Analyzing the effects of context-aware mobile design principles on student performance in undergraduate kinesiology courses

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ANALYZING THE EFFECTS OF CONTEXT-AWARE MOBILE DESIGN PRINCIPLES ON STUDENT PERFORMANCE IN UNDERGRADUATE KINESIOLOGY COURSES

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Educational Theory, Policy & Practice

by

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August 2013
DEDICATION

I would like to dedicate this work to my family for all their support during this process. Without your understanding, the accomplishment of this goal would not be possible.

To my lovely bride and mother of my four children, Jennifer Carpenter Seneca. Without your continued support and love, this life-long dream would remain just that, a dream. You have strived to maintain your sanity and a loving environment for our children during this long five-year process. Without you, I would be lost. Thank you.

To my children, Connor Matthew, Garrett Luke, Landon Nicholas and Isabella Grace, all of you are bright, happy and energetic children. You are the joy of my life. I will enjoy with great pride watching you grow into young adults. I cannot wait to see you set your own personal life goals and achieve them. Find what you enjoy and make that your career and be exceptional at it. Remember, act as you should, not as you want. Let this work be a testament to the ideal that with hard work and perseverance, no matter what obstacles will beset you in life, you can achieve your dreams.
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# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................ iv

LIST OF TABLES ................................................................................................................... vii

LIST OF FIGURES ................................................................................................................ viii

ABSTRACT ............................................................................................................................. ix

CHAPTER 1: INTRODUCTION ............................................................................................. 1
  Introduction to the Problem ................................................................................................. 3
  Statement of the Problem ................................................................................................... 4
  Purpose of the Study ........................................................................................................... 5
  Significance of the Study .................................................................................................... 5
  Justification of Study Limitations ..................................................................................... 6
  Definition of Terms ............................................................................................................ 8
  Summary ............................................................................................................................ 10

CHAPTER 2: REVIEW OF RELATED LITERATURE ............................................................. 11
  Technology Effects on Learning Context in a Modern World ........................................... 13
  Empirical Research on Context and Mobile Learning ....................................................... 19
  A Theoretical Foundation for Mobile Learning .................................................................. 28
  Community of Inquiry Framework for Mobile Learning .................................................. 30
  App Design Principles for a Mobile Learning Context .................................................... 34
  Summary ............................................................................................................................ 44

CHAPTER 3: RESEARCH METHODOLOGY ........................................................................ 46
  Research Questions ........................................................................................................... 46
  Research Design ................................................................................................................ 47
    Design Strengths .............................................................................................................. 49
    Design Limitations .......................................................................................................... 49
  Instrument .......................................................................................................................... 50
  Data Collection Procedures ............................................................................................... 52
  Data Analysis ..................................................................................................................... 56
  A Priori Statistical Power Analysis .................................................................................... 57
  Participants .......................................................................................................................... 57
  Post-hoc Statistical Power Analysis ................................................................................. 58
  Student Perception Survey ................................................................................................. 59
  Mobile App Instructional Design ....................................................................................... 61
  Mobile Learner Analytics ................................................................................................. 62
  Mobile App User-Interface Design .................................................................................... 64
  The Placebo App ............................................................................................................... 67
  Summary ............................................................................................................................ 68
CHAPTER 4: RESEARCH RESULTS .................................................................70
  Descriptive Characteristics of Participants ...........................................70
  Analysis of Pre/Post Testing Data ......................................................71
  Analysis of Participant App Usage Data .............................................72
  Qualitative Results from Student Reflections .......................................76
  Analysis of Student Survey Data .....................................................78
  Comparison of Treatment and Control Survey Data ..............................80
  Summary ............................................................................................81

CHAPTER 5: DISCUSSION AND CONCLUSIONS ..................................83
  Discussion of Findings .......................................................................83
  Conclusions ......................................................................................91
  Implications for Future Practice ......................................................92
  Implications for Future Research .....................................................93

REFERENCES .......................................................................................94

APPENDICES ......................................................................................105
  Appendix A - Informed Consent .......................................................105
  Appendix B - Our Lake of the Lake College IRB Approval ................106
  Appendix C - Louisiana State University IRB Approval .....................107
  Appendix D - Citi Collaborative Institutional Training ......................108
  Appendix E - National Institutes of Health Human Subjects Training ..110
  Appendix F - Pre/Post Test Instrument .............................................111
  Appendix G - Student Perception Survey ........................................116

VITA ...................................................................................................119
LIST OF TABLES

Table 3.1 – Breakdown of survey questions by theme ................................................................. 60

Table 4.1 – Education level of participants ............................................................................. 71

Table 4.2 – ANCOVA of Posttest Scores by Group Membership .............................................. 72

Table 4.3 – Instances of Access by Device Type ...................................................................... 74

Table 4.4 – Breakdown of survey questions for the Treatment Group ...................................... 79

Table 4.5 – Breakdown of survey questions for the Control Group .......................................... 80

Table 4.6 – Results of Mann-Whitney procedure to compare group results .............................. 81
LIST OF FIGURES

Figure 2.1 – The shift from broadcast to interactive learning ................................................. 16
Figure 2.2 – Balance between Mobile HCI and m-Learning ...................................................... 25
Figure 2.3 – Private inquiry model .......................................................................................... 33
Figure 3.1 - Sample tracking data from apps ......................................................................... 53
Figure 3.2 - Chunking of upper extremity ............................................................................. 61
Figure 3.3 - Chunking of shoulder girdle ............................................................................. 62
Figure 3.4 - Instant and cumulative feedback system ......................................................... 64
Figure 3.5 - Feedback navigation ......................................................................................... 65
Figure 3.6 - Vertical stack design of the learning apps ....................................................... 65
Figure 3.7 - Simple content access navigation .................................................................. 66
Figure 3.8 - Display of lecture material .............................................................................. 68
Figure 4.1 - Scatterplot for Time of Use and Posttest Score .............................................. 73
Figure 4.2 - Scatterplot of Content Access Events and Posttest Score ............................... 74
Figure 4.3 - Scatterplot of Self-Assessment Questions and Posttest Score ....................... 76
ABSTRACT

Learning occurs when content is accessed in a recursive process of awareness, exploration, reflection and resolution within one’s social context. With the rapid adoption of mobile technologies, mobile learning (m-Learning) researchers should incorporate aspects of mobile human-computer interaction research into the instructional design process. Specifically, the most visible, current definitions of and current research in m-Learning provide overviews of the learning theory informing mobility and focus on device characteristics, but do not focus on how people interact with mobile devices in their every day lives. The purpose of this convergent study was to determine what effect does the incorporation of research in mobile user context have on student learning. Six mobile design principles were extracted from literature and applied to mobile apps. Using a true experimental design, the study had 60 participants randomly assigned to treatment and control conditions. Participants in the treatment group received a series of apps designed according to the mobile design principles. The control group received a placebo app that mimicked content from the learning management system for their course. The results of the analysis of covariance procedure indicated the treatment group scored a significantly higher mean score than that of the control group. Further analysis of event tracking data indicated a statistically significant correlation between content access events and posttest scores. Students in the treatment group used their apps for less time, but had more content access events and subsequently higher posttest scores. The data suggests that m-Learning is something more than just an extension of what already exist. It is not just a luggable form of Web based learning. It’s more than a deep understanding of pedagogy or the delivery of course material to a mobile device. It requires the designer to understand instructional and software design, mobile human-computer usage patterns, and learning theory.
CHAPTER 1
INTRODUCTION

Learning occurs when content is accessed in a recursive process of awareness, exploration, reflection and resolution within one’s social context. In recent years, the adoption of smartphone technology in American society has been rapid and increasing. During a four year period from 2007 through 2011, smartphone ownership in America has gone from zero to 35% (Smith, 2011). Over the past 30 years, personal computers and smartphones have significantly changed how people assimilate and disseminate information (Tapscott, 1998). Tapscott (1998) asserts that access to the Internet and modern computer technologies are transforming a society once dominated by broadcast media into an information-on-demand, always connected one. He suggests that the rapid adoption of technology is changing how people consume information and our society is a culture that now operates in an interactive, highly mobile, information-on-demand world. Society's notions of communication and learning have been fundamentally transformed by the emergence of computer technology (Traxler, 2007). The implications for learning cannot be dismissed since learning cannot take place outside the societal context in which one lives (Merriam, Caffarella, & Baumgartner, 2007).

There can be little dispute that over the twenty-five years of the last century and the first decade of the current one, technology has had a significant influence over American society. In his 2001 paper, Prensky describes the effects of this rapid adoption of technology. He asserted these changes were never more evident than with his description of “digital natives” and “digital immigrants” (Prensky, 2001a). He characterized individuals raised under this new media as those who would possess a “native” technological touch. These digital natives are characterized as generations of individuals bombarded with a dizzying array of mobile and digital technologies, which in many cases, they adapt to flawlessly. Conversely, he defines a digital immigrant as one
that lacks the basic technology literacy necessary to function efficiently in this new society. He makes the argument that in an Internet driven, information-on-demand world, immigrants retain an “accent” of their pre-digital age socialization.

Evidence of Prensky and Tapscott’s assertions can be found in the increasing usage of the Internet. In 2010, 74.25% of the American population was Internet users, an increase from 31.12% at the beginning of the century ("Internet usage as percentage of population," 2010). This growth in Internet usage has coincided with the significant growth of access to cellular phone networks. It is estimated that 278.9 million Americans have a cellular phone subscription ("Mobile cellular subscriptions," 2010). A recent study found that 59% of all Americans access the Internet via wireless networks, a figure up 20% from 39% the previous year (Smith, 2010b). This increase in wireless access to the Internet is outpacing traditional hardwired systems.

Even more interesting is the fact that this new access medium seems to transcend traditional racial barriers with African-Americans and Latinos outpacing Caucasians in their use of handheld devices for data access (Smith, 2010b). Supporting Prensky’s assertion of a “digital divide” is more about understanding and usage of technology than traditional issues of race, age or socio-economic class (Prensky, 2001a). The shift in preference from a passive broadcast medium to one that is interactive, presents many challenges and opportunities to educators. But unlike the past, this new, highly mobile, information rich society requires instructional designers to rethink how information is presented. Smartphones, but more importantly the apps running on them, are increasingly becoming the preferred means that people use to access the Internet (Smith, 2010b). There is growing consensus that m-Learning needs to be considered within the context of the mobile smartphone (Laouris & Eteokleous, 2005). And, when one considers the
modern smartphone, nothing has had a larger impact on usage patterns than mobile apps (Purcell, Entner, & Henderson, 2010).

Consequently the question arises, what are apps? Apps are self-contained, mini-applications designed to run on a mobile device. In a report, The Rise of the Apps Culture, Pew Research estimates that nearly 35% of all Americans have some form of apps installed on their cell phone (Purcell et al., 2010). He also states that of those who download apps, 57% use those apps on a daily basis. The modern smartphone app gives the user the best of two worlds; a self-contained application that can have large volumes of data existing within its borders and the ability to use anywhere, anytime connectivity. This provides a user with a context of flexibility, intuitive interfaces and quick access to information (Elias, 2011). The average user today spends 9% more time using apps than Web-based consumption (Khan, 2011). Therefore, mobile Web browsers are becoming the second choice of users on their smartphones. Consider, the average person has 108 apps installed on their smartphone, but only uses mobile apps for an average of 84 minutes a day (Hodgkins, 2011). As Hodgkins (2011) points out, this presents a small window of opportunity for instruction to be delivered in a relevant and meaningful way. Given this requirement, consideration of mobile user context and user interface design should become a fundamental aspect of any m-Learning design.

Introduction to the Problem

m-Learning is a new field of educational research with its own set of pedagogical concerns (Botha, Greunen, & Herselman, 2010; Parsons & Ryu, 2006; Traxler, 2007; Traxler & Kukulska-Hulme, 2005). m-Learning has been defined as any educational provision where the sole or dominant technologies are handheld (Traxler, 2005). All of the m-learning descriptions indicate that good m-learning is defined via the device’s characteristics or learning theory.
However, a review of the literature reveals there is no firm consensus amongst m-Learning researchers of what constitutes a successful m-Learning environment (Najmi & Lee, 2009; Traxler, 2005, 2007).

Much of what we know about m-Learning comes primarily from the domain of education; and educational researchers dominate this new field. The various definitions of m-Learning presents difficulties for conducting research and although these mobile technologies have been incorporated into the field of education, there has only been cursory exploration of how mobile human-computer interactions effect student learning (Laouris & Eteokleous, 2005).

People are no longer using the personal computer exclusively to surf the Internet to find their needed information. They are increasingly turning to mobile apps, downloaded for very specific purposes, and using these apps for information acquisition (Elias, 2011). The world of today, specifically in the realms of m-Learning, requires the instructional designer have a deep knowledge of both learning theory and human-computer interactions. Designing learning activities, given the different characteristics of learners and devices, presents significant challenges for educators (Botha et al., 2010). How people interact with mobile devices is as important as the content or learning theory, but much of what is known about m-Learning focuses on pedagogy and not user-device interactions (Botha et al., 2010). If an interface design does not fit the context of a usage pattern, then the mobile activity could be a hindrance to learning.

Statement of the Problem

Prensky and Tapscott describe a clash between an information-on-demand society and a broadcast society, where traditional instructional design methods must now accommodate how and where a digital native uses a device (Prensky, 2001a; Tapscott, 1998; Traxler, 2010). The
usage patterns for mobile devices are significantly different than that of a personal computer (Dean, 2011). Although the future of mobile devices seems secure, how they should be used in an educational setting continues to be a subject of contention (Parsons & Ryu, 2006; Traxler, 2007). Most of the definitions for m-Learning attempt to define the phenomenon, but do not offer any principles to guide the design of a learning environment.

Specifically, the most visible, current definitions of and current research in m-Learning provide overviews of the learning theory informing mobility and focus on device characteristics, but do not focus on how people interact with mobile devices in learning environments (Parsons & Ryu, 2006; Traxler, 2007). Mobile human-computer interaction (Mobile HCI), research focuses on how people interact with mobile devices in their everyday life. Studying those usage patterns in learning environments is an important next step.

Purpose of the Study

The purpose of this convergent design was to determine what effect does the incorporation of research in mobile user context have on student learning. The rational for using both quantitative and qualitative data was to develop a deeper analysis of both gain score and participant perception. Insight into mobile user patterns was gained through connecting the quantitative data to the qualitative reflective composition.

Significance of the Study

The field of m-Learning is new and emerging. The significance of this study is based on the idea of leveraging both the field of human-computer interaction and learning theory. Mobile HCI research is primarily focused on how humans interface with mobile devices (Vavoula, Pachler, & Kukulska-Hume, 2009; Winters & Price, 2005). Although it is unlikely that any research will ever catch up with changing technology, it is possible to determine principles of
design for mobile devices that transcend individual devices. This study is an attempt to fill the voids that exist in the current research and to help establish a foundation for future research in the area of m-Learning and Mobile HCI.

Reviewing the literature, one can find many successes using m-Learning techniques to improve student learning, most significantly in the area of vocabulary acquisition (Basoglu & Akdemir, 2010; Chen & Li, 2010; Stockwell, 2010; Thornton & Houser, 2005; Wong & Looi, 2010; Zhang, Song, & Burston, 2011). These studies concentrate significantly on just the usage of mobility, but have yet to understand the significance of software design within that space (Dean, 2011; Smith, 2010b, 2011). This study will explore and present information about those usage patterns and models.

This study will introduce one set of mobile design principles. Principles informed by research in the areas of mobile usage patterns, human-computer interaction design and learning theory. These principles take advantage of current research into the usage patterns and interface designs for mobile users. This study will be significant insomuch as it will broaden the existing research in the area of Mobile HCI within the context of m-Learning. Consequently, these principles are not intended to define the “only” set of design principles for m-Learning. Finally, this study will suggest future areas of research within the area of m-Learning and Mobile HCI.

Justification of Study Limitations

The study proposed in this document is one element in a line-of-inquiry to evaluate the effects of mobile human-computer interactions on learning. It is intended to be a follow-up study as a “proof-of-concept” and to be the next step in a line of inquiry. This next step is based off the concept of a National Science Foundation’s (NSF) Proof-of Concept Grant expanding on a previously conducted pilot study. This proof-of concept study was designed to address and
improve on the limitation of the original pilot. To improve on the pilot, it was decided to use
three sections of students in a true experimental design and develop a placebo app that would
present the same content to the control group. The placebo app was designed to reduce the
amount of cross contamination between the treatment and control groups given that it is
impossible to completely segregate the two. For the proof-of-concept study, this was sufficient to
receive preliminary results before moving to a much larger study.

In the summer of 2011, the author conducted a pilot study to investigate the mobile
design principles. The pilot findings were presented at the *Ubiquitous Learning: An
International Conference*, Berkeley, California in December of 2011. The goals of the pilot study
were two-fold. The first goal was to determine if there were any problems with the mobile app
implementation and data capturing mechanism. The second was to determine if there would be
any effects on student learning in a pilot scenario. During the course of the pilot study, using
IBM’s RUP (Aked, 2003), rational unified process, method, essential software design elements
were married to existing research in the area of mobile learning theory and usage patterns.
Specifically, user-case flows were married to existing usage pattern research and constructivist
learning theory. During this process a number of software bugs were discovered and addressed.
In addition, the basic infrastructure of the software’s data capture mechanism was tested and
deemed working.

During the pilot study, access to mobile devices was limited. This required the researcher
to seek volunteers instead of being able to assign participants to groups. Enough subjects were
obtained to make a comparison between the control and treatment groups. Overall, learners
performed better on the posttest after all forms of instruction were applied. The pretest mean for
all learners was 8.67 (SD = 2.65); the posttest mean recorded was 18.57 (SD = 2.75), a mean
difference of 9.96. An independent-samples t-test was conducted to compare the app group to the non-app group on their gain scores. There was a significant difference in the gain scores for the app group (M = 11.31, SD = 3.12) over the non-app group (M = 7.63, SD = 3.93); t(19) = -2.383, p = .024) (Seneca & Aime, 2011). The pilot results suggested using the mobile design principles may have some effect on student learning; but given the limitations of sampling and device availability, no generalizations can be made from that study.

There were many limitations in the pilot study. This proof-of-concept study is intended to address those weaknesses. Additionally, the study will make the case for the consideration of Mobile HCI issues in the m-Learning space.

Definition of Terms

**Mobile Learning (m-Learning)** – learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies (O'Malley et al., 2003, p. 6). m-Learning is ubiquitous in its nature.

**HCI (Human-Computer Interaction)** – is a field that draws on experts from various fields to enhance a computer program for ease of use by a human.

