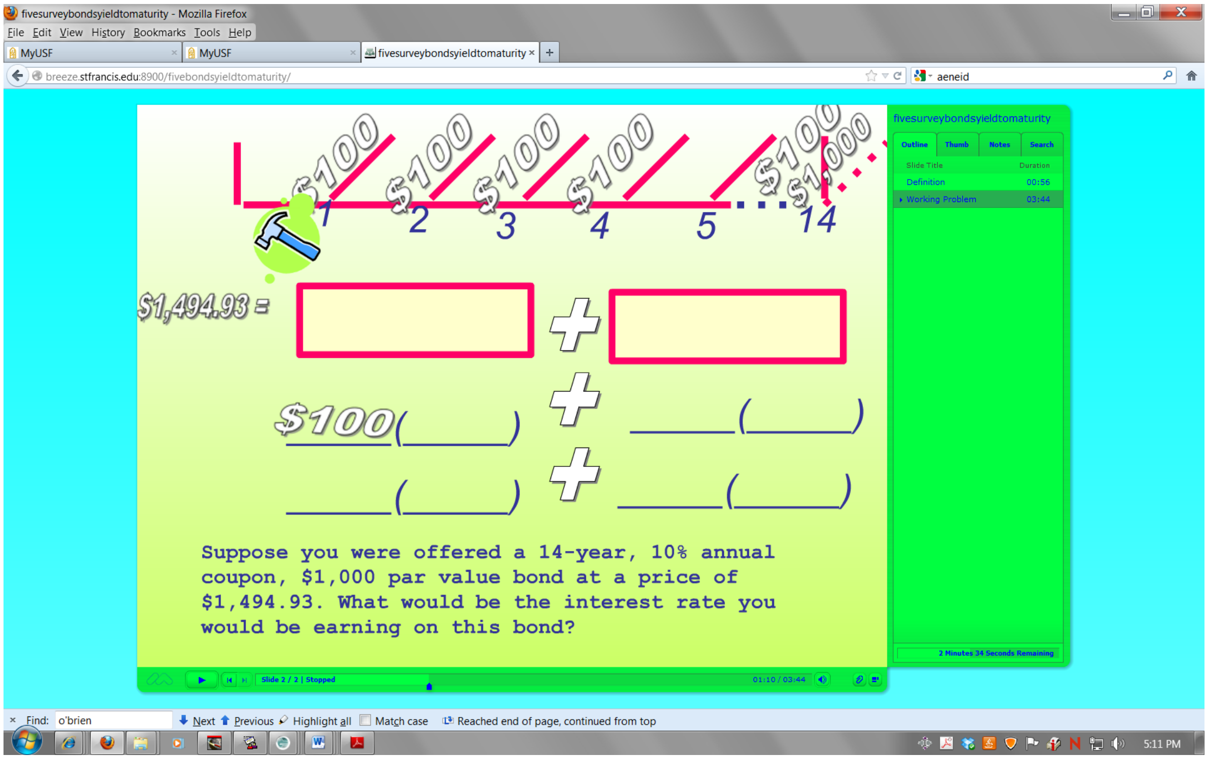


Figure 6: Multimedia presentation screen capture from research setting online streaming class content depicting page 196, Chapter 7: Bonds and The Valuation, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

7-4a Yield to Maturity

to Maturity (YTM)
te of return earned
ond if it is held to
ty.

Suppose you were offered a 14-year, 10% annual coupon, $1,000 par value bond at a price of $1,494.93. What rate of interest would you earn on your investment if you bought the bond, held it to maturity, and received the promised interest and maturity payments? This rate is called the bond's **yield to maturity (YTM),** and it is the interest rate generally discussed by investors when they talk about rates of return and the rate reported by *The Wall Street Journal* and other publications. To find the YTM, all you need to do is solve Equation 7-1 for r_d as follows:

$$V_B = \frac{INT}{(1+r_d)^1} + \frac{INT}{(1+r_d)^2} + \dots + \frac{INT}{(1+r_d)^N} + \frac{M}{(1+r_d)^N}$$

$$\$1{,}494.93 = \frac{\$100}{(1+r_d)^1} + \dots + \frac{\$100}{(1+r_d)^{14}} + \frac{\$1{,}000}{(1+r_d)^{14}}$$

You can substitute values for r_d until you find a value that "works" and force the sum of the PVs in the equation to equal $1,494.93. However, finding r_d = YTM by trial and error would be a tedious, time-consuming process. However, as you might guess, the calculation is easy with a financial calculator.[6] Here is the setup:

N	I/YR	PV	PMT	FV
14		−1494.93	100	1000
	5			

Simply enter N = 14, PV = −1494.93, PMT = 100, and FV = 1000; then press the I/YR key. The answer, 5%, will appear.

QUICK QUESTION

QUESTION:
You have just purchased an outstanding 15-year bond with a par value of $1,000 for $1,145.68. Its annual coupon payment is $75. What is the bond's yield to maturity?

ANSWER:
Using a financial calculator, we can determine that the bond's YTM is **6%.**

N	I/YR	PV	PMT	FV
15		−1145.68	75	1000
	6			

[6] You can also find the YTM with a spreadsheet. In Excel, you use the RATE function:

```
=RATE(14,100,-1494.93,1000)
```

This gives the YTM as 5%. Note that we didn't need to specify a value for type (since the cash flows occur at the end of the year) or guess.

Figure 7: Page 196, Chapter 7: Bonds and Their Valuation, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

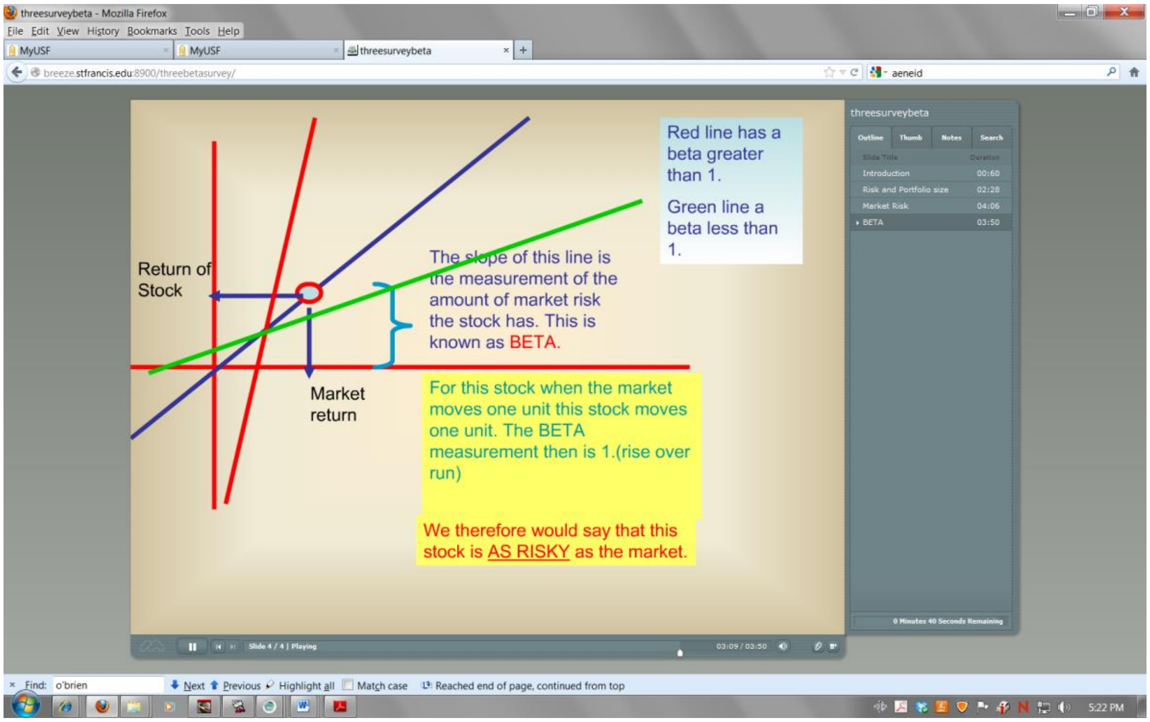
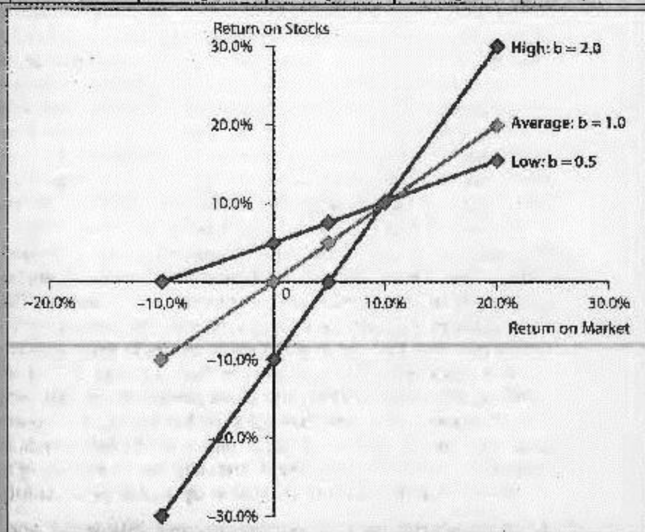


Figure 8*:* Multimedia presentation screen capture from research setting online streaming class content depicting page 245, Chapter 8: Risk and Rates of Return, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

FIGURE 8.7 Betas: Relative Volatility of Stocks H, A, and L



Year	r_M	r_H	r_A	r_L
1	10.0%	10.0%	10.0%	10.0%
2	20.0%	30.0%	20.0%	15.0%
3	−10.0%	−30.0%	−10.0%	0.0%
4	0.0%	−10.0%	0.0%	5.0%
5	5.0%	0.0%	5.0%	7.5%

Calculating beta:

1. Rise-Over-Run. Divide the vertical axis change that results from a given change on the horizontal change, i.e., the change in the stock's return divided by the change in the market return. For Stock H, when the market rises from −10% to +20%, or by 30%, the stock's return goes from −30% to +30%, or by 60%. Thus, beta H by the rise-over-run method is 60/30 = 2.0. In the same way, we find beta A to be 1.0 and beta L to be 0.5. This procedure is easy in our example because all the points lie on a straight line; but if the points were scattered around the trend line, we could not calculate an exact beta.

2. Financial Calculator. Financial calculators have a built-in function that can be used to calculate beta. The procedure differs somewhat from calculator to calculator. See our tutorial on the text's website for instructions on several calculators.

3. Excel. Excel's Slope function can be used to calculate betas. Here are the functions for our three stocks:

$Beta_H$	2.0	=SLOPE(C154:C158,B154:B158)
$Beta_A$	1.0	=SLOPE(D154:D158,B154:B158)
$Beta_L$	0.5	=SLOPE(E154:E158,B154:B158)

the slope coefficient for H is 2.0; for A, it is 1.0; and for L, it is 0.5.[19] Thus, beta measures a given stock's volatility relative to the market, and an **average stock's beta, b_A** = 1.0.

Average Stock's Beta, b_A
By definition, $b_A = 1$ because an average-risk stock is one that tends to move up and down in step with the general market.

[19]For more on calculating betas, see Brigham and Daves, *Intermediate Financial Management*, 10th edition (Mason, OH: South-Western/Cengage Learning, 2010), pp. 53–55 and pp. 86–93.

Figure 9: Page 245, Chapter 8: Risks and Rates of Return, from Wyrostek, F. (2011). Principles of finance. Mason, OH: Cengage.

regardless of what evidence experimental studies on multimedia versus text provide. This singular belief has led to the continued increase in the creation of multimedia to be used in place of text, and is consistent with the need to study cases where this activity still persists.

Study Instrument

This study utilized the BCTST--An adaptation of the CCTST for Employers and Business Educators and Professionals produced by Insight Assessment, a division of the California Academic Press located in Millbrae, California. Currently, Insight Assessment is producing validated tests for: critical thinking skills, business critical thinking skills, health sciences reasoning, legal studies reasoning, critical thinking dispositions, quantitative reasoning for math and science, business leadership, business reasoning test, business attribute inventory, critical thinking inventory, everyday reasoning, mental motivation, and military critical thinking. The BCTST reports five Subscales (Figure 10) each time a participant completes the test (a) Inductive Reasoning, (b) Deductive Reasoning, (c) Analysis, (d) Inference, and (e) Evaluation (Insight Assessment, 2010).

BCTST Subscales

Inductive Reasoning: The ability to infer that evidences shown and/or arguments given are based on conclusions and premises that include probabilistic relationships comprises this score. Confirmation and disconfirmation based on statistical, and other scientific methods, are examples of inductive reasoning that seeks to find what is most likely (or unlikely) to occur.

BCTST SUBSCALES

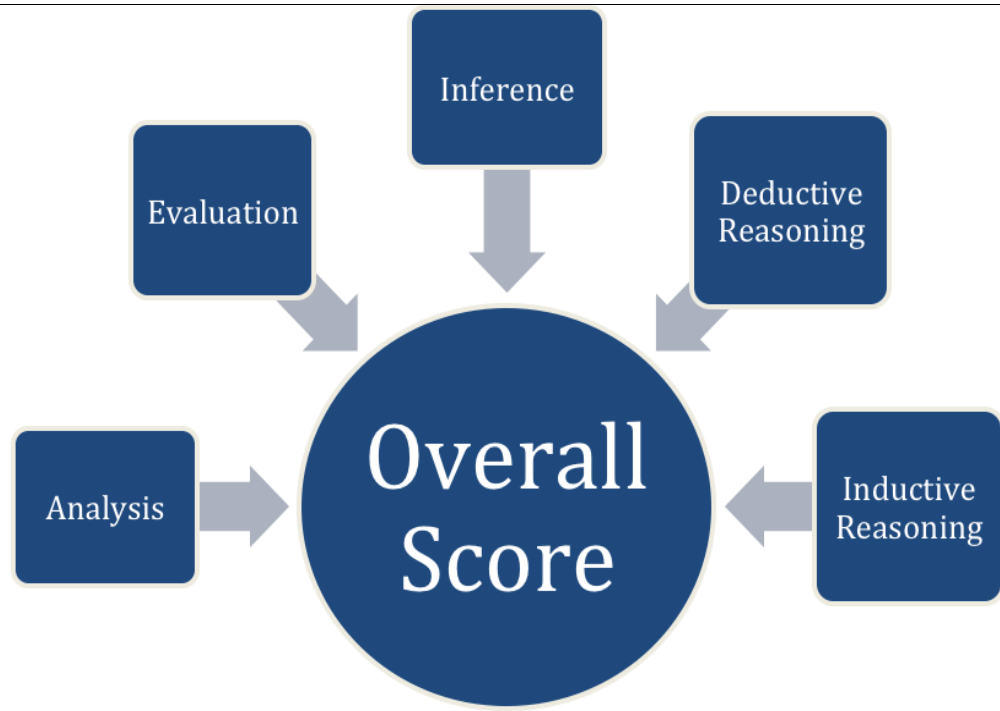


Figure 10: BCTST Subscales contributing to single Overall score.

Deductive Reasoning: This score shows strength in the test taker's ability to understand when conceptual, linguistic, and grammatical content presenting assumed premises have a relationship that necessitates the truth of a particular conclusion. Theoretical and algebraic/geometric proofs in mathematics, specific generalizations, traditional syllogisms, demonstrate these needed relationships which move understanding from assumed truth based on belief to conclusions that cannot be false if what is believed is actually tested and true.

Analysis: The ability to express and understand meanings and significances within a wide variety of exposures to data, judgments, events, situations, rules, procedures, criteria and belief make the core of this score. Strong interpretation and analytical skills show a keen level of insight toward patterns and how elements interact.

Inference: The ability to form hypotheses and conjectures, determine consequences from data, statements, opinions, representations, and evidence, and to keenly consider relevant information leading to conclusions comprise this score. Thoughtful suggestions, recommendations, and analyses can be achieved through high levels of inference skill.

Evaluation (s): This score describes a test taker's ability to assess claims, arguments, and descriptions of a person's opinions, experiences, and/or beliefs. Strong evaluation skills show the ability to assess logical strengths of statements along with the creditability of accounts based on perceptions.

Overall: This score shows the test taker's overall propensity and strength in the utilization of reason to reflectively make judgments regarding what to do or believe about a given situation (N. C. Facione, 2012).

The BCTST was never designed to test specific business content knowledge related to the traditional business subjects of accounting, finance, management, and marketing. The items within the BCTST were structured from relevant business settings revolving around everyday business concerns. Each item in the test provided all pertinent information required to answer the question correctly. This structure provides a good level of validity as a pretest and posttest tool for analysis (Facione, Winterhalter, Winterhalter, Facione, & Blohm, 2011). The BCTST is appropriate for assessing critical thinking strengths and weaknesses of persons entering collegiate business education programs as well as for individuals actively working in business settings for many years. The test collects the following demographic data about each test taker as shown in Appendix A: name, date, identification number, group number, ethnicity, gender, and education level. Names were left blank on the CAPSCORE form. Each student was assigned a unique identification number that left their name confidential to the author. The cooperating faculty member checked names against a database of identification number to ensure that each student took the test. The course instructor, however, did not see individual names with test scores.

BCTST Score Validity

The validity of scores on the BCTST is derived from the results of the APA Delphi report which provides a consensus definition for CT (Insight Assessment, 2011). There is bias against multiple choice-item or closed-framed tests as valid and reliable methods for capturing evidence of competency in skillsets like critical thinking. Measurement science, however, provides clear a clear counterpoint to this bias by providing evidence that cognitive skills and higher-order thinking skills, like critical thinking, can in fact be measured through well-crafted multiple choice examinations (Haldyna, 1994). Validity for scores from the BCTST is divided into three distinct sections (a) Content Validity, (b) Construct Validity, and (c) Criterion Validity. Each of these types of validity is described as follows:

Content Validity

Content validity is related to the ability of a standardized test to measure an intended domain. Proper isolation of the correct domain (through agreement of a group of experts) is essential to obtaining content validity. The work of the Delphi research study (P.A. Facione, 1990) to both define the domain of critical thinking, and to provide a framework for reasonable and proper methods of test construction ensures an adequate sample of the domain of critical thinking, because each item on the BCTST covers the cognitive skills identified by the Delphi experts as interpretation, analysis, evaluation, explanation, and inference. Content validity of the BCTST is also supported by the frequent use of the BCTST by human resource professionals and collegiate business faculty (and their supporting departments) for the purpose of employee placement and screening, and new undergraduate and graduate student admissions placement at their respective institutions. Adoption of the BCTST for numerous research projects, peer-reviewed article publications, dissertations, and national and internationally accepted books focused on critical thinking and higher-order thinking skills provides continued support for the content validity of the test (N. C. Facione et al., 2011).

Construct Validity

Construct validity refers to the ability of a test to measure what it is targeted to measure. In the case of the BCTST, construct validity refers to the ability of the test to measure what the Delphi group has conceptualized as the definition of critical thinking. Bias toward social class, gender, and age have all been avoided during the development of the test. Equal numbers of males and females (students and practicing professionals) have been pretested in variety of different samples to assess test-taker appeal, prior experience with the instrument and ultimate performance. The Delphi participants, and writers of texts related to performance measurement, agree that well-crafted multiple choice format exams can validly and reliably measure CT and other higher-order cognitive skills (Facione et al., 2011).

Insight Assessment and the California Academic Press report,

> Forms of the CCTST have demonstrated strong correlations with other instruments that purport to include a measure of critical thinking or higher-order reasoning as a component of their scores or ratings. High correlations with standardized tests of college-level preparedness in higher-order reasoning have been demonstrated (GRE Total Score: Pearson $r = .719$, $p<.001$; GRE Analytic $r = .708$, $p<.001$; GRE Verbal $r = .716$, $p<.001$; GRE Quantitative, $r = .582$, $p<.001$). A number of these relationships were reported in a large multi-site research study involving 50 programs of health science education assessing students' critical thinking. (N. C. Facione, 2012, p. 45)

New clients who wish to use the BCTST have the ability for individual consultations with Insight Assessment administrative staff as part of the test package in the initial design phase. When test takers encounter the BCTST, they are required to formulate judgments based on short business scenarios presented in a question stem. Test taker performance gains after taking the BCTST are to be expected when specific CT educational training interventions are administered after a pretest has been given. Well-designed and well-executed interventions on motivated test takers will show posttest increases in scores. Two studies have validated this construct for the test instrument family used in this study.

The first study involved an analysis of undergraduate students completing a semester-long class specifically focused on CT skills. The control group for the study was an equivalent sample class of undergraduates who had not completed such a course in CT. The two groups were used to validate the BCTST family of tests. N. C. Facione (2012) reports:

> Critical thinking courses in this study had been approved as such by a university committee overseeing the critical thinking educational requirement. This research, which employed a treatment and control group design, used both the crosssectional and the matched-pairs pretest-posttest measures. Significant gains were seen in both the cross-sectional ($t=2.44$, one-tailed $p < .008$) and matched-pairs analysis ($t = 6.60$, $df = 231$, $p <.001$). The average student in the paired sample moved from the 55^{th} percentile to the 70^{th} percentile (posttest percentiles based on the pretest group). The control groups (no specified critical thinking educational intervention) in both the cross-sectional and the matched-pairs experiments showed no significant gains. (pp. 45-46)

A second study (N. C. Facione & Facione, 1997) aggregated data from both undergraduate and graduate programs which demonstrated performance gains after completion of the focused programs. This study collected data from 50 different programs consisting of 145 different student sample groups (n=7,926 cases). Data collected from 1992 to 1997 showed statistically significant relationships between the BCTST parent test, the CCTST, two different measures of CT, GPA, and standardized test scores. Age, GPA and accumulation of college credits, however, were not statistically significant predictors of CT skill at the time.

