User Acceptance of a Novel Anatomical Sciences Mobile App for Medical Education-
An Extension of the Technology Acceptance Model

DISSERTATION

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Abstract

There continues to be a decrease in contact hours for anatomy sub-discipline instruction to medical students. Along with the change in contact hours, medical schools are transitioning from individual discipline-based courses to integrated curricula. Medical educators have attempted to counteract the decrease in time spent with the students by creating numerous electronic learning (e-learning) and mobile learning (m-learning) resources. The rapid expansion of mobile technology in higher education has provided students the opportunity to take the content provided from their schools with them, making it accessible at anytime and at any place. The powerful hardware and software within mobile devices like Apple’s iPad allows developers to create intuitive, interactive and effective mobile applications (apps). Medical educators to this point have not taken advantage of the mobile technology available to create an integrated anatomy resource to supplement the integrated curricula of current medical schools. The goal of this study is to: 1) Assess the current state of mobile technology usage by medical students; 2) develop a novel integrated anatomy mobile app (i.e., 4natomy); 3) measure the acceptance and usage of the mobile app by medical students; 4) gather feedback to determine the future viability of the mobile resource.

The outcomes from a group interview conducted with second year medical students within an integrated curriculum revealed that they use multiple devices while studying and are very comfortable with mobile technology. The students collectively
downloaded forty-eight different mobile apps for studying purposes and gross anatomy was the discipline with the most commonly downloaded app. Students prefer anatomy apps with three-dimensional (3D) models, as well as detailed text descriptions and had a high response rate (98.3%) in regards to their interest in using an integrated anatomy app.

The 4natomy mobile app of the spinal cord was developed through collaborations with computer science and digital design students to reflect responses from the focus group. The app was distributed during the neurological disorders learning block at The Ohio State University College of Medicine (OSU-COM). A post-survey was sent out following the learning block to measure acceptance and usage of the app using the technology acceptance model (TAM). The results indicate that students found the app to be useful and easy to use, predicting continued usage of the app in the future. A group interview conducted with twenty first-year medical students occurred following use of the mobile app to provide insight into future development. For future versions students requested expanding the anatomy content to cover the entire learning block, including a quiz component, integrating more clinical correlations and developing more videos and animations. A total of 95% first year medical students that participated in the final group interview sessions would like to see the app expanded to all other learning blocks. Small sample sizes and potential observer bias are limitations of the three main components of this study (i.e., both group interviews and post-survey responses).

The data gathered from this study illustrates the current landscape of mobile technology used by medical students at one university and what resources they prefer to use on those devices. The results from this study provide valuable data for the continued
development of mobile educational resources, specifically within the integrated medical curricula.
Dedication

This document is dedicated to my family.
Acknowledgments

There are many individuals who have provided unwavering support to me over the past five years and for that I am incredibly thankful.

I first would like to thank my committee members: Dr. Bolte, Dr. Burgoon, Dr. Danforth, Professor Alan Price, Dr. McHugh, and Dr. Kalmar. The effort, guidance, feedback, and time you each provided to me was crucial in the development of this project. Dr. Bolte as an advisor you have served as a mentor and supporter of me as both a graduate student and an educator. While I am not an engineer, you consistently provided your unique perspective to my thoughts and ideas throughout the course of this project. You always found time to meet with me to discuss not only my project, but to ensure that I was continually pushing myself to be a better educator. Thank you for accepting me as one of your students and pushing me to always improve.

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Lastly, I would like to thank my family and friends for providing support as I continued my education. You helped me throughout the stressful events that occurred throughout my five years of graduate school and were always there to provide the necessary words of encouragement. Thank you all for everything.
Vita

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Fields of Study

Major Field: Anatomy
Table of Contents

Abstract ................................................................................................................................. ii

Dedication ............................................................................................................................. v

Acknowledgments .............................................................................................................. vi

Vita ......................................................................................................................................... viii

Fields of Study .................................................................................................................... viii

Table of Contents ................................................................................................................. ix

List of Tables ....................................................................................................................... xiii

List of Figures ..................................................................................................................... xvi

Abbreviation Term List ....................................................................................................... xix

Chapter 1: Introduction and Significance ........................................................................ 1

1.1: Anatomy Education in Medical Schools ................................................................ 4

1.2: Mobile Learning Definition and Characteristics ............................................... 8

1.3: Mobile Learning through PDAs .............................................................................. 9

1.4: Technology Acceptance Model ............................................................................. 10

1.5: Human Computer Interaction and Usability ......................................................... 16

1.6: Learning with Mobile Apps ................................................................................... 19
5.3 Data Analysis .................................................................................................................. 143
5.4 Results ............................................................................................................................. 143
5.5 Discussion .......................................................................................................................... 149
5.6 Limitations ....................................................................................................................... 153
5.7 Conclusions ....................................................................................................................... 154
Chapter 6: Conclusions and Future Recommendations ...................................................... 156
References ............................................................................................................................... 164
Appendix A: Second Year Medical Student Focus Group Questions .............................. 174
Appendix B: Mobile Apps Downloaded by Second Year Medical Students at the OSU-COM ........................................................................................................................................... 175
Appendix C: App Feature Combinations Listed by Second Year Medical Students ..... 177
Appendix D: Survey Instrument with Questions from the Technology Acceptance Model ........................................................................................................................................ 178
Appendix E: First Year Medical Student Focus Group Questions ................................. 180
Appendix F: Final Group Interview Responses ................................................................. 181
Appendix G: IRB Research Approval ..................................................................................... 187
List of Tables