**Mobile HCI (Mobile Human-Computer Interaction)** – is an emerging field that draws on experts from various fields to enhance how a computer program works on a mobile device for humans.

**UI** – this term is an abbreviation of user interface.

**PDA** – this term is an abbreviation for a personal digital assistant.

**Multi-touch interface** – introduced by Apple Corporation in 2007, this interface is one that primarily uses human touch to initiate events on a mobile device instead of some type of stylus or keypad.
**Context** – this is the learner’s patterns-of-usage in an external environment.

**iOS** – this is a mobile operating system developed by the Apple corporation. It is the base software that runs modern Apple smartphone and tablet technology.

**Chunk** - the smallest unit of information that the subject matter expert believed would be meaningful to the student (Cennamo & Kalk, 2005).

**Relational Database Management System (RDBMS)** – this is a database management system based on a relational model used to store data.

**Meta Tag** – this is a category tag used to track what a self-assessment question is assessing.

**PHP** – is a widely used, server side scripting language for Website development.

**Extensible Markup Language (XML)** - is a language used to encode data in a format that is readable by both humans and computers.

**Hypertext Markup Language (HTML)** – is the main mark-up language for creating Webpages that is displayed via a Web browser.

**Smartphone** – is a mobile phone built on a mobile operating system with more advanced capabilities and connectivity than a regular cellular phone.

**Apps** - are self-contained mini-applications designed to run on a mobile device.

**Web apps** – are self-contained mini-applications that require the Internet and a mobile browser to operate.

**Mini-Tablet** – is a one-piece computer that is managed via a multi-touch sensitive display. The device screen size ranges from the size of a modern smartphone up to 7-inch display.

**Tablet** – is a one-piece computer that is managed via a multi-touch sensitive display. The device screen size ranges from 8-inch to 11-inch.
Summary

This study reviewed relevant literature in the areas of mobile learning and mobile human-computer interactions. Building on previous research, it attempted to define and test a set of mobile learning design principles informed by these two distinct academic research fields. This study reviews one set of mobile design principles. It seems an important first step to address issues of human-computer interactions for field of m-Learning.
CHAPTER 2
REVIEW OF RELATED LITERATURE

Looking at a typical learning situation today, a top down approach is predominantly demonstrated both in practical instruction, classroom setup and the technology employed. This approach is an example of broadcast education where the student is nothing more than the passive receiver of information, but today’s student requires a different approach to learning. Recognizing these changes, today’s educators have begun to develop online and blended course offerings. The primary alternative means of delivering instruction is through Web-based systems that are primarily accessed via personal computers. The current growth rates of online courses, 10%, far exceed that of traditional lecture courses of 2% (Allen & Seaman, 2011). This trend of moving from face-to-face instruction to online instruction has lagged slightly behind the adoption rates of personal computers. As technology usage patterns have shifted, educators have compensated by attempting to adjust old learning paradigms to new media.

Today’s incarnation of education has one advantage; humans are no longer constrained by the boundary of their physical location. In the past, social networks operated only within the confines of a limited physical location that was primarily face-to-face with spoken language. With the invention of the World Wide Web, humans are no longer constrained by the bounds of physical location. Increasingly people in our society are turning to technology as the vehicle for social connections across vast distances. This new ability has transformed our society and education must follow.

Technology is the engine that drives modern society; and at the heart of that engine is seemingly infinite information and rich media. Based on this fact, the importance of using rich media in instruction cannot be understated. Increasingly, rich media will be needed by educators to simply engage the student. During the past twenty years a field of study, m-Learning, has
developed as the progression from the personal digital assistant (PDA) to a cellular phone combination that merged into the modern smartphone. In parallel and independently, the academic field of human-computer interactions has developed as society has transitioned from broadcast to interactive media and from television to personal computer to mobile technology.

How people use mobile technology within a learning context should an important element at the heart of m-Learning. But, much of the work in m-Learning does not include accommodations for the role of human-computer interaction or user context. Recognizing that the duties of the instructional designer today are similar to the software architect begs the question should human-computer interactions be a consideration of instructional design? New research in the area of human-computer interactions is demonstrating how people use these new tools, but it is up to teachers to add academic value to the tools students already know how to use (Hlodan, 2010).

Understanding theory that drives learning in mobile spaces is of paramount importance, but studies that take that singular approach will be incomplete without understanding how and where individuals access learning materials. The democratization of app development and distribution networks has resulted in an explosion of small, compact computer programs available for just about any purpose. Increasingly, these apps are being used for education. The smartphone, as well as the mobile app, have ushered in a new paradigm of technology usage.

This literature review will discuss the shifting tides of human usage patterns from personal computer to mobile. It will introduce the reader to the concept of context-awareness in mobile application design and what learning context looks like in mobile spaces. It will describe the empirical evidence of m-Learning and Mobile HCI. It will discuss mobile user context and define a set of design principles for the development of mobile learning apps.
Technology Effects on Learning Context in a Modern World

So what do shifting technology usage patterns mean for learning? The debate within the field of instructional technology is what effect, if any, does the use of technology and media have on learning. Richard Clark (1983) synthesized a firm hypothesis about technology’s effects on instruction. He asserted that consistent evidence was found to support the generalization that there is no learning benefit to be gained from using specific medium. He also suggested that perceived time savings and novelty learning were negligible with no evidence there was a lasting effect on learning. His assertion was counter-intuitive to the position of most in the instructional technology field. Clark’s assertion is that technology merely acts as a vehicle for instruction and has no direct influence over student achievement.

In response to Clark’s work, Kozma (1994) delivered a firm counter-point in his investigation of technology and media. Looking at symbol systems, books and television, he asserted learning that uses these media was not completely independent of the media itself. Specifically, he cited evidence that indicated the processing capability of computers could influence the mental representations and cognitive processes of learners. The central issue where both Clark and Kozma agree is that there was no significant evidence that media or its attributes influence learning (R. Clark, 1994; Kozma, 1991). Clark points to significant negative evidence to back his claim. He states positive evidence is accepted easily but negative evidence is suspect and believed to be flawed. Essentially, Clark asserts that the lack of evidence pointing to a conclusive technological effect on learning is proof that it will never have an effect (R. Clark, 1994). Kozma counters that absence of proof is not proof of absence (Kozma, 1994).

The significance of this debate cannot be understated. Even today, many educators are not convinced of the need to use technology to engage learning. Many point to Clark’s work as
evidence for this assertion. Subscribing to the belief that technology has no effect on learning allows for practitioners to focus solely on areas of instructional design and learning theory. Interestingly, the Clark/Kozma debate took place during the rise of the PC revolution, but before there were any significant societal changes as a result of the Internet. Prior to 1994, the dominant form of media in the United States was still television. It is important to note that by its nature, television is an authoritative, broadcast medium with the receiver taking a very passive role as consumer of information. Like television, many face-to-face lecture classrooms provide an authoritative, broadcast approach to delivery of information with an emphasis on instruction, not learning. Much of Clark’s evidence is based on the investigation of passive media being consumed by passive learners in this authoritative instructional model (Kozma, 1994).

A significant shift in media usage began to take root in the mid-1980’s. In the year 1983, personal computer sales in the United States rose from 1.6 million purchased annually in 1981 to 6 million dollars annually (Rosenberg, 1997). Just a decade later annual sales of personal computers were approximately 40 million (Rosenberg, 1997). Generations of people began to explore a world of interactive media and control, but the personal computer alone was not enough of a catalyst to significantly change society. This new media type did not significantly penetrate society until the explosion of the World Wide Web in the mid 1990’s.

The Internet is a phenomenon that has allowed individuals to transcend traditional barriers of location and time. As a society, our success has been defined by our ability to pool talent, knowledge and resources within social networks (Newark-French, 2012). Our entire understanding of life and the universe comes from our ability to gather and develop concepts within a social “arena-of-ideas.” Traditionally, those social networks were limited by physical distance; but with today’s social networks, human experience is no longer limited to physical
location. Broadcast media once dominated our society, but today’s culture now operates in an interactive, information-on-demand world (Tapscott, 1998). Has changes in society and its preferred media usage relegated Clark’s research to a bygone era and a society that no longer exist; one dominated by broadcast learners obtaining their information via passive means (R. Clark, 1994; R. E. Clark, 1983)?

In 1994, Kozma reframed the debate to concentrate on how technology effected student achievement in terms of method. He focused on the cognitive and social processes by which knowledge is constructed and facilitated via technology. In essence, understanding that the relationship between technology and learning is an interaction between cognitive process and the characteristics of the environment; its context (Kozma, 1994). His point was that although there was no evidence, at that time, that technology influenced learning, that does not mean there will never be evidence of technology effecting learning; a firm counter-point to Clark’s assertion. His point was that at some time in the future, technology saturation will reach such a tipping point that evidence of technological effects on learning would be found.

In the span of just 18 years since Clark and Kozma had their debate, the rapid adoption of technology in American society has caused a paradigm shift in how people obtain information. In his book, Growing up Digital: The Rise of the Net Generation, Tapscott (1998) asserted that today’s generation of individuals differs from proceeding generations in that their preferred form of media usage is interactive rather than broadcast. He asserted that the phenomenon of the Internet has transformed the basic mechanism of how people obtain and assimilate information. This shift from physical to electronic media and from broadcast to interactive learning has taken place in the span of little more than two decades. To better illustrate the point, Figure 2.1 defines the characteristics of this transition.
He recognizes eight characteristic shifts to interactive learning and the language describing those shifts. He argues that new generations of learners are different in they have transitioned (1) from linear, sequential/serial to hypermedia learning (2) from instruction to construction and discovery (3) from teacher-centered to learner-centered education (4) from absorbing material to learning how to navigate and how to learn (5) from school to lifelong learning (6) from one-size-fits-all to customized learning (7) from learning as torture to learning as fun and (8) from the teacher as transmitter to the teacher as facilitator (Tapscott, 1998, pp. 142-147). What Tapscott is advocating is a move away from instructional design science to learning science. He was pointing to a time when traditional instructional techniques would not suffice for generations of individuals who did not learn in a broadcast fashion. He was calling for a reevaluation of instruction, not just with technology, but a fundamental change from a more rigid educational context focused on instruction to one that was focused on learning.

Tapscott’s work defines not only technological effects on society; he also recognizes that the context for learning has changed. In this new learning context, how and where the technology is used could have a profound result on student learning. This new context is one of discovery-
based learning, an environment where information is available anywhere at any time and on a multitude of devices (Tapscott, 1998). He is pointing to the idea where the abundance of information is such that students are able to tailor or customize their learning experience to their individual need. He describes a society where tools become highly specialized to deliver small slivers of information on-demand.

Going further, Prensky (2001a) asserted that students had so radically changed that our current educational system was not sufficient to support their style of learning. He was pointing to individuals that think and process information differently. In his follow-up to the original paper, *Digital Natives, Digital Immigrants*, Prensky defines this form of information access by stating that

Children raised with the computer think differently from the rest of us. They develop hypertext minds. They leap around. It’s as though their cognitive structures were parallel, not sequential. Linear thought processes that dominate educational systems now can actually retard learning for brains developed through game and Web-surfing processes on the computer.

Some have surmised that teenagers use different parts of their brain and think in different ways than adults when at the computer. We now know that it goes even further—they brains are almost certainly physiologically different. But these differences, most observers agree, are less a matter of kind than a difference of degree. For example as a result of repeated experiences, particular brain areas are larger and more highly developed, and others are less so (Prensky, 2001b, p. 4).

Prensky is asserting that these changes are not superficial; they go to the very physiology of the learners’ brain. His idea is that over their lifetime, today’s students have been exposed to computer games and interactive media. This exposure leads to thinking skills that are inductive, discovery based, including multidimensional visual-spatial skills and mental maps. Given the differences of learners today, one cannot take broadcast content and deliver it on technological devices assuming that is enough to engage learning. New user contexts requires that information be structured into slivers and consumed by the student incrementally (Bowen, 2012). To harness
today’s students’ innate ability of discovery learning would require an interface design that takes into account a new user context. How new generations use technology for self-regulated, discovery learning is not just a preference, it is how their brains work (Prensky, 2001a, 2001b; Tapscott, 1998).

Given some of these changes in how students learn, subsequently, it will require fundamental changes in the practitioner’s techniques. With this new learning context, are what instructional designers doing sufficient? Or is there a new facet of design that must be taken into account when deciding on how to chunk and present learning material? Where does the instructional design end and software architecture begin? The similarities between the fields are striking. As stated by Lang:

Through defining and outlining the roles of the software architect and the instructional designer, it should be clear that these roles share strikingly similar characteristics and mutual responsibilities. The software architect might perform a requirements gathering session while an instructional designer performs a needs analysis, but these are, in reality, the same activities in which both are seeking to understand what the needs are and the scope of the problem to be solved is. Just as architects seek to test the validity of the end-product through ongoing unit testing and final system integration testing prior to shipping, the instructional designer performs ongoing formative evaluation with final summative evaluation to produce the right instructional end-product. Where the software architect must have a solid understanding of the client's and end-user's needs and what makes for usable software, the instructional designer must understand the client's and learner's needs and what makes for an effective learning tool. The software architect must contrive of a general roadmap/blueprint using sound architecting principles to design, envision and specify the overarching design elements of the software just as the instructional designer must come up with an approach to learning that is consistently incorporated and follows sound principles of learning theory and instructional design concepts and develop the blueprint to get there (Lang, 2005, pp. 11-12).

But despite these similarities, the field of instructional design has developed separately from other fields. Lang (2005) states that software architects and instructional designers belong to two distinct fields of research describing their roles, responsibilities and practices. With very little exception do the instructional designers look to other fields for aspects of software or computer-based design. It is his contention that instructional design alone is not sufficient because a large
component of how this new generation of individuals learn is based solely on their context. An instructional designer working on learning techniques in today’s society needs to have a fundamental understanding of the user’s context and how that person will interface with the technology to obtain information. It may be beneficial for instructional designers to look to the field of human-computer interaction for interfaces designed to fit within a modern user context.

Empirical Research on Context and Mobile Learning

The term mobile device is used to represent an entire array of technology devices from laptop computers, to cell phones, to smartphones (Sahilu, Ahmad, & Haron, 2011). This diversity of technical devices makes it difficult to design interfaces for mobile applications and define the exact context in which they are used. For instance, a laptop is a mobile computing device, but its purpose and usability profile is vastly different than a smartphone. To better define the type of devices for mobile learning, Traxler pointed to narrowing design for “hand-held” devices (Traxler, 2005); implying technology that can be held in one’s hand is the predominate technology for mobile learning. Although some of the traditional usability structures may be sufficient for m-Learning, not all will work. Ryan and Gonsalves (2005) recommend designs that would limit the amount of data input, control what is being displayed on the screen, and the use of context should be strictly from a mobile application perspective. It is their assertion that context models for personal computers differ significantly from that of mobile devices. Given this, instructional and interface design should be adjusted accordingly.

Exploiting personal digital assistants, smartphones, and ultra mobile computers, a growing body of evidence supports the assertion that students are learning using mobile devices (Basoglu & Akdemir, 2010; Chen & Li, 2010; Stockwell, 2010; Thornton & Houser, 2005; Wong & Looi, 2010; Zhang et al., 2011). PDAs have been used to enhance vocabulary learning
of English in Turkey and China (Basoglu & Akdemir, 2010). In the health professions, mobile devices are helping to educate patients and allow physicians to access vital medical databases (Ranson, Boothby, Mazmanian, & Alvanzo, 2007). Also, mobile devices are being used to teach mathematics in secondary schools in South Africa (Roberts & Vanska, 2011) and for geo-tagging photographs in student field work in geography (Welsh, France, Whalley, & Park, 2012). But, in spite of all these successes, a review of the literature reveals there is no firm consensus amongst researchers on what constitutes a successful m-Learning environment (Laouris & Eteokleous, 2005; Najmi & Lee, 2009; Traxler, 2007) and very few studies connect to research in the area of Mobile HCI context (Botha et al., 2010).

To understand what m-Learning or mobile learning is or should be, one must understand how it is currently constituted. Today’s educational environment can best be described as one where competing visions of m-Learning dominate. There are numerous and varied views of m-Learning. In its broadest sense, m-Learning is when the learner takes advantage of the learning opportunities offered by mobile technologies (O'Malley et al., 2003). A more techno-centric view of m-Learning is using a mobile device, such as a smartphone, to deliver instructional content (Parsons & Ryu, 2006), any instruction that occurs through a mobile device (Trifonova, 2003), or the processes of using mobile devices to access and study learning materials (Ally, 2009). Sharples (2006) defines the following perspectives on m-Learning:

- **Technocentric.** This is the predominate view in the literature defining mobile learning in terms of the device characteristics such as an iPod touch or smartphone;
- **Relationship to e-learning.** This perspective defines m-Learning as an extension of e-Learning;
• **Augmenting formal education.** Formal education is often characterized as face-to-face instruction and m-Learning is often classified as an augmentation or extension of that environment;

• **Learner-centered.** A strong body of work in the literature has begun to recognize that m-Learning may not be best defined by the device characteristics, but from the learner’s perspective.

Sharples made significant progress in focusing in on the concept of m-Learning; but it could be stated that a good learning environment could be techno-centric or learner centric. He makes the point that the reasons students may want to use the mobile environment is because 1) they have control, 2) they have ownership of the experience, 3) its fun for the student and 4) its how they naturally communicate.

Current definitions of m-Learning provide an overview of the learning theory informing mobility and focus on device characteristics (Parsons & Ryu, 2006; Traxler, 2007). Traxler (2005) defined m-Learning as any educational provision where the sole or dominant technologies are handheld or palmtop devices. In the same year, Traxler and Kukulska-Hume (2005) also defined m-Learning as a personal, unobtrusive anywhere, anytime way to learn. In a later review of mobile learning, Traxler (2007) asserted the various definitions of mobile learning were constraining, too focused on technology and tied to current technological innovations. But more importantly, he suggests that the definitions should be reconsidered away from techno-centric definitions. He recognized that mobile technology is changing society, creating new forms of knowledge and new ways to access that knowledge.

The changing nature of using mobile devices in society does force one to look at how those devices are used in the learning experience, the user context. Traxler (2007) calls for an
exploration of other definitions of m-Learning that focus on the learner’s experience in this new society. His observations are astute in that he recognizes the difference between m-Learning, e-Learning, and traditional broadcast instruction, may be a combination of learner usage, instructional design, situated cognition and device usage. It’s his assertion that the phenomenon of mobile education or mobile learning is still an emerging field; hence the ambiguity is still to be expected.