Oral administration of the test family used in this study has shown that test takers in posttest can recall some of the items of the question stems, but must work through and re-reason correct responses in just two weeks after a pretest has been administered. Test takers in college and professional work settings described the BCTST as a difficult and engaging test (N. C. Facione, 2012). A brief selection of independent research using the BCTST family of tests appears in Appendix H.

Criterion Validity

Criterion validity refers to the ability of a test to predict external behavior that is not part of the test itself. Criterion validity can be considered to be the most important aspect of validity in a test, because test administrators are very interested in the predictive nature of tests like the BCTST to anticipate which professionals could pass a professional licensing exam, for example. The BCTST, as a part of the CCTST family, is 15 years younger than the CCTST itself. The CCTST test family has already shown strong correlation with other popular standardized tests (shown in Table 1) that also purport to assess CT from test takers (N. C. Facione et al., 2011).

BCTST Reliability

Reliable measurement instruments produce stable and consistent measurements from the same group of study participants under the same conditions (Gravetter & Wallnau, 2008). The BCTST contains dichotomous measures of CT skill. For this reason, the Kuder-Richardson Formula 20 was used to assess reliability (Kuder & Richardson,1937). The BCTST test achieves KR-20 internal consistency estimates ranging from .78-82 for the Overall measure, and .55 to .77 for the subscale measures. Factor loadings for items in each of the five subscale measures are ranged between .300 to .770 (N. C. Facione et al., 2011). Nunnally and Bernstein (1994) recommend that testing instruments achieve a KR-20 score above .69 if they are used in research studies bearing no determination on the immediate fate of individual test takers.

Table 1

CCTST Correlations with Other Measures

Variable	r	N	Group	p-value
GRE Total	.719	143	A	<.001
GRE Analytic	.708	143	A	<.001
GRE Verbal	.716	143	A	<.001
GRE Quantitative	.582	143	A	<.001
ACT	.402	446	B	<.001
SAT Verbal	.545	123	B	<.001
SAT Verbal	.55	333	C	<.001
SAT Math	.422	123	B	<.001
SAT Math	.44	333	C	<.001
College GPA	.20	473	C	<.001
Nelson-Denny	.49	42	C	<.001
Age	-.006	479	C	.449
Credits Earned	.03	473	C	.262

Notes: A= Entry Master's degree students, B= Entry level undergraduate students, C= 4 year college freshmen. Adapted from the BCTST Manual.

Restatement of the Research Questions

A review of the literature related to CT and multimedia effects in higher education was the genesis of the identification of the problem statement leading to the development of the research questions. Given what has been explored above, the following research questions emerge:

1. Does the use of multimedia versus text-based information sources in a higher education classroom affect student CT outcomes?
2. Do the demographic characteristics of gender, ethnicity, or education level moderate the effect of multimedia on CT outcomes?

Null Hypotheses

There were two distinct null hypotheses matching the research questions for this study.

1. There will be no differences between students enrolled in the comparison (Fall 2012) and treatment (Spring 2013) groups on each of the CT outcomes.
2. No demographic characteristics will moderate the effects of the treatment on CT scores.

Data Collection and Analysis

Data for the BCTST was collected via paper scoring sheets. The researcher chose this method of collection, partially because it required the least disruption to the existing scheduling, physical location, and original design of the course. The course research settings used for this study were traditional classrooms with unwired desks for students along with one computer used for instructor projection only. Numerous studies have shown high equivalency between paper-and-pencil quantitative assessments compared against online equivalents (Buchanan et al., 2005). Having numerous years of experience (graduate and undergraduate levels), the researcher determined, however, that participation in the research study not bearing on participants' grades combined with possible distractions brought by internet access accompanying all research setting campus computers would result in higher incidents of test taker apathy delivering thoughtless responses. For this reason, computerized testing methods were not selected for this study. Students were provided with all BCTST materials (test booklet with questions, CAPSCORE form, and a #2 pencil) in physical paper format.

Backup scans of all CAPSCORE forms were saved by the author of this study before sending originals directly to Insight Assessment via certified mail. Rudimentary results reports from the BCTST were sent back to the author. Each report presented means and ranges for the pre and posttests, individual results on the sub-scales (Induction, Deduction, Analysis, Inference and Evaluation), an Overall score, and then percentile rankings. Histograms were also generated by Insight Assessment and sent to the author. The raw data were entered into SPSS by the author for statistical analysis to determine the effects of the independent variables (the text-only class and the multimedia-only class) on the dependent variables.

Summary

This study included undergraduate business students at a small, Midwestern university to investigate the effect on CT skills impacted by multimedia information resources, and to find possible demographic moderators involved with CT skills outcomes. The students were the only participants in the study taking a 35-item multiple choice test (pretest/posttest design) within two sections of the same higher-level business course in an attempt to reveal the impact of multimedia on CT skills outcomes. A general description of the classroom environment, information materials used in the comparison and treatment groups, the BCTST tool and complete administration of the study was presented. The basis for the theoretical model and study design was influenced by P. A. Facione (1990), Halpern (2003), Kumta et al. (2003), and Gerjets et al. (2008). The next chapter will provide discussion on the findings of the study.

CHAPTER 4

DATA ANALYSIS AND RESULTS

Introduction

The purpose of this quasi-experimental, pretest/post design study was to investigate the potential impact of multimedia learning resources compared to equivalent text-based resources on CT outcomes. This chapter describes the results of the analyses for the dependent variables overall and five subscales. Data were analyzed using SPSS.

Sample Description

The subjects for this study were 43 students attending two consecutive semesters (Fall 2012 and Spring 2013) of a face-to-face finance course at a small, Midwestern university. Twenty-two of the subjects (Group 1) came from the Fall 2012 course. Twenty-one of the subjects (Group 2) came from the Spring 2013 course. The students in both sections were administered the Business Critical Thinking Skills Test (BCTST) in a pretest/posttest design at weeks 1 and 15 during a 16-week semester. Information on gender, ethnicity, and education level were also collected (Table 2).

Table 2

Demographic Detail of Study Sample Participants

		Comparison Group		Treatment Group	
		Frequency	Percent	Frequency	Percent
Gender					
	Male	13	59.1%	15	71.5%
	Female	9	40.9%	6	28.5%
Ethnicity					
	Anglo	12	54.6%	14	66.7%
	Non-Anglo	10	45.4%	7	33.3%
Education Level					
	Upperclass	17	77.3%	17	80.9%
	Lowerclass	5	22.7%	4	19.1%

The treatment between weeks 1 and 15 was the use of a textbook by the control course participants (Fall 2012), and multimedia content in place of this same textbook content for the treatment group (Spring 2013). Neither of the groups used both information source types (text and multimedia) at any time throughout the study period. CT scores on the BCTST were gathered in six areas: Overall Score, Induction, Deduction, Analysis, Inference, and Evaluation.

Statistical Analysis

Repeated measures analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) were was conducted to evaluate data collected in this study (Becker, 1999; Howell, 2009; Mertler & Vannatta, 2010). Repeated measures ANOVA was performed on the Overall score to test for differences in CT outcomes for the between-subjects factor (group: text and multimedia) and the within-subjects factor (time: pretest and posttest). MANOVA (Tabachnick & Fidell, 2006) was used to simultaneously assess differences on the subscales (analysis, inference, evaluation, induction and deduction) by treatment group as well as by demographic factors (gender, ethnicity, and education level). An alpha level of .05 was set for testing hypotheses significant differences for all tests, except for univariate ANOVA tests following MANOVA, for which a Bonferroni-corrected alpha level of .02 was specified to limit the overall familywise error rate to alpha = .10. Bonferroni correction is appropriate for tests of multiple hypotheses to control the familywise error-rate (Simes, 1986; Hochberg, 1988); it was applied in this case to the univariate tests only as a conservative comparison given the small number of hypotheses in the overall study. There were no extreme outliers found in the tests scores of both groups. Score distributions in both the pretest and posttest groups were normal. Statistical analyses were conducted using SPSS 20 and 21 for Windows.

Research Questions/Hypotheses and Results

The following research questions are addressed in this study:

Question (1): Does the use of multimedia versus text-based information sources in a higher education classroom affect student CT outcomes?

H_0 (1): There will be no differences between students enrolled in the comparison (Fall 2012) and treatment (Spring 2013) groups on the Overall score and on the Subscale scores.

H_a (1): There will be differences between students enrolled in the comparison (Fall 2012) and treatment (Spring 2013) groups on the Overall score and on the Subscale scores.

The present study (using the BCTST administered to traditional-aged undergraduate students at a small, Midwestern university) sought to determine whether there was a change in the scores of five different Subscales of the BCTST (induction, deduction, analysis, inference, evaluation), and the Overall score resulting from a treatment of multimedia information in place of the traditional text-based information source for the same class. This study employed the use of a repeated measures analysis of variance (ANOVA), and multivariate analysis of variance (MANOVA). MANOVA statistically compensates for multiple comparisons of multiple dependent variables providing a single result whether the groups under investigation are statistically different (Field, 2009; Garson, 2003; O'Brien & Kaiser, 1985; Tabachnick & Fidell, 2006). Cronk (2010) adds that when using repeated measures ANOVA, the basic ANOVA procedure is extended to within-subjects variables when sample participants provide data for more than one level of any particular independent variable.

Assumptions for repeated measures ANOVA were reviewed in the following manner: First, homogeneity of variance was assessed using Levene's test and Box's M test. Levene's (1960) test showed variance homogeneity for all dependent variables ($p > .05$) for pretest and posttest Overall and Subscales of the BCTST (Tables 3 and 4).

Table 3

Levene's Test for the Equality of Variances—Overall BCTST Score

	F	df1	df2	Sig.
Pretest Overall Score	.441	1	41	.978
Posttest Overall Score	.148	1	41	.461

Box's *M* test was carried out on the Overall CT outcome score. Box's *M* was not significant (p = .624) in any case showing variance-covariance homogeneity between groups. Following assumption checks, repeated measures ANOVA was carried out to ascertain group differences in the change between pretest and posttest for the Overall score, and MANOVA was used to ascertain group differences on all five Subscales (induction, deduction, analysis, inference and evaluation) on the BCTST. The between-subjects factor of group ("text" and "multimedia"), and within-subjects factor of time ("pretest" and "posttest") were identified in this analysis making this research a mixed factorial design analysis (Hall, 1998).

Table 5 shows the descriptive statistics for the four Overall BCTST scores by group. Table 6 shows the descriptive statistics for the five Subscale scores by group. The mean differences between the Overall pretest and posttest scores for the text and multimedia groups were 0.68 and -2.71, respectively. At the sample level, the text group scored higher mean Overall scores while the multimedia group scored lower. Mean score differences between pretest and posttest Subscale scores are listed in Table 7. At the sample level, multimedia mean scores are lower for all five Subscales. Text mean scores are lower in one Subscale only: Analysis.

Table 4

Levene's Test for the Equality of Variances—Five BCTST Subscales

	F	df1	df2	Sig.
Pretest Induction Score	2.204	1	41	.145
Posttest Induction Score	1.748	1	41	.193
Pretest Deduction Score	.135	1	41	.716
Posttest Deduction Score	1.248	1	41	.270
Pretest Analysis Score	.108	1	41	.745
Posttest Analysis Score	.006	1	41	.941
Pretest Inference Score	.009	1	41	.925
Posttest Inference Score	.189	1	41	.666
Pretest Evaluation Score	1.840	1	41	.182
Posttest Evaluation Score	.373	1	41	.545

Table 5

Descriptive Statistics for Overall BCTST Score (n = 43)

	Treatment	Mean	Std. Deviation	N
Pretest Overall Score	Text	19.18	5.086	22
	Multimedia	18.38	4.706	21
	Total	18.79	4.863	43
Posttest Overall Score	Text	19.86	6.089	22
	Multimedia	15.67	5.023	21
	Total	17.81	5.921	43

Table 6

Descriptive Statistics for Five BCTST Subscales (n = 43)

	Treatment	Mean	Std. Deviation	N
Pretest Induction Score	Text	12.32	2.398	22
	Multimedia	11.57	2.925	21
	Total	11.95	2.663	43
Posttest Induction Score	Text	12.32	3.123	22
	Multimedia	9.62	3.457	21
	Total	11.00	3.525	43
Pretest Deduction Score	Text	6.86	3.357	22
	Multimedia	6.81	2.874	21
	Total	6.84	3.093	43
Posttest Deduction Score	Text	7.55	3.582	22
	Multimedia	6.05	2.312	21
	Total	6.81	3.088	43
Pretest Analysis Score	Text	7.18	2.039	22
	Multimedia	6.71	1.793	21
	Total	6.95	1.914	43
Posttest Analysis Score	Text	6.36	2.105	22
	Multimedia	5.76	2.119	21
	Total	6.07	2.109	43
Pretest Inference Score	Text	7.18	2.922	22
	Multimedia	6.71	2.390	21
	Total	6.95	2.654	43
Posttest Inference Score	Text	8.14	3.137	22
	Multimedia	6.05	2.617	21
	Total	7.12	3.049	43
Pretest Evaluation Score	Text	4.82	1.563	22
	Multimedia	4.95	1.910	21
	Total	4.88	1.721	43
Posttest Evaluation Score	Text	5.36	2.194	22
	Multimedia	3.86	1.957	21
	Total	4.63	2.193	43

Table 7

Univariate Within-Subjects Effects for Overall Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	22.192	1	22.192	2.489	.122
time * Treatment	61.959	1	61.959	6.950	.012
Error(time)	365.529	41	8.915		

The results of the repeated measures ANOVA for the Overall score are shown in Table 7 and indicate a statistically significant group difference in the change in scores; $F(1, 41) = 6.95$, $p = .012$. The effect size for the treatment on the Overall outcome was $\eta^2 = .14$. This is a large effect per Cohen's guidelines (Becker, 1999). Figure 11 shows a plot of means for the Overall outcome by treatment.

Results from the MANOVA (Table 8) considering all five BCTST subscales simultaneously showed an overall effect of the treatment (Wilks' $\Lambda = .75$, $F(4, 38) = 3.12$, $p = .026$). The effect size for the treatment on the five BCTST subscales was $\eta^2 = .14$. Using the Bonferroni-corrected alpha level, univariate analysis (Table 9) of each subscale showed statistically significant group differences on two of the five subscales (Induction and Evaluation). Specific test statistics were: Induction $F(4, 38) = 6.48$, $p = .015$, $\eta^2 = .12$; Deduction $F(4, 38) = 2.81$, $p = .101$, $\eta^2 = .06$; Inference $F(4, 38) = 5.13$, $p = .029$, $\eta^2 = .11$; Analysis $F(4, 38) = .05$, $p = .818$, $\eta^2 = .06$; Evaluation $F(4, 38) = 6.07$, $p = .018$, $\eta^2 = .12$.

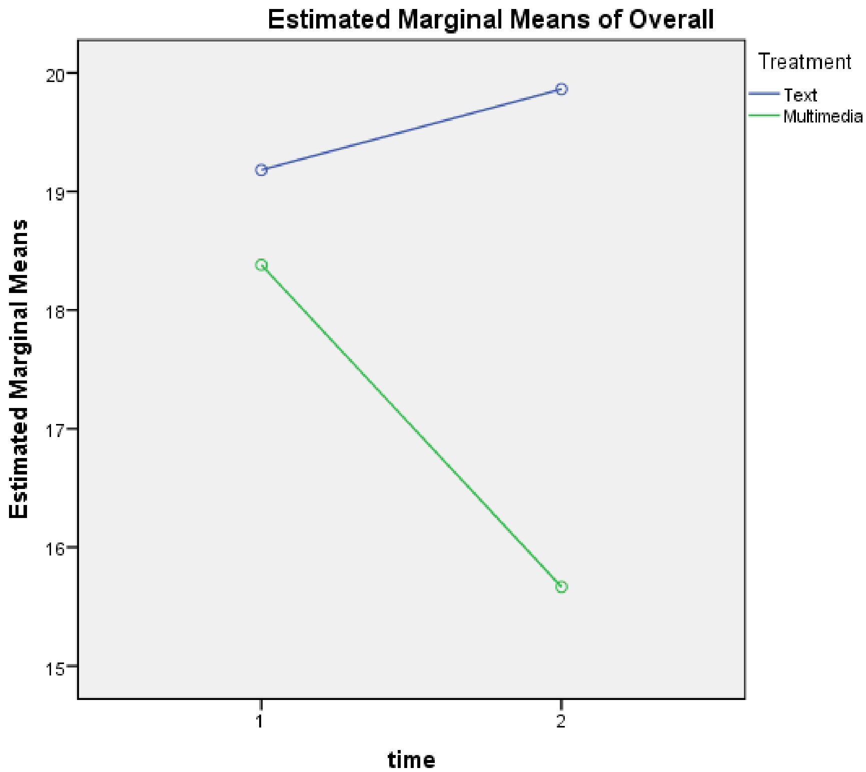


Figure 11: Plot of means for Overall Score of Text and Multimedia Groups.

For the two outcomes of Induction and Evaluation, the treatment showed large effect sizes using Cohen's (1988) guidelines (.01 = small; .06 = medium; .14 = large). Figures 12 and 13 show a plot of means for the significantly affected subscale outcomes of Induction and Evaluation. As can be seen in these figures, the scores for the text condition maintained or increased over time, while the scores for the multimedia group decreased.

Table 8

Multivariate Within-Subjects Effects for the Five BCTST Subscales

		Value	F	Hypothesis df	Error df	Sig.
Time	Wilks' Lambda	.748	3.201[a]	4.000	38.000	.023
time * Treatment	Wilks' Lambda	.753	3.121[a]	4.000	38.000	.026

Table 9

Univariate Within-Subjects Effects of Treatment on the Five BCTST Subscales

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Induction	20.477	1	20.477	6.484	.015
	Deduction	.034	1	.034	.009	.926
	Analysis	16.841	1	16.841	9.317	.004
	Inference	.445	1	.445	.162	.690
	Evaluation	1.624	1	1.624	.682	.414
time * Treatment	Induction	20.477	1	20.477	6.484	.015
	Deduction	11.197	1	11.197	2.811	.101
	Analysis	.097	1	.097	.054	.818
	Inference	14.120	1	14.120	5.132	.029
	Evaluation	14.461	1	14.461	6.073	.018
Error(time)	Induction	129.476	41	3.158		
	Deduction	163.291	41	3.983		
	Analysis	74.113	41	1.808		
	Inference	112.811	41	2.751		
	Evaluation	97.632	41	2.381		

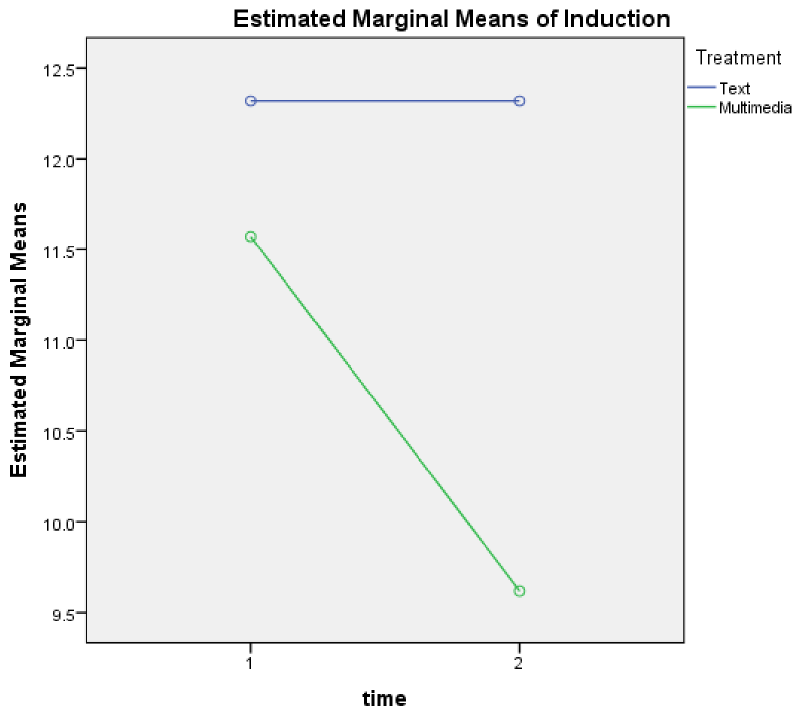


Figure 12: Plot of means for Induction BCTST Subscale outcome of Text and Multimedia Groups.

In summary, the analyses show that a treatment of multimedia versus text had a statistically significant effect of the treatment on the Overall score, as well as on two out of five Subscales (Induction and Evaluation). Ultimately, because a statistically significant effect of the treatment on the CT outcomes were found, the null hypothesis H_0 (1) for research question one was rejected.