Table 1. Smartphone brands owned by second-year medical students (n= 59). N/A for this table refers to the one student that did not own a smartphone. .............................. 39

Table 2. Number of apps downloaded on mobile devices for studying by students (n=59).  ......................................................................................................................... 42

Table 3. Anatomy specific mobile apps downloaded mentioned by medical students (n=59).................................................................................................................. 43

Table 4. Percent of medical students that downloaded between 0-3 anatomy mobile apps (n=59)............................................................................................................. 44

Table 5. Beneficial features of educational mobile apps indicated by medical students (n=59)................................................................................................................. 45

Table 6. Relationship between comfort level and number of apps downloaded of 2nd year medical students. ................................................................................................................. 47

Table 7. Demographic information gathered from the survey of participating medical students (n=80). .................................................................................................................. 103

Table 8. Factor loadings, average variance extracted, composite reliability and Cronbach's alpha of observed variables ............................................................................ 111
Table 9. Mean, standard deviation, and estimated correlations among constructs. The bolded numbers represent the square roots of the average variance extracted (AVE) values for each construct.

Table 10. Model fit indices for measurement model.

Table 11. Beta coefficients, t-values and results of hypotheses from structural equation model analysis. Key: *p<0.05 but > .01, **p<0.01 but >.001, and ***p<0.001............

Table 12. Factor loadings, average variance extracted, composite reliability and Cronbach’s alpha of observed variables for modified model. Created by rescaling observed variables.

Table 13. Mean, standard deviation and estimated correlations among constructs for modified model. The bolded numbers represent the square roots of the average variance extracted (AVE) values for each construct.

Table 14. Model fit indices for modified measurement model.

Table 15. Beta coefficients, t-values, and results of hypotheses from structural equation model analysis of modified model once observed variables were rescaled. Key: *p<0.05 but > .01, **p<0.01 but >.001, and ***p<0.001...........................................

Table 16. Relationship between behavioral intention (BIAvg) and app usage (AppUsage).

Table 17. Descriptive statistics for anatomy scores and acceptance.

Table 18. Relationship between acceptance and anatomy scores.

Table 19. Chapter 4 Hypotheses 1-4 results.

Table 20. Chapter 4 Hypothesis 5 results.
Table 21. Chapter 4 Hypotheses 6-7 results. ................................................................. 135
Table 22. Chapter 4 Hypotheses 8-10 results. ................................................................. 135
Table 23. Chapter 4 Hypothesis 11 results. ................................................................. 136
Table 24. Chapter 4 Hypothesis 12 results. ................................................................. 137
Table 25. Chapter 4 Hypothesis 13 results. ................................................................. 138
Table 26. Results of hypotheses for modified model .................................................. 138
List of Figures

Figure 1. Original technology acceptance model (TAM), (Davis, 1986) .................. 11
Figure 2. Updated technology acceptance model (TAM) including motivation. (Lee et al., 2005) H= Hypothesis ................................................................. 13
Figure 3. Updated technology acceptance model (TAM) including personal innovativeness and subdividing perceived usefulness into near-term and long-term usefulness, (Liu et al., 2010). + = Hypothesized positive relationships. ..................... 15
Figure 4. Theoretical research model. H= Hypothesis ........................................ 16
Figure 5. Self-reported comfort level with mobile device usage. Measured on a 1 (very uncomfortable) - 10 (very comfortable) scale. .................................................. 40
Figure 6. Percent of mobile devices used by medical students (n= 59) when studying. .. 41
Figure 7. Frequency distribution of the number of apps downloaded by students (n=59). ............................................................................................................ 42
Figure 8. Anatomy sub-discipline specific mobile app downloads by medical students (n=59). N/A for this figure refers to no anatomy apps downloaded................................. 45
Figure 9. Medical student responses to using an integrated anatomy mobile app (n=59). 46
Figure 10. Initial layout for 4natomy app integration by computer science and engineering students................................................................................................. 65
Figure 11. Screenshot of 4natomy prototype index .................................................... 67
Figure 12. Screenshot of 4natomy prototype neuroanatomy home page......................... 68
Figure 13. Screenshot of 4natomy gross anatomy home page................................. 69
Figure 14. Thoracic spinal cord with labeled efferent and afferent spinal tracts in the
4natomy mobile app................................................................................................. 71
Figure 15. Screenshots from the lateral corticospinal tract animation in the 4natomy
mobile app.............................................................................................................. 72
Figure 16. Still image from the spinal cord prosection demonstration in the 4natomy
mobile app.............................................................................................................. 74
Figure 17. Series of screenshot images displaying the integration of the 4natomy mobile
app, gross anatomy (top left), embryology (top right) and histology (bottom)............. 75
Figure 18. Example of daily email report for the 4natomy mobile app sent by Crashlytics.
................................................................................................................................. 77
Figure 19. Crashlytics web-based dashboard providing data analytics on the 4natomy
mobile app. The top chart displays median session length and the bottom chart displays
time in app per user, with the peaks representing times. ........................................ 77
Figure 20. Worldwide iPad sales Q3 2010 through Q1 2015 (Statista, 2015).............. 81
Figure 21. Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980).................... 84
Figure 22. Original Technology Acceptance Model (TAM) (Davis, 1986)............... 85
Figure 23. Results from updated technology acceptance model (TAM) including
motivation (Lee et al., 2005). Key: AGFI= Adjusted goodness of fit index; RMSEA=
Root mean square error of approximation ............................................................. 89
Figure 24. Results from the updated TAM research model (Liu et al., 2010).............. 91
Figure 25. Theoretical research model for the current study. Key: H= Hypothesis. ........ 93