Muddying the waters for m-Learning is that much of the literature attempts to define the phenomenon in terms of what already exist, e-Learning (Male & Pattinson, 2011). e-Learning is defined as Web-based learning, online learning, distributed learning, computer-assisted instruction, or Internet-based learning that have traditionally used computer assisted instruction (Jethro, Grace, & Thomas, 2012). Specifically, Jethro et al. (2012) stated that e-Learning is mainly a provision where information is consumed on personal computers accessing the World Wide Web. By their definition of e-Learning, m-Learning being a subset of the phenomenon only works if one accepts the most basic definition for computerized devices.

Is mobile learning merely a ‘luggable’ form of e-Learning (Traxler, 2010)? Many authors view mobile learning as simply a natural evolution of e-Learning but there are distinct differences (Laouris & Eteokleous, 2005). Laouris and Eteokleous (2005) point to a shift in terminology to describe m-Learning that is distinctly different than that of e-Learning. It is their assertion that the terminology used to describe the two phenomenon are basically different. Terms like computer versus mobile, bandwidth versus 3G, and distance learning versus situated learning, all point to natural differences in the two phenomenon. The most distinct difference between the two phenomenon being pedagogical in nature; text and graphic based lecture style.
instruction for e-Learning versus more voice, graphics and animation in the field learning for m-learning.

In 2010, Traxler points to the broader definitions of distance education to reframe the debate on m-Learning. He noted there were many difficulties in conceptualizing mobile learning. He suggests that this form of learning does have a quasi-permanent separation of teacher and learner, like e-Learning, with organizational factors from the instructor in the planning and preparation of learning materials. He noted a use of technological medium to connect student and teacher, and the possibility of meetings between participants for both socialization and didactic reasons. It is his suggestion that reviewing definitions of distance learning there is great overlap between it and mobile learning, but in some respects m-Learning is broader. The main difference being that distance education encompasses a more explicit and larger blend of technologies.

Traxler (2010) points to the issue of various learning theory that can be used in m-Learning situations, but adeptly defines the scope of the technologies that can be used. Although these definition of m-Learning are ambiguous, its Traxler’s point that over the past decade m-Learning has demonstrated success. He asserted the following categorization of examples,

The mobile learning community has demonstrated, though not proved in any sense, across a wide variety of contexts, that it can:
- Enhance, extend and enrich the concept and activity of learning itself, beyond earlier conceptions of learning. This includes:
  - contingent learning, where learners can react and respond to their environment and their changing experiences, for example data collection in real-time on geography field trips;
  - situated learning, where learning takes place in surroundings that make learning meaningful, for example learning about religions whilst visiting temples, mosques, churches and synagogues;
  - authentic learning, where meaningful learning tasks are related to immediate learning goals, for example basic literacy or numeracy in work-based learning on the job;
  - context aware learning, where learning is informed by the history, surroundings and environment of the learner, for example learning in museums, game parks or heritage sights;
- augmented reality mobile learning, where learning builds on local context supplemented by an audio or video overlay;
- personalized learning, where learning is customized for the preferences, history and abilities of individual learners or groups of learners

- Take learning to individuals, communities and countries that were previously too remote or distant, for example culturally, economically, socially or geographically, for other educational interventions to reach. This category has included addressing:
  - geographical or spatial distance, for example reaching into deeply rural areas;
  - sparsity, connecting thinly spread and perhaps nomadic learners to create viable communities of learners, or exploiting learning niches and perhaps the 'long tail';
  - infrastructural or technical barriers, for example, areas in sub Saharan Africa, supporting those communities lacking mains electricity, secure clean buildings or land-line connectivity;
  - social exclusion, for example reaching students unfamiliar with and lacking confidence in formal learning and its institutions, for example the homeless, gypsies, marginal groups, those ‘not-in-education, employment-or-training’ (NEETs);
  - physiological or cognitive different, and distant, for example supporting learning opportunities for the hearing impaired or people with dyslexia privacy and connection, for example helping secluded women and girls in some cultures to access informal and social learning (Traxler, 2010, pp. 131-132).

This mix of pedagogical and geographical successes can be attributed to the ubiquitous and portable nature of the technologies being used. It points to a mixture of technology and learning theory necessary for any successful m-Learning experience. Although the concept of m-Learning is not solely driven by the characteristics of the technology, as he points out, those items are essential to the environment and define the context of use. Indirectly, Traxler is pointing to the need to understand both learning theory and user context to define m-Learning.

It is important to note that learning is not just something that happens in one's head; it is fundamental to the social processes experienced by the student (Lave & Wenger, 1991). Lave and Wenger (1991) asserts that learning is a process of "situated activity" called legitimate peripheral practice; the processes by which newcomers become more experienced members in a community of practice. Vygotsky (1978) claims that the socio-cultural situation of the individual
is primarily responsible for instances of learning. Merriam, et. al. (2007) suggested the ways in which one learns, to a great extent, are determined by the nature of one’s society at any one particular time. The situated cognition approach allows for learning that is dependent on an individual’s social context. The physical and social experiences, situation in which learners find themselves, as well as the tools used by learners, are all integral components of the learning process (Merriam et al., 2007). Learning is a situated activity, one that cannot happen outside the social context of the learner’s situation or environment (Lave & Wenger, 1991; Merriam et al., 2007; Vygotsky, 1978).

Keskin and Metcalf (2011) stated that there are many different focuses in the area of mobile learning: devices, mobility, individualism, ubiquitous and e-Learning perspectives all dominate. Much of what is known about m-Learning focuses on pedagogy and not user-device interactions or context (Botha et al., 2010). Botha et al. (2010) states that human-computer interaction, HCI, is an academic discipline that studies design practices and tools that are used in situations involving people and technology. A subset of that field is Mobile HCI, applying HCI research to situations involving people and mobile technology. The field investigates the ways people interact with mobile devices and the data that is acquired. They assert that the relationship between mobile learning and mobile HCI is interwoven and dependent. That pedagogical
requirements of mobile learning drives the affordances of Mobile HCI design, but one is not
dominant over the other. See Figure 2.2. What Traxler and Botha point to is any definition of m-
Learning from solely a learning or technological perspective may paint an incomplete picture.
Interestingly, these researchers are arriving at the same conclusion from two distinct research
backgrounds. Views where technology solely drives the experience may not account for how
students learn (Knowles, Holton, & Swanson, 2011; Traxler, 2010). Conversely, those
researchers that merely concentrate on pedagogy and learning theory alone, may be missing the
essential element of mobile context (Coursaris & Kim, 2006; O'Malley et al., 2003).
Unintentionally, many perspectives that exclude Mobile HCI as a focus of m-Learning may
dismiss the context in which the users consume the information.

The objective of Mobile HCI design is to recognize that the context and design interfaces
assist users to more easily accomplish tasks. Context is a discipline concerned with
implementation and evaluation of interactive computing system used to characterize the situation
of an entity (Preece et al., 1994). Context concerns of where the device will be used should be
taken into account when looking at learning activity, learning theory, and user interface design.
Situational awareness and knowing the limitations of the hardware are important components of
the user experience overlooked by many m-Learning researchers. Specifically, looking at what is
the goal of the task, where is the user expected to perform the task, what is the prior knowledge
of the user and physical capabilities of the device should be significant factors in m-Learning
design (Selker, 2000).

As Dey (2001, p. 4) states, a system is “context-aware if it uses context to provide
relevant information and/or services to the user, where relevancy depends on the user’s
task.” Context-awareness plays a major role in order (1) to adhere to changing expectations and
knowledge of users, (2) to adapt to changing device and application constraints and (3) to optimize the quality of service to the end user (Stojanovic, 2009). It is the capability of anticipating a users’ situation in all its forms and adapting the system design and behavior to comply with those changing situations (Chaari, Ejigu, Laforest, & Scuturici, 2007). It is important to have design principles or a framework (1) in which applications are composed out of loosely associated distributed components, enhanced with (2) an adaptation framework that provides solutions to facilitate context-aware adaptation of applications and (3) the content supplied by those applications (Stojanovic, 2009). Understanding this concept of context-awareness allows the instructional designer/software developer to better define patterns of use in a situated learning context. As Dey (2001) points out, the designer must look at the “whole situation.” But context is more than about time and place (Winters & Price, 2005). It is Winters and Price’s (2005) assertion that it is important to investigate how interactions occur focusing on the social, cultural and organizational elements.

As previously discussed, the usage patterns for mobile and personal computers are significantly different. How people interact with mobile devices is vital to the content structure and interface design. But, although the definition of m-Learning is a bit nebulous, maybe one can step back to review certain common characteristics that define the phenomenon; flexibility, simple and intuitive interfaces, quick information access and perceptible information (Elias, 2011). The primary user interface (UI) and learning framework must account for various usage patterns (Reuss, Menozzi, Buchi, Koller, & Krueger, 2004) and limitations of the device (Elias, 2011). Given this consideration, the UI design should take into account factors such as recursive learning, small amounts of time available, small screens, limited bandwidth, limited memory, and device type (Elias, 2011). The same is true for the learning theory and instructional design.
A Theoretical Foundation for Mobile Learning

The central question for m-Learning researchers is how does one learn with understanding? Humans instinctively construct a knowledge ecosystem tailored to each individual person within their social context. Even babies do not enter a world where every stimuli are of equal prominence (Bransford, Brown, & Cocking, 2000). Some information is apex based on context or importance while other items are secondary or even become extinct. As the conditions change or new items are introduced, there is a reorganization of those facts and figures within one’s social context and prior knowledge to develop new meanings (Bransford et al., 2000). According to Jean Piaget, knowledge is the process of developing an interwoven relationship of all our facts and figures within the context of one’s experience (Capra, 1996; Ozmon & Craver, 2003). But, facts and figures are useless without some contextual understanding or meaning provided by one’s social context (Kant, 1781; Knowles, 1980; Merriam et al., 2007).

True understanding of information requires an individual to go through an experiential process of connecting underlying facts in such a way to construct an individual understanding (Knowles, 1980; Merriam et al., 2007). Discovery and active learning are the keys to the awakening of dormant critical thinking skills and a good method of engaging students. The m-Learning environment lends itself to this constructivist approach where users create their own path to understanding (Cummings, 2000; Kant, 1781; Knowles, 1980). m-Learning should be considered unbounded, asynchronous and synchronous, with decentralized control, dynamic, searchable, multidimensional, and use of evolving technologies (Traxler, 2005); a constructivist point of view.
Malcolm Knowles (1980) described a constructivist approach for m-Learning environments in his book, *The Modern Practice of Adult Education: From Pedagogy to Andragogy*. He presented four principles of adult education (1) that adults need to be involved in the planning and evaluation of their instruction, (2) that adults need experience including mistakes to provide a basis for learning activities, (3) adults are most interested in learning subjects that have immediate relevance to their job or personal life and (4) adult learning is problem-centered rather than content-oriented. Given these characteristics of m-Learning as defined by Traxler (2005) one can see those Knowlesian principles at work. “Unbounded, decentralized control” implies that the faculty member is no longer in complete control of instruction and by definition the student is in more control (Knowles, 1980; Knowles et al., 2011). “Dynamic, searchable, multidimensional” implies a certain amount of experiential learning and relevance to one’s life is “discovered” during the learning process, as the student is able to mold the subject material to their own wants, needs and desires (Knowles, 1980; Knowles et al., 2011).

Knowles’ work was a movement away from instructional toward learning sciences. Learning sciences are the convergence of activity systems design, cognition, and sociocultural context (Reiser & Dempsey, 2007). Reiser and Dempsey (2007) stated that the learning sciences approaches the examination of learning from a different set of assumption and scientific perspectives juxtaposed to the instructional sciences. They assert the learning sciences rely more heavily on constructivist cognitive anthropology, situated learning, and reflective cognition. Barab and Duffy (2000) asserts that knowledge is constructed individually as well as being co-constructed within a social context with meaning emerging from practice, activity or discussion. They point to the constructivist approach to learning, but with the missing ingredient of recursive

Community of Inquiry Framework for Mobile Learning

It is vital that the instructional design for any mobile application or learning environment be flexible enough to assume students are in various states of puzzlement, information exchange, communication, or knowledge construction (Garrison & Vaughan, 2008). As a means of better defining a theoretical learning framework for blended learning in higher education, Garrison, Anderson, and Archer (2000) developed the Community of Inquiry (CoI) framework. Although the CoI was developed for blended learning, the conceptual framework applies nicely to a constructivist m-Learning context. The foundation of the CoI is the belief that a collaborative constructivist inquiry model is the core of the ideal educational transaction (Garrison & Vaughan, 2008). Garrison and Vaughan (2008) asserted that the intersection of social, cognitive, and teaching presence is the educational experience.

Teaching presence is vitally important to build and maintain a meaningful community of inquiry. The teaching presence is one of design, facilitation and direction of cognitive and social processes for the purpose of meaningful educational experiences with worthwhile learning outcomes (Rourke, Anderson, Garrison, & Archer, 2001). The importance of this presence cannot be understated within the context of the framework. To this point, Nagel and Kotze (2009) asserted that of the three elements in the framework, teaching presence was the strongest. It is the assertion of Garrison et al. (2000) that content related interactions is not the only ingredient necessary to ensure effective learning. Teaching presence may not be limited to a
course instructor; the constructivist orientation holds that teaching presence could also be established by the redefinition of student roles within the community (Rourke et al., 2001).

The role of the teacher is to provide information and guidance (Bransford et al., 2000). Traditionally the teacher has been the central focus of the educational experience, but to reach today’s students in an m-Learning setting, that must change. The teacher must now act as mentor, guide, instructional designer and now software designer (Lang, 2005). This is not to say that the instructor should not have strong beliefs. As stated by Ozmon and Craver (2003), “teachers should have strong beliefs and commitments of their own but they should not expect students to accept these beliefs unless the students have thought them out for themselves” (p. 257). This mentor approach to education serves the digital generations because the student is in control of the learning process (Knowles, 1980). This concept of mentor is also supported by the pragmatic view that teachers should help learners identify problems, frame questions, and locate appropriate bodies of knowledge to better understand issues (Ozmon & Craver, 2003).

The methods of teaching should be whatever is necessary for the subject or student interest at the time. Those methods should be recursive in nature, but should lead to an overall purpose of allowing the student to construct some larger meaning from the activity within their environmental or social situation. The assignments and curricula should be flexible, molding itself to the student’s interests or needs. This is not to say that assignments should not direct the student to important concepts to better understand material, but the purpose of teaching methods should not be to have every student regurgitate the exact same meaning for a particular concept. These concepts of teaching are in the vein of postmodern thought where instruction should organize itself from the inside-out, from the concrete personal identities, histories and ordinary experiences of the students (Ozmon & Craver, 2003).
Social presence may be defined as the ability of participants to identify with a community, for those participants to communicate within that environment in a trusting way and to develop inter-personal relationships by way of individual personality projection (Garrison, Cleveland-Innes, & Fung, 2010). Given the highly social nature of digital generations, the importance of this presence cannot be understated (Newark-French, 2012). The three main aspects of social presence, as defined by Garrison and Arbaugh (2007), are effective communication, open communication and group cohesion. It is their contention that the presence of these factors is irrelevant without clearly defining meaning for the social connectivity. They believe students must recognize that membership in this learning community is not purely for social reasons, but that this community is built around a specific purpose.

Additionally, social presence is of less importance if learning activities are purely information acquisition and there is no collaborative assignment where student can benefit from community membership (Picciano, 2002). Beuchot and Bullen’s (2005) findings suggest that an increase in the sociability of students in a course will lead to increase interactions and cognition. They assert their findings suggest that social presence is a necessary element for the development of cognitive presences. These studies support Garrison and Arbaugh’s (2007) assertion that social presence is needed for cognitive presence in blended environments.

Cognitive presence is the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse (Garrison & Arbaugh, 2007). The practical inquiry model is grounded in the work of Dewey on reflective thinking (Garrison, 2007). The nature of the relationship between social and cognitive presences is not entirely clear in the literature, but to better explain the relationship, the CoI framework utilizes the Private Inquiry Model (PIM). The PIM is built as the recursive process of conception, action, perception and
deliberation that allows students to take construct meaning from their experience (Garrison & Vaughan, 2008). Figure 2.3 illustrates this model. Within this model, two of the three presences are recursively experience by the members participating in a CoI with the third presence, teaching, assuming the role of designer, implementer or facilitator. Specifically, although one can read the model as something that is linear or immutable, the model is a recursive process where students can jump from one element to the other (Garrison & Vaughan, 2008). A triggering event may lead to better perception or reflection, with true inquiry being exploratory and often unpredictable (Burbules, 2004).

Accordingly, the extent to which this cognitive (reflective) presence is sustained in the CoI framework, partly depends on how communication is restricted or enhanced (Garrison & Vaughan, 2008). But although the implication is that this process only takes place within social groups in communication, one can point to internal mental conversations individuals have about their personal performance. This metacognition is the ability of an individual to contemplate on one’s own performance and improve on that performance (Bransford et al., 2000).

![Private inquiry model](image)

Figure 2.3 - Private inquiry model

How m-Learning environments influence learning will depend on how one intends to use that structure in the process of learning. For instance, one can set up a sophisticated decentralized
dynamic learning activity, but if “sage-on-the-stage” instructional techniques are the primary method of information delivery, it is unlikely to influence learning. Conversely, if one considers basic learning principles, understands the strengths and weaknesses of different m-Learning techniques, device characteristics and user context, then that setting could have a greater influence over learning.

App Design Principles for a Mobile Learning Context

There is no shortage of technology adoption for Americans and the rest of the world today. Always-on Internet connection has become a standard of living for most Americans ("Internet usage as percentage of population," 2010). A recent study by Pew research indicates that 76% of Americans own either a desktop or laptop computer, but 85% own a cell phone (Smith, 2010a). The preferred technology just five short years ago, the personal computer, is being replace with a new, highly mobile device; the smartphone (Palfrey & Gasser, 2008; Tapscott, 1998). A smartphone combines all the capabilities of a desktop computer into a handheld device. If one considers the characteristics of the modern smartphone; small, compact, powerful and with always-on access to the Internet, it is no surprise its adoption is growing significantly (Smith, 2011). Nothing has changed society more in the past five years than the rapid adoption of these devices. The smartphone is restructuring how people assimilate and disseminate information. Today’s generations are characterized by their high use of mobile technologies, their tendencies to multitask, their tendency to express themselves through the use of social medias and their patterns of using technology to access and use information to create knowledge and art; with the primary instrument of these activities being the smartphone (Palfrey & Gasser, 2008). In this new environment, computing is pushed away from the desktop to
smaller embedded network devices. The shift from laptop as mobile to smartphone as mobile is reflected in the literature (Traxler, 2010).