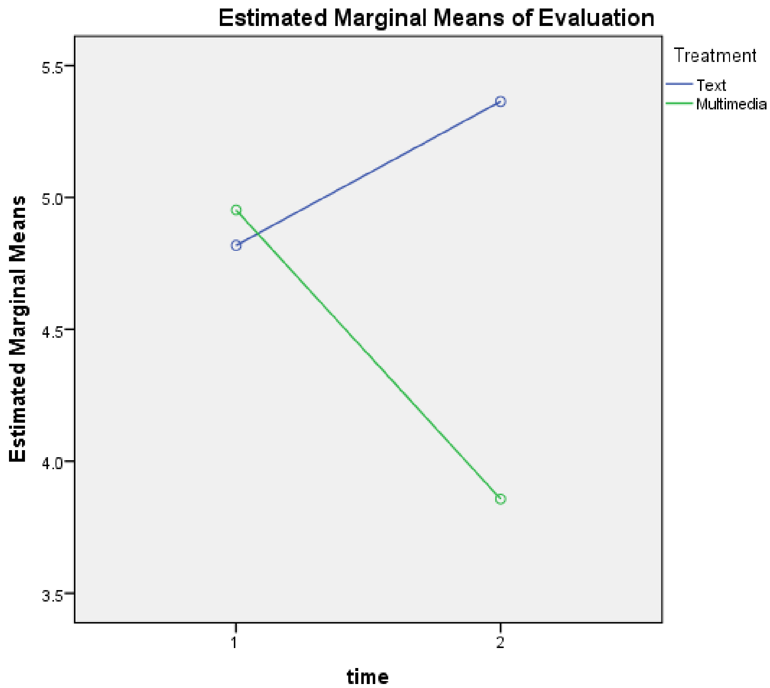


Figure 13: Plot of means for Evaluation BCTST Subscale outcome of Text and Multimedia Groups.

Question (2): Do the demographic characteristics of gender, ethnicity, or education level moderate the effect of multimedia on CT outcomes?

H_0 (2): No demographic characteristics will moderate the effects of the treatment on CT scores.

H_a (2): One or more demographic characteristics will moderate the effects of the treatment on CT scores.

With research question 1, the primary focus was to determine whether mean differences in BCTST Overall and Subscales were evident as a result of an intervention involving replacing multimedia for text as the primary resource for a college business course. Research question 2 extends the investigation of research question 1 by examining if the effect of the treatment on the dependent variables (BCTST Overall and the five Subscales) were was moderated by specific demographic characteristics (gender, ethnicity, and education level).

Figure 14 shows mean values for Overall scores by each of the demographic characteristics (gender, ethnicity and education level). Box's *M* was not significant (p = .559) indicating equality of covariance matrices.

A repeated-measures ANOVA (Table 10) using the Overall scores (pretest and posttest) Showed no significant main effects for gender $F(4, 32) = 0.16$, $p = .692$; ethnicity $F(4, 32) = .693$, $p = .411$; education level $F(4, 32) = .264$, $p = .611$.

Similarly, results from the MANOVA (Table 11) showed no significant moderating effects of the demographic variables on the effect of the treatment on the five BCTST subscales. Specific test statistics were Wilks' $\Lambda = .98$, $F(4, 32) = 0.14$, $p = .965$ (gender); Wilks' $\Lambda = .83$, $F(4, 32) = 1.54$ $p = .212$ (ethnicity); Wilks' $\Lambda = .98$, $F(4, 32) = 0.10$, $p = .982$ (educational level). With no statistically significant interactions found between select demographic characteristics and any CT outcomes, the null hypothesis H_0 (2) is not rejected.

Summary

The current study examined two research questions:

1. Does the use of multimedia versus text-based information sources in a higher education classroom affect student CT outcomes?
2. Do the demographic characteristics of gender, ethnicity, or education level moderate the effect of multimedia on CT outcomes?

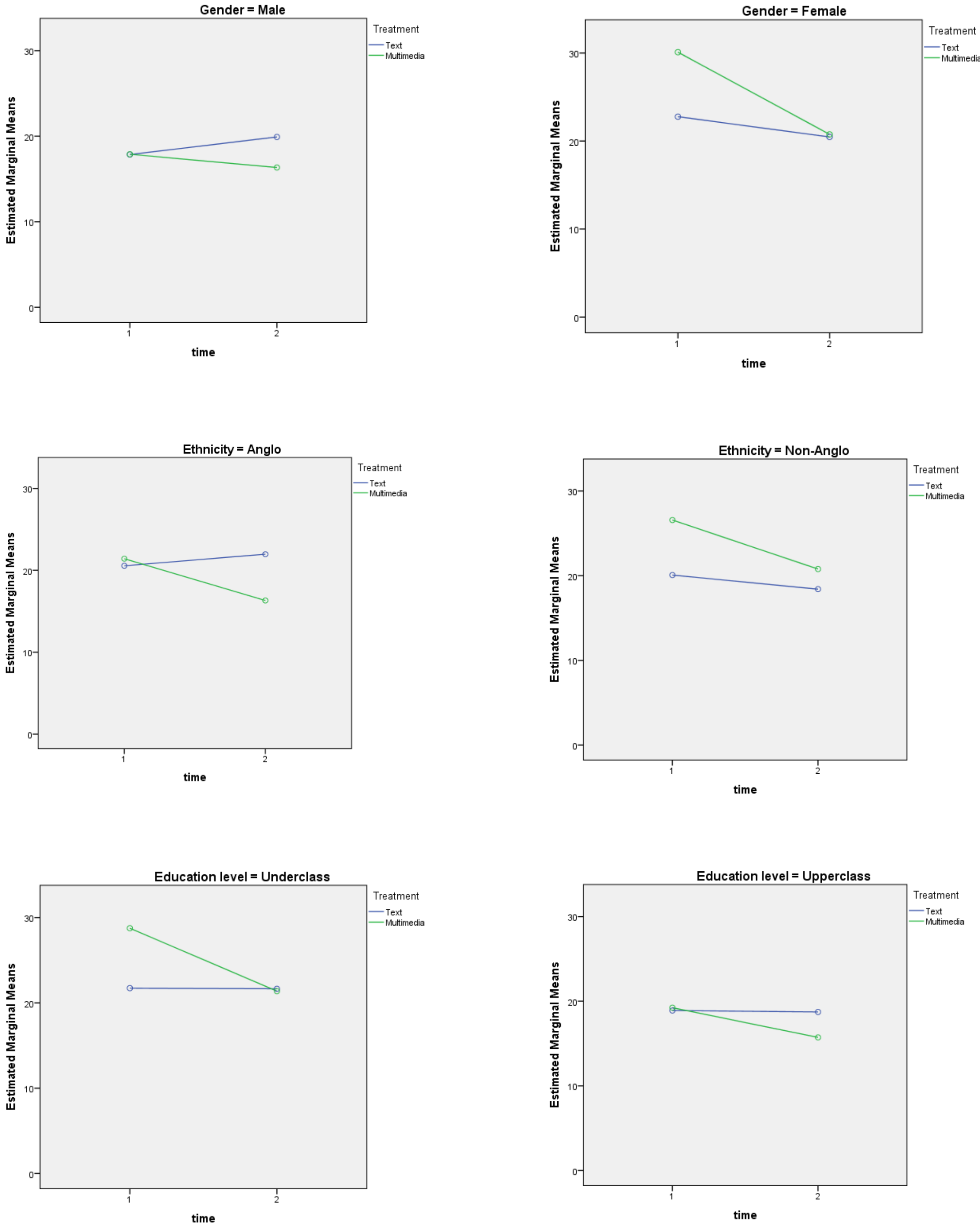


Figure 14: Plot of means for Overall BCTST scores by gender, ethnicity and education level.

Table 10

Univariate Within-Subjects Effects for Overall Score by Gender, Ethnicity and Education Level

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
time	2.460	1	2.460	.269	.607
time * Treatment	29.452	1	29.452	3.219	.081
time * EthnicCode	.220	1	.220	.024	.878
time * GenderCODE	6.439	1	6.439	.704	.407
time * EdLevelCODE	16.545	1	16.545	1.808	.187
time * Treatment * EthnicCode	6.338	1	6.338	.693	.411
time * Treatment * GenderCODE	1.463	1	1.463	.160	.692
time * Treatment * EdLevelCODE	2.413	1	2.413	.264	.611
Error(time)	320.212	35	9.149		

The study's results are mixed. There is some evidence against the null hypotheses for research question 1. There are two subscales (Induction and Evaluation) of CT affected by the use of multimedia in place of text. Screening for multivariate normality involved examining boxplots and normal Q-Q plots (Appendix I, Figures 15-50) all reflecting normality. Mean plots corresponding to each univariate outcome are provided in Appendix I (Figures 51-55).

Table 11

Multivariate Within-Subjects Effects for Demographic Variables on the Five BCTST Subscales

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
time	Wilks' Lambda	.922	.677[c]	4.000	32.000	.613
time * Treatment	Wilks' Lambda	.836	1.566[c]	4.000	32.000	.207
time * EthnicCode	Wilks' Lambda	.969	.257[c]	4.000	32.000	.903
time * GenderCODE	Wilks' Lambda	.968	.265[c]	4.000	32.000	.898
time * EdLevelCODE	Wilks' Lambda	.884	1.049[c]	4.000	32.000	.397
time * Treatment * EthnicCode	Wilks' Lambda	.838	1.548[c]	4.000	32.000	.212
time * Treatment * GenderCODE	Wilks' Lambda	.982	.143[c]	4.000	32.000	.965
time * Treatment * EdLevelCODE	Wilks' Lambda	.988	.100[c]	4.000	32.000	.982

Repeated measures ANOVA and MANOVA showed a statistically significant change in the Overall and two of the five Subscales (Induction and Evaluation) due to the treatment. Specifically, scores for multimedia group decreased, while scores for the text group were maintained or increased. Large effect sizes were observed for all statistically significant effects. Research question 2 extended analysis into the effect of multimedia on CT outcomes by exploring if selected demographic characteristics (gender, ethnicity, and education level) moderated any effects on CT outcomes. Repeated measures ANOVA and MANOVA showed no statistically significant moderating effects of the demographic characteristics on treatment effect for each of the CT outcomes.

Chapter 5 will provide discussion and conclusions regarding research findings presented in Chapter 4 in light of previous research into the effect of multimedia on CT outcomes. An explanation of the implications of this research study related to future adoption of multimedia resources in place of text will also be conducted. Specific and general recommendations for future research will be given for those who wish to either: a) replace text-based resources with multimedia equivalents, or b) pursue the investigation of what CT outcomes can be expected as text becomes less and less appealing to both instructors and students as a learning resource in favor of equivalent multimedia.

CHAPTER 5

DISCUSSION

This chapter provides a review of the concluding results of the previous chapter and discusses the effects of multimedia on CT outcomes. Following this review, implications, study limitations and overall general recommendations are made for future research.

Overview

The purpose of this quasi-experimental, pretest/post design study was to investigate the potential impact of multimedia learning resources compared to equivalent text-based resources on CT outcomes. Furthermore, in addition to an analysis CT performance outcomes, select demographic characteristics (viz., gender, ethnicity, and education level) of the study participants were also explored as potential moderating factors. The goal of the research was to add to the current body of literature that seeks to investigate how CT outcomes are potentially impacted by multimedia. The framework for this study came from Halpern (1998; 1999; 2003) and P. A. Facione's (1990), P. A. Facione & Facione's (2007) and N. C. Facione's (2012) work into the growing importance of CT skills as a learning outcome worth investigating and targeting for the future of higher education excellence, and Mayer and Moreno's work (1998a;

1998b; 2003) focusing on multimedia's effect on all aspects of cognitive load—CT being just one of the potential areas to explore for researchers and instructors.

Research Questions

There were two research questions in this study:

1. Does the use of multimedia versus text-based information sources in a higher education classroom affect student CT outcomes?
2. Do the demographic characteristics of gender, ethnicity, or education level moderate the effect of multimedia on CT outcomes?

Findings

A pretest examination was used to measure the CT outcomes of each of the two study groups before treatment was applied to one of the groups throughout the classroom experience. A posttest examination was used as a repeat measure of the CT performance of the two groups after 15 weeks of treatment (multimedia course resources in the form of moving images and audio text) for the treatment group and non-treatment (textbook) for the comparison group. The results of the pretest showed no significant difference between the two study groups before treatment commenced.

Research Question 1 concerned the effect of the treatment of multimedia on the outcomes of Overall and five subscales. Analysis confirmed that multimedia was a statistically significant negative factor affecting the educational outcomes of Overall and the specific subscales of Induction and Evaluation. As in the results of Barlett and Strough (2003), and Chuang and Ku (2011), students at all demographic analytical points in this author's study improved their educational outcomes through the use of text-based materials versus multimedia. Unlike the results of Cavalier and Weber (2002), and Kingsley and Boone's (2008) large-scale multi-institutional study, multimedia was not a statistically significant cause for increased cognitive function in study participants at any level. Also, unlike the studies of Redsell et al. (2003), Starbek et al. (2010), and Kayaoglu et al. (2011), there was a significant lowering in CT understanding due to multimedia being substituted for equivalent text, as this author's study participants did not have the advantage of using both text and multimedia at the same time. Each of Redsell et al. (2003), Starbeck et al. (2010), and Kayaoglu et al.'s (2011) studies recommended a combination, in fact, of both information resource types as the best way to increase educational outcomes. Overall, the results in this study showed a statistically significant negative impact on CT outcomes for treatment group, with a high magnitude.

Research Question 2 in this study explored the potential moderating effects of selected demographic characteristics (gender, ethnicity, and education level) on the treatment's impact on CT. Analysis confirmed that all selected demographic characteristics had no statistical moderating effect on any of the explored CT outcomes. Studies from Hegarty and Just (1993), Barron and Atkins (1994), Mousavi et al. (1995), Gunawardena, Lowe, and Anderson (1997), Jonassen et al. (1998), Stoney and Oliver (1999), Kalyuga (2000), Beccue et al. (2001), Kalyuga, Chandler and Sweller (2001), Thomas et al. (2001), Bartlett and Strough (2003), Redsell et al. (2003), Kalyuga (2002), Passerini (2007), Gerjets et al. (2008), Sullivan-Mann et al. (2009), Teoh and Neo (2007), Rinck (2008), Sun et al. (2008), and Bagarukayo et al. (2012) explored one or more demographic aspects as modifying factors on cognitive educational outcomes influenced by one or more forms of multimedia information resources. These studies' findings, however, were inconsistent from one to the next. This necessitated the need to add a research component including demographic characteristics to the body of knowledge investigating CT outcomes impacted by multimedia.

Discussion

Multimedia resources offer learning convenience and flexibility (Hu, 2011; Hurdle, 2011). The potential for this resource type is only beginning to take shape, as the world is increasingly able to connect to the internet at faster and faster speeds. Immediate access allows the uploading and downloading of multimedia instructional content from many diffuse sources at various price points on mobile and fixed devices. Multimedia can provide learners with new strategies and methods for knowledge acquisition. Multimedia also provides new ideas for, and about, learning--as well as challenges. Does this, then, mean multimedia is the new "king" of information resources for learning for the next century? The fact that the author of this study encountered little to no resistance (from involved faculty and administration) to completely removing a regularly required printed information resource from an entire 16-week college course should both warrant caution in instructional design management, and serve as a contribution towards potential new theories related to competing media types. Before the advent of the printed word, no media competition existed. Then, the book began to compete with live audio and visuals—human oral communication tradition. Next, radio and television entered the media sphere to compete with books and journals. Now multimedia, as a combination of all previous media information sources, enters the human experience and is seen as a potentially superior replacement for all information communications methods of the past. Multimedia, as a media type, is winning the competition for attention and consumption. For example, video games, providing the ultimate in multimedia experience to date, are outpacing the development and sales budgets of even the largest of blockbuster Hollywood films (Baer, 2005; Villapaz, 2013). Some single video games sell more individual copies than the sales of entire global music industry combined (Bleeker, 2013). Books, and other printed-word information sources, pale in comparison when considering their ability to compete with other media types.

Multimedia everywhere may be becoming a fact of life for the future. Differing media types competing for the attention of education and entertainment seekers alike is the new landscape reality. The effects of multimedia, therefore, on the highly popular and often-thought essential learning outcome of CT was explored in this study to continue to expand educators' considerations of what information sources they ought to use to teach their students in the most productive and effective way possible. Given the persistent efforts to both encourage and educate users of all types to become consumers of multimedia instructional content in contrast to the traditional efforts to encourage the reading of text as the primary means of transmitting knowledge and information, the results of this study can be used as a cautionary guide adding to the body of knowledge aimed at assessing multimedia's impact over text on CT outcomes. Strategies which enable instructors of all types to provide text alternatives to their multimedia can be designed and implemented using the results of this study, and similar studies, as a means of better achieving student success in CT. Instructors can use research like this author's study as a means of expressing the importance of reading over watching, listening and speaking in the face of a world seemingly obsessed with the continuing marginalization of all things non-multimedia. Even today, beyond education, wills and estate decrees are increasingly appearing less and less in printed form as a way of better communicating last wishes of the recently deceased (American Bar Association, 2014). Letters to friends and family are replaced with video calls and messages containing images, songs and voices combined.

The ETS Proficiency Profile (Educational Testing Service, 2010) examination selected by many institutions of higher learning as part of their Voluntary System of Accountability (Hardison et al. 2009; McPherson & Schapiro, 2008; Miller, 2008) includes CT as a major component for grading the historical product of colleges and universities—knowledge acquisition. All students enrolled across all majors of study at the research setting institution used in this author's research take the ETS Proficiency Profile during their senior year of studies. The administration of the ETS Proficiency Profile is the first and last time the participants in this study at the research setting institution encounter an examination which investigates their CT abilities. Participating in this author's research provided the participants with an additional opportunity to experience a CT exam—one that is also focused within their specific chosen field of profession. Through ex post facto correspondence with the author of this study, some of the participants expressed mixed feelings over being given a CT test as part of their course time. The students expressed a genuine sense of challenge with the BCTST material, as it was different than other tests they had previously encountered. Some wondered if their peers would approach the exercise seriously due to being ensured there was no connection between the final results on the BCTST and their final course grade. Most participants had no problem working through the test and attempting to provide correct answers to the items. All students who spoke with or emailed the author of this study expressed a high interest in reading the final results of this study. The participants expressed as equal an interest in improving their own CT as many higher education institutions do in their stated goals.

It is understood that instructional technologies, like multimedia, continue to be intimately intertwined within the future of education (K-12, higher education and corporate education/training) through the simple fact of large-scale adoption of LMS software for learning settings (Straumsheim, 2013). Couple this software expansion with the use of hardware tools like SmartBoards and iPads increasing for educational use, and the focus on education becomes clear. Mobile and interactive hardware fused with software enhanced with multimedia is going to be a continuing component of the teaching and learning mix going forward, as it is being adopted by rote without much thought beyond the advantages found in convenience, replicability, portability and transmission (Friedman, 2013; Kanaracus, 2014). It remains to be seen whether or not using these technologies for instructional and training goals is the best decision for the achievement of increased outcomes, like CT. If more research like this author's study emerges to show multimedia (or other types of instructional technology) to be a potentially negative influence on CT (or other outcomes measures), future accountability problems could increase for educational institutions which adopt multimedia in place of text. A paradox should be acknowledged throughout the American educational landscape that while on one hand higher education institutions may be able to provide increasing evidence that multimedia is negatively impacting outcomes (like CT), on the other hand K-12 is moving in a very clear direction with the mass adoption of media technologies for learning. K-12 institutions continue to replace print texts with e-books (Davis, 2013), thereby socially forcing higher education to keep up or face being viewed as out-of-touch, behind the times, and potentially irrelevant.

Limitations

The overall size of the research sample groups, the sample's quasi-random nature, and the sample's geographically close location limit the potential for the generalizability of this study's findings. Students were drawn from a pool of traditionally aged on-campus business undergraduate students from a small, Midwestern university. Studying any combination of onsite traditional students or online students may yield significantly different results. The sample used in this study is too limited to represent an overall population of learners as business is a one of the most popular fields of study for U.S. college students (National Center for Educational Statistics, 2011). A much larger sample, therefore, spanning multiple years of study might yield more generalizable results. The statistical power for the follow-up tests examining group differences in each of the CT outcomes and assuming a moderate effect size, for example, was only 50%. Although group differences were found, it is possible that additional population group differences may exist and these differences may be captured with a larger sample. While all students taking the BCTST took between 35 to 50 minutes each to complete the exam, the willingness of each participant to honestly and diligently apply their full attention to each test item is the only factor ensuring an accurate measure of cognitive ability found in this research. Some researchers may find this aspect of the research too limiting as it requires constant face-to-face observation during the entire paper-and-pencil testing process. In an effort to ensure diligence in participant effort, test-takers were not left in the classroom by themselves where distractions could affect the test-taking process. The participants, the author of this study and the cooperating faculty member were immersed together during all four rounds (2 pretest/2 posttest) of examination where study participants were encouraged to feel comfortable and secure that their confidentiality was protected throughout the course of the research (Moustakas, 1994). The convenience of computerized testing and/or online testing was not a viable option in this study design as a result, even though both aforementioned data-gathering methodologies would have allowed much faster collection and subsequent analysis processing. The need for a larger sample of participants combined with the face-to-face research methodology employed in this study, therefore, is not pragmatically possible for large sample sizes without multiple proctors present during test administration.