Figure 26. Theoretical proposed model for current study, with observed variables from Appendix D. ................................................................. 106

Figure 27. Confirmatory Factor Analysis of Proposed Model. ........................................... 113

Figure 28. Results of structural equation model analysis. Key: *p<0.05 but > .01,
**p<0.01 but >.001, and ***p<0.001. ............................................................................ 116

Figure 29. Results of the structural equation model analysis for the modified model created by rescaling the observed variables. Key: *p<0.05 but > .01, **p<0.01 but >.001,
and ***p<0.001. ............................................................................................................. 122

Figure 30. Components to be improved upon for future versions of the 4natomy mobile app based on the medical students (n = 20) interviews. ..................................................... 145

Figure 31. Features to be included in future versions of the 4natomy mobile app based on medical student (n = 20) interviews. .............................................................................. 147

Figure 32. Medical student (n= 20) responses to expanding the 4natomy mobile app to cover all other integrated learning blocks at The OSU-COM. ........................................... 148
### Abbreviation Term List

- **3D**: Three Dimensional
- **ACCAD**: Advanced Computing Center for the Arts and Design
- **ACGME**: Accreditation Council for Graduate Medical Education
- **AMS**: Alpert Medical School
- **API**: Application Program Interface
- **AVE**: Average Variance Extracted
- **BI**: Behavioral Intention
- **CFI**: Comparative Fit Index
- **CR**: Composite Reliability
- **DF**: Degrees of Freedom
- **E-learning**: Electronic Learning
- **GPA**: Grade Point Average
- **HCI**: Human Computer Interaction
- **HD**: High-definition
- **IDE**: Integrated Development Environment
- **IFI**: Incremental Fit Index
- **iOS**: iOperating System
- **IS**: Information Systems
- **IT**: Information Technology
- **M-learning**: Mobile Learning
- **MBA**: Masters of Business Administration
- **MCAT**: Medical College Admissions Test
- **ML**: Maximum Likelihood
- **NFI**: Normed Fit Index
- **PBL**: Problem Based Learning
- **PC**: Personal Computer
• **PDA**: Personal Digital Assistants

• **PE**: Perceived enjoyment

• **PEOU**: Perceived ease of use

• **PI**: Personal innovativeness

• **PLTU**: Perceived long term usefulness

• **PNTU**: Perceived near term usefulness

• **PU**: Perceived usefulness

• **OECRD**: Office of Evaluation, Curriculum Research & Development

• **OSU-COM**: The Ohio State University College of Medicine

• **RMSEA**: Root Mean Square Error of Approximation

• **SEM**: Structural Equation Modeling

• **SPSS**: Statistical Package for the Social Sciences

• **TAM**: Technology Acceptance Model

• **TLI**: Tucker-Lewis Index
• **UI:** User Interface
• **UK:** United Kingdom
• **US:** United States
• **USMLE:** United State Medical Licensing Exam
Chapter 1: Introduction and Significance

The decreased amount of contact time between educators and students has created the need for educational institutions to find ways to more efficiently teach their course content. From the years 1967 to 2001 the total number of hours devoted to gross anatomy in medical schools decreased by 40%, with a 50% decrease in time specifically for dissection in the laboratory (Gartner, 2003). Gross anatomy has suffered the greatest decrease in contact time, with the other anatomical sub-disciplines (i.e., histology, neuroanatomy, and embryology) also seeing an overall decrease in contact hours in medical schools (Gartner, 2003).

The education field is viewed as an early adopter of technological advances and is known for allocating a large amount of resources on new technologies with the goal of improving the teaching and learning process (Vinu, Sherimon, & Krishnan, 2011). Electronic learning (e-learning) is a learning method that utilizes computers without requiring the student to be physically present within the classroom. The advantage of e-learning is the ability to increase the accessibility of higher education to everyone regardless of time or geographical location (Gupta & Koo, 2010). E-learning first emerged in the late 1980s/early 1990s, with the technologies behind the pedagogical framework improving over time (Hashemi, Aziznezhad, Najafi, & Nesari, 2011). E-learning, which is mainly delivered through the use of personal computers (PCs), has
limitations due to the user being constricted to a certain location because of issues such as internet access and the lack of mobility of PCs. Mobile learning (m-learning) has been viewed as the natural evolution of education from e-learning due to the continual growth in development and the ownership of mobile technology mainly through smart phones and tablet computers (Martin & Ertzberger, 2013). An increase in the percentage of the population that owns a mobile device has increased the demand for m-learning programs, specifically in higher education.