But prior to the introduction of multi-touch interfaces and high resolutions screens, the ability of the PDA and older smartphones was limited and so was adoption. Although the smartphone pre-dates 2007, it is the arrival of the Apple iPhone that transformed ownership of these devices from a luxury to necessity of modern life. In the report, Understanding the Mobile Consumer, the most recent statistics from Google shows that smartphone adoption is up 13% in the last year (2012). Google also reported that 80% of respondents never leave their homes without their smartphone and use the device in many different settings including restaurants, doctor’s offices, coffee shops, and just on-the-go. Users report that these devices are the gateway for informing their daily lives. The device acts as a multi-activity portal for communication, education, information gathering and entertainment. Some have estimated that by the end of 2012, the cumulative number of installs of iOS and Android, the two dominate mobile operating systems, will be greater than 1 billion (Newark-French, 2012). This indicates that smartphones are being adopted at a rate four times that of the personal computer (Newark-French, 2012). This rapid adoption rate indicates significant changes in how Americans and those around the world are accessing information.

Along with the smartphone came the ability to download apps that can do just about any type of information retrieval. Bowen (2012) defines apps as highly customized slivers of the Internet. According to the International Telecommunication Union, just one year after Apple Corporation launched its ‘App’ store, 1.5 billion apps had been downloaded ("Mobile applications reach new milestone," 2009). Since that time, our appetite for apps continues to grow. According to Pew Research, nearly half of all Americans, 46%, have downloaded and
installed apps on their cellular phones; a figure up by 24% from 2009 (Purcell, 2011). But, what is truly significant is that the use of mobile apps are outpacing the use of Web browsers to access the Internet (Newark-French, 2012; Purcell et al., 2010). In 2010, consumers were using apps only an average of 43 minutes a day (Purcell et al., 2010). In 2011, the average Apple iPhone users owned 108 apps and use them for 84 minutes a day (Hodgkins, 2011). Current statistics indicate that number has grown to 94 minutes a day; out pacing that of Web browser consumption (Khan, 2011; Newark-French, 2012).

The predominate reasons stated for using the smartphone was games and access to social media (Newark-French, 2012; Purcell et al., 2010). Although these statistics seem to point to the domination of mobile devices for personal social media and games (Hodgkins, 2011; Purcell et al., 2010), purpose seems to drive usage. With the growth of the tablet in recent years and the introduction of mobility into corporate and business settings, one is seeing a shift of usage based on purpose, as a different demographic begins adopting the devices. For example, the usage model for mobile differs if one is asked how the devices are used in your business versus personal life. In a recent survey, Fidelman (2012) found that an average of 76% of participants indicated they used their tablet for Web browsing in their personal and business life. He also reported that to a lesser degree, 71% of the same participants indicated they use the device for email. Respondents reported the largest deviation of usage between personal and business life was using their device for remote desktop access at work as opposed to games. He asserts that when it comes to mobile usage, purpose drives usage patterns and education would be one of the most impacted industries in the year 2012.

The current state of the literature on technology usage indicates that games and social media dominate the mobile space, but slowly a shift is beginning to take place. Evidence of this
shift can be found in the statistic that 47% of Americans reported that they get some, if not all, of their local news from mobile devices (Purcell, Rainie, Rosenstiel, & Mitchell, 2011). This statistic is supported by a Google report that found that 94% of smartphone users look for local information and 90% acted on that information (Google, 2012). In another instance, the presidential campaign of 2012 saw a rise in smartphone usage by individuals to get information about the campaign, share their views on the candidates, or interact with others on political issues (Smith & Duggan, 2012). Although many, 45%, are still using these devices for reading other’s comments on the candidates, there was a growing segment of smartphone users primarily using that device to monitor the campaign and text-messaging others information (Smith & Duggan, 2012).

Although app downloads are growing, it does not mean that people are using those apps on a constant basis. Purcell’s (2010) survey found that only about two-thirds of Americans that download apps actually use them on a regular basis. He reported that when those apps are used, the window of usage is very small. The survey results state that 57% of adults use their apps daily but for less than 30 minutes, although that figure is constantly growing as previously stated. This presents a very small window of opportunity to have a successful app downloaded and used by consumers. This pattern of download and low usage is consistent across the literature.

Although in many cases usage is low, when adults use their ‘apps’, they use them in very different usage patterns than personal computers. In a survey of University of Colorado students in 2011, when asked about reading news articles on their mobile device, 56% indicated they read less than three paragraphs of an article, watched less than one minute of a video report and listen to less than 30 seconds of an audio news report (Dean, 2011). In addition, students indicated a willingness to access the information for short burst during free time: 93% (n=253) while riding
in a bus, train, or car; 92% (n=253) during idle time at work or school; 85% (n=228) waiting in line (grocery store, coffee shop checkout, etc.); 82% (n=223) for school-related tasks; 77% (n=208) first wake up in the morning, and 72% (n=195) use it before they go to sleep.

Interestingly, in the various locations that people use mobile devices, they indicate a high level of multi-tasking. For instance, in a Google (2012) survey, 86% (n=843) of respondents indicated multi-tasking using the device at the same time as watching TV, using the Internet on a personal computer, or while reading a book and listening to music. This usage pattern of quick access and in unique places is seen across the spectrum of the literature as well as the author’s pilot study of the mobile design principles. In that study, students indicated through qualitative interviews a willingness to use mobile devices in short, frequent bursts to study in their car or at night before going to bed (Seneca & Aime, 2011).

The post-Internet generation of students presents unique challenges based on how they obtain information (Read, Shah, S-O’Brien, & Woolcott, 2012). These students are characterized by their substantial use of social media and mobile technologies as a primary form of communication with peers and instructors. Their taste for technology is moving away from the personal computer or laptop to mobile technologies. The arrival of these millennial students have forced institutions to recognize these new usage patterns and adopt technology at an ever increasing pace (Lippincott, 2012). Increasingly instructors are understanding they need to provide more flexible learning environments and in many cases change how they instruct this new breed of student (Lippincott, 2012).

It is becoming increasingly clear the importance of considering both instructional and user interface design when building mobile learning environments. Today’s students are increasingly turning to apps for customized access to the Internet (Bowen, 2012). Prior to 2007,
the tool of this new technological society was the personal computer, but the dominant online/blended course offering today is Web-based. Products like Moodle and Blackboard have dominated the online and blended experience of students, but trends indicate a slow but steady move away from the desktop environments to mobile. According to a 2010 report from The Campus Computing Project, 73% of those surveyed believe that mobile learning management system (LMS) apps are an important part of a technology plan for a campus, but many of these apps are in early phase of implementation (Green, 2010). Translating a user profile from a desktop environment to mobile is simply not “shrinking” down the presentation, which is what mobile LMS apps attempt.

Given this new user context model, consideration of user interface design is paramount in smartphone-based m-Learning. This context is a world where students quickly access apps to obtain “slivers” of information and incorporate those slivers into their prior knowledge to create new meanings. To better define what constitutes instructional and interface design for m-Learning apps, the following design principles were extracted from the literature:

- **Every topic within an app must have both text and corresponding audio/video components.** Mobile users have indicated a strong desire to use both visual text and audio/video on their devices. Students exposed to text, graphics and spoken language performed better than those only exposed to a single form of stimulation (Kim & Gilman, 2008). Specifically, Kim and Gilman (2008) found that when students were presented with text and graphics, they were more motivated to learn. Their findings suggest that when both text and audio were included, the audio component could reduce memory load. They found that this instruction based on reduced text, with added spoken text, allowed for better vocabulary acquisition. Along with showing
promise to help students with learning by including text and audio/video component, surveys show that modern users frequently use their mobile device to watch video. Supporting this assertion, a report found that 76% of respondents used their smartphone to watch video, with 25% of those individuals viewing video once a day (Google, 2012).

- **Self-assessment is used to allow students to self diagnose their own understanding of the material at hand.** Taking ownership of one’s learning is a necessary element of m-Learning. Given the spontaneous, ubiquitous nature of m-Learning, students need a means by which they can perform self-assessment. A longitudinal study found the usefulness of self-administered formative assessment material indicates that student populations are making significant use of these materials and it aids in learning (Peat & Franklin, 2002). Students in learning situations are able to review information and reflect on items in their mental portfolio. Yancey, defines the process of reflection “as the processes by which we know what we have accomplished and by which we articulate accomplishment and the products of those processes” (1998, p. 6). Specifically, a review of 63 studies on forms of assessment suggest that the usage of these types of assessments encourages students to be more responsible for their education and more reflective (Dochy, Segers, & Sluismans, 1999). Effects on student learning included (1) an increase in student confidence in their own ability, (2) an increased self-awareness of the quality of their work, (3) more students taking responsibility for their own learning, and (4) increased reflection on the student’s own performance (Dochy et al., 1999). There should be a question bank of relevant self-assessment questions. The questions should be chosen
at random by a learner analytic algorithm within the app. The system should track the progress of the students providing feedback on key areas where additional review is needed.

- **All text-based instructional material is constructed to be completely read within 90 seconds of access with a maximum read time of 180 seconds.** Students in this new user context do not access material for long periods of time (Dean, 2011). This new type of user has grown up with the Internet and technology from infancy and by their nature are discovery learners (Palfrey & Gasser, 2008; Prensky, 2001a). Instructional materials should be subdivided into multiple chunks. Based on a usage pattern allowing for small amounts of time to inject formal learning into informal learning situations, keeping reading and listening to a short burst is appropriate. With the rise of micro-blogging systems like Twitter, individuals are increasingly receiving their information in very small bits of text. In a recent study on micro-blogging, blog entries less than 140 characters, Ebner, Leinhardt, Rohs, and Meyers (2010) found that students responded positively to the use of this form of information presentation in their course. Based on their observation, the researchers asserted that micro-blogging should be considered a new form of communication in the 21st century. Additionally, in their review of literature on the subject of micro-blogging, Gao, Luo and Zhang (2012) found that micro-blogging encouraged participation, engagement, reflective thinking, and collaborative learning in various settings.

- **All video and audio-based instructional material is recommended not to exceed two minutes with a maximum viewing time of five minutes.** The use of podcast is popular. According to a report by Edison Research, 45% of Americans, up from 43%
in the previous year, have watched or listen to a podcast, a figure equating to 70 million individuals (Webster, 2010). Of those individuals, two thirds have listened to podcast by connecting their iPod or MP3 player to their vehicle’s audio sound system (Webster, 2010). Guertin (2010) asserted that there are many different ways one can use podcasting to improve student learning outcomes. Small slivers of audio allows a student to quickly and easily download and review course content on mobile devices (Webster, 2010). Reviewing the literature on podcast yields mixed results on length. Abt and Barry (2007) found that most students indicated their preferred listening time is about five minutes. In another study, the majority of students indicated they preferred a listening time of nine to ten minutes (Chan & Lee, 2005). Results from a study by Muppala and Kong (2007) indicated that students preferred a listening time of five to 20 minutes. Although there is no definitive evidence to point to the ideal listening time for an audio/video component, the evidence does point to a much shorter duration.

- **Primary instructional material exists on the device and should not require Internet based cloud services to operate.** The limitation of devices like smartphones in comparison to laptops or desktop computers is significant. Small screen size and limited bandwidth are just two examples. Most of us today have always-on high-speed Internet connections at our work, home or school, but for those spaces devoid of Wi-Fi access, Internet bandwidth can become spotty and very slow. Given these limitations, usability becomes a paramount issue (Coursaris & Kim, 2011). Although the access to the Internet is almost universal, access speeds are still limited. Given the need for both text and audio/video capability, having content existing within the
borders of the app itself allows for increased usability for the end user. Furthermore, the size of these video and audio files should be what is minimally needed to operate on a small screen, thus reducing the overall file size of videos. The advantage to this approach is that the vast majority of the information needed for the students is at their fingertips, with all necessary instructional material being downloaded at the time of app installation, not while the student is trying to access needed information on-the-go.

- **All instructional materials should be available within 15 seconds of app launch with a maximum of five interface touches to access relevant information.** Given the constructivist learning theory of private inquiry and current user context profile, an app needs to be designed with two basic concepts in mind, quick content access and easy content navigation. It must have a high degree of learnability addressing principles of vertical stack, performance, learnability, satisfaction, and task completion (Tidwell, 2010; Welie & Troetteberg, 2000). This combination of UI elements allows for a simple three to five touch interface design where the content, specifically audio and video, is allowed to dominate the experience (Tidwell, 2010). Instructional material should be broken down into multiple topic areas. Each topic area will be further subdivided into logical units subsequently broken down into chunks; the smallest unit of information that the instructor believes will be meaningful to the student (Cennamo & Kalk, 2005). Each chunk will contain instructional information in both text and corresponding audio/visual material.
Summary

With the rapid adoption of smartphone and tablet technology, how people assimilate and disseminate information has changed. The technology of today is ushering in the era of the hyper-media mind; one that learns via discovery by accessing slivers of information for learning. This new means of communication and information access requires a different approach to instruction both from a learning and information delivery perspective. Instruction in mobile spaces needs to take into account that a student may be in various states of learning. At any one time a student can recursively bounce in and out of various learning states of awareness, exploration, reflection and resolution as they go about their daily lives. This new situated cognition requires a different approach to information delivery, one that is non-linear and recursive; allowing for an inquiry at any time, from any place using mobile devices.

The literature paints a reasonably clear picture of new technology usage patterns. New generations of individuals prefer mobile technology and have distinctly different usage patterns than previous generations. Technology adoption, particularly smartphones, has become pervasive. Adoption of mobile technologies is outpacing the adoption rate of personal computers with people using these devices to access information ubiquitously. Individuals are more likely to download apps, but the usage patterns for those apps presents a very narrow window of opportunity to engage students. Individuals are willing to access information, in short bursts, multiple times a day using mobile devices. It is clear a smaller screen size does not deter information consumption.

Finally instructional material cannot be a “shrunken” down or “luggable” version of what already exists, it must be tailored to the smaller, mobile interface. The application or learning
environment needs to account for limitations of devices and a mobile user context. Consideration of user interface design is paramount in smartphone-based mobile learning situation.
CHAPTER 3
RESEARCH METHODOLOGY

Understanding mobile apps and how consumers use them, may allow for more meaningful learning experiences. In order to understand if the mobile design principles would affect learning, this study investigated the use of mobile apps for learning muscle anatomy. The overall goal of app-based learning is to use the power of mobile devices to inject formal instruction into informal learning opportunities. The mobile design principles defined in Chapter 2 inform the instructional and user interface design for this study.

This study collected both quantitative and qualitative data in a convergent design. Collection of quantitative data was through three main mechanisms: (1) a pretest, posttest instrument; (2) tracking of self-assessment data within the mobile app; and (3) tracking the amount of time the student used the learning app. Collection of qualitative data was via student written reflections on their experience with mobile apps during the study. Additionally, a quantitative survey instrument was given to elicit student’s perception of the apps. The study design is described in the following sections: (1) Research Methodology; (2) Research Questions; (3) Research Design; (4) Design Strengths; (5) Design Limitations; (6) Instrument; (7) Data Collection Procedures; (8) Data Analysis; (9) A Priori Statistical Power Analysis; (10) Participants; (11) Post-hoc Statistical Power Analysis; (12) Student Perception Survey; (13) Mobile App Instructional Design; (14) Mobile Learner Analytics; (15) Mobile HCI App User-Interface Design; (16) The Placebo App, and (17) Summary.

Research Questions

The following research questions guided this study:

1. Do the design principles, applied in a mobile context, allow learners to develop knowledge content and understanding?
2. Does the length of time using an app have an effect on student learning?

Research Design

Kinesiology is a very difficult concept for the novice Physical Therapy Assisting (PTA) students to grasp. The kinesiology course is a pre-requisite course for admittance to the Physical Therapy Assisting program at a local College. It requires a vast understanding of muscle and skeletal anatomy as well as understanding the physics of movement. In the past, the retention rate for this course has been low given the fast pace nature of the course and lack of prerequisite knowledge of muscle anatomy needed to be successful. Over the past couple of years, various teaching techniques have been used to stem the tide of dropouts and failures, but despite most efforts, that failure rate remains higher than desired. In 2012, a series of mobile apps, using specific mobile design principles, was designed and distributed to kinesiology students. These apps define the origin, insertions, nerve supply and actions of muscles in the human body. Course evaluations indicated that student positively received the use of these apps. Anecdotal evidence supported the assertion that the apps could help reduce dropout and failure rate.

This study was commissioned by the PTA program and funded via Mother Marie Crowley Endowed Professorship to determine what effect, if any, do apps using mobile design principles have on student learning. This study was causal in nature with a pretest-posttest control group design (Creswell, 2009). It attempted to combine existing literature and data about m-Learning and Mobile HCI. Based on the results of a previous mixed-method pilot study, the researcher decided to focus on quantifying the performance gains or losses experienced by participants. This research utilized both descriptive and inferential statistics. The study had 60 participants, randomly assigned to a treatment or control group. These participants were students taking three sections of kinesiology at a local non-profit, accredited college. The study lasted for
a period of six weeks. On day one, the researcher explained to the potential participants the purpose for the study and informed consent paper work was collected. Once the participants consented, a pretest was administered consisting of 25 questions taking approximately 60 minutes.

Participants were randomly placed in either the treatment or control group and the pretest was analyzed using an independent sample t-test procedure to ensure there was no significant difference between the groups. Each student, in the treatment group received six Apple iOS apps covering the following anatomical areas: (1) shoulder girdle, (2) shoulder, (3) ventral forearm, (4) dorsal forearm, (5) elbow and (6) hand. The apps assigned to the treatment group were specifically designed to adhere to the following mobile design principles:

• All instructional materials should be available within 15 seconds of app launch with a maximum of five interface touches to access relevant information;

• Primary instructional materials exist on the device and will not require Internet based cloud services to operate;

• All video and audio-based instructional materials is recommended not to exceed two minutes with a maximum viewing time of five minutes;

• All text-based instructional materials is constructed to be completely read within 90 seconds of access with a maximum read time of 180 seconds;

• Self-assessment is used to allow students to self diagnose their own understanding of the material at hand;

• Every topic within an app must have both text and corresponding audio/video components.
Another mobile app was created, covering the same anatomical features, as the placebo. The app, assigned to the control group, was a copy of what is already presented to the students in the College’s learning management system, Moodle.

The participants were allowed to use the apps for a period of six weeks during February and March 2013; the length of the upper extremities component of the kinesiology class. They were instructed not to share any apps with fellow participants during the course of the study. During the length of the study, the apps logged the results of all self-assessment data as well as tracked the usage patterns of the students. At the end of the six-week period, the posttest was administered to collect results.