Additionally, the effect of using multimedia materials in place of text materials on the participants' ability to learn under the theory of Universal Design for Learning (Rose & Mayer, 2002) could have played a role during the course of the study period. While the research setting institution does encourage students to disclose their needs for learning accommodations throughout a semester, and all participants signed informed consent documents, a participant in the study could have willingly neglected to mention their need to learn via an alternative treatment, thereby potentially impacting the accuracy of the assessment of CT outcomes. Allowing participants to choose whether or not they wanted a multimedia or text information source class (treatment vs. comparison) may have allowed for different CT outcomes as well. Finally, neither the multimedia materials nor text materials used for the study have been tested for their complexity level or readability. The materials used for the course are assumed to be effective by the authority of the administration of the research setting institution, and by virtue of the instructor of the course (and author of this study's text and multimedia materials) being a department chair, full professor, and tenured faculty member at the research setting.

Recommendations for Future Research

Given that the results of this research indicate negative relationships between CT and multimedia, future studies can include replacing textbook materials with multimedia loaded on a specific device to test the educational impact of both the hardware and software change in format from textbooks. This author's study involved testing students who used desktop and laptop computers as the access point to the course multimedia. The materials (at the time) were not compatible on tablet or smartphone devices. Over time, tablet devices and smartphones may be preferred for accessing multimedia content, because of their closer similarity to the portability and convenience found in books, magazines, and other traditional print formats. Ahmet (2013) tested students using iPads to access multimedia information on mathematics in place of a textbook, finding that some aspects of math achievement improved while aspects of both the hardware and the software proved to be a great distraction for learners. David Wiley (2013) explains that Open Educational Resources (OERs), commonly including rich multimedia content, have been found to be better at increasing educational outcomes versus traditional texts. Wiley also cites an extensive research project from *Nature* comparing the quality of content from Wikipedia to peer-reviewed, for-purchase traditional text materials, viz., *Encyclopaedia Britannica* (Giles, 2005). The parity in the number of errors in like-minded content sections of the various information sources tested demonstrates the power to be found in multimedia educational resources, some of which allow free access to material commonly used by students toward their learning outcomes. Britannica responded to *Nature*'s research with a comprehensive negation of all results (Encyclopaedia Britannica, 2006). Similar to the Clark (1994) and Kozma (1994a: 1994b) debate 20 years ago, *Nature* has returned with another response, providing access to its research data and methodology and leaving room for future debate. What is undeniable is that students want open content, and will use it as proliferation increases. It is also important for researchers to accept that students will augment instructor-created (or approved) multimedia content with random content they find on their own. This may skew research efforts in the future as researchers lose less and less of a sense of which multimedia (approved or unapproved) is helping/hurting students' learning outcomes. If educational multimedia content from anywhere (and hosted everywhere) is increasingly becoming impactful toward learning objectives, further research is warranted.

Testing the CT outcomes of college students impacted by multimedia could be done in a variety of ways and in a variety of disciplines. Insight Assessment (owner of the BCTST) offers the following tests for CT and CT-related outcomes in addition to the BCTST (a) the CCTST—California Critical Thinking Skills Test used for all disciplines in all fields, (b) the HSRT—Health Sciences Reasoning Test, (c) the TER—Test of Everyday Reasoning, (d) the CCTDI—California Critical Thinking Dispositions Inventory, and (e) the Quant Q for measuring quantitative reasoning. The CCTST is the most popular of these tests, and the most well-researched. As other investigators in other disciplines realize the need to better predict CT outcomes for their learners, they can replicate aspects of this author's study for their own disciplines using the BCTST or any number of other Insight Assessment tests.

Other CT tests and assessments like Watson-Glaser, CT exams from The Foundation for Critical Thinking (2013) and the ETS Proficiency Profile itself can be introduced at any time into environments where text and multimedia compete for the positive impact on educational outcomes. It is the recommendation of the author of this study that at the very least one of these tests is administered to higher education students each year, if institutions of higher learning are genuine when they express the utmost concern for CT. These examinations bear an impact on instructional budgets, and therefore, must be properly allocated for before use. For the field of higher education to continually emphasize the importance of CT while at the same time devoting little more than lip service to the teaching and testing of skillsets required for students to perform well on standardized CT assessments appears to be a strategic misstep. Students are told, in the media and in the classroom, they have poor CT skills (Arum & Roksa, 2011; Mataconis, 2011; Rimer, 2011) and are then left to themselves to try to improve without understanding that their goal is a moving target and not fully agreed upon by diffuse faculty and administrators. Ultimately, CT skills are said to be poor for college students across the United States, but few effective suggestions on how to improve outcomes in this regard can be found.

When adding the results of this research to the extant body of knowledge on the subject, it is also suggested that consideration of the author of the multimedia and/or textual materials for any class be scrutinized, as previous studies do little to explore this dynamic. The professor of a college course may be good at lecturing, but poor at designing instructional content. This situation will bear an impact on learning outcomes. This study's design could be viewed as a more "pure" information resource environment due to the unique circumstance of having the course instructor, text author and multimedia creator as the sole source for educational information used in this research. While many studies have been performed involving text and multimedia where one information type is created by one author and the next by different individuals, no studies (like this author's research) include materials on both sides of the spectrum created by the same individual with the drive and passion to be willing to learn the skills necessarily to transfer the same ideas in multiple formats. This aspect of the research design of this study is unique could serve to reduce the amount of author-centered impact on the cognitive performance of the learners in both study groups. On the contrary, the same instructor authoring the multimedia and text could indeed prove to be a hindrance to learner outcomes, if the instructor in question has any aspect of his or her speech that a learner may find difficult in understanding (e.g., accents, impediments, volume recording problems, etc.), or frequently uses colloquialisms unfamiliar to learners. All factors like these should be taken into consideration when designing future studies.

Only one student in the treatment group expressed initial nervousness about the lack of text requirement for the entirety of his course. This individual reported that once it was realized that the multimedia content for the class was created by the same person who wrote the previously-assigned text, and that this content was transposed directly from the text-based material, appreciation was given for this option for learning instead of through a standard textbook. This individual cited the primary advantage that many others cite with multimedia for learning: Multimedia can be stopped, paused, and rewound at will. The content speaks to learners and visualizes the material in a similar fashion to live interaction with an instructor (Talbert 2013; Thompson, 2011). This participant even expressed confidence in choosing to miss a few of the face-to-face sessions of the course, because of the understanding that the multimedia content was available any time for consumption. A future study involving some participants willingly removing themselves from a large portion of the face-to-face lecture sections of a course, and viewing only multimedia during this time, would provide insight into the impact of lecturing combined with multimedia on CT outcomes. An additional future research study that first clearly explains the stated importance of CT in higher learning to students, and then asks students how they feel they may best achieve higher CT outcomes (via text or multimedia) would provide further insight into potential correlations between participants deliberately focusing on CT skills throughout their interactions with one of the two media types, and then being tested under an atmosphere of better prior understanding of what CT is and why it is important.

While the editing of scholarly texts is fairly homogenous with only a few publishers using similar standards for formatting and text presentation on printed pages, the creation and editing of instructional multimedia content has few, if any, standards (aside from ADA concerns, if they are enforced). The internet allows an infinite number of creators of multimedia content to present their materials at any time. The instructor in this author's study worked closely with master's and doctoral degree-holding instructional technologists on the design and development of his multimedia content. The instructor was not, however, an instructional designer. Variances in the aspects of the creation of learning media can, and should, be explored much more in-depth as more potentially willing cooperating faculty for research such as this author's study begin to create multimedia content for their classes with or without outside expertise.

Although this study found no statistically significant moderating effects brought to CT outcomes by the demographic characteristics of gender, ethnicity (non-Anglo/Anglo), and education level (upperclass/lowerclass), potential research into a myriad of other demographic characteristics can be pursued. The author of this study did not have access to a larger, and more ethnically diverse, sample group along with an instructor who created the text and multimedia for testing. As a result, the uniqueness of the instructor as sole author of all materials was preferred to the aspect of ethnic diversity in the study. The sample sizes for this study are small enough to be practical for small institutions only. Replication of this project with a larger sample, however, should be carried out to more fully assess the impact of multimedia on CT outcomes. A much larger sample involving multiple ethnic groups, education levels, student types (athlete/non-athlete, honors/non-honors student), GPAs, majors, and other individual characteristics would facilitate a fuller investigation to improve generalizability of results. Overall, to effectively "move the needle" on CT, more testing will need to be conducted after pedagogical methods and lesson plans are changed. Getting these changes to take pragmatic shape will require a focus on CT at every level of the curriculum through embedding core principles explained by test designers. Objectivity in determining exactly what constitutes CT for any particular discipline will most likely require replication of the Delphi Study (P. A. Facione, 1990) where subject-specific, rather than overall, CT is identified and agreed upon by numerous experts in specific fields.

Future work should explore what multimedia is doing inside the minds of learners as it is presented to students in conjunction with text and other material types as the future of routine adoption of multimedia-capable, cheap, lightweight, and mobile devices continues to supplant the traditional physically printed word (Hu, 2011; Hurdle, 2011; Schaffhauser, 2011). Studies that seek to indicate that a mixture of material types yields the best educational outcomes may become more necessary as ADA requirements, the long-standing impact and debate of Multiple Intelligences Theory (Gardner, 1985), and the newest addition of Universal Design for Learning (Orkwis & McLane, 1998) impact all levels of education. The presentation of the same material in a variety of different formats (involving different or the same authors) could be found to hinder certain outcomes and improve others. Determinations on which outcomes are preferred in certain educational environments are a perplexing problem necessitating future research.

Implications

The findings of this study revealed a statistically significant (and large in magnitude) negative effect for substituting multimedia resources directly for traditional text-based resources on the outcome CT skills of Induction, Evaluation, and Overall. In contrast, the subscale outcome skills of Deduction, Inference, and Analysis were not statistically significantly affected by multimedia versus the use of textual course materials. Demographic characteristics had no statistically significant moderating effect on the negative outcomes affected by multimedia substituted for text. Therefore, a more evidenced-based strategy informed by research is recommended for guiding future decisions on using multimedia instead of text in learning environments. The results from this study should serve as a caution to educators, and educational leaders, to proceed carefully as they consider adopting multimedia for education as it grows in popularity in the consumer and entertainment worlds. The results of this study do not support multimedia as a positive instructional delivery method for CT skills acquisition.

Higher education instructors aspiring to design and use instructional multimedia which includes educational content that is convenient for a mass audience, entertaining to multiple senses, and potentially absorbed very quickly (versus traditional text-driven content) will find insight from this author's study and any future replicating research going forward. Participants in this study did not demonstrate improved CT outcomes through multimedia delivery of content regardless of gender, ethnicity or educational level. As popular as multimedia may be, educators today are potentially faced with many difficult choices regarding the use and popularity of multimedia over text (Broussard, 2014; Flood, 2012; Kurzweil, 2005; Vinge, 1993). While this study has reviewed the historically substantiating literature, the importance of text-based materials to learning is evident over hundreds of years of tradition since the time of the invention of the printing press. It cannot be ignored, however, that multimedia changes the educational landscape in a way that is often initially perceived as a universal benefit containing few, if any, potentially negative learning consequences. Why would students not want to learn via a method that combines text with audio, video, and/or images? Why would this medium not be the best option in all cases for learning? Ex post facto conversations and email between participating students and the author of this study revealed that students in the treatment group perceived that they were: a) learning more through equivalent multimedia, b) enjoyed not being required to purchase a course text book, and c) anticipated higher CT outcomes for themselves after their course semester was concluded. The study participants' perceived higher CT outcomes through multimedia, however, were not realized. These individuals viewed their educational experiences with multimedia as a benefit without actually knowing how well or poorly they performed on the CT examination or their final grades in the course.

Given the paradox of lower CT outcomes being observed through the results of this study while higher outcomes are commonly expected through multimedia use combined with students potentially not having a shared understanding of what CT is and how it is a core component of higher education learning expectations, the following concerns are evident. Is it appropriate for higher education instructors to test for CT without first setting curricular direction toward explaining stated CT definitions and subscale components (e.g., Induction, Deduction, Inference, Analysis, and Evaluation) so students know what is expected of them? If students are performing poorly on CT examinations because of the impact of multimedia, should a return to text-based materials be advocated for more insistently? Are new CT assessment tools needed which account for the understanding of the potentially unstoppable growth of multimedia resources in a post-textual world?

Pursuing these questions will impact various types of instructional technologists and instructional policy makers as they struggle to meet the challenge of the mass adoption of multimedia content for learning. Institutions can use questions like these as strategic markers for conversations regarding directions for the advancement of their own student learning goals and objectives. Regardless, the need for further research in the topics of multimedia and CT is clear. Better understanding of how to either decrease the damage done to CT outcomes by multimedia, or how to better integrate the positive cognitive benefits of text into multimedia, is a goal that will benefit students in the future.

Summary

The results of this author’s study suggest that regardless of the gender, ethnicity, or education level of students, the use of multimedia (a) in place of text because of cost concerns related to textbooks, or (b) because of the popularity of multimedia as an emotionally attractive information format as found by Xu et al. (2009), or (c) the need for instructors to be “progressive” or perceived as “in-tune” with technology, should be researched further before routine adoption of multimedia content and the replacement/removal of text-based material within college courses begins. Serra and Dunlosky (2010), and now the author of this study, have found that students’ self-efficacy about their positive learning outcome potential through multimedia does not always translate to actual higher performance on learning objectives.

Higher education instructors and administrators sharing a sense of excitement over the perceived advantages to be reaped from students engaging in multimedia content for the most important of educational outcomes, like CT, may also be far from a reality. Rather than being passive victims of technological innovations in education, educators should be active participants in instructional technology integration and strategic development so that increased learning can remain the primary goal of education despite advances in technology which have yet to be maturely evaluated.

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APPENDICES

APPENDIX A

BCTST SAMPLE ITEMS AND CAPSCORE TEST TAKER RESPONSE FORM

THE BUSINESS CRITICAL THINKING SKILLS TEST

(BCTST)

Effective business decision-making and problem-solving demand strong critical thinking skills in analysis, inference, and evaluation. This test measures those reasoning skills using questions drawn from a variety of business contexts. There are no trick questions; words are used in their ordinary, everyday meanings. The questions themselves supply most of the information needed to reason to the correct answer. Your experience, basic education, and critical thinking supply the rest.

Peter A. Facione, Ph. D.
Stephen W. Blohm, MA, MS
Noreen C. Facione, Ph.D.

INSIGHT ASSESSMENT

California Academic Press

www.insightassessment.com

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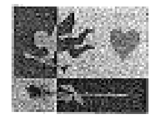
ISBN [illegible]

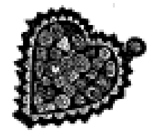


Questions 18 and 19 refer to a report which states that a company's revenue from Valentines Day greeting card sales is 20% higher in February than it was in January. The author of the report interprets this as strong evidence that the advertising campaign for Valentines Day greeting cards, which started at the end of January, had a positive effect.

18. Which of the following information, if true, best refutes the author's interpretation?

A= Greeting card sales are affected by the change in price of other products, such as candy gift boxes, which can be substituted for greeting cards.
B= We can only be 95% confident that the difference in sales revenue was 20%.
C= For some days in February the sales revenues were not 20% higher than the sales revenue for the average day in January.
D= Last year, when there was no advertising campaign, Valentine card sales revenue was 20% higher in February than in January.

19. Which of the following would be a reasonable inference to draw?

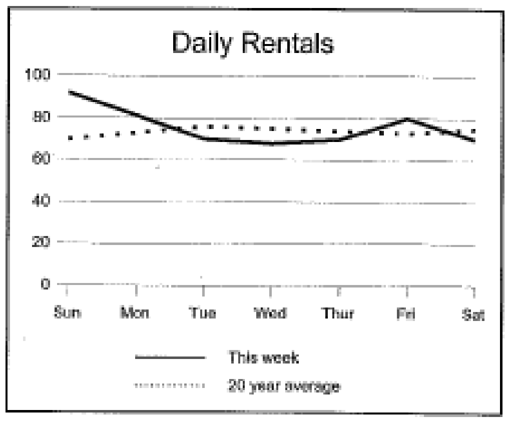


A= A month of data is enough to produce strong conclusions.
B= The company should increase its advertising next year.
C= Advertising is a cost-effective method for increasing sales revenue.
D= Card sales increased because Valentines Day is in February.
E= The advertising was successful in increasing card sales revenue.

Questions 20 and 21 relate to the chart below entitled "Daily Rentals"

20: In the graph to the right a car rental agency has recorded its daily rentals against its daily average for the same week over the past twenty years. On what percentage of the days this week did it exceed its average?

A= 3
B= 4
C= 43
D= 57
E= Cannot be determined.



21. Which of the following would be the least plausible explanation for the large, positive difference between the number of daily rentals for Sunday this week and the average for the past 20 years?

A= This year the company had more cars available to rent.
B= More people are taking driving vacations this year, rather than flying.
C= Sunday statistics this year were not kept with the same accuracy as in prior years.
D= Business travelers now tend to rent cars on Sunday and drive around for pleasure.
E= Because of fuel costs, more customers this year requested smaller rental cars.

CAPSCORE Response Form - Academic Version
Insight Assessment

BCTST 07.1.07

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Name______________________
Date______________________

Respond by filling bubble with a solid dark mark using a #2 soft lead pencil. These response forms are computer scored; make sure all your erasures are complete. **DO NOT USE A PEN!**

PLEASE USE NO. 2 PENCIL

RIGHT | WRONG

Identification Number

Group

This CAPSCORE form will remain valid until March 31st 2014

Gender
- Male
- Female

Class Level
- Freshman
- Sophomore
- Junior
- Senior
- Credential Student
- Master's Student
- Doctoral Student

How do you identify yourself?
- African American
- Anglo American, Caucasian
- Asian American/Pacific Islander
- Hispanic, Latino, Mexican American
- Native American
- Mixed/Other

APPENDIX B

BCTST CAPSCORE RETURN SHEET

INSIGHT ASSESSMENT - CapScore™ Return Sheet

Please complete and return this sheet with your completed CapScore™ response forms to:

Insight Assessment
ATTN: CapScore™
217 La Cruz Ave
Millbrae CA 94030

- Please inspect your completed response forms to assure that "Identification Number" and "Group" field bubble responses are complete and accurate.
- Please place the completed response forms in a box or cardboard envelope to ensure that they do not get tattered during shipping.
- We suggest use package delivery service that includes offers package tracking so you can know when your response forms are received.
- Please do not send photocopied forms. They cannot be scanned
- Please do not send forms marked by any means other than No. 2 pencil. They cannot be scanned.
- If you are returning response forms from two different testing instruments, please use a separate return sheet for each instrument.
- Results are returned by email. Be sure to supply a valid email address below.

Today's Date ______________________
Name ______________________
Email ______________________
Org. / Institution ______________________
Best Contact Phone ______________________

I am returning ____ (number) response forms for the ______________________ (please indicate test instrument and code number, e.g. CCTST 10.1.10)

2011 Basic CapScore™ Reporting Services:
Included in the purchase of testing instruments:

- ✓ Individual test-taker scores on all scales.
- ✓ Group descriptive statistics for the whole batch of response forms contained in the package you send, if the number of forms returned is of adequate size.
- ✓ If the "Group" indicator field is used, descriptive statistics for each group of adequate size.
- ✓ Presentation ready bar graphs for scale scores.
- ✓ Electronic data files spreadsheet with all scale scores and demographic responses

Group descriptive statistics returned include: size of the group, mean, median, standard deviation, standard error of the mean, lowest score, highest score, first quartile score and third quartile score. For skills tests, we also return the percentile of the mean of the group as compared to a pre-selected external norm group. We regard 20 cases as a size minimally adequate for descriptive statistical analysis.

Premium CapScore™ Analysis and Reporting

To request premium statistical analysis and reporting services contact IA. Some of the available premium services are listed below. Premium analysis and reporting services are based on the scope of the work involved. We will prepare a price quote. Contact us by phone to discuss your specific project needs. Phone: 650-697-5628

- ❑ Custom report preparation for accreditations, executive briefings, or public presentations.
- ❑ Integration of additional data from client's organizational / institutional / research sources.
- ❑ Group descriptive statistics on a response form demographic factor not represented by the "Group" response field.
- ❑ Statistical comparison of one set of scores with another set of scores.
- ❑ Reliability coefficients for scale scores for client's dataset.

Additional Processing Requests

A number of additional processing services are available. Charges are based scope of the work involved. We will prepare a price quote at your request. Pre-payment is required for these services. Credit cards accepted. *Indicate name on card, type of card (e.g. Visa), card number, and expiration date.* Some of the additional processing services available are:

- ❑ Splitting a single batch of returned forms into two or more separately scored groups of forms. Priced per additional scanning and scoring pass required.
- ❑ Aggregation of a separate batch of response forms with a batch scored at an earlier time and rescoring the entire set.
- ❑ Archival search for client's own test results previously scored and returned to client.
- ❑ Rush Service – 5 business days from receipt of your package of response forms. Minimum charge $50
- ❑ Return of your response forms by mail or UPS ground shipping. Minimum charge $50 plus shipping.