The Ohio State University-College of Medicine (OSU-COM) has been at the forefront of providing the leading technology to their incoming medical students. In 2000, the OSU-COM began providing Personal Digital Assistants (PDAs) to first year medical students. Then, beginning in 2009, the university transitioned to iPod touches for incoming medical students (Vonderbrink, 2009). Finally, beginning in the fall of 2013, the incoming medical students at the OSU-COM were given iPads to be used throughout their schooling and this iPad program remains in place today. iDevices (i.e., Apple made portable devices) allow The OSU-COM students to: 1) view high quality images of the body from multiple angles; 2) to revisit old lectures through podcasts; 3) view numerous videos describing different medical and surgical procedures; and 4) to take gross anatomy practical examinations. The OSU-COM issued iPads are open to customization due to the large number of mobile apps and other resources available to the students. One of the goals for the iPad program at The OSU-COM is to further integrate content delivery across the various medical disciplines (Geier, 2013).
Since 2007, approximately 825 million iPhones and iPads have been sold, all of which run on a version of Apple’s software iOperating System (iOS) (Statista, 2015). iOS is the mobile operating system running on the iPhone and iPads. Apple opened their App Store in June 2008 and, as of October 20th, 2014, the 85 billionth app has been downloaded (Perez, 2014). The App Store is a digital marketplace where consumers can purchase applications that have been developed specifically to run on iOS devices. There are over 1.4 million apps developed for distribution through The App Store, with over 60,000 apps added per month (Adjust, 2014; Monaghan, 2015). The continual growth in market ownership by Apple in total devices sold and mobile applications available has initiated a transformation in education to take advantage of this growing market.

As numerous medical schools have or are beginning to make the transition to an integrated curriculum, there is a need for resources that integrates discipline specific content. According to a survey conducted by Drake, McBride and Pawlina (2014), 45% of medical schools teach Gross Anatomy within an integrated curriculum, which is a rapid increase from 30% in 2009. To date, m-learning resources have been seen as convenient additions to the traditional lecture and textbook format of higher education, but not as principal resources developed to supplement a curriculum. Investigation of user acceptance, motivation to use, and the actual usage of a mobile educational resource for medical students through the technology acceptance model (TAM) has not been done to date. The feasibility of an educational mobile application for medical students should be investigated for a number of reasons: 1) the increasing population of students that own mobile devices; 2) the decreased amount of time devoted to teaching the anatomical
sciences; 3) the shift of medical curricula to an integrated model; and 4) the shift of medical education from a traditional textbook format to a field that utilizes interactive technology to provide information. Therefore goal of this study is to:

1. Assess the current state of mobile technology usage by medical students
2. Develop a novel integrated anatomy mobile app
3. Measure the acceptance and usage of the mobile app by medical students
4. Gather feedback to determine the future viability of the mobile resource

1.1: Anatomy Education in Medical Schools

Throughout the past century, there has been a continual decrease in curricular time devoted to the anatomical sub-disciplines (i.e., gross anatomy, histology, neuroanatomy and embryology). According to a report published in 1909 by the Council on Medical Education of the American Medical Association, anatomy instruction accounted for 800-1000 total hours within the medical curriculum (Drake, McBride, Lachman & Pawlina, 2009). In the 1930s, the anatomy curricular contact hours began to decrease averaging 780 total hours, with a range of 480-1185 hours. This trend of declining teaching hours devoted to the medical anatomy curriculum continued through the later part of the 20th century with the average number of hours decreasing on average from 248 in 1967 to 143 hours by 2001 (Gartner, 2003). According to a survey conducted by Drake et al. (2009), the average hours devoted specifically to gross anatomy alone decreased (~11%) to 149 hours compared to the Drake et al., (2002) survey results of 196 hours. The average number of lecture hours was 43 and the average number of lab hours was 94. Hours
devoted to histology within the medical curriculum have seen a similar decline, with an average of 134 hours in 1967 to 81 hours in 2001 (Gartner, 2003). In 2009, Drake et al. reported the hours dedicated to histology continued to decline to an average of 73 hours. From the same survey data collected from 45 histology courses, 13 described their labs as utilizing microscopes alone, 20 utilizing virtual microscopy, and 12 using a combination of both. This trend of declining hours is also evident in neuroanatomy, with the hours decreasing from 91 hours to 72 hours from the years 1967 to 2001. Drake et al. (2009), however reported the hours in neuroanatomy have slightly increased from 2001 to 2009, with an average of 79 hours. There were 31 neuroanatomy courses that responded to the 2009 survey, with 12 of the respondents describing their Neuroanatomy course as part of an integrated approach and 19 reporting as a stand-alone course. Embryology as a course has seen drastic changes over the years. From 1967 to 2001, the total hours devoted to embryology decreased from an average of 28.5 hours to 15 hours. The survey conducted by Drake et al. (2009), details that approximately only 1 in 5 of the schools that responded have a stand-alone embryology course. Nearly 80% of the schools reported that embryology is part of an integrated course. A more recent survey conducted by Drake et al. (2014) shows that 45% of gross anatomy courses are now part of an integrated curriculum as compared to only 30% when the 2009 survey was conducted.