Design Strengths

The use of the pretest was to make sure the treatment and control groups are equivalent to strengthen the internal validity of the study. This design was selected to localize the effects of the mobile design principles through the use of the pretest and the placebo app. The placebo app was designed to mitigate the effects of students in the control group not receiving an app as well as any spillover between the two groups. Specifically the placebo app mimicked what students received in their course’s learning management system. Also, with the pretest/posttest design, it is possible to do a variety of comparisons between groups as well as within the group.

Design Limitations

One of the limitations to this design was the concept that even with a pretest, there is no guarantee that this instrument will not influence the results of the posttest given that no baseline data exists for the participants (Creswell, 2009). This could present a threat to the external validity of the study. To mitigate the potential effects of the pretest, the covariant design was selected to control the effects of the pretest on the posttest scores. The research design utilized
the analysis of covariance (ANCOVA) procedure that allows for adjusting for the effects of the pretest on the posttest results. This design was selected to reduce the effects the pretest will have on the posttest because the pretest is the most likely variable to be highly correlated to the posttest. By reducing or removing the noise, the ANCOVA allows us to remove most of the extraneous variability from the posttest thus giving us a clearer picture of student learning (Trochim, 2006).

Another limitation with the design is that it will be impossible to separate and isolate the two groups (Trochim, 2006). A consideration of using one section of students for the treatment and one for the control was dismissed for the potential of selection bias. To address the isolation limitation of the design, the researcher introduced a placebo app to the control. The placebo was designed to account for participants in the control recognizing they did not receive an app. Although there is no way to completely isolate these participants, the concept of the placebo app should mitigate any cross contamination between the control and treatment group.

Instrument

The pre/post test was administered containing 25-questions about kinesiology material and took an estimated 60 minutes to complete. These assessment questions were characteristic of the types of questions used by faculty during tests and quizzes. Participants were prescribed an hour to complete the pretest, but was given additional time if they felt it was needed. Respondents were given a total of five potential choices for each question. The posttest was of the same questions given in a randomized order with one-hour allotment for completion. Again, additional time was provided if the participants felt it was needed. The following is a sample question for the pretest/posttest instrument; the full instrument can be found in Appendix E:

1. Which of the following is NOT an origin of the trapezius?
   a. Nuchal Ligament
b. External Occipital Protuberance  

c. *Lateral 1/2 of the Spine of the Scapula*  
d. Spines of the Cervical Vertebrae  
e. Spines of the Thoracic Vertebrae  

Content validity for the instrument used to measure student learning was provided by a panel of three physical therapy faculty. The panel reviewed the content of the course and instrument’s questions and arrived at the conclusion that the questions in the instrument are reflective of the material understanding needed for muscle/skeletal anatomy of the upper extremity. This panel of experts has a combined 79 years of experience as physical therapists in a clinical setting. Additionally, they have a combined 39 years of educational experience in both in a university and clinical setting. All members of the review panel are university educated with the highest educational attainment being Doctorate of Physical Therapy. In addition to their university education, members of the panel hold various professional certifications. To avoid confusion, this study provides operational definitions of key terms and concept. Those definitions are as follows:

- **Student Learning** - the amount of content knowledge of upper extremity muscle anatomy acquired by the students during the length of the study. The gain score from the pretest to the posttest measures it. The instrument used to collect this data was 25 questions long covering all muscle groups in the upper extremity. With no standardized instrument available to measure student learning as defined above, the researcher relied on a high degree of content validity to affirm the instrument was measuring properly.

- **Mobile Design Principles** - a set of six design principles combining research in two academic fields, m-Learning and Mobile HCI, applied to the construction of mobile apps for the treatment group.
• **Time of Use (TOU)** - this is the total amount of time a student uses an app in the study. It is measured by monitoring the total amount of time a student uses a mobile app.

• **Content Access Event (CAE)** - this is the instance a person accesses specific content elements within an app. Tracking every action within an app and logging them with a relational database management system measure it.

**Data Collection Procedures**

Data collection for this study was twofold. First, the pretest and posttest scores were collected via a paper and pencil instrument. The information was collected via Scantron form and graded according to a key then entered into SPSS. This testing procedure is the program’s normal testing procedure for students. The study complied with program policies for testing when conducting the pretest and posttest.

Second, each app, both the treatment and placebo apps, tracked the time of use (TOU) and content access events (CAEs). Real-time data collection took place for a period of six weeks between the pretest and posttest. As the participants used the apps, the software tracked what an individual was doing at any one time in the application. As a requirement of app installation, each participant was required to input a research identification number in his or her app settings. Using this unique identifier allowed for tracking at of events. Tracking these events is important due to the fact that most modern smartphones do not kill an app from running when the “home” button on the device is pressed. At any time, an app can spend hours in the background as a running process. This has the potential to give inflated results of usage.

To account for this possibility, each app generated a run key. This run key was used to tag each event along with a timestamp to track an active session. Each time the participant launched the app or retrieved it from the background, a unique run key was generated based on
the number of seconds that have expired since 1970. That key was saved in the memory of the device and tagged to each event as a session identifier. Given the unique nature of the research identification number and the unique run key, the researcher was able to track individual instances of user activity. Figure 3.1 represents a sample of the information capture from the participant activity.

![Sample tracking data from apps](image)

Figure 3.1- Sample tracking data from apps

The second level of tracking was devised to track what users were doing in each app. Primarily each event in the app was tagged with a unique message. For instance, when a user launched the app then selected a category, the tag of `<category>_TopText` was recorded in the relational database management system. As the participant “scrolled” down and reached the bottom of the text, the `<category>_BottomText` message was recorded. With every message being time stamped, the researcher was able to track the amount of time a participant spent working in an app. Additionally, the app tracked how long the participants listen to the podcast within the apps. The apps had the ability to track the events of `<category>_AudioPlay`, `<category>_AudioPause`, and `<category>_AudioPlaybackFinished`. 
This process of tracking was accomplished via the use of a Website that would accept each entry and log it into a database. Using the PHP scripting language, the tracker software Webpage was designed to accept tracking data via a HTML GET variable pass through and insert those values into a relational database management system running on MySQL. This database contained two table structures; one for tracking app activity and the other for tracking self-assessment question results. The first was a research table that was used to track all the app activities for both the control and the treatment group. The breakdown of fields for the software tracking system was the following:

- research_id (bigint (20)) – this field is an auto incremented big integer field used to create a primary key for each row inserted into the table;
- message (varchar(255)) – this field is a variable character field that was used to capture the event message;
- message_dt_tm (datetime) – the field is a datetime field used to track the time stamp of when a row as inserted into the database;
- app_id (varchar(255)) – this field is a variable character field used to capture the unique identifier for the app that is sending the message;
- subject_id (bigint (20)) – this field is a big integer field used to hold the research identification number for the participant;
- runkey (bigint(20)) – this field is a big integer field used to hold the session identification number for each time a participant started and stopped the app. Each session received a unique number based on the number of seconds since January 1, 1970;
device_type (varchar (255)) – this is a variable character field designed to track the type of device that was used to access the information. Expected values were iPhone, iPod touch, and iPad.

Finally, as the participants used the self-assessment questions, the results were tracked. This information was logged into a MySQL relational database management system used to track the progress of the student as they review the learning materials. The question table, research_qa, was used to track the number of correct and incorrect questions. The breakdown of fields for the software tracking system was the following:

- research_qa_id (bigint (20)) - this field is an auto incremented big integer field used to create a primary key for each row inserted into the table;
- message_dt_tm (datetime) – the field is a datetime field used to track the time stamp of when a row as inserted into the database;
- app_id (varchar(255)) – this field is a variable character field used to capture the unique identifier for the app that is sending the message;
- subject_id (bigint (20)) – this field is a big integer field used to hold the research identification number for the participant;
- runkey (bigint(20)) – this field is a big integer field used to hold the session identification number for each time a participant started and stopped the app. Each session received a unique number based on the number of seconds since January 1, 1970;
- device_type (varchar (255)) – this is a variable character field designed to track the type of device that was used to access the information. Expected values were iPhone, iPod touch, and iPad;
• correct_ind (enum (‘Yes’, ‘No’)) – this is a boolean field used to track if the student answered the question correctly or not. Expected values were Yes or No;

• question_id (bigint (20)) – this is a big integer field designed to track the unique identification number provided by Moodle for each question;

• qcat (varchar(200)) – this is a variable character field that describe what muscle the questions is pertaining too.

Tracking the results of questions was used to give feedback to students on their progress. It is important to note that the tracking software renders the user’s identity anonymous because it uses the research identification number that cannot be linked to an individual.

Data Analysis

To address the first research question, the difference between the two groups on their pre and post test score was analyzed using the analysis of covariance (ANCOVA) procedure. This is a well known statistical analysis (Hinkle, Wiersma, & Jurs, 2003) for the behavioral sciences. For this analysis an alpha of .05 ($\alpha = .05$) was used. The ANCOVA statistic was selected for its abilities to control the effects of the covariant within the study. As asserted by Hinkle, et al. (2003), the reduction of the variability of outcome measures increases the statistical power over a paired or independent t-test. This should reduce the probability of a Type II error in the calculation. Since the probability of the Type II error is inversely related to statistical power, the ANCOVA provides a more powerful test than the paired t, independent t or analysis of variance (ANOVA) procedure.

The pretest results were the covariant. This makes an ideal covariant because it is not directly affected by the independent variable, mobile design principles. This addresses the first assumption of the ANCOVA test which is that there is a linear relationship of the covariant
(Creswell, 2009; Hinkle et al., 2003). The second assumption with pretesting of the control and treatment groups, it was assumed the individual groups would have parallel slopes on their regression line; the homogeneity of the regression slopes (Hinkle et al., 2003).

To address the second research question, the total amount of time a participant used their apps were summed up. That amount of time was subsequently loaded into a Pearson’s product-moment correlation coefficient or Pearson’s r as it is commonly referred too. The Pearson’s r procedure was selected because it is a widely used measure of strength between two variables (Hinkle et al., 2003). Although the Pearson’s r procedure does not completely characterize the relationship between the two variables, it does give us a good indicator of the strength of the relationship between the two variables.

A Priori Statistical Power Analysis

An a priori power analysis was conducted using the software package GPower*3 for the analysis of covariance procedure (Faul, Erdfelder, Lang, & Buchner, 2009). The analysis calculation, based on an alpha value of 0.05, a beta value of 0.8, and an effect size of 0.5 yielded a recommended sample size of 34 to address research question one.

An a priori power analysis was conducted using GPower*3 software package for the linear regression procedure (Faul et al., 2009). The analysis calculation, based on an alpha value of 0.05, a beta value of 0.8, and an effect size of 0.5 yielded a recommended sample size of 18 to address research question two.

Participants

The sample size for this study was 60 students. The students were enrolled in three separate sections of a kinesiology course. As previously stated, the control group consisted of 30
randomly assigned participants that received a placebo app. The treatment group consisted of 30 randomly assigned participants that received six apps adhering to the mobile design principles.

The random assignment was accomplished by the use of a random number generator from the Website, http://www.random.org. The Website was used to generate a list of 75 random numbers and the corresponding Microsoft Excel row was match until 30 participants were identified for the treatment group. To ensure homogeneity between the groups, an independent-samples t-test procedure was conducted to compare the treatment group to the control group. The pretest mean for the treatment group was 9.17 (SD = 2.817); the pretest mean for the control group was 9.37 (SD = 2.814). There was no significant difference in the mean scores for the two groups; $t(58) = .262$, $p = .794$.

Post-hoc Statistical Power Analysis

A post hoc power analysis was conducted for the analysis of covariance (ANCOVA) using the software package, GPower*3 (Faul et al., 2009). The sample size of 60 was used for the statistical power analyses and a one-predictor variable equation was used as a baseline. The recommended effect size used for this study was 0.5. The alpha level used for this analysis was $p < .05$. The numerator degree of freedom was set to one, the number of groups was defined as two and the covariant was one, the pretest. The post hoc analyses revealed the statistical power for the ANCOVA procedure exceeded 0.96 for the detection of a moderate to large effect size for research question one. Thus, there was more than adequate power, greater than 80%, at the moderate to large effect size level for the study to detect any difference in the gain score.

A post hoc power analysis was conducted for the linear regression procedure using the software package, GPower*3 (Faul et al., 2009). The sample size of 60 was used for the statistical power analyses and one-predictor variable. The recommended effect size used for this
study was 0.5. The alpha level used for this analysis was \( p < .05 \). The post hoc analyses revealed the statistical power for this study exceeded 0.98 for the detection of a moderate to large effect size for research question two. Thus, there was more than adequate power, greater than 80\%, at the moderate to large effect size level for the study to detect a correlation between time using an app and gain score if one exists.

**Student Perception Survey**

The survey asked five basic demographic questions: age, gender, education level, previous exposure to anatomy, and race. The demographic questions were selected specifically to see how students would perform based on previous educational experience in this introductory course. Additionally, to better understand student’s perceptions, an 11-question scale survey was designed and administered during the posttest. See Appendix G for the instrument. Table 3.1 shows the categorization of 10 questions that were designed on a Likert scale ranging from strongly disagrees to strongly agrees. The remaining question was an open-ended question inviting the student to write a reflection of their experiences with the mobile apps. The survey was designed to look at two main constructs: willingness to use and performance of mobile apps. The survey consisted of six questions exploring the student’s “willingness to use” mobile learning apps extracted from a previously given survey (Pollara, 2011). The remaining four questions were constructed to get the student’s perceptions of their performance with mobile apps. The information gained from the survey was analyzed using both descriptive and inferential statistics to compare the results between treatment and control groups. Tables with the results of this survey were generated.

The final section of the survey was an opportunity for the participants to write reflective composition on their experience during the study. To better understand the responses presented,
a series of steps were followed. First, the researcher transcribed all responses into a Microsoft Word format. Once transcribed, a multi-stage process was undertaken to connect the qualitative results to the quantitative data. Daly (2007) describes a basic four-step framework for Grounded Theory with (1) open coding and the creation of concepts, (2) creating categories, (3) making linkages in the data and (4) creating a theoretical story line.

Table 3.1 - Breakdown of survey questions by theme

<table>
<thead>
<tr>
<th>Theme</th>
<th>Items</th>
</tr>
</thead>
</table>
| Willingness to Use        | 1. I would participate in class if I could use my mobile device;  
2. I would like to be able to download mobile applications that could help me study;  
3. I would be more likely to participate in class activities outside of the class time if I could do so through my mobile device unique places to learn;  
4. I would be more likely to ask for help if I could communicate through my mobile device;  
5. The mobile app allowed me to learn and study in places I could not normally learn or study in;  
6. I would spend more time on classwork if I could access materials anytime, anywhere on my mobile device. |
| Performance               | 1. It was not a lot of effort to learn how to use my mobile app designed for my class;  
2. I found the mobile app useful and aided my learning;  
3. The audio included in the app to be useful and aided in my learning;  
4. The practice quizzes and feedback provided by the app allowed me to gauge my strengths and weaknesses on the learning material. |

Although this study is not intended to be a Grounded Theory study, in that the theories are not derived from the data, the framework of steps served well for coding and categorizing major themes extracted from participant reflections. In stage one, the open coding stage, the process of naming segments of data was applied to the text and major themes were developed. In stage two, major categories were defined from the coding and segments of the reflective writing were fit into categories. The purpose of these first two stages was to analyze the qualitative data
and dissect it into its meaningful parts. In stage three, the dissected comments were linked to existing quantitative data to determine the relevance of student perception to the overall hypothesis of the study. In the final stage, the relevant items were constructed to create a theoretical story line to align with the quantitative data.

Mobile App Instructional Design

The concept of muscle and skeletal anatomy was logically chunked into four different topic areas. Each topic area was further subdivided into logical units broken down into chunks; the smallest unit of information that the subject matter expert believed would be meaningful to the student (Cennamo & Kalk, 2005). The concept was divided into four main areas, upper extremities, lower extremities, trunk and spine. Figure 3.2 graphically demonstrates how human anatomy was divided in the treatment apps. Each of the main topic areas was broken down into sub areas. For the purposes of the study, the upper extremities section was chosen. The primary reason this particular topic was selected was because of its difficulty. The subject matter expert advised that students have the most trouble with upper extremity anatomy in kinesiology course; it's the most complex to learn. Also, given that the course sequence starts with the upper extremity, the students have less time to comprehend the material.

Figure 3.2 - Chunking of upper extremity
Taking the upper extremity module, the subject was divided into six categories ranging from shoulder girdle to hand. Then each section was further subdivided into an average of six chunks. Figure 3.3 gives an example of how each item was subdivided. For example the chunks that were created for shoulder girdle ranged from middle trapezius to pectoralis minor. Each chunk covered the origin, insertion, nerve supply and action for the corresponding muscle; all elements necessary to understand muscle anatomy of a particular item. Each chunk conformed to the mobile design principles. In addition to addressing the learning objectives, the introduction informed students what knowledge of the chunk was needed from that app to be successful in the course.

Mobile Learner Analytics

To give participants a better understanding of their strengths and weaknesses with the learning material, each chunk was associated with questions in the question bank. For the upper extremity, the system included a question bank of 213 self-assessment questions. Every chunk had a minimum of four questions relevant to understanding the material. Each question was meta-
tagged and associated with a major anatomical feature. For example, all items in the question group dealing with shoulder girdle were tagged appropriately.

The algorithm used by the learner analytics system for question selection was as follows. To begin, the questions were chosen at random in groups of five when the participant accessed the quiz. For each question presented, an Extensible Markup Language (XML) log file tracked the number of attempts, the number of times the question was answered correctly and the question meta tag. Each time the learner launched the self-assessment quiz, the analytic system interrogated that log file to determine what questions to present next.

The minimum number of times a question would be presented is three. This number was settled on using probabilities. It was determined that the probability of guessing an answer correctly by random chance is one in five. Given those odds, there is a less than one percent chance of guessing the correct answer three times in a row. Therefore, the minimum number of times a student would see a question was three.

Once a student missed a question and assuming the attempt count is below three, the analytic system began to use a simple percentage to determine a question’s viability. The threshold rate of 75% was determined based on the minimal passing rate of the course. Once a learner achieved a value of 75% or higher on a question that have been missed in the past, the system would move on to other items in the question bank.

This information was used to provide instant and cumulative feedback to the learner. The instant feedback was designed to give participants results at the moment of answering the question. If the student selected the wrong answer, the system would give them the correct answer, record the incorrect attempt and ask the question again in the future.
The second form of feedback was cumulative. Built within the app was an information button that allowed the student to receive cumulative feedback on questions. Additionally, the cumulative feedback allowed the participant to track where they were spending the majority of their study time with the app. On a categorical basis, a learner could see exactly how well the content was being learned. Figure 3.4 shows this feedback system.

Figure 3.4- Instant and cumulative feedback system

The cumulative feedback system gave the learner ideas about how many questions they had answered correct and incorrect.