CapScore™ results are returned by email as spreadsheet and document files.

Insight Assessment www.insightassessment.com (650) 697-5628 217 La Cruz Ave. Millbrae, CA 94030
capscore@insightassessment.com

APPENDIX C

INSIGHT ASSESSMENT SCORING AGREEMENT

Insight Assessment

217 La Cruz Ave., Millbrae CA 94030, Phone (650) 697-5628, FAX (650) 692-0141
www.insightassessment.com

e-mail info@insightassessment.com

Dear Colleague:

Thank you for ordering CAPSCORE™ response forms and scoring service. Separate instructions for using these answer sheets are enclosed in this package. For administration instructions specific to a given assessment tool please refer to that tool's manual. When you are finished with your assessment administration please forward the completed response forms to the following address:

Insight Assessment
ATTN: CAPSCORE™
217 La Cruz Ave
Millbrae, CA 94030-2406

Basic CAPSCORE™ scoring provides total scores and sub-scale scores for each individual assessed. Scores are reported by the ID number these individuals mark on the CAPSCORE™ answer sheet. We also included basic descriptive statistics of the sub-scales and total score for the group as a whole. Further statistical analyses are available for an additional fee.

Please note that unless the entire set of purchased CAPSCORE™ response forms are all returned at one time, you will incur an additional charge. In other words, you should not purchase 200 CAPSCORE™ answer sheets and send them back to Insight Assessment 10 at a time. Our prices reflect the scoring of one large batch of answer sheets. If you wish to have the response forms scored in batches and do not use the group indicator number to differentiate your groupings, there could be extra charges. Visit our website for complete details regarding current retail and educational prices for CapScore™ services.

After your CapScore™ results are returned to you, remember to backup those files and retain those data. Insight Assessment does not guarantee long term CapScore™ data storage.

Sincerely,

Lynne Quirke
Director of Client Services
lquirke@insightassessment.com

CAPSCORE

Leaders in Critical Thinking Assessment

APPENDIX D

RESEARCH PARTICIPANT INVITATION

An Assessment of the Effect of Multimedia on Critical Thinking Outcomes

Research Participant Invitation

My name is Terrance Cottrell. I am a doctoral student at Northern Illinois University with a major in Educational Technology. My doctoral dissertation research involves understanding a) What factors of student critical thinking outcomes are affected by the use of multimedia versus text-based information sources in a higher education classroom, and b) Which demographic characteristics moderate the effect of multimedia on those outcomes. I am currently recruiting participants who are willing to take one paper and pencil, 35-question, multiple choice test twice during this current semester. The test has an estimated time of 30-45 minutes.

Your permission to participate is requested. A summary of the findings of this research will be provided to all participants as a way to allow you to compare and contrast the results to your own exploration into your ability to think critically. Insight can be gained guiding your future choices in a) attending classes that emphasize multimedia over text, or vice a versa, and b) thinking more strategically about supplementing your own individual research efforts with the information source that best impacts your specific critical thinking outcomes.

The test will be conducted during your normal class time. The test does not require any special prerequisites other than those that were required to gain entry into this course.

Your participation will assist in furthering theory and practice in the fields of Educational and Instructional Technology.

Sincerely,

Terrance L. Cottrell
tcottrell@niu.edu
815-740-4292

APPENDIX E

NIU INFORMED CONSENT

I agree to participate in the research project titled, An Assessment of the Effect of Multimedia on Critical Thinking Outcomes, being conducted by Terrance Cottrell a graduate student at Northern Illinois University. I have been informed that the purpose of this study is to uncover the impact of multimedia learning resources compared to text-based learning resources on the outcome of critical thinking in higher education learners.

I understand that if I agree to participate in this study, I will be asked to complete a 35-question multiple choice examination two times during the current semester. I understand that this examination is the only data collected for this study. I also understand that the examination will ask questions to gather demographic information. I further understand that I may be asked to provide an email address to the researcher.

I am aware that my participation is voluntary and may be withdrawn at any time without penalty or prejudice, and without affecting my relationship with the University of St. Francis. I understand that if I have any additional questions concerning this study, I may contact Terrance Cottrell at tcottrell@niu.edu or via telephone at (815) 740-4292, or the Northern Illinois University supervising faculty member for this dissertation research project, Dr. Rhonda Robinson, at rrobinson@niu.edu. I understand that if I wish further information regarding my rights as a research subject, I may contact the Office of Research Compliance at Northern Illinois University at (815) 753-8588.

I understand that the intended benefits of this study involve the results being used by faculty and higher education administrators as they seek to understand more about how multimedia is impacting learning and CT outcomes. I understand that the benefits of this study also involve providing insight into how to best plan for a future that may include more multimedia and fewer static text resources available for students.

I have been informed that there are no known risks and/or discomforts associated with this study. I understand that all information gathered during this study will be kept confidential by restricting access to the data to the investigator alone, by assigning case numbers and not names to the responses during analysis being made by a third party provider.

I understand that my consent to participate in this project does not constitute a waiver of any legal rights or redress I might have as a result of my participation, and I acknowledge that I have received a copy of this consent form.

By signing this form I am attesting that I have read and understand the information above and I freely give my voluntary consent/assent to participate in this research with full knowledge of the nature and purpose of the procedures.

Participant Name (Printed):____

Participant Signature:____

APPENDIX F

NOTICE OF PRIVACY PRACTICES

ACKNOWLEDGEMENT OF NOTICE OF PRIVACY PRACTICES

The Notice of Privacy Practices tells you how we may use and share your personal information for the project: AN ASSESSMENT OF THE EFFECT OF MULTIMEDIA ON CRITICAL THINKING OUTCOMES.

Please read carefully.

- We will only use and share your personal information to provide you alone with information related to your performance.

- We may use your personal information (without using your name, address or phone number) for educational or research purposes.

- We will use and share your personal information as required by law.

- We may use and share your personal information internally to improve our quality of teaching.

You have the following rights with respect to your personal information:

1. You have the right to look at and receive a copy of your personal information.

2. You have the right to receive a list of to whom we have given your personal information.

3. You have the right to ask us to correct a mistake in your personal information.

4. You have the right to ask that we not use or share your personal information.

5. You have the right to ask us to change the way we contact you.

APPENDIX G

LETTER OF CONSENT FROM RESEARCH SETTING ADMINISTRATION

March 26, 2012

We, the undersigned, give consent to Mr. Terrance Cottrell to conduct the research project entitled, "An Assessment of the Effect of Multimedia on Critical Thinking Outcomes", using the University of St. Francis as the primary testing location.

Dr. Frank Wyrostek (cooperating faculty)

Professor of Business Administration, Finance
University of St. Francis
500 Wilcox St. Joliet, IL 60435

Dr. Frank Pascoe

Provost
University of St. Francis
500 Wilcox St. Joliet, IL 60435

APPENDIX H

A SELECTION OF RESEARCH USING THE BCTST FAMILY OF TESTS

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APPENDIX I

DATA SCREENING FIGURES

SUBSCORE BOXPLOTS

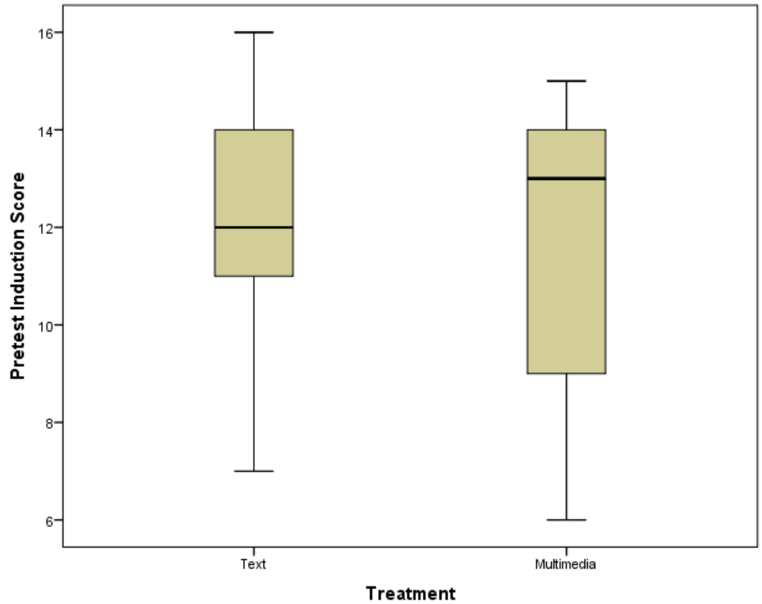


Figure 15: Boxplots for the Pretest Induction Scores for Text and Multimedia groups with 43 Cases.

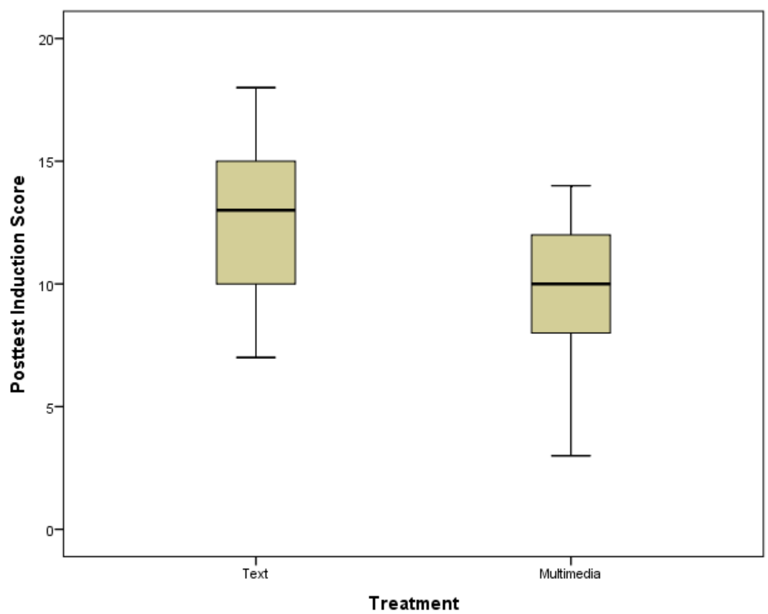


Figure 16: Boxplots for the Posttest Induction Scores for Text and Multimedia groups with 43 Cases.

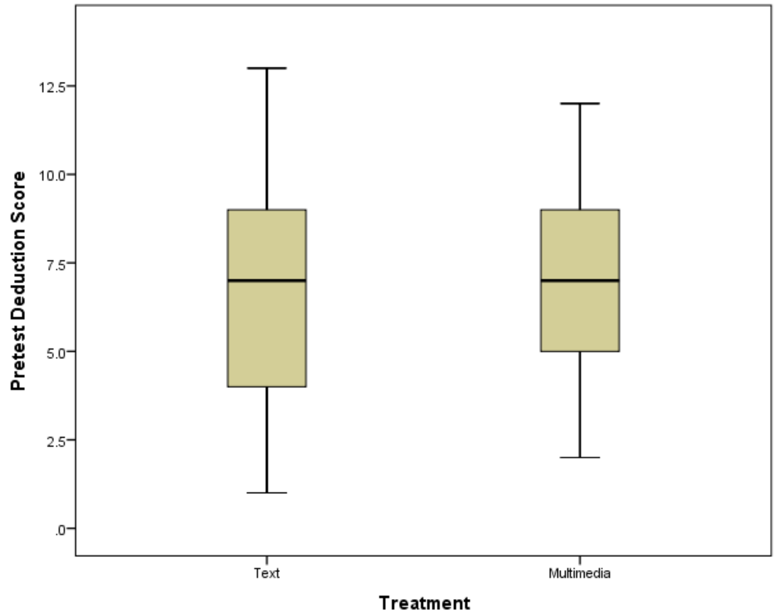


Figure 17: Boxplots for the Pretest Deduction Scores for Text and Multimedia groups with 43 Cases.

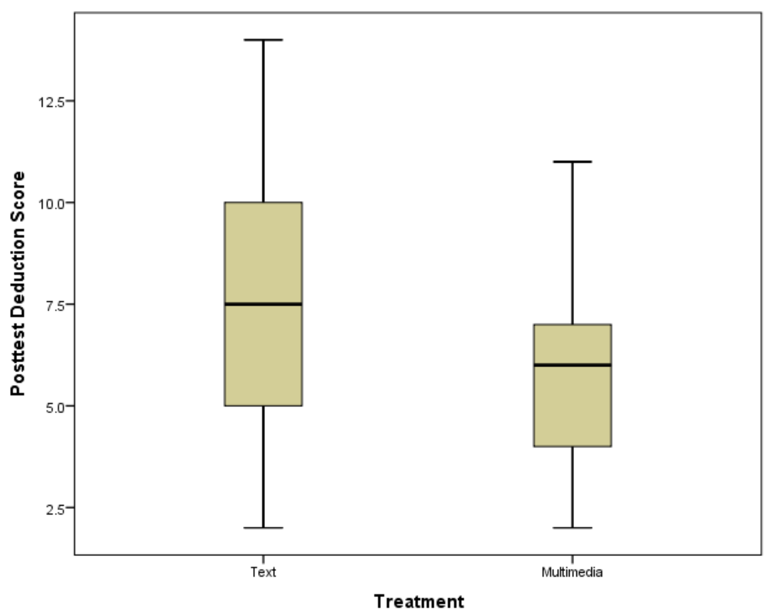


Figure 18: Boxplots for the Posttest Deduction Scores for Text and Multimedia groups with 43 Cases.

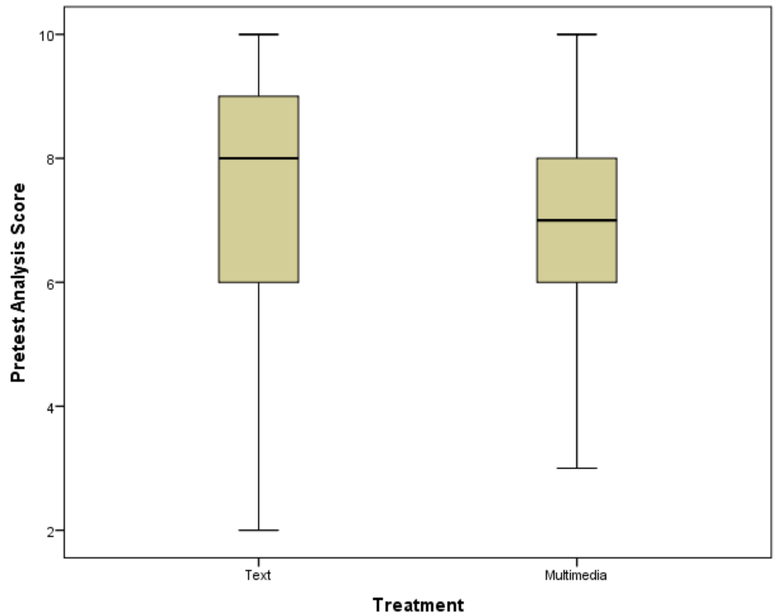


Figure 19: Boxplots for the Pretest Analysis Scores for Text and Multimedia groups with 43 Cases.

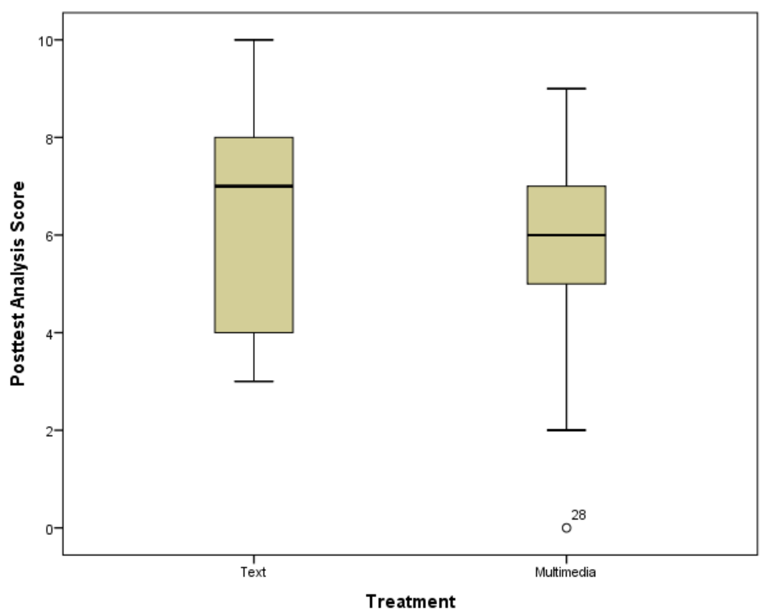


Figure 20: Boxplots for the Posttest Analysis Scores for Text and Multimedia groups with 43 Cases.

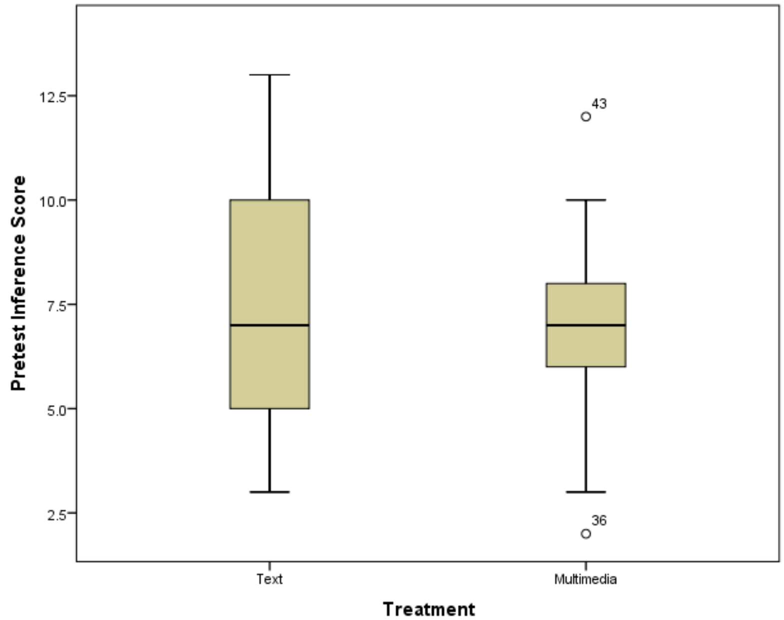


Figure 21: Boxplots for the Pretest Inference Scores for Text and Multimedia groups with 43 Cases.

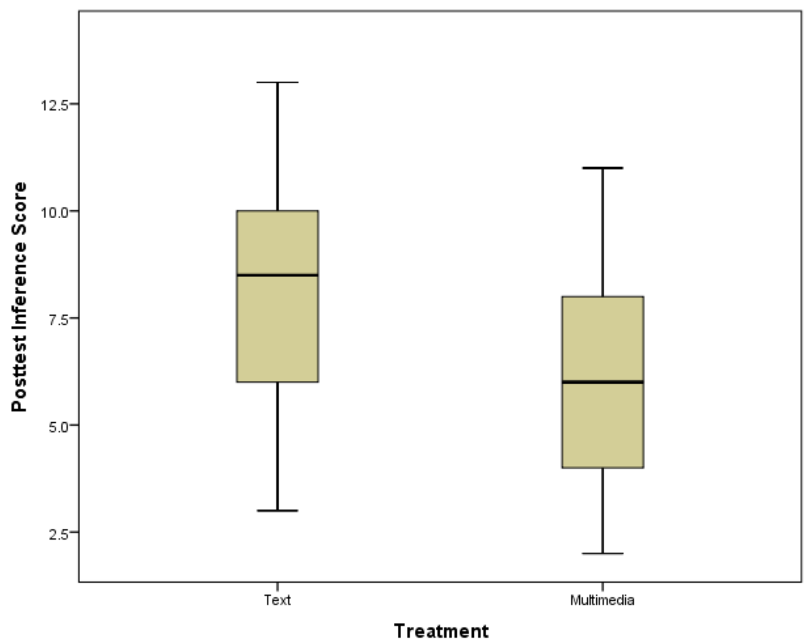


Figure 22: Boxplots for the Posttest Inference Scores for Text and Multimedia groups with 43 Cases.

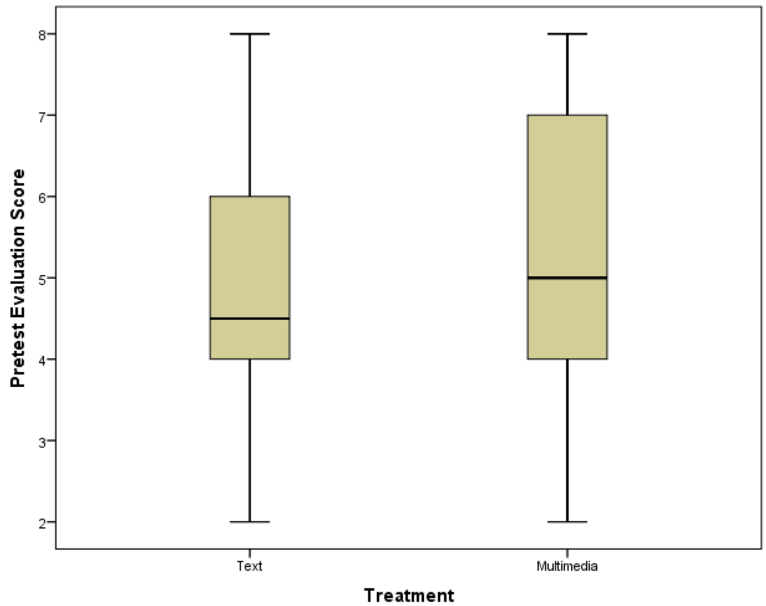


Figure 23: Boxplots for the Pretest Evaluation Scores for Text and Multimedia groups with 43 Cases.