Having a fundamental knowledge of the human body in medical education is necessary for clinical application and in order to develop effective clinical reasoning and decision making (Finnerty et al., 2010). The decrease in overall time devoted to the anatomical sciences has led numerous schools to look for more efficient means to teach
the material. Petersson, Sinkvist, Wang and Smedby (2009) detailed the development of an interactive three-dimensional (3D) learning tool of major blood vessels. Findings from the study indicate that increased utilization of computer-aided tools was well received by students and was associated with improved learning based on the knowledge assessment results of the test group compared to the control group, as well as improved understanding of spatial anatomy. In another related study, McNulty, Sonntag and Sinacore (2009) described a six-year evaluation of a computer-aided instruction program in a gross anatomy course. The final course grades of students that utilized the computer-aided instruction were significantly higher as compared to students who never accessed the program. McNulty et al. (2009) discussed a general conclusion drawn from multiple other papers that “computer-aided instruction is equal to, and sometimes better than, conventional methods of teaching in level of student satisfaction and knowledge gains (p. 2).”

Curriculum specific to the nervous system is often viewed as conceptually difficult to students. Bryner, Saddawi-Konefka and Gest (2008) created interactive modules of the autonomic nervous system, lobes of the cerebral cortex, and cranial nerves based on the suggestions from faculty members of concepts typically difficult for students to master. In the Bryner et al. (2008) study, medical students were randomly assigned to a control group that studied the assigned concepts using existing materials such as lecture notes, slides, textbooks, etc., or to the experimental group that could use computerized educational modules in addition to the same material as the control group. The experimental group had higher mean quiz scores for each concept, though the difference
was not statistically significant. The perceived level of difficulty was statistically lower for the experimental group \((p<0.001)\), and the amount of study time was significantly higher for the experimental group \((p=0.028)\) (Bryner et al., 2008). Nowinski et al. (2009) created a 3D neuroanatomy atlas for the computer, as well as a mobile application. The program allows instructors to customize the test criteria for students to complete. Students have the ability to view numerous cerebral and vascular anatomy slices, as well as the ability to access the program’s test mode. The program has a function built in to randomly generate test questions from the atlas models. The randomization of test questions from the cerebral and vascular slices creates versatile tests for self-assessment of the students.

Decreased time allotted for lab in histology courses has led to the development of more efficient teaching methods. Sugand, Abrahams and Khurana (2010) described how multimedia tools have greatly improved the study of histology through virtual microscopy due to software magnification and associated labeling. Triola and Holloway (2011) created an open source virtual microscopy system based on the Google Maps engine. The virtual microscopy system consists of 1,037 slides and allows for slide annotation from the faculty. Upon implementation the virtual microscopy system was so efficient that the amount of time allotted for each laboratory session was reduced from three to two hours. Triola and Holloway (2011) then compared the examination scores of the medical students that used the virtual microscopy system to the students that did not use the virtual microscopy system the prior year. The virtual microscopy group scored
higher on average compared to the group the prior year, although the difference was not significant.

1.2: Mobile Learning Definition and Characteristics

M-learning is defined as learning by using a mobile device such as a smart phone, tablet, PDA, or mp3 player in a non-fixed location at the convenience of the user (Cronje & El-Hussein, 2010; Gupta & Koo, 2001; Vinu et al. 2011). M-learning as a method of education enables students to access course material at their convenience through devices such as smart phones and tablets. These devices are constantly “connected” to the Internet via data networks or WIFI networks, which allows for continuous communication between the instructor and the student through a teaching program (Vinu et al., 2011).

The adoption of PDA devices initially created the ability of many students to take their learning with them outside of the classroom. Quinn (2000) described m-learning as being at the intersection of mobile computing and e-learning. Specifically he stated “[mobile learning provides] accessible resources wherever you are, strong search capabilities, rich interaction, powerful support for effective learning and performance-based assessment”.

When developing m-learning products, Ozdamli and Cavus (2011) listed seven major characteristics to describe m-learning: 1) ubiquitous/spontaneous; 2) portable size of mobile tools; 3) blended; 4) private; 5) interactive; 6) collaborative; and 7) instant
information. Three of the seven characteristics listed are described in more detail in relation to m-learning, specifically ubiquitous/spontaneous, interactive, and instant information. Ubiquitous/spontaneous is a defining aspect of mobile learning, with the ability of the user to access course material anytime or anywhere (Martin & Ertzberger, 2013; Ozdamli & Cavus, 2011). Interactivity is a characteristic of m-learning that has great potential as mobile devices are continually being developed with faster processors, larger and higher quality multi-touch screens, and larger hard drive capacity. The continual improvements made in mobile devices allows for more powerful applications that create high-resolution interactive 3D models, high-definition (HD) video and audio streaming support (Lewis, Burnett, Tunstall & Abrahams, 2014). The ability of the user to manipulate life-like realistic models and to watch or listen multiple times to informative videos or audio recordings is a powerful characteristic of mobile devices (Mayfield, Ohara & O’Sullivan, 2012). Instant information provided by m-learning devices allows the user to immediately answer specific questions that may be contained within a learning module, as well as giving the user complete accessibility to the internet for further detail on any topic (Rossing, Miller, Cecil & Stamper, 2012).