Additionally, the navigation system displayed a visual cue of student learning by topic. As the participant navigated through the learning material, the app marked items in red indicated a lack of content mastery. The green highlighted items indicated content where the learner was demonstrating mastery. Additionally, black items indicated not enough data had been collected to make a determination. Figure 3.5 shows an example of this visual feedback navigation.

Mobile App User-Interface Design

The treatment apps were designed to address the principles of vertical stack, performance, learnability, satisfaction, and task completion (Tidwell, 2010; Welie & Troetteberg, 2000). Central to the idea of user mobility and a limited user time frame was performance. Given that
user experiences with 3G/4G LTE wireless and downloading audio/video could be slow or impractical in the short timeframes needed, it was determined that all instructional modalities; text, audio, and video needed to exist on the device. This concept front-loads the majority of the “downloading” of instructional material to the app installation, and not during information access. This provided for a more responsive, quicker user interface and no “lag” time for the student.

The interface was designed around a vertical stack concept to optimize the feeling of the device in a user’s hand. The stack contained three elements: a toolbar, a content window, and information bar. Figure 3.6 shows the vertical stack configuration for the treatment apps.
The purpose of limiting the use of the app to a vertical stack only, instead of a hybrid vertical/horizontal stack relates to time issues. Predominantly, the audio/video created by the subject matter expert in these apps were podcasted audio. Therefore there is very little advantage to the end user to have an app that can rotate between a vertical and horizontal interface. Additionally, in the pilot study conducted by the primary investigator, participants indicated the vertical, portrait mode to be preferable (Seneca & Aime, 2011).

To address learnability, the app was designed with limited options for obtaining information. Figure 3.7 illustrates the three button actions of the toolbar. To access the instructional content, the user only had one possible button to progress into the app. A touch on the muscles button reveals a list of items that allows the user to view possible selections. Once the user selected an item, they move to the instructional content navigation system. Figure 3.7 shows once selected, the text-based instruction immediately appears for the user with only two additional new actions.

![Figure 3.7 – Simple content access navigation](image-url)
The first was access to the audio/video component of the chunk. The second was access to the self-assessment quiz. Once a quiz had begun, the user needed to complete the five questions before reviewing more content. As the user moved through the app, the system modified the visibility of the buttons based on what functionality was available at that point in time. For instance, once one navigates to a content screen and plays an audio file, the user must stop or wait for the audio to finish before the question button will reappear. All of the elements were designed to allow the user to quickly and intuitively learn how to use the app. The purpose of this is to ensure the UI design was easily learnable and did not become a hindrance to learning.

The combination of UI design and chunked content material was purposefully designed to increase user satisfaction by providing quick access to small pieces of instructional material within a just-in-time usability framework. This UI design has been previously tested and users rated the interface as having a high degree of simplicity and quick access. Central to the concept to task completion is the self-assessment tool. Designed as a multiple choice question bank, this design element allowed the user to feel a sense of accomplishment or inform them of an area that needs to be improved.

The Placebo App

To better understand the effects of the mobile design principles, the primary investigator developed a placebo app. Specifically; this app was designed to mimic the content provided in the participants’ learning management system. Extracted from the Moodle course was the following topic areas: Introduction, Shoulder Girdle, Shoulder Joint, Elbow and Wrist Joints and Hand. Each section contained an anatomical image as well as a Microsoft Word Document outlining material for the section. In addition, there was a corresponding Microsoft PowerPoint presentation for the section. Each document was downloaded and converted into Adobe PDF
format for displaying within the mobile devices. Once a topic was selected, the placebo app would allow the user to select between the module outline and the lecture material for viewing. Once a user selected an item, it would display in the content browser. Figure 3.8 shows the display of lecture material for the shoulder girdle module.

Like the treatment apps, the placebo app tracked the progress of the student. It also included the same question bank as the treatment apps. Like the treatment apps, questions were presented five at a time giving instant feedback, but unlike the treatment apps, the placebo app presented no cumulative progress. Also, there were no learner analytics build into the system; the app just presented five random questions similar to the participation quizzes in Moodle.

![Figure 3.8 - Display of lecture material](image)

**Summary**

The purpose of this study was to gather empirical evidence to address the following research questions: do the design principles, applied in a mobile context, allow learners to develop knowledge content and understanding and does the length of time using an app have an effect on student learning? Using a true experimental design, this study had 60 participants with two randomly assigned groups of 30. The study featured a set of treatment apps adhering to the mobile design principles. In addition to the treatment apps, a placebo app for the control group
was constructed to mitigate the effects of any cross contamination between the treatment and control. Data were collected over a period of six weeks in the months of February and March 2013.

The apps given to all participants covered the instructional materials for the muscle anatomy of the upper extremity. For the treatment apps, each group of muscles was chunked into small slivers of information conforming to the mobile design principles. During the period when the study was active, the mobile apps tracked the amount of time for each individual.

Two primary statistical procedures were employed during the study. An analysis of covariance was conducted to evaluate the gain score of the two groups using the pretest as a covariant. The timing data was captured and a linear regression was conducted to determine if there was any correlation between the amount of time a participant used an app and their posttest score.
CHAPTER 4  
RESEARCH RESULTS

This research study was undertaken to determine if there are any differences between two groups. The treatment group used apps designed according to a specific set of mobile designed principles with the control group app using no specific design principles. Additionally, the researcher wanted to determine if there was any correlation between the amount of time spent with a mobile app and learning. Means of pretest results were compared using an independent t-test procedure to ensure no difference between the randomly selected groups. Then, after all assumptions were met, the pretest and posttest scores were compared using an analysis of covariance procedure to understand if there were any significant differences between the groups. Additionally, a linear regression analysis was conducted on time and posttest score to see if there was any direct correlation between the two variables. A qualitative reflective writings of the participants’ app experience were collected as well as a ten-question Likert scale survey.

The results of the study are reported in the following sections of this chapter: (1) Descriptive Characteristics of Participants; (2) Analysis of Pre/Post Testing Data; (3) Analysis of Participant App Usage Data; (4) Qualitative Results from Student Reflections; (5) Analysis of Student Survey Data; (6) Comparison of Treatment and Control Survey Data; and (7) Summary.

Descriptive Characteristics of Participants

The overall number of participants in the study was 60. Participants ranged in age from 18 to 54 with a mean age of 26.37 years. Of the participants, 73.3% were female and the remaining 26.7% were males. The racial breakdown of the participants are 83.3% reported being Caucasian and 16.7% reported being African-American with no other races represented.

Access to a mobile device was a requirement to participate in the study. Funding allowed for the purchasing of a number of devices for participants who did not own an Apple iOS device.
Of the 60 participants in the study, 85% already owned an iOS device; an iPad, iPad mini, iPhone or iPod touch. The remainder, 15% or 9 participants was provided with an Apple iPod touch to use for the balance of the semester.

All participants indicated taking previous anatomy courses. Of the participants, the majority, 43.3%, indicated having already received an Associate’s degree. The second largest group of responses, 38.3%, indicated having received a Bachelor’s degree in another subject.

Table 4.1 - Education level of participants

<table>
<thead>
<tr>
<th>Level of Education</th>
<th>Number of Respondents</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school graduate</td>
<td>3</td>
<td>5.0%</td>
</tr>
<tr>
<td>Some college credit, but less than 1 year</td>
<td>2</td>
<td>3.3%</td>
</tr>
<tr>
<td>1 or more years of college, no degree</td>
<td>26</td>
<td>43.3%</td>
</tr>
<tr>
<td>Associates Degree</td>
<td>5</td>
<td>8.3%</td>
</tr>
<tr>
<td>Bachelor's degree</td>
<td>23</td>
<td>38.3%</td>
</tr>
<tr>
<td>Master's degree</td>
<td>1</td>
<td>1.7%</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>100%</td>
</tr>
</tbody>
</table>

Analysis of Pre/Post Testing Data

An analysis of covariance (ANCOVA) procedure was conducted on the pretest and posttest data for this study. The independent variable, mobile design principles, had a single level. The dependent variable was the student’s achievement scores on the posttest and the covariant was the pretest score. Prior to running the ANCOVA procedure, tests were conducted to satisfy two assumptions, homogeneity-of-regression and the linear relationship between the covariant and dependent variable. An analysis was conducted to determine the homogeneity-of-regression (slopes) between the covariant and dependent variable did not differ significantly as a function of
the independent variable, $F(1, 56) = .003, p = .958$. The second assumption was met with a finding of no significant difference in equality of error variances, $F(1,58) = 2.76, p = .101$.

Having met both assumptions, the ANCOVA procedure was conducted and the results were significant, $F(1,57) = 7.2, p = .01$ (See Table 4.2).

<table>
<thead>
<tr>
<th>Source</th>
<th>$SS$</th>
<th>$df$</th>
<th>$MS$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Score</td>
<td>36.204</td>
<td>1</td>
<td>36.204</td>
<td>3.141</td>
<td>.082</td>
</tr>
<tr>
<td>Group Membership</td>
<td>82.989</td>
<td>1</td>
<td>82.989</td>
<td>7.2</td>
<td>.010</td>
</tr>
<tr>
<td>Error</td>
<td>657.029</td>
<td>57</td>
<td>11.527</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>772.583</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A follow-up test was conducted to evaluate the pairwise differences among the treatment and control group. The results showed that the treatment group’s mean score ($M = 20.093, sd = 2.935$) was significantly higher, controlling for the effects of the pretest, than that of the control group ($M = 17.740, sd = 3.910$).

**Analysis of Participant App Usage Data**

Participants used the apps for a period of six weeks. The study was limited to the use of devices that could run Apple iOS 5.0 or higher. During the duration of the study, the students in the control group used the placebo app for a period of 120.27 hours with a mean time per user being 4.40 hours. In contrast, the treatment group used their apps for a period of 99.18 hours with a mean time per user being 3.3 hours during the study. To investigate if there was any correlation between the time an app was used and student learning, a Pearson product-moment correlation, commonly known as Pearson’s $r$, was computed.
To insure there was no underlying correlation between the pretest and posttest score, a Pearson’s r was conducted on those values. There was a positive, but non-significant, correlation between the pre and posttest variables, \( r = 0.205, n = 60, p = 0.116 \). After establishing no significant correlation between the pretest and posttest, a Pearson’s r was computed to assess any relationship between the time of use and the posttest score. There was a positive, but non-significant, correlation between these two variables, \( r = 0.211, n = 60, p = 0.106 \). A scatterplot summarizes the results in Figure 4.1.

![Figure 4.1 - Scatterplot for Time of Use and Posttest Score](image)

More than just looking at time, another way to view student usage is content access events. The accessing of the content was divided between two different device types. A frequency analysis shows that the preferred device to access content was a smartphone. It was used to access content 63.09%. A tablet device was used 24.60% of the time to access content and mini-tablet was used 12.31% of time for the same purpose. The primary device used by the control group was a tablet (26.94%). In contrast, the majority of the treatment group used a smartphone to access their content, (35.66%). See Table 4.3 for the breakdown of time and content access.
Table 4.3 - Instances of Access by Device Type

<table>
<thead>
<tr>
<th>Group</th>
<th>Device Type</th>
<th>CAEs</th>
<th>Questions</th>
<th>Percent Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>iPhone (Smartphone)</td>
<td>2,835</td>
<td>2,591</td>
<td>15.95%</td>
</tr>
<tr>
<td></td>
<td>iPod touch (mini-Tablet)</td>
<td>456</td>
<td>138</td>
<td>1.91%</td>
</tr>
<tr>
<td>120.27</td>
<td>iPad (Tablet)</td>
<td>2,718</td>
<td>5,655</td>
<td>26.94%</td>
</tr>
<tr>
<td>Treatment</td>
<td>iPhone (Smartphone)</td>
<td>8,493</td>
<td>2,591</td>
<td>35.66%</td>
</tr>
<tr>
<td></td>
<td>iPod touch (mini-Tablet)</td>
<td>1,754</td>
<td>928</td>
<td>8.63%</td>
</tr>
<tr>
<td>99.18</td>
<td>iPad (Tablet)</td>
<td>1,699</td>
<td>1,693</td>
<td>10.91%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>17,955</td>
<td>13,127</td>
<td>100%</td>
</tr>
</tbody>
</table>

To further investigate the relationship between CAEs and posttest score, an analysis comparing the number of CAEs and posttest score was conducted using a Pearson’s r correlation. There was a medium strength, positive relationship to the number of times a participant accessed content via a mobile app and posttest score, $r = 0.302, n = 60, p = 0.019$. A scatterplot summarizes the results in Figure 4.2.

![Figure 4.2 - Scatterplot of Content Access Events and Posttest Score](image-url)
A review of the scatterplot in Figure 4.2 indicates an outlier. This participant logged twice as CAEs than any other participants, but did not use the treatment apps for as much time of use as others in the treatment as well as the control group. To determine what affect this outlier had on the Pearson’s r, a Spearmen’s rho was conducted because the procedure is less sensitive to outliers. The Spearmen’s rho revealed a statistically significant relationship between content access events (independent variable) and posttest scores (dependent variable), F (60) = .437, p = .000. There was a medium strength, positive relationship between content access events and posttest scores.

Further exploring the outlier, it was removed from the data set and the Pearson’s r was conducted once again. Once removed, the Pearson’s r indicated there was no significant relationship between the two variables, F (59) = 0.255, p = 0.051. Again, with the outlier removed the Spearmen’s rho was conducted. That procedure revealed a statistically significant relationship between the two variables with the outlier removed, F (59) = 0.409, p = 0.001.

Additionally, this outlier logged a total of 2503 CAEs, but did not have the largest amount to time using the apps. For instance, some control group participants used their app for more time than the outlier. In one instance, a control group participant used the app for 23.21 hours versus the outlier, 11.39 hours. Reviewing the number of CAEs for each group, the mean total for the control was 122 events and for the treatment it was 339. Juxtaposition to the CAE count, the mean time of use for the control group 153 minutes versus 125 minutes for the treatment. This outlier perfectly demonstrated the high CAEs, low TOU mobile usage profile.

An analysis of self-assessment questions answered and posttest score was conducted to determine if there was any relationship. A Pearson’s r was conducted with a finding of no
significant relationship between the two variables, $r = 0.077$, $n = 60$, $p = .556$. A scatterplot summarizes the results in Figure 4.3.

![Figure 4.3 - Scatterplot of Self-Assessment Questions and Posttest Score](image)

Qualitative Results from Student Reflections

To better understand how apps aided their learning, participants were asked to write a one-page reflection on their experiences during the study. Those reflections were coded for themes. Overall the perception of the apps by both the treatment and control was positive. Two major themes emerged for the treatment group. One of the themes that emerged was that participants liked the ubiquitous and convenient access to learning material. All participants indicated that access to instructional material at informal times was a significant advantage. Nancy\(^1\) reflected,

> The apps were useful because they made it easier to study anytime without needing your books with you. They contain a great deal of info. The pictures were detailed enough to really see the origins and insertions. The apps could use improvement in navigation between the different muscles. Having the muscle pictures and info in more of a flashcard type arrangement might be more functional. I did like that the apps had an option for listening to the information as well as reading it.

\(^1\) Nancy is a pseudonym
The theme continued as John reflected on how he used the mobile apps installed on his phone. John stated, “I found the app very useful since it allowed me to study on the go. If I had a quick question on a muscle it was easier to look it up on the app than finding the book out of my stuffed book sack or waiting for my computer to load up Moodle.” Mark reflected on one unique way he used the apps for his studies. He stated, “I really enjoyed the apps and they were very useful. The apps were very convenient. By convenient I mean you could use them anywhere whether it be in a library or church.”

Another theme that emerged from the reflections is participants used small amounts of time to inject formal instruction into informal learning opportunities. Throughout the study, participants continually reported positive results based on the ability to quickly access graphics, listen to audio and read micro lectures anywhere, anytime in short bursts. Mary stated, “I enjoyed the apps. It gave me a visual of each muscle. The apps allowed me to study when I had a smaller amount of time or did not have any books with me. Overall, the apps have helped me further improve my knowledge on the muscles.”

The theme continued when Barry reflected that, “The apps were useful because they made it easier to study anytime without needing your books with you. They contain a great deal of info. The pictures were detailed enough to really see the origins and insertions.” Tim agreed with Barry in his reflection. He stated, “I enjoyed the apps. It gave me a visual of each muscle. The apps allowed me to study when I had a smaller amount of time or did not have any books with me.”

Overall the review of the apps by the placebo group was positive, but many questioned the content. The major theme that came to the surface for the control group was the presentation of the information directly from Moodle into an app. As Denise stated,
I didn’t think the app was very useful compared to other apps I’ve used in the past. It wasn’t interactive enough. I felt we should be able to interact with the muscles and have more visuals. I don’t think it was necessary to have the notes on there because we already have them on Moodle.

Another participant, Steve, expected much more than a Moodle app. He stated,

I was under the impression that the app would be more supplemental to the lecture and lab. Meaning, not the same exact material as what was given on Moodle. Being able to pick a body part and move it around on the app would have been better than just showing the skeleton and highlighting parts. After looking at the app 2-3 times I stopped using it.

Betty also noted content mistakes in the Moodle course. She stated, “It was very helpful to have the app. I use it mainly to learn the origin and insertion, nerve and actions. Some of the modules did not have the nerve roots. I did not like that the app did not provide answers to the questions.”

The overall response to mobile apps for learning regardless of group was positive. Many students in the control group indicated they wanted more apps and suggested many ways to improve the placebo app. In contrast, the treatment group did ask for improvements, but most were superficial and would not require changes to the mobile design principles. The one item that was consistent across both groups is that students perceive that apps would be useful in their learning.