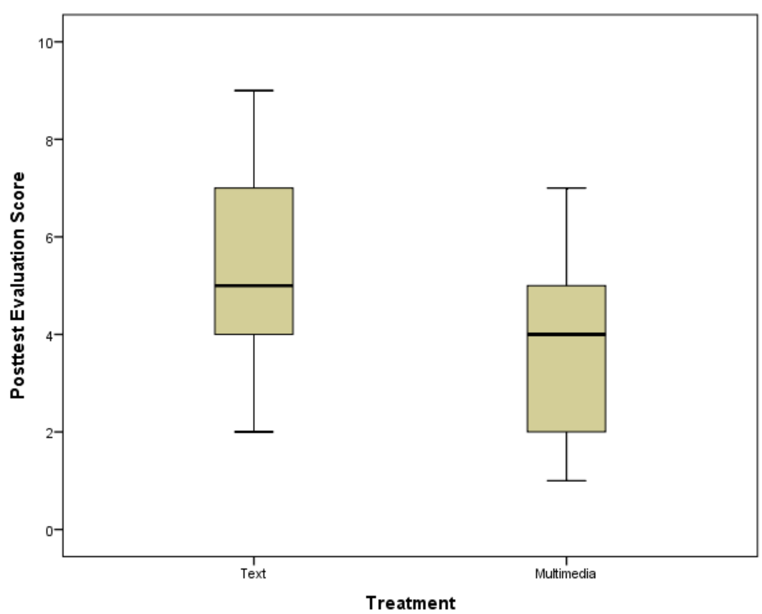


Figure 24: Boxplots for the Posttest Evaluation Scores for Text and Multimedia groups with 43 Cases.

OVERALL BOXPLOTS

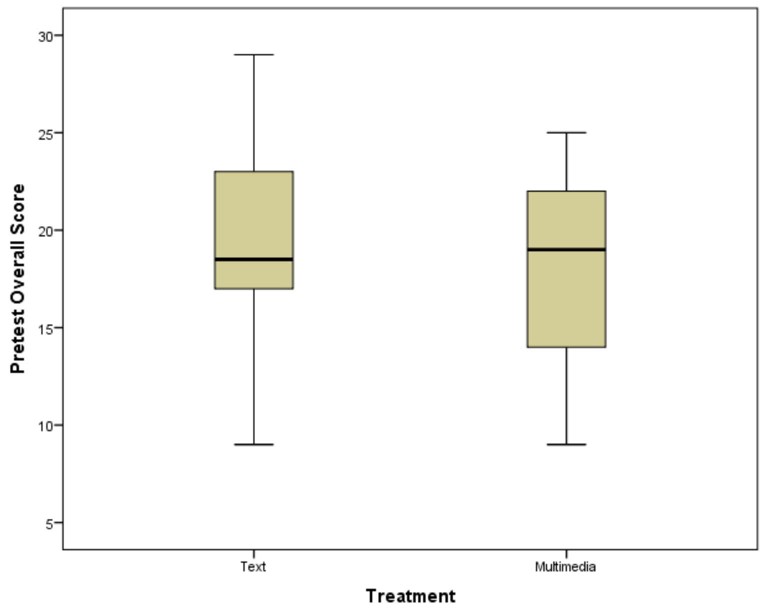


Figure 25: Boxplots for the Pretest Overall Scores for Text and Multimedia groups with 43 Cases.

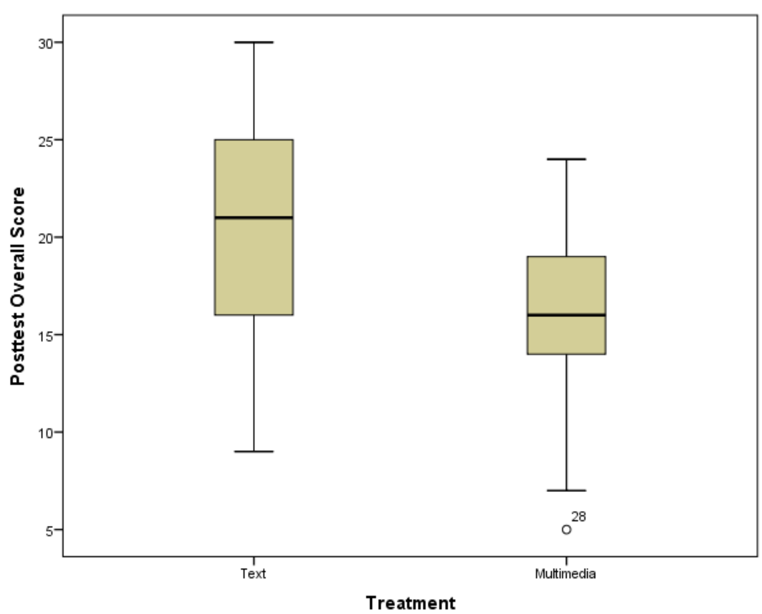


Figure 26: Boxplots for the Posttest Overall Scores for Text and Multimedia groups with 43 Cases.

SUBSCORE Q-Q PLOTS

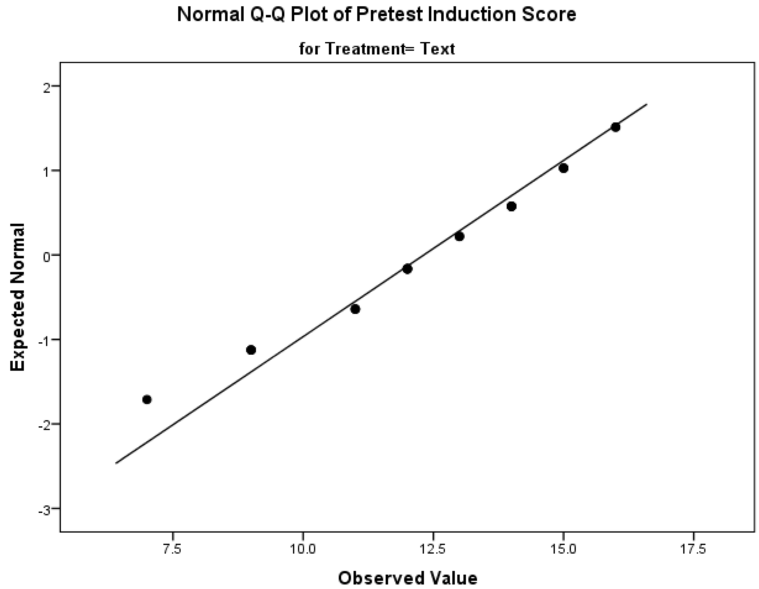


Figure 27: Normal Q-Q Plot of the Pretest Induction Scores for Text Group.

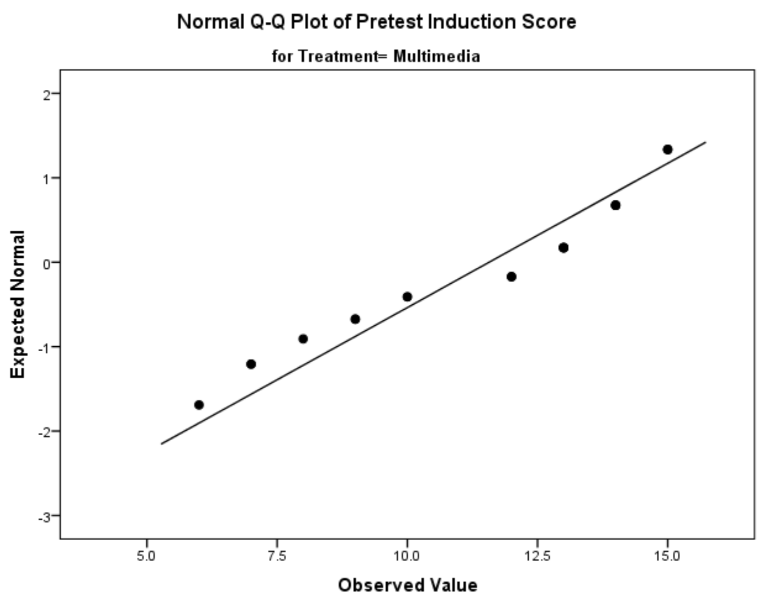


Figure 28: Normal Q-Q Plot of the Pretest Induction Scores for Multimedia Group.

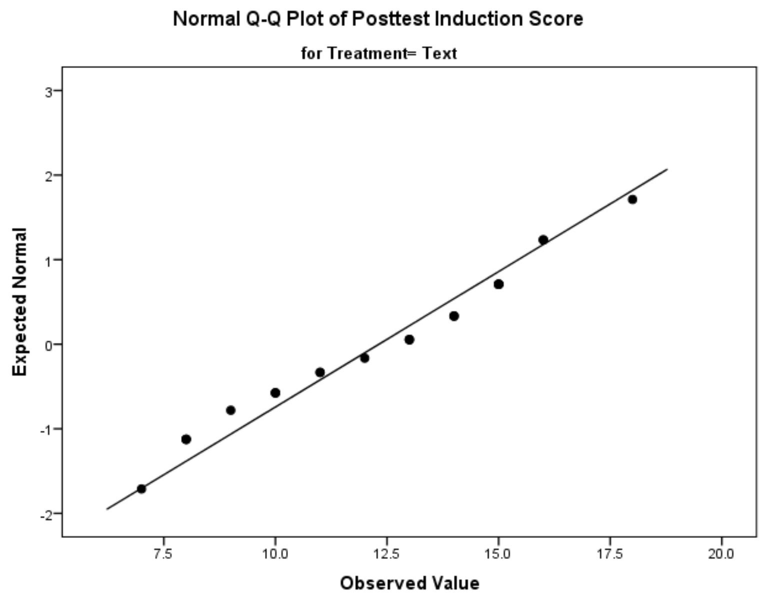


Figure 29: Normal Q-Q Plot of the Posttest Induction Scores for Text Group.

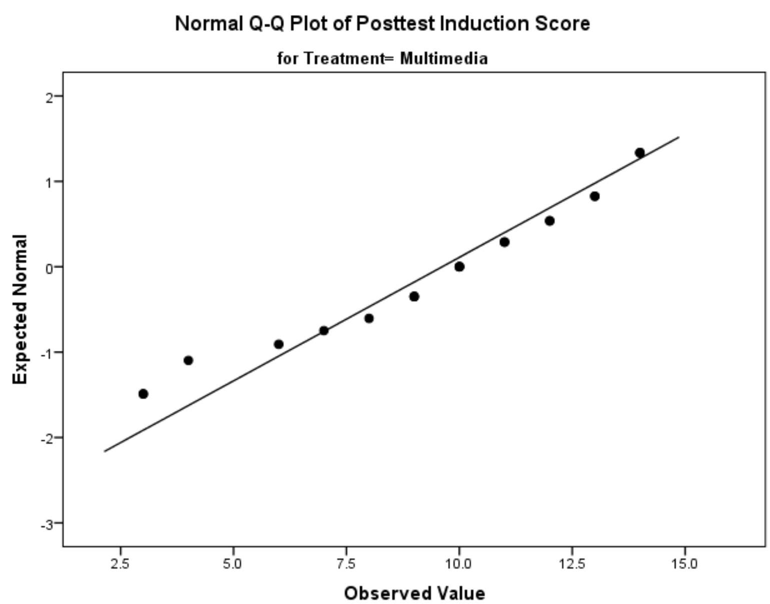


Figure 30: Normal Q-Q Plot of the Posttest Induction Scores for Multimedia Group.

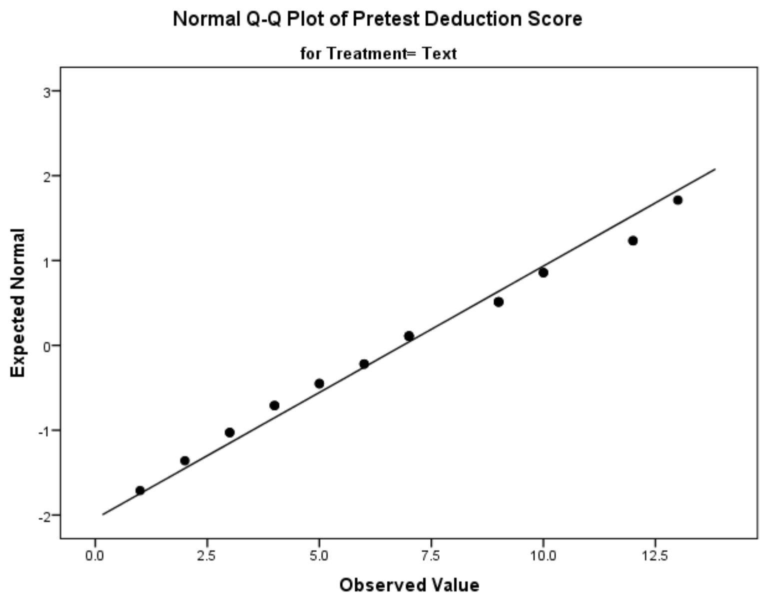


Figure 31: Normal Q-Q Plot of the Pretest Deduction Scores for Text Group.

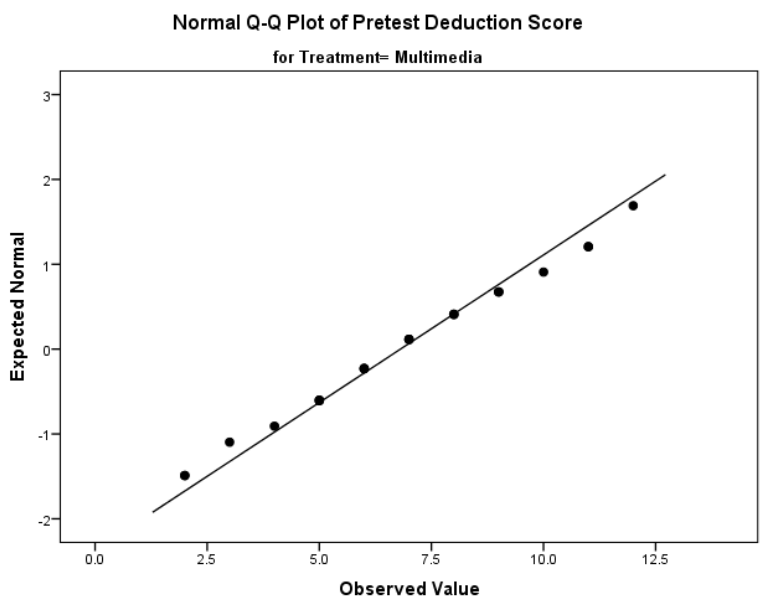


Figure 32: Normal Q-Q Plot of the Pretest Deduction Scores for Multimedia Group.

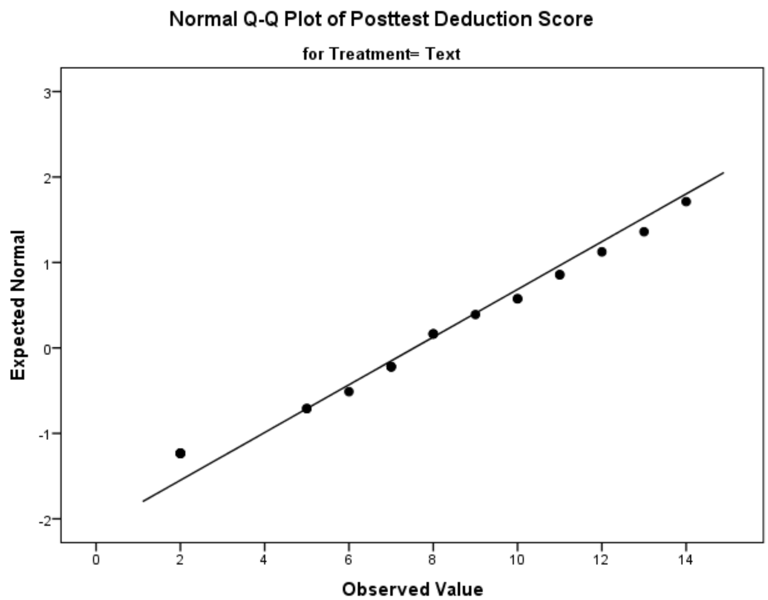


Figure 33: Normal Q-Q Plot of the Posttest Deduction Scores for Text Group.

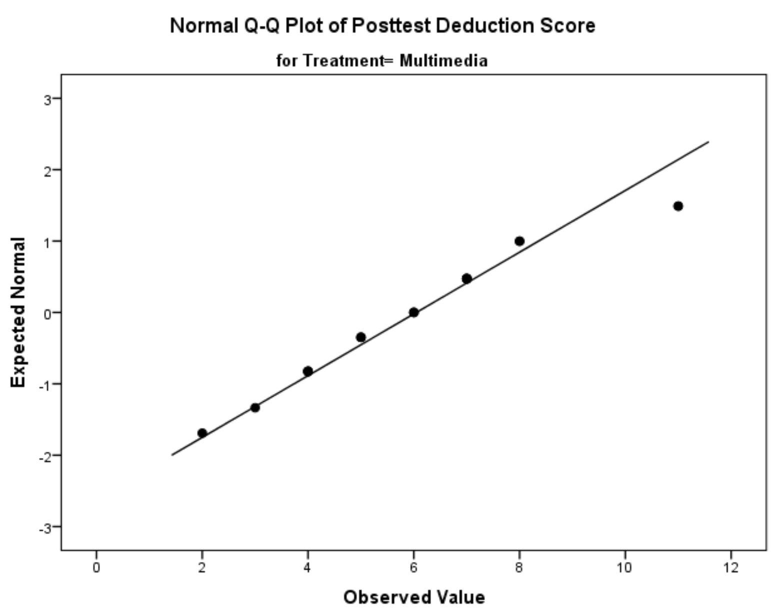


Figure 34: Normal Q-Q Plot of the Posttest Deduction Scores for Multimedia Group.

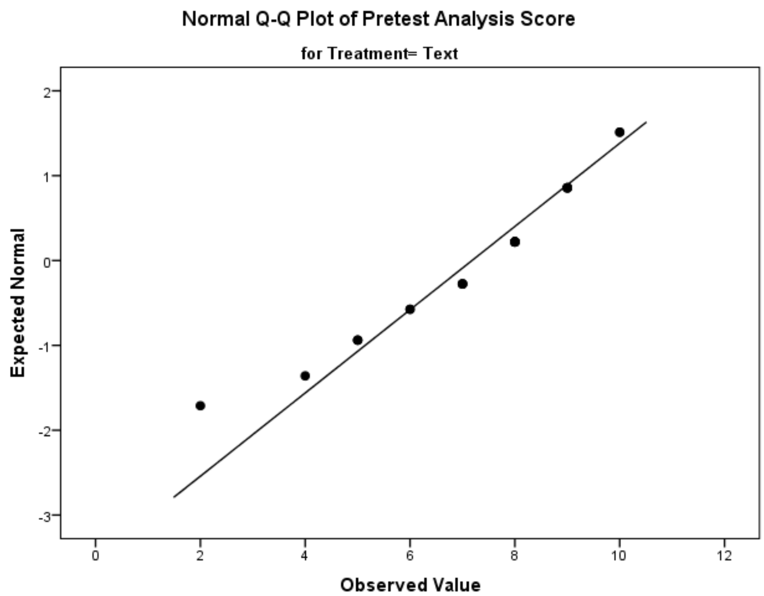


Figure 35: Normal Q-Q Plot of the Pretest Analysis Scores for Text Group.

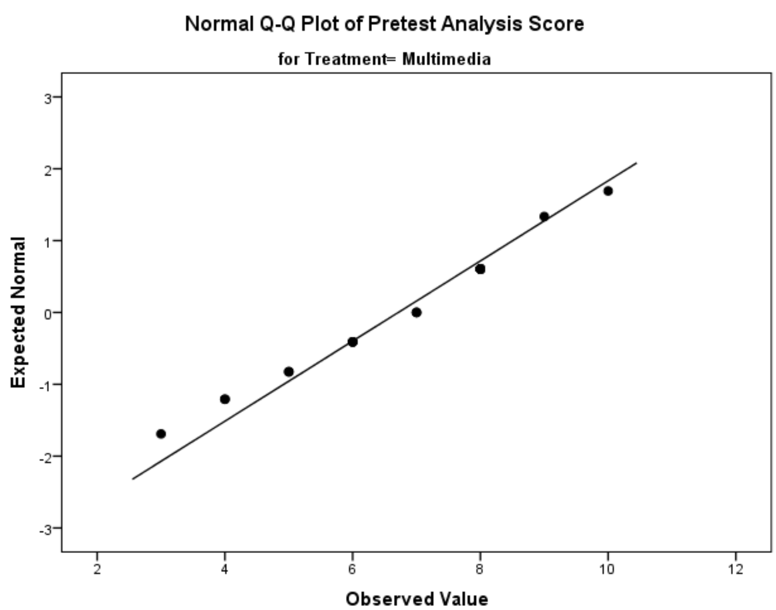


Figure 36: Normal Q-Q Plot of the Pretest Analysis Scores for Multimedia Group.