1.3: Mobile Learning through PDAs

PDAs were first commercially available in 1984 through the company Psion. Multiple companies have attempted making their own PDA, with Nokia producing the world’s best-selling PDA, the 9000 Communicator in 1996 (Viken, 2009). Findings from a study conducted by Davies et al. (2012) with third year medical students during clinical
rotations in which PDAs were distributed, was that these students were able to access key facts in a timely manner, which they coined as “learning in context”. The medical students also described PDAs as aiding in the consolidation of required knowledge through the process of repetition and making the best use of what would otherwise be wasted time. A negative reaction by medical students in a study by Davies et al. (2012) was that the PDAs were seen merely as a supplemental learning tool instead of a complete replacement of prior learning strategies. Luanrattana, Win, Fulcher and Iverson (2012) conducted interviews with medical school faculty members, clinical academics, and education technology specialists within the University of Wollongong at the Graduate School of Medicine. The qualitative interviews were done in order to assess the feasibility of incorporating PDAs into the future medical school curriculum. Similarly, Luanrattana et al. (2012) found those interviewed believed PDAs would be beneficial as reference tools for medical students at an immediate time of need. Specifically, a positive reason indicated for implementing PDAs in the Graduate School of Medicine was the ability of students to access their resources anytime day or night allowing for repetitive learning as well as the ability to learn in context.

1.4: Technology Acceptance Model

The technology acceptance model (TAM) was first proposed by Davis (1986) as a way to explain user acceptance of information technology (IT) and information systems (IS). The TAM has been studied in the private sector (Gefen & Straub, 1997; Igbaria, Guimaraes & Davis, 1995), as well as in the educational field to study student acceptance
of e-learning (Park, 2009) and m-learning (Calisir, Gumussoy, Bayraktaroglu & Karaali, 2014; Lee & Lehto, 2013; Liu, Li and Carlsson 2010; Park, Nam & Cha, 2012). The TAM proposed by Davis is based on two determinants: 1) the perceived usefulness (PU); and 2) the perceived ease of use (PEOU) of the system. PU is defined as the user’s belief that using the system will improve his or her job performance and PEOU is defined as the degree to which a person believes that using a particular system would be free of effort (Davis, 1989). In the TAM, system usage is determined by the user’s behavioral intention (BI), which is affected directly by the user’s attitude towards the system and PU, and indirectly by PEOU. PU and PEOU directly affect attitude towards the system, and PEOU has a direct effect on PU (Lee, Cheung & Chen, 2005). Figure 1 depicts the original TAM (Davis, 1986).

Figure 1. Original technology acceptance model (TAM), (Davis, 1986).
The original TAM has been widely used in IS and IT research, but overtime has drawn critiques due to the lack of components that can provide a broader view and better explanation of system adoption (Legris, Ingham & Collerette, 2003). The TAM is a robust model to predict behavioral intention when use of the system is voluntary, where the user’s motivation to use a system is maintained by the user’s goals (Lee & Lehto, 2013; Rawstorne, Jayasuriya & Caputi, 1998). Venkatesh, Speier and Morris (2002) integrated aspects from the motivational model with the TAM. Their new model brought in the constructs of intrinsic and extrinsic motivation to be combined with the constructs of PU and PEOU. Schunk, Pintrich, and Meece (2008) described intrinsic motivation as the motivation to engage in an activity for its own sake, where in the participation of the activity itself is the reward. While Schunk et al. (2008) described extrinsic motivation as the motivation to engage in an activity because of the anticipated outcomes, for example improved job performance, promotions and improved test scores. In order to integrate the two models, Venkatesh et al. (2002) discussed how both extrinsic motivation and PU were both emphasizing an individual’s personal gains based on use of the technology and, thus, combined both constructs into PU. The TAM has no construct measuring intrinsic motivation and the motivational model has no construct related to PEOU, thus the new model contains both constructs. Lee et al. (2005) took the original TAM and integrated the motivational perspective discussed by Venkatesh et al. (2002) by including perceived enjoyment (PE) as the intrinsic motivation construct. Figure 2 depicts the updated model by Lee et al. (2005).
Figure 2. Updated technology acceptance model (TAM) including motivation. (Lee et al., 2005) H= Hypothesis.