Analysis of Student Survey Data

In addition to the qualitative reflection, an instrument to study student perception of the mobile apps was given as part of the posttest. This survey can be found in Appendix G. After students completed the posttest, they were given 10 statements about mobile learning to evaluate. Those statements were divided into two main categories, willingness to use the apps and performance of the apps. Table 4.4 shows the results from the treatment group.
<table>
<thead>
<tr>
<th>Theme</th>
<th>Items</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to Use</td>
<td>I would participate in class if I could use my mobile device.</td>
<td>3.44</td>
<td>1.155</td>
</tr>
<tr>
<td></td>
<td>I would like to be able to download mobile applications that could help me study.</td>
<td>4.19</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>I would be more likely to participate in class activities outside of the class time if I could do so through my mobile device unique places to learn;</td>
<td>3.26</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>I would be more likely to ask for help if I could communicate through my mobile device.</td>
<td>3.22</td>
<td>1.155</td>
</tr>
<tr>
<td></td>
<td>The mobile app allowed me to learn and study in places I could not normally learn or study in.</td>
<td>3.52</td>
<td>1.341</td>
</tr>
<tr>
<td></td>
<td>I would spend more time on classwork if I could access materials anytime, anywhere on my mobile device.</td>
<td>3.89</td>
<td>1.155</td>
</tr>
<tr>
<td>Performance</td>
<td>It was not a lot of effort to learn how to use my mobile app designed for my class.</td>
<td>3.78</td>
<td>1.251</td>
</tr>
<tr>
<td></td>
<td>I found the mobile app useful and aided my learning.</td>
<td>3.52</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>The audio included in the app to be useful and aided in my learning.</td>
<td>3.41</td>
<td>0.931</td>
</tr>
<tr>
<td></td>
<td>The practice quizzes and feedback provided by the app allowed me to gauge my strengths and weaknesses on the learning material.</td>
<td>3.74</td>
<td>1.289</td>
</tr>
</tbody>
</table>

With the exception of the item “I would like to be able to download mobile applications that could help me study”, most of the respondents reported slightly positive agreement with most statements. The results of the survey of the control group were similar. Table 4.5 shows the results from the control group.
Table 4.5 - Breakdown of survey questions for the Control Group (N = 27)

<table>
<thead>
<tr>
<th>Theme</th>
<th>Items</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to Use</td>
<td>I would participate in class if I could use my mobile device.</td>
<td>3.26</td>
<td>1.13</td>
</tr>
<tr>
<td></td>
<td>I would like to be able to download mobile applications that could help me study.</td>
<td>3.22</td>
<td>1.155</td>
</tr>
<tr>
<td></td>
<td>I would be more likely to participate in class activities outside of the class time if I could do so through my mobile device unique places to learn;</td>
<td>3.44</td>
<td>1.155</td>
</tr>
<tr>
<td></td>
<td>I would be more likely to ask for help if I could communicate through my mobile device.</td>
<td>4.19</td>
<td>1.121</td>
</tr>
<tr>
<td></td>
<td>The mobile app allowed me to learn and study in places I could not normally learn or study in.</td>
<td>3.52</td>
<td>1.341</td>
</tr>
<tr>
<td></td>
<td>I would spend more time on classwork if I could access materials anytime, anywhere on my mobile device.</td>
<td>3.89</td>
<td>1.155</td>
</tr>
<tr>
<td>Performance</td>
<td>It was not a lot of effort to learn how to use my mobile app designed for my class.</td>
<td>3.78</td>
<td>1.251</td>
</tr>
<tr>
<td></td>
<td>I found the mobile app useful and aided my learning.</td>
<td>3.52</td>
<td>1.189</td>
</tr>
<tr>
<td></td>
<td>The audio included in the app to be useful and aided in my learning.</td>
<td>3.41</td>
<td>0.931</td>
</tr>
<tr>
<td></td>
<td>The practice quizzes and feedback provided by the app allowed me to gauge my strengths and weaknesses on the learning material.</td>
<td>3.74</td>
<td>1.289</td>
</tr>
</tbody>
</table>

Comparison of Treatment and Control Survey Data

In this section, the results of the survey for the treatment and control groups are compared.

To compare the two groups, a Mann-Whitney U test was performed to determine if there were any differences between the perceptions of the control and treatment groups. Table 4.6 shows those results.
Table 4.6 - Results of Mann-Whitney procedure to compare group results

<table>
<thead>
<tr>
<th>Theme</th>
<th>Question</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to Use</td>
<td>I would be more likely to participate in class if I could use my mobile device.</td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>It was not a lot of effort to learn how to use my mobile app designed for my class.</td>
<td>0.759</td>
</tr>
<tr>
<td></td>
<td>I would like to be able to download mobile applications that could help me study.</td>
<td>0.501</td>
</tr>
<tr>
<td></td>
<td>I found the mobile app useful and aided my learning.</td>
<td>0.552</td>
</tr>
<tr>
<td></td>
<td>I would be more likely to participate in class activities outside of the class time if I could do so through my mobile device.</td>
<td>0.739</td>
</tr>
<tr>
<td>Performance</td>
<td>The audio included in the app to be useful and aided in my learning.</td>
<td>0.552</td>
</tr>
<tr>
<td></td>
<td>The practice quizzes and feedback provided by the app allowed me to gauge my strengths and weaknesses on the learning material.</td>
<td>0.975</td>
</tr>
<tr>
<td></td>
<td>I would be more likely to ask for help if I could communicate through my mobile device.</td>
<td>0.963</td>
</tr>
<tr>
<td></td>
<td>The mobile app allowed me to learn and study in places I could not normally learn or study in.</td>
<td>0.189</td>
</tr>
<tr>
<td></td>
<td>I would spend more time on classwork if I could access materials anytime, anywhere on my mobile device.</td>
<td>0.785</td>
</tr>
</tbody>
</table>

The Mann-Whitney U procedure revealed there was no significant difference between the perception of the treatment and control groups.

Summary

The study was designed to provide data on student usage of mobile apps conforming to specific mobile design principles. An ANCOVA procedure was used to analyze the participants’ pretest and posttest scores using the independent variable, mobile design principles. The result of the procedure was significant, $F(1,57) = 7.2, p = .01$. It showed that students in the treatment group ($M = 20.093, sd = 2.935$) scored a significantly higher mean score, controlling for the effects of the pretest, than that of the control group ($M = 17.740, sd = 3.910$).
In addition to the testing data, app events were tracked using time stamped data. A Pearson’s r was computed to assess any relationship between the time a participant used an app and the posttest score. There was a positive, but non-significant, correlation between these two variables, r = 0.211, n = 60, p = 0.106. But, although the time of use using apps was a non-significant correlation, an analysis of the number of times a participant content access events and posttest score was conducted using a Pearson’s r correlation. There was a medium strength, positive relationship to the number of times a participant accessed the content and their posttest score, r = 0.302, n = 60, p = 0.019. A further correlative analysis of content access events and posttest results using a Spearmen’s rho indicated a significant relationship between the two variables, F (60) = .437, p = .000.

To gauge students’ perception of mobile learning, a survey was conducted containing two parts: a reflective writing composition and a ten question Likert scale survey. Regardless of group membership, the overall response to mobile apps for learning was positive. The one item that was consistent across both groups is the idea that mobile apps would be useful in their learning. Students indicated they wanted more apps and suggested many ways to improve the app experience.

The results of the survey for the treatment and control group were compared. To compare the two groups, a Mann-Whitney U test was performed to determine if there were any differences between the perceptions of the control and treatment group. The procedure revealed there was no significant difference in perception between the two groups.
CHAPTER 5
DISCUSSION AND CONCLUSIONS

This study was designed to collect data to review two primary research questions: do the design principles, applied in a mobile context, allow learners to develop knowledge content and understanding; and does the length of time using an app have an effect on student learning? The study explored factors that make a successful mobile learning environment using both quantitative and qualitative methods.

This chapter is organized into four sections: (1) Discussion of Findings; (2) Conclusions; (3) Implication for Practice and (4) Implications for Future Research.

Discussion of Findings

The rise of a technology culture and how consumers use mobile devices has profound implications for learning in the 21st century. It is acknowledged that there are many different learning theories to address the needs of modern learners. Regardless of instructional perspective, it may be prudent to acknowledge that society has shifted from the industrial age to the technological age. Humans use different technology devices in different ways and for unique purposes. Our society has shifted from television to personal computers to smartphones in the span of 20 years. The smartphone today represents a primary tool used by individuals for information acquisition that has implications for learning. The literature supports the assertion that current technology usage patterns are changing from one dominated by the personal computer desktop to a culture that is highly mobile using smartphones. This means both instructional and user interface design must follow.

Mobile devices, specifically the smartphone, are here to stay. Learning rarely happens in splendid isolation from the world around the student (Merriam et al., 2007). People today are increasingly turning to mobile apps for information and research to learn in small “slivers.”
When designing any technologically based learning experience, one must take into account the nature and context of the technology being used. Instructors that design learning environments must take into account all aspects of the learning experience, not just the cognitive aspect. Significant shifts in media and technology usage patterns should be considered as part of m-Learning design. The data suggest that it is not enough to simply deliver existing content on a mobile device. Both instructional and interface design needs to be purposefully constructed to take into account for mobile user context. This holistic approach allows for a conception of technology as something more than just a vehicle for learning; how people use technology frames and molds the learning experience. Understanding mobile user context and device characteristics dictates a specific interface and instructional design that is not consistent with most incarnations of e-Learning (online and blended) or face-to-face designs.

The smartphone today has wonderful capabilities, but it will take specific instructional and interface design to make these devices useful for learning. The inclusion of Mobile HCI research in the instructional design process allows for the educator to adjust content presentation to user context. The traditional view of students pouring over material for hours may no longer apply. Therefore, the construction of content in such a way to be consumed in small slivers may be the most effective way for students to learn.

Each individual creates his or her own path to knowledge. How and when people use mobile devices is a primary factor to consider when constructing a mobile learning experience. Content constructed to fit the limitations of mobile devices can make a content access event more meaningful to the student. The data suggest that it’s not about the amount of time one spends with the content, but how effective each interaction is with that material.
Traxler (2007) defines m-Learning as personalized learning that recognizes different learning styles and approaches and recognizes social, cognitive, and physical difference and diversity. Designing learning apps that fit a mobile user’s context is of paramount importance. Additionally, apps that present a one-size-fits-all user experience may not be effective. Each person takes his or her own path to understanding, so it is important for the mobile app design to recognize that fact and account for the individual experience. Specifically, the data shows that no two users followed the same usage pattern.

The literature defines a specific set of criteria for today’s mobile learning. Mobile learners today access content for short periods of time but on a frequent basis. The mobile design principles are constructed to account for mobile user context in both instructional and interface design. Following the principles allows for the development of both content and a user interface design that best fits this learning situation. The findings of this study support the notion that treatment participants were able to use apps to develop their own path to understanding. The framework of content and user interface design created a flexible structured that could react to individual user needs. The mobile design principles were structure in such a way to account for this ambiguity in end-user progress. The learner analytics built into the system allowed the users to get instant and cumulative feedback on their progress and adapt their content access to address their weaknesses. This flexible framework allows each individual to control the experience, developing an individual path to understanding.

Specifically, both groups, treatment and control, demonstrated a willingness to access course material frequently, but the treatment group’s apps were more effective for the participants. Looking at the data, one can see an inverse relationship. The control group accessed their learning material for more total time than the treatment, but scored on average 2.35 points
lower. The participants demonstrated willingness to access instructional content and self-assessment material spontaneously, multiple times, and in an unprompted environment for impromptu learning. But, access without some form of direction provided a less effective experience for the control.

Students were willing to access content for learning in unique and different ways. The data suggest that the more content is accessed in smaller chunks, as opposed to the amount of time one spends with the content, can effect learning. This type of consumption most fits their typical usage pattern for communication with the outside world via text messaging, tweets, and social network postings.

m-Learning is more than a deep understanding of pedagogy or delivery of existing course material to a mobile device. The data from this study suggest that it is something more than just an extension of what already exist. It is not just a luggable form of e-Learning (Traxler, 2010) or a deep understanding of pedagogy or the delivery of course material to a mobile device. It requires an instructional designer to understand instructional and software design, mobile human-computer usage patterns, and learning theory. Botha’s (2010) assertion is that there is an inverse relationship between m-Learning and Mobile HCI. The data from this study supports the assertion from Traxler and Botha that defining m-Learning from solely a technological or learning perspective may exclude a needed element; mobile context. m-Learning is a phenomenon that has its own set of user constraints and a usability profile that in many ways dictates how the learning environment should be structure. Understanding how and when users consume information on mobile devices can be a significant benefits students and instructors.

When one takes both the content and how students go about a learning task in today’s society, then one can see the logic of marrying the two academic fields. A relationship where
neither m-Learning nor Mobile HCI dominate. Using mobile apps that are not specifically designed with a mobile user context in mind may not be used or useful to the student. Conversely, an app design with only the interface and technology in mind, may not aid learning. The data suggests it is important to consider both content structures as well as make affordances for such things as limited screen size, limited bandwidth, and limited usage times.

The usage patterns demonstrated in this study indicate that the treatment group was willing to access content more often, although for shorter periods of time. This usage pattern was very consistent throughout this study and the previous pilot study. Over and over again, students in the treatment group demonstrated willingness to access content, specifically and with a purpose. The qualitative data suggest that students would use the apps for studying at work, in church, before going to sleep at night and on their morning and afternoon commutes. This usage pattern is consistent with what one sees in the literature.

The implications of the literature and data from this study are clear; students are increasingly switching to mobile devices to obtain information. Smartphones and apps have become so pervasive in our society that many colleges and universities are rushing to adopt mobility. Shapes (2006) synthesized from sources that the reason students may want to use mobile is because (1) they have control, (2) they have ownership of the experience, (3) its fun for the students and (4) its how they naturally communicate. It’s important to note what makes the mobile learning environment successful. Interestingly, these basic ideas of control and ownership are key principles to the theories of andragogy (Knowles, 1980). A broadcast approach to education is in direct conflict with the information-on-demand generation’s desire to explore and construct knowledge.
Reviewing the access to content and self-assessment questions, one can see a very interesting pattern develop. The control group accesses the practice self-assessment questions 10,975 times. Much more than the treatment group’s 5,212 times. But the control group’s access did not seem to lead to any additional content access events with the treatment group far outpacing the control. Remember, the control groups question system was simply random; it gave the participant instant feedback on the correctness of their answer, but nothing more. Unlike the control, the treatment group’s question system had built in learner analytics. Not only did that system track the progress of the participant providing instant feedback, it gave the user visual cues to their cumulative strengths and weaknesses. This lead to a significantly higher number of content access events for the treatment group. This begs the question; did this electronic performance support system effect learning?

The age-old debate about media’s role in learning is one that cannot be settled within the scope of this study. It is hard to argue with Clark’s (R. E. Clark, 1983) statement that a vehicle delivering our groceries cannot enhance the nutrition of its contents, until one realizes a truck with square wheels can certainly effect the nutritional value of the contents in a negative way. If a learning system exhibits the same passive delivery characteristics as a television or lecture; then its effects on learning will be minimal if not non-existent given today’s society. On the other hand, a learning delivery system that exhibits some decision-making ability about learning, independent of the faculty member’s immediate intervention, could have an effect on learning. McKay and Wagner (McKay & Wagner, 2007) suggested that the use of a true electronic performance support system (EPSS) that can adjust instruction on an individual basis, could effect learning. With the built-in learner analytics of the treatment apps, feedback, independent of immediate faculty intervention, allowed students to track performance. The learner analytic
system gave student cues on what to study next for self-regulated instruction. This feedback loop directed each student down a path that allowed them to develop their own individual understanding of the material. Given the mobile learner analytics embedded in the treatment apps, the data suggest that students were able to identify their weaknesses and alter their learning patterns accordingly. This system aided in their learning by providing a feedback loop. As students progressed from one item to the next the system provided an individual path to remediation for their weaknesses. The data from the study suggests that an electronic performance support system can affect learning.

The data supports the assertion that a LMS that presents information in a desktop context to a mobile device may not be very effective at engaging student learning. What makes the treatment apps context-aware is the design that understands the basics of where and when the apps will be used for learning. This is not only a where and when but also what state of learning a student may be in at the time. Simple and intuitive navigation allows a student to quickly access a piece of information that is giving them trouble. Anticipating that basic usage pattern allows for the designing of both a user interface and content structure that is flexible and can be used in an infinite number of ways for learning. A failure to recognize the differences between a desktop environment and a mobile one, can result in less effective instruction. Interestingly, in the qualitative reflections, both groups presented a positive view of using apps for learning. Regardless of the group, students agreed with the concept of using mobile apps for learning and many indicated that the apps prompted them to search for other apps to aid their learning. The perceptions of both groups were equal. Overall each participant in the study, regardless of group membership, found using an app to be a positive experience and requested more apps for future courses.
Smartphones and apps have become so common in our society that many colleges and universities are rushing to adopt mobility for their learning management systems (LMS). Many LMS vendors are offering to deliver course material from the desktop LMS to the mobile device, promising more access to learning. This is a natural evolution for many commercial products given the rapid adoption of the smartphone and tablet devices on campus. But, one has to stop and consider the implication of simply implementing an app in this manner for learning. In addition to this shift in preference for a certain technology device, there is a movement away from Web-based content on mobile devices.

In today’s society, students prefer interactive media to traditional broadcast models. More than simply a learning preference, the media students choose to use today increasingly defines them. Specifically in many cases, the mobile LMS app does not account for a mobile learner’s context. In many cases the content is not designed in such a way to be consumed in short bursts or slivers. If one assumes a pattern of usage that is characterized by an individual engaging with material via a desktop interface for long periods of time, then the LMS app is not taking a mobile user’s context into account.

Furthermore, many LMS apps simply display what exist in the course with no attempt to enforce any conformity to a usage profile. Implementation of mobile LMS apps may provide easy access to directions and grades, but the data in this study suggest that presenting information from a LMS that has not been specifically designed for display on mobile devices and logically chunked is less effective. The data supports the assertion that LMS apps may not be as effective simply because the content and user interface design is dominated by the desktop view. The data further suggests that delivery of instructional content designed for the typical learning management system will not hinder learning, but may not help it. This begs the question,
why should a university invest funds in both implementation and information technology support cost to implement LMS mobile apps? The data suggest it may not be as useful in an m-Learning situation.

Conclusions

In conclusion, the significance of this work is that it points to the need to merge the two academic fields: m-Learning and Mobile HCI. The conclusion in this section is organized by the two research questions. The purpose of this work was to demonstrate the need to account for mobile usage patterns in both interface and instructional structure.

Research Question 1: Do the design principles, applied in a mobile context, allow learners to develop knowledge content and understanding?

The purpose of this study was to explore how mobile design principles can affect the learning experience of mobile learners. The quantitative data collected suggest that the mobile design principles do have some effect on learning. More specifically, understanding learner context may be an essential element to the design of any instruction in an m-Learning environment. The data collected in this study suggest that the mobile design principles allowed for a more effective learning experience for the students. These principles, extracted from the literature, take into account mobile user context, learning theory, and user interface design. Students in the treatment group reported using apps significantly for their learning.

Research Question 2: Does the length of time using an app have an effect on student learning?

There was no evidence to support the conclusion that the amount of time a student spent using a mobile app correlated to more learning. Students in a mobile context do not use apps for long periods of time like the model on a traditional learning management system. The results
suggest that increasing the number of times content is accessed is more effective than amount of time spend with material. More accurately, learning in this new paradigm may be based on the number of times a student accesses the content in a recursive process of awareness, exploration, reflection and resolution.