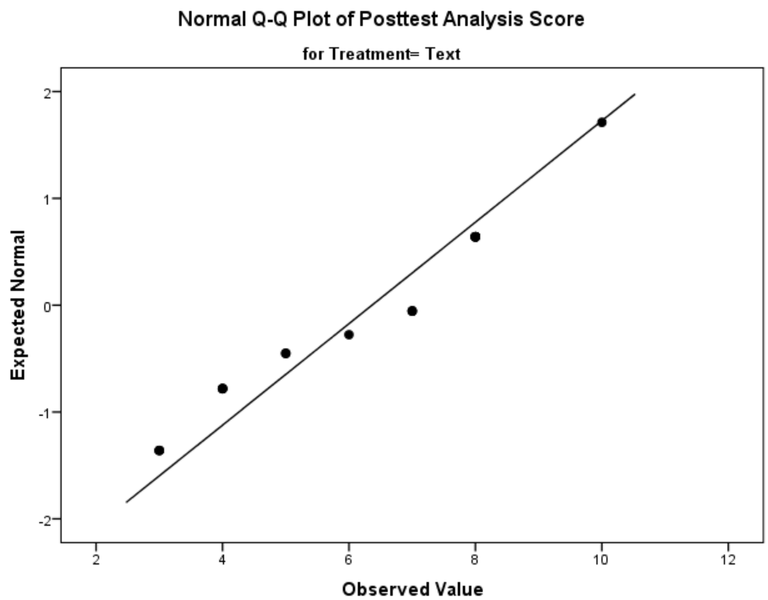


Figure 37: Normal Q-Q Plot of the Posttest Analysis Scores for Text Group.

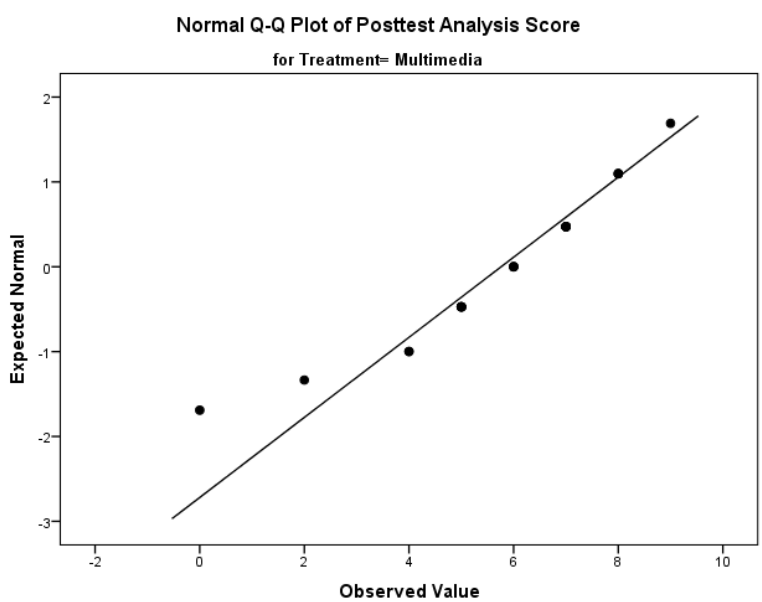


Figure 38: Normal Q-Q Plot of the Posttest Analysis Scores for Multimedia Group.

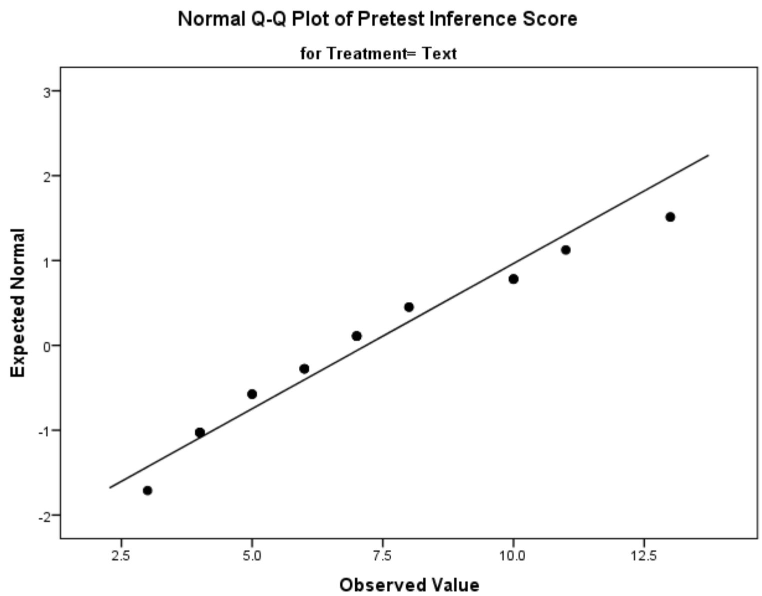


Figure 39: Normal Q-Q Plot of the Pretest Inference Scores for Text Group.

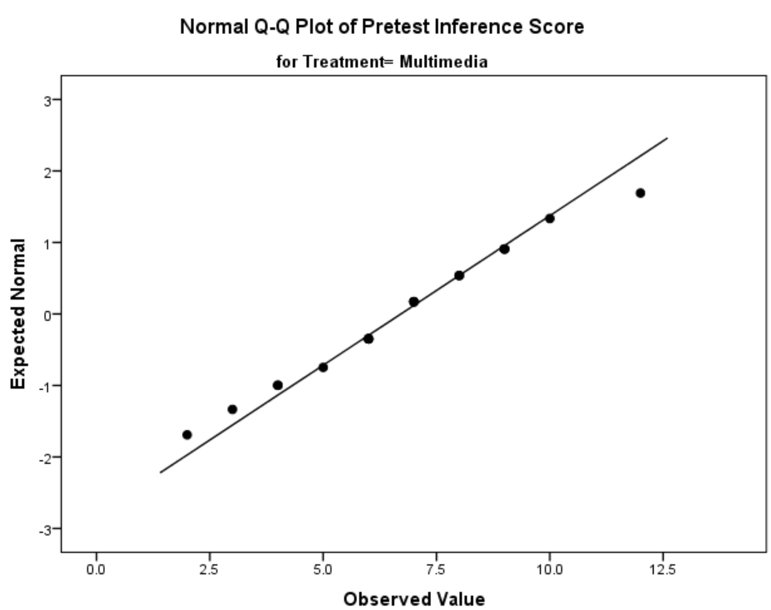


Figure 40: Normal Q-Q Plot of the Pretest Inference Scores for Multimedia Group.

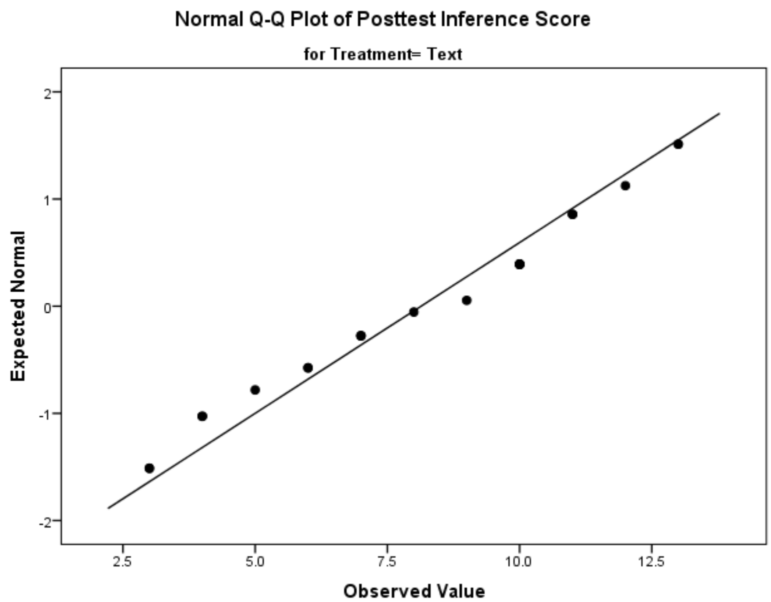


Figure 41: Normal Q-Q Plot of the Posttest Inference Scores for Text Group.

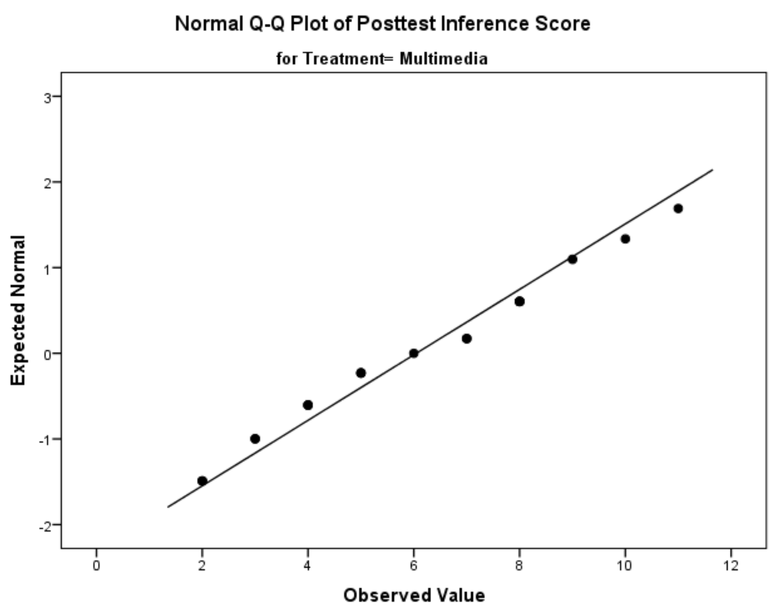


Figure 42: Normal Q-Q Plot of the Posttest Inference Scores for Multimedia Group.

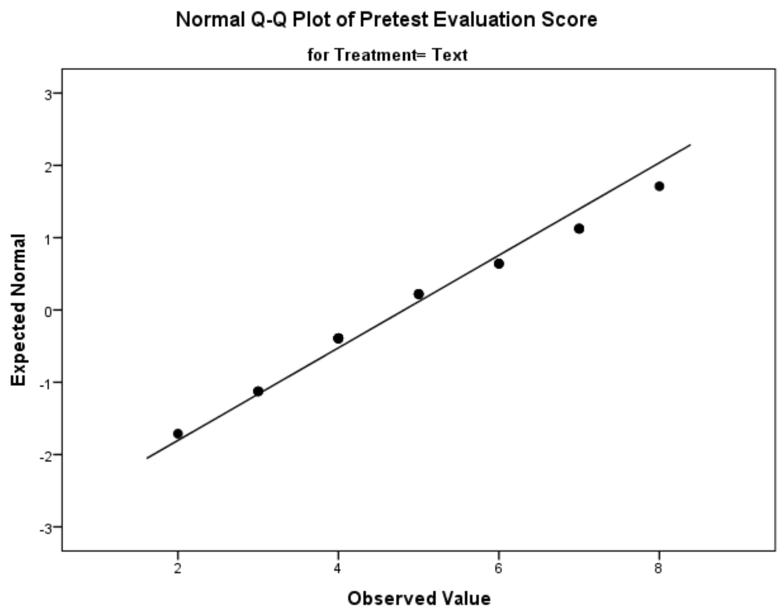


Figure 43: Normal Q-Q Plot of the Pretest Evaluation Scores for Text Group.

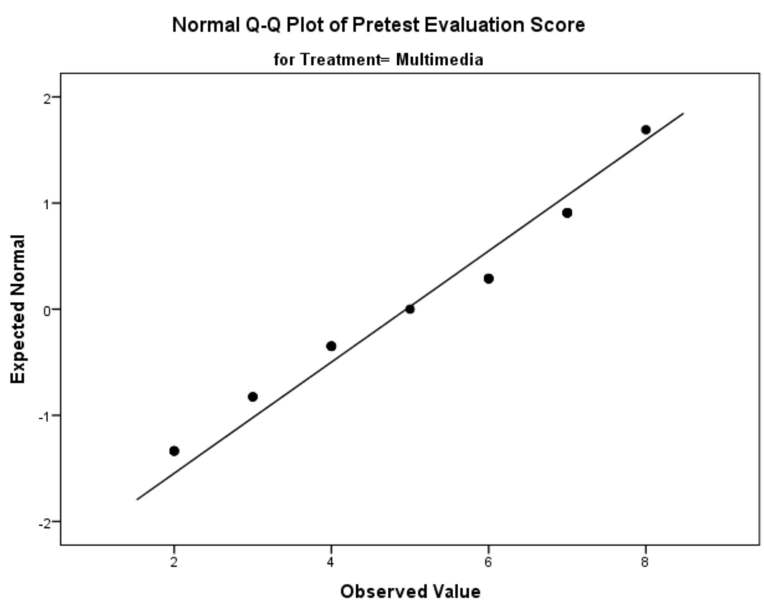


Figure 44: Normal Q-Q Plot of the Pretest Evaluation Scores for Multimedia Group.

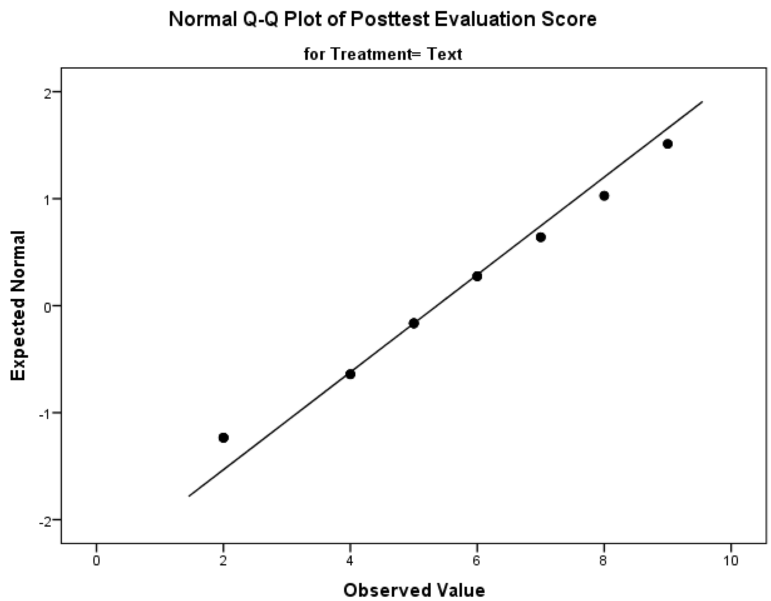


Figure 45: Normal Q-Q Plot of the Posttest Evaluation Scores for Text Group.

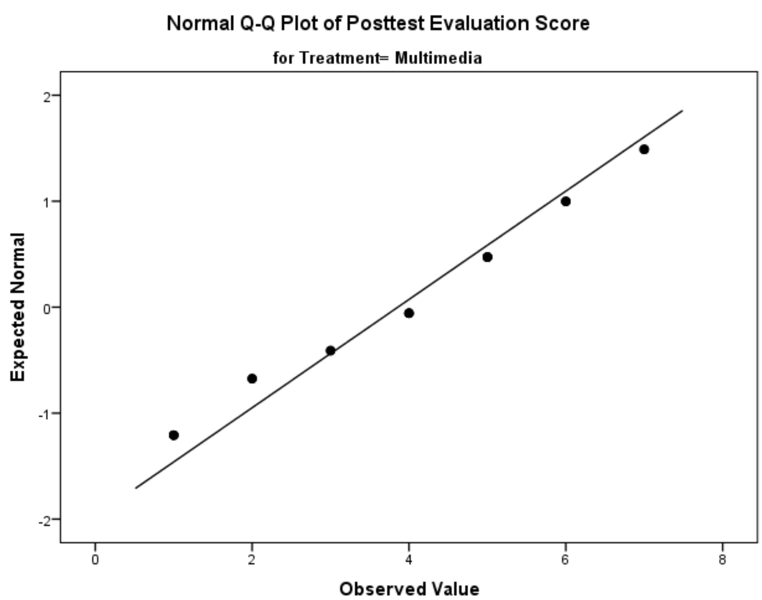


Figure 46. Normal Q-Q Plot of the Posttest Evaluation Scores for Multimedia Group.

OVERALL Q-Q PLOTS

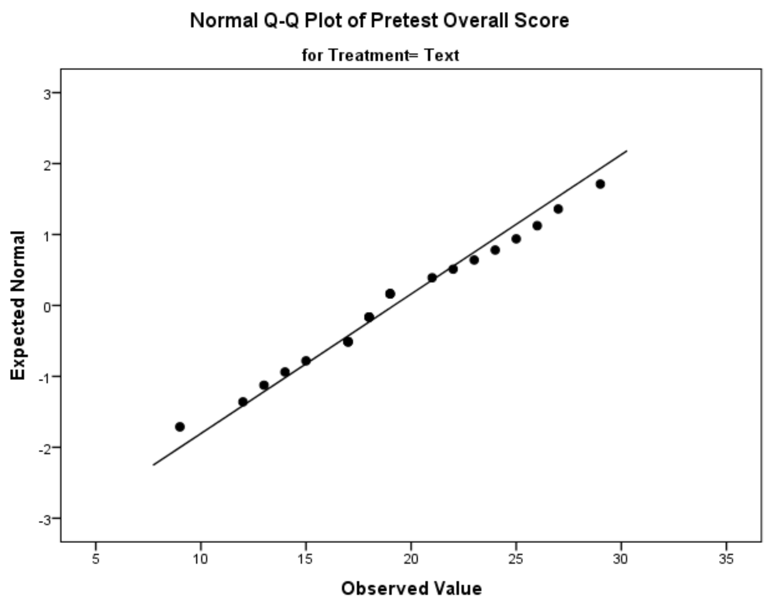


Figure 47: Normal Q-Q Plot of the Pretest Overall Scores for Text Group.

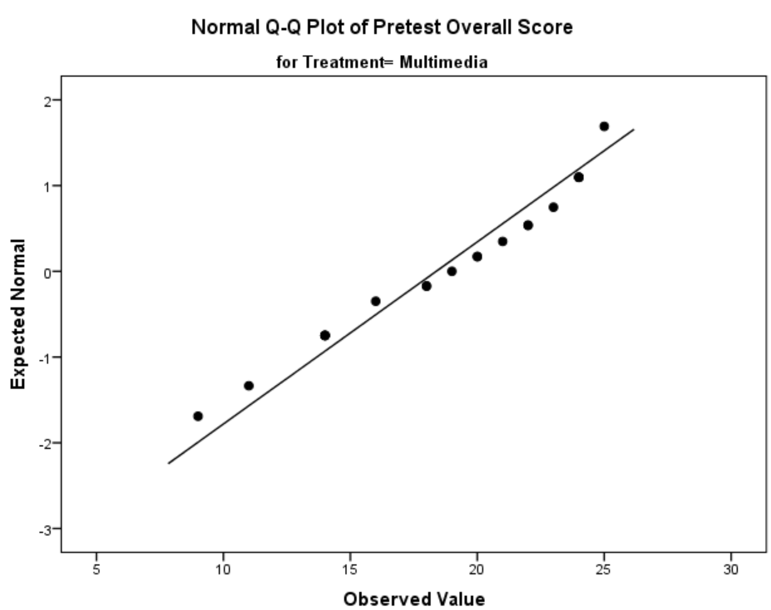


Figure 48: Normal Q-Q Plot of the Pretest Overall Scores for Multimedia Group.

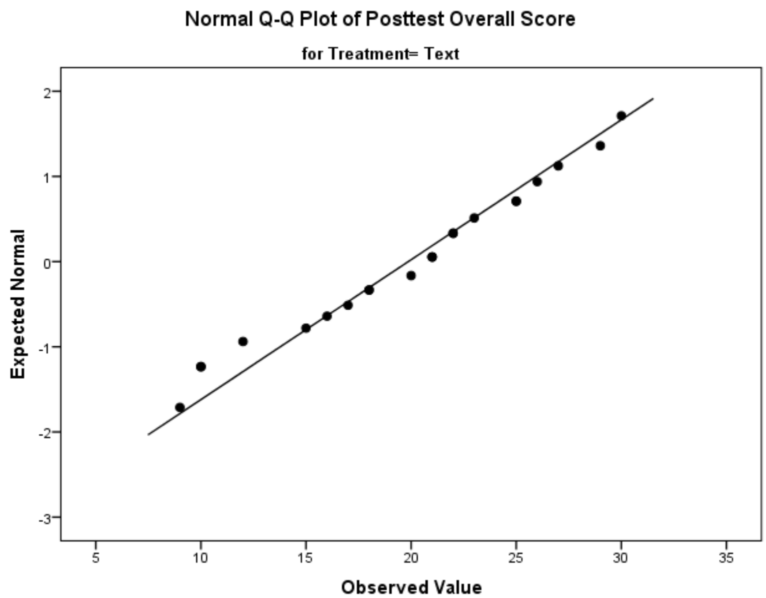


Figure 49: Normal Q-Q Plot of the Posttest Overall Scores for Text Group.