Liu et al. (2010) utilized the TAM to investigate the key motivating factors for students to adopt m-learning. The original TAM was altered for the study to include three different constructs: 1) perceived near-term usefulness (PNTU); 2) perceived long-term usefulness (PLTU); and 3) personal innovativeness (PI). Liu et al. (2010) subdivided the original construct of PU into two more specific constructs, near-term and long-term usefulness, due to criticisms of PU being too broadly based. From the literature review, Liu et al. (2010) found near-term and long-term to both have significant impact on intentions to use IT. Chiu and Wang (2008) discussed that an educational system can simultaneously have near-term and long-term usefulness for students. Improved learning performance, effectiveness, and productivity represent students’ perceived near-term
usefulness, while graduating, obtaining a job or passing distant qualifying exams are examples of perceived long-term usefulness. Both perceived near-term and long-term usefulness have been shown to be significant predictors of student’s behavioral intention (Chiu & Wang, 2008). Davis (1989) found that the construct for attitude did not fully mediate the effect of perceived usefulness and perceived ease of use on behavior, which led to the suggestion of a more parsimonious TAM by removing attitude. Liu et al. (2010) removed attitude as a measured construct in their study and introduced personal innovativeness as a new construct into the updated TAM. Personal innovativeness, within an IS context, is described as an individuals’ willingness to adopt new technology. Based on prior research the construct of personal innovativeness has shown to be a significant predictor of PEOU (Lu et al., 2005; Serenko, 2008; Yi, Jackson, Park & Probst, 2006) and behavioral intention (Crespo & Rodriguez, 2008; Taylor, 2007). Figure 3 is the updated TAM presented by Liu et al. (2010).
Figure 3. Updated technology acceptance model (TAM) including personal innovativeness and subdividing perceived usefulness into near-term and long-term usefulness, (Liu et al., 2010). + = Hypothesized positive relationships.

The theoretical research model for this study was created (Figure 4) through a combination of the previously discussed models. The constructs measured in the studies conducted by Lee et. al (2005) and Liu et al. (2010) were chosen because both were attempting to measure student acceptance of mobile learning technology. These two studies are the closest in relation to the current study compared to other TAM published studies. The model proposed for this study incorporates the construct of perceived enjoyment previously studied in the user acceptance of an Internet learning medium by Lee et al. (2005) in an attempt to measure a student’s intrinsic motivation towards using a mobile resource. The proposed model also adopted the sub-divided perceived usefulness
constructs (i.e., near-term and long-term usefulness), as well as personal innovativeness, previously studied in student acceptance of m-learning by Liu et al. (2010).

Figure 4. Theoretical research model. H= Hypothesis

1.5: Human Computer Interaction and Usability

Human computer interaction (HCI) is “a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Oulasvirta & Brewster, 2008, p.1). Berg (2000) discussed HCI principles that should be taken into account when designing
educational software. One principle to be incorporated into the design is human factors. Berg (2000) focused on five human factors: 1) time to learn; 2) speed of performance; 3) rate of errors; 4) subjective satisfaction; and 5) retention over time. Berg (2000) also detailed the use of animations in educational software as an effective tool for explication of the topic to the user. Animations are powerful tools that can aid in reviewing material, provide choices within complex menus, demonstrate actions of a program, provide clear explanations, and provide guidance to the user when necessary. Interface design is an important component of HCI, as it is specifically focused on the input and output interactions between the user and computer, which traditionally has only been possible through input of the mouse and keyboard and output through the screen. Interface design principles have been forced to change in the recent years due to the popularity in mobile devices. The interaction between mobile devices and the user is now largely through touch screen manipulation, without the use of a mouse or physical keyboard. Mobile HCI is a relatively recent field of research with much of the literature focusing on the interaction between the environment of the user and the context of the information (Oulasvirta & Brewster, 2008). “Emerging technologies have made it possible for mobile computers to sense or access information about their user’s contextual setting, such as their physical environment, their location, their social setting, and their current activity” (Kjeldskov & Paay, 2010, p. 1). Oulasvirta and Brewster (2008) discussed that the mobile technologies have a great advantage over traditional computing technologies due to the ability of mobile technologies to take advantage of their contexts in order to benefit the user.
Usability is a design principle that evaluates whether a computer system functions in the way it was initially created (Berg, 2000). Gu, Gu and Laffey (2011) described usability as a system’s acceptability and continues to say that useable systems are “regarded as being reliable, compatible, efficient and effective to use as well as enjoyable for users (p. 206).” Nayebi, Dasharnais and Abran (2012) described three types of evaluation methodologies that are currently used in mobile usability studies: 1) Laboratory experiments in which human participants use a mobile app within a controlled laboratory setting; 2) field studies in which the participants use a mobile app in the user’s natural environment; and 3) hands-on measurements used to quantitatively measure the mobile application’s usability. Laboratory experiments are useful in testing mobile application usability because it allows the experimenter to control the environment while also giving defined tasks to the user. The defined tasks allow the experimenter to test quantitatively the usability of the mobile application, while blocking extraneous variables from interfering with the experiment. Laboratory experiments however can be expensive to administer, and, by predetermining the environment, the user may have a different experience than if they’re using the application in the “real world”. Field studies are useful because the user can voice their complaints, praises, and critiques of the interaction with the application to the experimenter directly. Field studies are viewed as useful early in the development of mobile applications in order to collect user requirements (Nayebi et al., 2012). Kaikkonen, Kekäläinen, Cankar, Kallio and Kankainen (2005) found no difference in the number of usability problems while testing their mobile application in a laboratory setting and a field test.
Nielsen described usability in his 1993 book *Usability Engineering* as typically measured by having a representative population of intended users test the system by performing a number of predefined tasks. Nielsen defined five components of usability goals for a system: 1) learnability; 2) efficiency of use; 3) memorability; 4) few and noncatastrophic errors; and 5) satisfaction of the user. Nielsen (1993) defined learnability as the most fundamental aspect of a system, because the user must be able to learn how to use the system quickly and easily, usually on the first attempt of use. Efficiency of use is measured by formulating a definition of expertise, gathering the representative user sample with the defined level of expertise and to measure the time it takes for the experts to complete the predetermined tasks in the developed system. Memorability is in reference to the interface being easy to remember for returning users. Few and noncatastrophic errors refers to the user not committing errors when using the developed system. Errors are typically defined as an action that does not accomplish the desired goal. Satisfaction of the user is simply defined as the system being enjoyable to use.