**Implications for Future Practice**

The quick nature in which technology changes presents a problem for instructional designers and content experts when it comes to the construction of apps. It is recommended that content be structured in such a way that it will become a learning object that can be pulled into any type of user interface. The advantage of this approach is that content becomes reusable in various formats.

Delivery on multiple devices types continues to be a challenge. Limited resources and availability of programmers makes it hard to convince a faculty member to begin moving their content in this direction. One may want to consider limiting development to a single device type until programming tools advance to the point of allowing the publication of a single code set onto multiple platforms.

Increasingly, education will need to deliver rich media experiences to students. Consistently throughout this study, students requested that the “apps” have more animations, audio, video and control. The students reported consistently they wanted more control of the experience. As society continues to evolve, education will increasingly be delivered via rich media technology with activities controlled by students; embrace it.

The data in this study does not suggest the prevention of using an LMS app for students. But, to make the expenses worth it, significant work will need to go into the content structure to make it educational significant in a mobile context. A significant instructional design effort
should surround the implementation of any mobile apps for learning regardless if those developments are custom or using a mobile learning management system.

Implication for Future Research

This study identifies a need to incorporate the academic field of mobile human-computer interaction research into m-Learning. Researchers in the area of m-Learning may want to further explore including an understanding of Mobile HCI into the instructional design process.

The study was limited insomuch as it was unable to explore various mobile operating systems. Future researchers may want to explore any potential differences in device characteristics such as screen size and ever increasing bandwidth.

Future researchers may want to investigate the delivery of instructional content to a mobile device via LMS apps. Better understanding of the relationship between instructional design and software architecture may provide better learning environments for students using those types of apps. Researchers may want to investigate how content design effects learning when using LMS apps.

The data in this study suggest that it's the number of times a student effectively accesses information that can aid learning, not the amount of time spent with the material. Researchers may want to explore ways to increase the number of times learning materials are accessed.
REFERENCES


Traxler, J. (2010). Distance education and mobile learning: Catching up, taking stock. Distance Education, 31(2), 129-130.


APPENDICES

Appendix A – Informed Consent

Consent Form for Study Involving Only Minimal Risk

Introduction
I, __________________, have been asked to participate in the study: Analyzing the effects of context-aware mobile design principles on student performance in undergraduate kinesiology courses. Mr. Eric Seneca who is conducting this research to investigate the effects of context-aware mobile design principles on student learning. He has explained the study to me.

Purpose of the Study
The purpose of this study is to establish efficacy for a specific set of mobile design principles.

Description of Procedures
Approximately 60 participants may be in this study. I will be asked to complete a pretest, which will take approximately thirty minutes to complete. I will receive a mobile app for learning material on upper extremity anatomy. At the end of the six-week period, I will be asked to complete a posttest, which will be approximately thirty minutes to complete. I understand that participation in this study will have no effect on my grade.

Risks and Discomforts
There are no known or expected risks from participating in this study, except for mild frustration sometimes associated with performance on a written test.

Benefits
I understand that this study is not expected to be of direct benefit to me, but the knowledge gained may be of benefit to others.

Contact Persons
For more information about this research, I can contact Mr. Eric Seneca at 225-768-0804. For information regarding my rights as a research participant, I may contact the Chair of the Institutional Review Board, Dr. Mike Dresnick, 225-214-6982.

Confidentiality
I understand that any information obtained as a result of my participation in this research will be kept as confidential as legally possible. I understand that these research records, just like hospital records, may be subpoenaed by court order or may be inspected by federal authorities. In any publications that result from this research, neither my name nor any information from which I might be identified will be published without my consent.

Voluntary Participation
Participation in this study is voluntary. I understand that I may withdraw from this study at any time. Refusal to participate or withdrawal will involve no penalty or loss of benefits for me. I have been given the opportunity to ask question about the research, and I have received answers concerning areas I did not understand. Upon signing this form, I willingly consent to my participation in this study.

_____________________________  _________________________
Signature of Participant                  Date

_____________________________  _________________________
Signature of Investigator or Investigator’s Representative       Date
Appendix B – Our Lady of the Lake College IRB Approval

OUR LADY OF THE LAKE COLLEGE
Franciscan Missionaries of Our Lady Health System

Date: November 27, 2012
Study Number: 1225
Study Title: Analyzing the Effects of Context-Aware Mobile HCI Design Principles on Student Performance in Undergraduate Kinesiology Courses
Primary Investigator: Eric Seneca, M.Ed., Director of Distributed Learning
Secondary Investigators: None
Approval Designation: Expedited Review
Primary Reviewer (Date): Michael Dreznick (November 27, 2012)
Secondary Reviewer (Date): Annette Knobloch (November 27, 2012)

Dear Mr. Seneca,

I am pleased to inform you that Michael Dreznick and Annette Knobloch of the Our Lady of the Lake College Institutional Review Board have reviewed and approved your proposed study entitled Analyzing the Effects of Context-Aware Mobile HCI Design Principles on Student Performance in Undergraduate Kinesiology Courses conducted by Eric Seneca.

Thank you for your submission and I would like to wish you success with your study.

Best regards,

Dr. Michael T. Dreznick,
Associate Professor and OLOL College IRB Chair
Appendix C – Louisiana State University IRB Approval

Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from institutional review board (IRB) oversight, all LSU research/ projects using living humans as subjects, on samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This form helps the PI determine if a project may be exempted, and is used to request an exemption.

Applicant/PI: Please fill out the application in its entirety and include the completed application as well as parts A-F listed below. When submitting to the IRB, once the application is complete, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of the committee can be found at http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard/lSUIRBLIRBl2Item24737.html

- A Complete Application Includes All of the Following:
  (A) Two copies of this completed form and two copies of parts B through F.
  (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  (C) Copies of all instruments to be used.
  (D) If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment materials.
  (E) The consent form that you will use in the study (see part 3 for more information.)
  (F) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: http://privacytraining.com/users/login.php
  (F) IRB Security of Data Agreement: https://research.lsu.edu/files/Item26774.pdf

1) Principal Investigator: Eric Sameca
   Dept: ETPP
   Ph: 225-505-6566
   E-mail: isameca@lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each
   *If student, please identify and name supervising professor in this space

3) Project Title: ANALYZING THE EFFECTS OF CONTEXT-AWARE MOBILE HCI DESIGN PRINCIPLES ON STUDENT PERFORMANCE IN UNDERGRADUATE KINESIOLOGY COURSES.

4) Proposal? (Yes or No) No If Yes, LSU Proposal Number
   Also, if YES, either
   ○ This application completely matches the scope of work in the grant
   OR ○ More IRB Applications will be filed later

5) Subject pool (e.g. Psychology students)
   *Circle any "vulnerable populations" to be used: (children <18; the mentally ill/paired; pregnant women; the aged; others) Projects with incarcerated persons cannot be exempted.

6) PI Signature: [Signature]
   Date: 11/11/2013

** I certify that my responses are accurate and complete. If the project scope or design is later changed, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted

Signed Consent Waived: Yes/No
   Reviewer: Kristin A. Complo
   Signature: [Signature]
   Date: 11/15/2013

LSU Institutional Review Board
Dr. Robert Matthews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
Ph: 225-578-8692
F: 225-578-5883
rjm@lsu.edu
Appendix D – CITI Collaborative Institutional Training

Social & Behavioral Research - Basic/Refresher Curriculum Completion Report

Printed on 11/21/2012

Learner: Eric Seneca
Institution: Franciscan Missionaries of Our Lady Health System
Contact Information: 5421 Didesse Drive
Baton Rouge, LA 70808 United States
Department: Office of Academic Technology
Phone: 2257680804
Email: eric.seneca@ololcollege.edu

Social & Behavioral Research - Basic/Refresher: Choose this group to satisfy CITI training requirements for Investigators and staff involved primarily in Social/Behavioral Research with human subjects.

Stage 1. Basic Course Passed on 11/21/12 (Ref # 9207889)

<table>
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<tr>
<th>Required Modules</th>
<th>Date Completed</th>
<th>Score</th>
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<tr>
<td>Ethical Disclaimer</td>
<td>11/20/12</td>
<td>1/1 (100%)</td>
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<tr>
<td>Conflicts of Interest in Research Involving Human Subjects</td>
<td>11/21/12</td>
<td>5/5 (100%)</td>
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<tr>
<td>History and Ethical Principles - SBR</td>
<td>11/21/12</td>
<td>5/5 (100%)</td>
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<tr>
<td>Defining Research with Human Subjects - SBR</td>
<td>11/21/12</td>
<td>5/5 (100%)</td>
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<tr>
<td>The Regulations and The Social and Behavioral Sciences - SBR</td>
<td>11/21/12</td>
<td>5/5 (100%)</td>
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<td>Assessing Risk in Social and Behavioral Sciences - SBR</td>
<td>11/21/12</td>
<td>5/5 (100%)</td>
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<tr>
<td>Informed Consent - SBR</td>
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<td>5/5 (100%)</td>
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<td>Privacy and Confidentiality - SBR</td>
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<tr>
<td>Research with Prisoners - SBR</td>
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<td>4/4 (100%)</td>
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<tr>
<td>Research with Children - SBR</td>
<td>11/21/12</td>
<td>4/4 (100%)</td>
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<tr>
<td>Research in Public Elementary and Secondary Schools - SBR</td>
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<td>3/4 (75%)</td>
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<td>Belmont Report and CITI Course Introduction</td>
<td>11/21/12</td>
<td>2/3 (67%)</td>
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</table>

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator
Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that Eric Seneca successfully completed the NIH Web-based training course “Protecting Human Research Participants”.

Date of completion: 04/24/2009

Certification Number: 221822
Appendix F – Pre/Post Test Instrument

ANSWER KEY

Instructions: Please take the next 60 minutes, if necessary, to review and complete each item on the test. Remember, this will not affect your grade or be included in any grade calculation. Also, leave nothing unanswered, do your best. Thank you for participating in this study.

Study name: ANALYZING THE EFFECTS OF CONTEXT-AWARE MOBILE DESIGN PRINCIPLES ON STUDENT PERFORMANCE IN UNDERGRADUATE KINESIOLOGY COURSES.

1. The opponens digiti minimi is innervated by which of the following peripheral nerves?
   a. Median Nerve
   b. **Ulnar Nerve**
   c. Radial Nerve
   d. Hypothenar Nerve
   e. Superficial Palmar Nerve

2. Which of the following nerve roots supplies the peripheral nerve that innervates the levator scapula?
   a. C5
   b. C6
   c. C7
   d. C8
   e. T1

3. The nerve roots which contribute to the peripheral nerve that innervates the serratus anterior includes:
   a. C8-T1
   b. **C5, C6 and C7**
   c. C5 and C6
   d. C5-T1
   e. C6, C7 and C8

4. Which of the following best describes the primary action of the teres minor?
   a. Medial rotation of the humerus
   b. Extension of the humerus
   c. Flexion of the humerus
   d. **Lateral rotation of the humerus**
   e. Horizontal adduction of the humerus

5. Which of the following muscle actions best characterizes the function of the whole pectoralis major?
   a. **Horizontal Adduction**
   b. Shoulder Abduction
c. Shoulder External Rotation  
d. Shoulder Extension  
e. Shoulder Flexion  

6. Which of the following peripheral nerves provides innervation to the coracobrachialis?  
a. Ulnar Nerve  
b. Radial Nerve  
c. Median Nerve  
d. Musculocutaneous Nerve  
e. Axillary Nerve  

7. The long head of the biceps brachii originates from which of the following bony landmarks?  
a. Supraglenoid Tubercle  
b. Infraglenoid Tubercle  
c. Greater Tuberosity  
d. Lesser Tuberosity  
e. Coracoid Process of the Scapula  

8. The teres major inserts into which of the following landmarks?  
a. Greater tuberosity  
b. Lesser tuberosity  
c. Lateral lip (crest) of the bicipital groove  
d. Medial lip of the bicipital groove  
e. Infraglenoid tubercle  

9. The flexor carpi radialis inserts into which of the following bony landmarks?  
a. Base of the Proximal Phalanx of the Thumb  
b. 2nd Metacarpal  
c. Scaphoid  
d. Trapezium  
e. Trapezoid  

10. The flexor carpi ulnaris inserts into which of the following bony landmarks?  
a. Triquetrum and Pisiform  
b. Pisiform and Hamate  
c. Hamate Only  
d. Lunate  
e. Head of the 5th Metacarpal  

11. The flexor digitorum superficialis inserts into which of the following bony landmarks?  
a. Base of the Proximal Phalangeal Segments of the Medial 4 Fingers  
b. Base of the Middle Phalangeal Segments of the Medial 4 Fingers  
c. Base of the Distal Phalangeal Segments of the Medial 4 Fingers
d. Extensor Expansion  
e. Lumbrical Tubercle

12. The flexor digitorum profundus inserts into which of the following bony landmarks?  
   a. Base of the Proximal Phalangeal Segments of the Medial 4 Fingers  
   b. Base of the Middle Phalangeal Segments of the Medial 4 Fingers  
   c. Base of the Distal Phalangeal Segments of the Medial 4 Fingers  
   d. Extensor Expansion  
   e. Head of the Distal Phalangeal Segments of the Medial 4 Fingers

13. Which of the following peripheral nerves provides nervous innervation to the extensor carpi radialis brevis?  
   a. Median Nerve  
   b. Ulnar Nerve  
   c. Posterior Interosseous Nerve  
   d. Anterior Interosseous Nerve  
   e. Radial Nerve

14. Which of the following peripheral nerves provides nervous innervation to the extensor carpi ulnaris?  
   a. Radial Nerve  
   b. Ulnar Nerve  
   c. Median Nerve  
   d. Musculocutaneous Nerve  
   e. Axillary Nerve

15. The subclavius muscle inserts into which of the following landmarks?  
   a. Acromion process of the scapula  
   b. Clavicle  
   c. First rib  
   d. Coracoid process of the scapula  
   e. Sternum

16. Which of the following best describes the action of the abductor pollicis brevis?  
   a. Abducts the CMC of the Thumb  
   b. Extends the CMC of the Thumb  
   c. Extends the MCP of the Thumb  
   d. Abducts the MCP of the Thumb  
   e. Flexes the IP Joint of the Thumb

17. The deltoid inserts into which of the following bony landmarks?  
   a. Greater Tuberosity  
   b. Lesser Tuberosity  
   c. Coronoid Process
d. Lateral Supracondylar Ridge  

18. The supraspinatus inserts into which of the following bony landmarks?  
   a. Greater Tuberosity - Inferior Facet  
   b. Greater Tuberosity - Middle Facet  
   c. Greater Tuberosity - Superior Facet  
   d. Lesser Tuberosity  
   e. Crest of the Greater Tubercle  

19. The infraspinatus originates at which of the following bony landmarks?  
   a. Spine of the Scapula  
   b. Infraspinous Fossa  
   c. Superior Angle of the Scapula  
   d. Inferior Angle of the Scapula  
   e. Axillary Border of the Scapula  

20. The pectoralis minor originates from which of the following landmarks?  
   a. Clavicle  
   b. Ribs 1 and 2  
   c. Sternum  
   d. Coracoid process  
   e. Ribs 3, 4 and 5  

21. The abductor digiti minimi is innervated by which of the following peripheral nerves?  
   a. Hypothenar Nerve  
   b. Radial Nerve  
   c. Median Nerve  
   d. Abducens Nerve  
   e. Ulnar Nerve  

22. The brachioradialis inserts into which of the following bony landmarks?  
   a. Palmar Aponeurosis  
   b. Ulnar Styloid  
   c. Radial Styloid  
   d. Lister's Tubercle  
   e. Scaphoid Bone  

23. The brachialis inserts into which of the following bony landmarks?  
   a. Ulnar Tuberosity  
   b. Radial Tuberosity  
   c. Interosseous Membrane  
   d. Olecranon Process  
   e. Ulnar Crest
24. The triceps brachii inserts into which of the following bony landmarks?
   a. Triceps Tuberosity
   b. Ulnar Tuberosity
   c. Olecranon Process
   d. Lateral Epicondyle
   e. Radial Head

25. The lumbricals of the hand originate from which of the following landmarks?
   a. Heads of Metacarpals 2-5
   b. Tendons of Palmar Interossei
   c. Tendons of Dorsal Interossei
   d. Tendons of the Flexor Digitorum Profundus
   e. Tendons of the Flexor Digitorum Superficialis
Appendix G – Student Perception Survey

Research ID _______________________

Using the provided Scranton form, please complete this 10-question survey by bubbling in the your most appropriate response.

Please answer the following questions using the scale below
1 – Strongly Disagree
2 – Disagree
3 – Neutral
4 – Agree
5 – Strongly Agree

51. I would be more likely to participate in class if I could use my mobile device.

Strongly Disagree 1 2 3 4 5 Strongly Agree

52. It was not a lot of effort to learn how to use my mobile app designed for my class.

Strongly Disagree 1 2 3 4 5 Strongly Agree

53. I would like to be able to download mobile applications that could help me study.

Strongly Disagree 1 2 3 4 5 Strongly Agree

54. I found the mobile app useful and aided my learning.

Strongly Disagree 1 2 3 4 5 Strongly Agree

55. I would be more likely to participate in class activities outside of the class time if I could do so through my mobile device.

Strongly Disagree 1 2 3 4 5 Strongly Agree

56. The audio included in the app to be useful and aided in my learning.
57. The practice quizzes and feedback provided by the app allowed me to gauge my strengths and weaknesses on the learning material.

58. I would be more likely to ask for help if I could communicate through my mobile device.

59. The mobile app allowed me to learn and study in places I could not normally learn or study in.

60. I would spend more time on classwork if I could access materials anytime, anywhere on my mobile device.
Research ID  

Please give us your feedback.

This is your chance to let us know what you think about the app/s. Please use this page to tell us anything about your experience with the app/s. We want to know how to improve the experience as well as what worked for you. How did you like the app/s? Were they useful? How can they be improved? What is good about them? Please feel free to give us both positive and negative feedback. As always your results will remain anonymous.
VITA

Eric John Seneca, is a native of Addis, Louisiana. A graduate of Southeastern Louisiana University with a Masters of Education in Technology Leadership and Bachelor of Science in Computer Science, he has worked in various business and educational settings. He has over seventeen years of experience in management and system design in high paced information technology departments with specialties in instructional technology, project management, database design, program design, and UNIX system engineering. His interest in graduate work grew when his third son was born deaf and received cochlear implants. He was admitted to the Department of Educational Theory, Policy, and Practice at Louisiana State University in 2010. His current research interests are in mobile learning, electronic performance support systems, and special needs learning. He will receive his Doctorate of Philosophy degree and plans to continue his work on learning apps for special needs children.