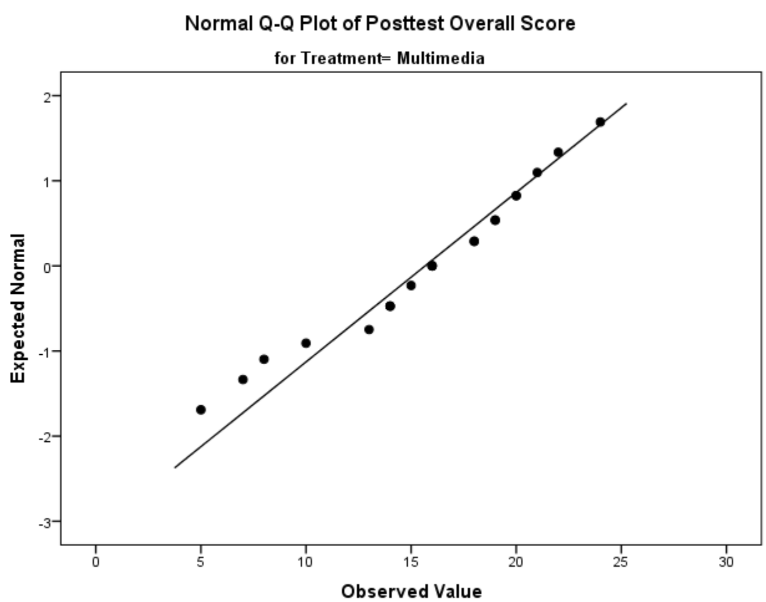


Figure 50: Normal Q-Q Plot of the Posttest Overall Scores for Multimedia Group.

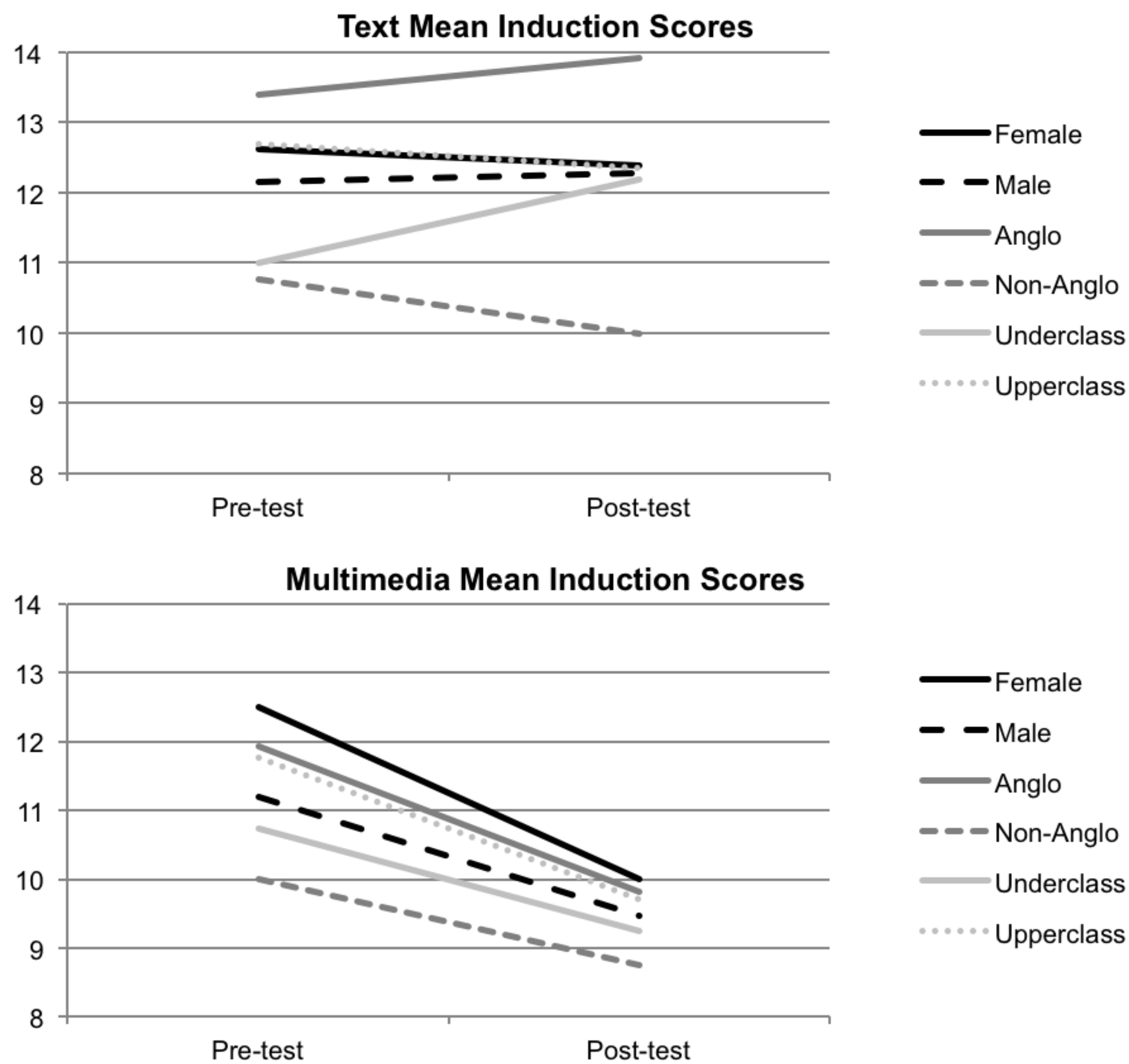
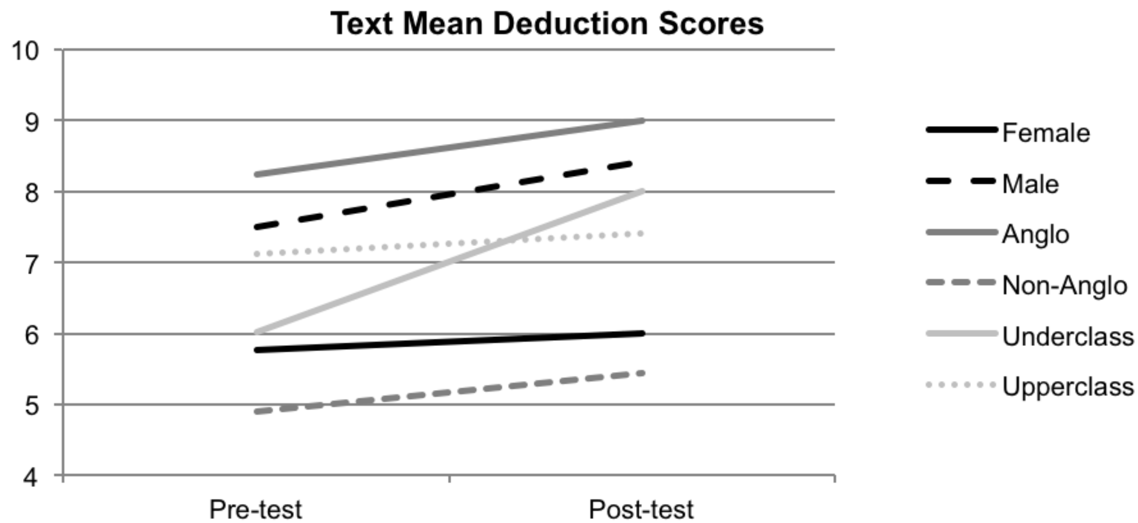


Figure 51: Mean plots for Induction Subscale by demographic characteristics.



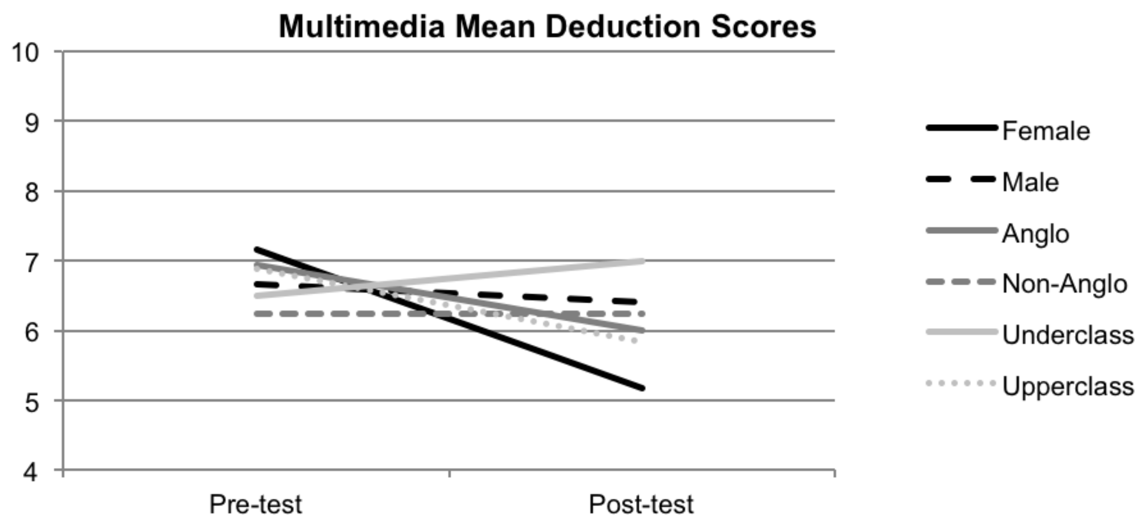


Figure 52: Mean plots for Deduction Subscale by demographic characteristics.

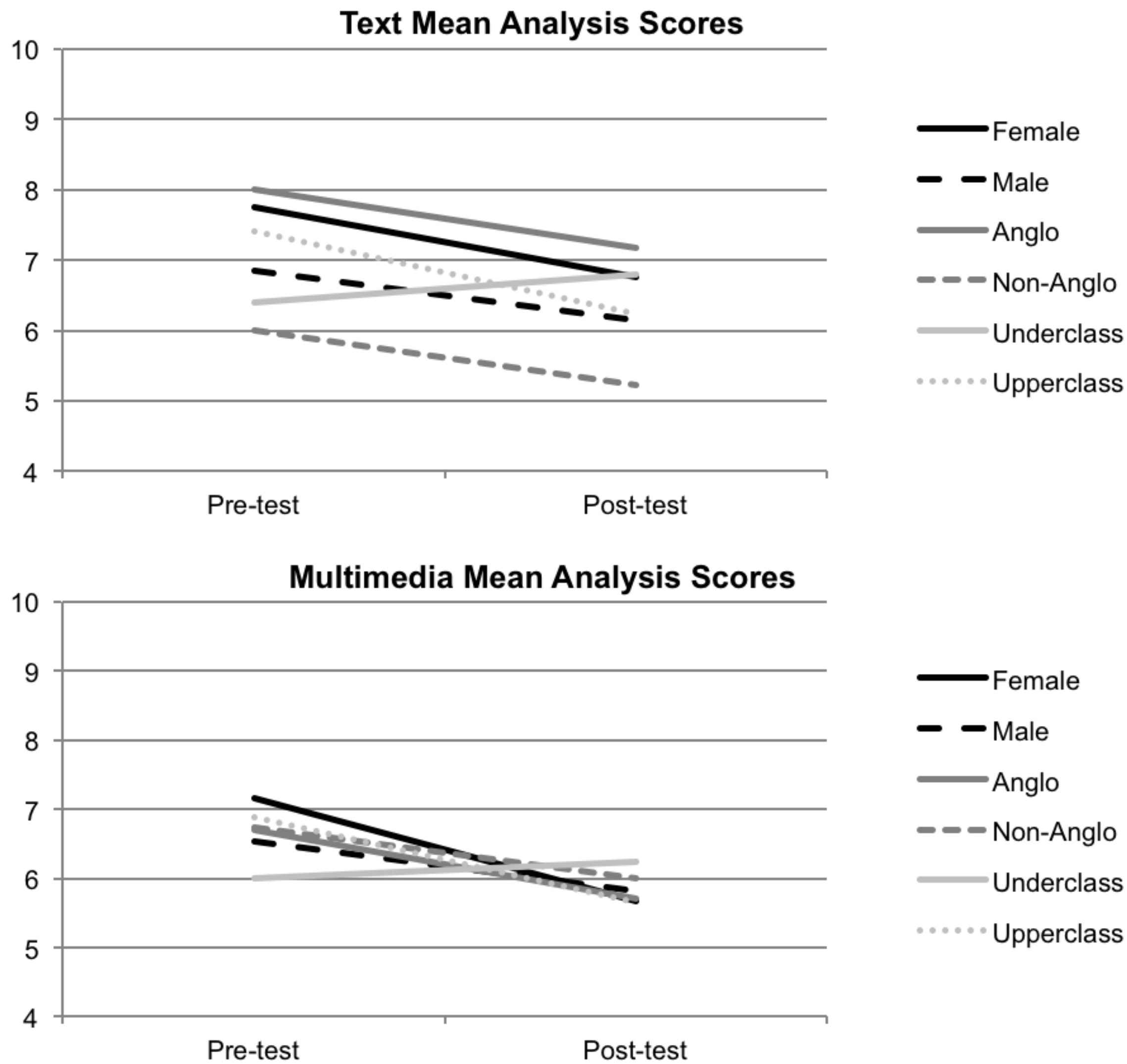


Figure 53: Mean plots for Analysis Subscale by demographic characteristics.

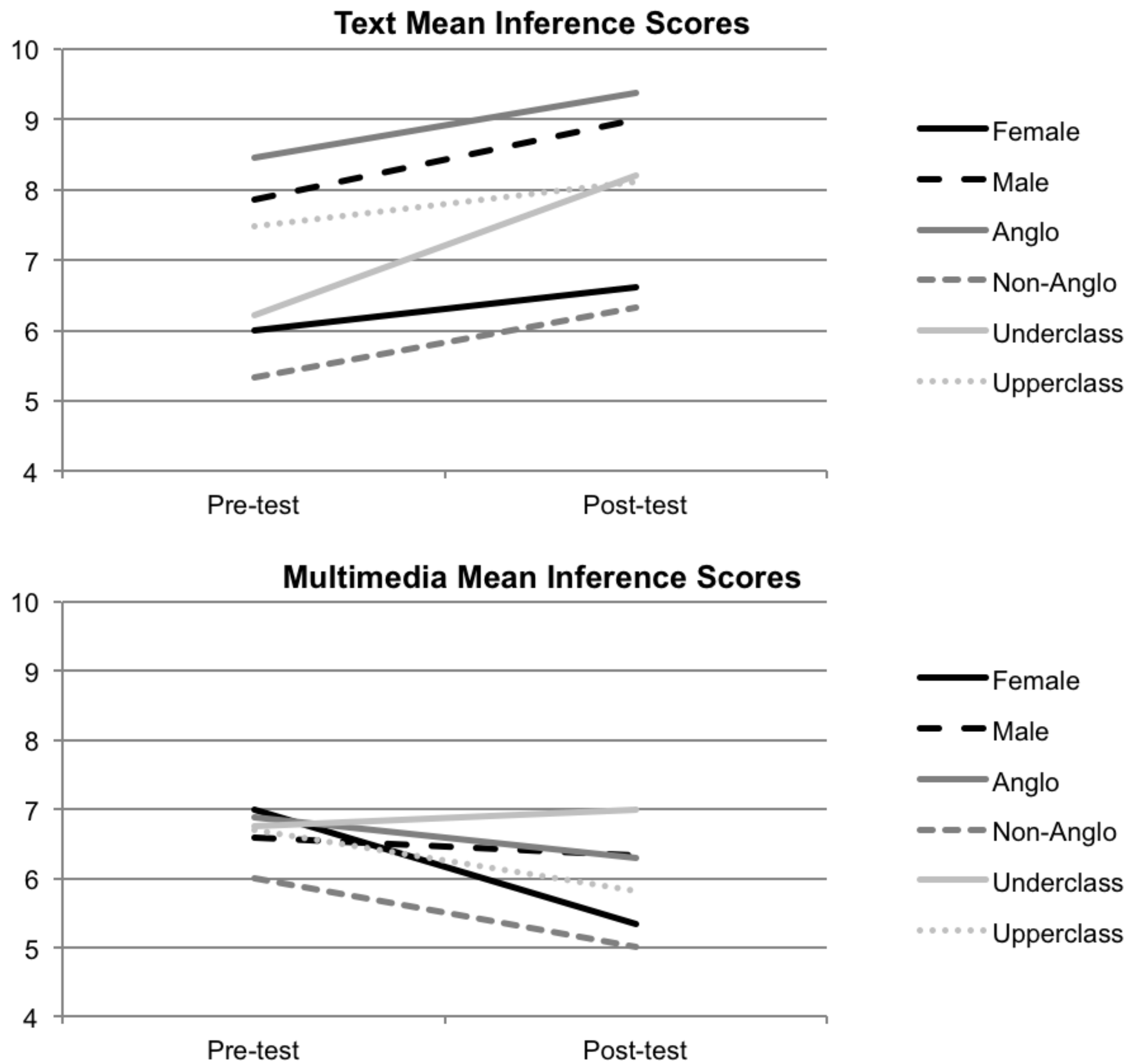


Figure 54: Mean plots for Inference Subscale by demographic characteristics.

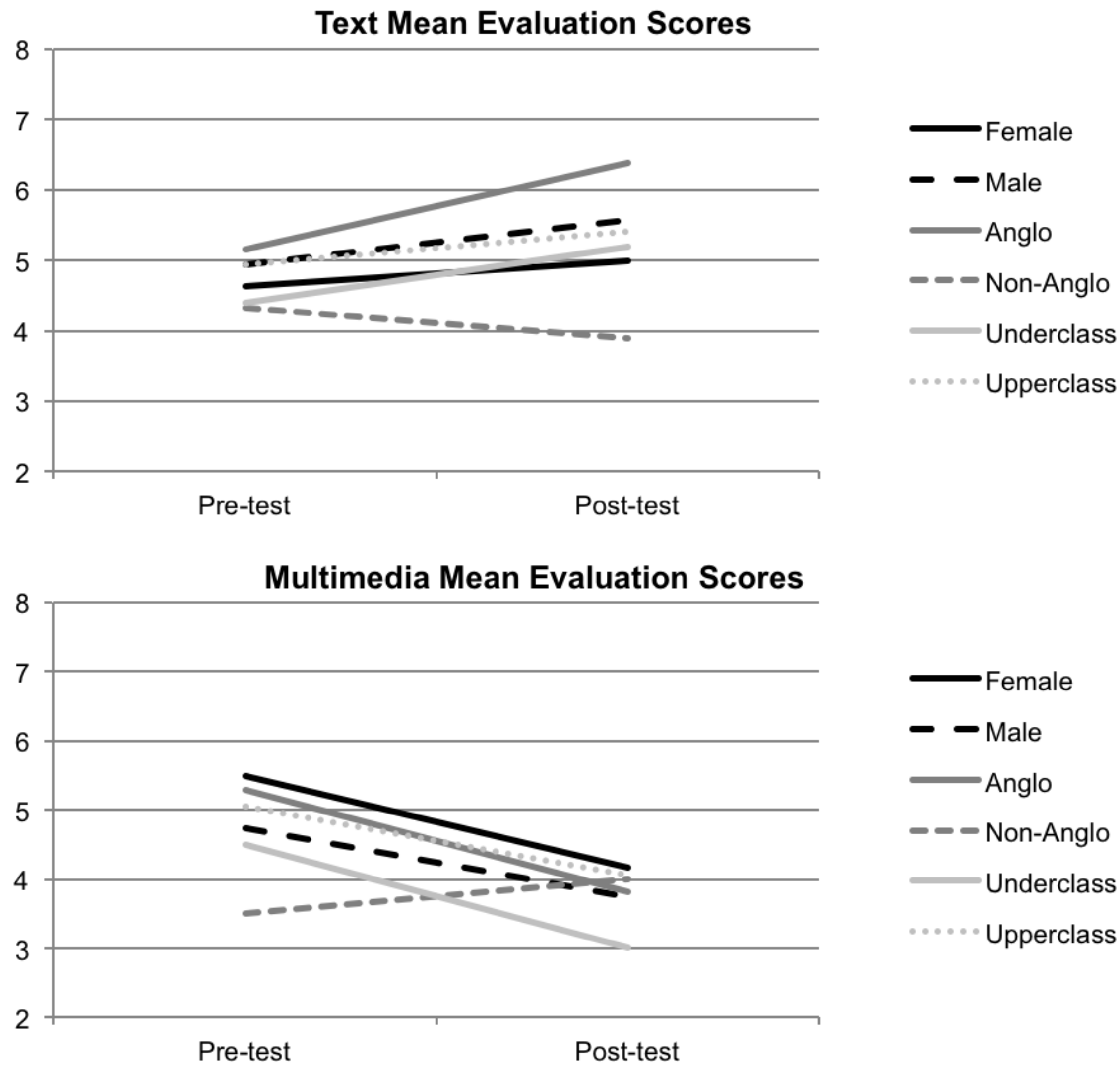


Figure 55: Mean plots for Evaluation Subscale by demographic characteristics.