1.6: Learning with Mobile Apps

Mobile apps, specifically those created for a particular course or subject are still in the infancy stage in researching their effectiveness. There are, however, a few studies on the use of mobile apps with students in primary school and in higher education. Kiger, Herro, and Prunty (2012) conducted a study teaching fractions to third graders from Park Elementary in Chicago. In the study, two intact classrooms were taught fractions using the traditional methods, such as “Everyday Mathematics” and flashcards. Two other
intact classrooms at Park Elementary used the traditional methods of teaching fractions and, in addition, iPod touches pre-loaded with numerous mathematics apps were distributed each day to students for practice. The results from the Kiger et al. (2012) study showed a statistically significant difference between the classrooms that did not use the iPod touches compared to the classrooms that did utilize the iPod touch. The classrooms that used the iPod touches with the mobile mathematic apps showed a medium-sized performance advantage at a .01 alpha level.

Risconcente (2012) described a study conducted with 122 fifth graders from two separate schools in Southern California. The study was based on the use of a mobile app created for the iPad called Motion Math. Motion Math was created by graduate students from Stanford University and was designed to strengthen children’s understanding of fractions, proportions, and percentages. The study was conducted using a repeated-measure crossover design. Participants from each school were randomly assigned to group 1 or group 2. There was a pretest at the beginning of the study in order to assure equal groups. For the first week, participants within group 1 would use Motion Math, while group 2 was the control group and did not use the app. Following the first week a midtest was conducted for both groups. Group 1 had a significantly higher score on the midtest compared to group 2 who did not use the app. After the midtest, the roles of the groups were reversed, where group 2 now used the Motion Math app, while group 1 did not for a week. Following the second week, a posttest was administered. The results of the posttest show that the two groups were once again equivalent as in the pretest results.
Mayfield et al. (2012) conducted a study examining the effects of using an iPad-based dissection manual during gross anatomy laboratory on the learner’s perception of anatomy dissection. The iPad-based manual contained the same step-by-step dissection instructions as the paper version and the same digital images found in the paper version, as well as videos clips and images found in the previous day’s lecture. Three dissection tables served as the experimental group utilizing the iPads, while three dissection tables served as the control group using the traditional dissection materials (i.e., Grant’s Atlas of Anatomy and Netter’s Atlas of Human Anatomy). From the study they found that students who used the iPad-based laboratory manual were both observed and self-reported to be more engaged, achieved more objectives for each lab, and spent more time on task during the dissection compared to the control group of students.

Teri et al. (2013) conducted a study in which a mobile app (i.e., NutriBiochem) was specifically designed for nursing students enrolled in Biochemistry and Metabolism II at the University of Guelph-Humber in the fall of 2012 and the winter of 2013. Results from the study found that over half of the class accessed the app at least once, with the most common mobile device used being smart phones. Students with a higher level of comfort towards technology were more likely to utilize the app compared to lower comfort level individuals. Over 75% of the students agreed that NutriBiochem was a useful learning tool for both courses. Teri et al. (2013) concluded the study by describing how the use of mobile apps in education and particularly science education have shown to be: “effective in enhancing students’ learning experience, relevant and important as an emergent method of learning given modern pressures facing higher education, and met
with positive student attitudes and perceptions in terms of adopting and using such technology for educational purposes (p. 134).”

1.6.1 Purpose of the Study

The studies discussed throughout the literature review detail the change that has occurred in education over the past few decades. As access and connectivity between students and instructors has increased through online course web sites, e-mail, and collaborative mobile devices, assessment of the efficiency and effectiveness of mobile resources must be addressed. Mobile learning has widespread appeal due to the number of devices capable of providing resources, the large number of professional students who already own and are familiar with mobile technology, and the powerful hardware and software built into and available for these devices. The anatomical sciences have seen a dramatic decrease in contact hours from 1955-2009 (Drake et al., 2014) and the need for effective mobile anatomical resources will likely continue to grow as medical schools are increasingly providing students with tablet computers (Dolan, 2011). The goal of this study was to identify popular mobile apps used by medical students and features within the identified apps that are of the highest demand through group interviews with second year medical students. Following the group interviews, a novel integrated anatomical mobile app (i.e., Anatomy) on the spinal cord content was developed. The app was distributed to students during the Neurological Disorders Learning Block and survey data was collected following the block’s final exam in order to assess the student’s acceptance
and usage of the mobile app based on the TAM. The results from the survey and feedback from the final group interviews of students who used the app provided information on the future viability of an integrated mobile resource. Due to the lack of data on mobile resources created for medical students during the first two years of medical school, this study will provide valuable information for future resource and curricular development.

1.7: Overall Research Design

The first group interview sessions with second year medical students from the OSU-COM were conducted in order to produce qualitative and quantitative data about medical student mobile device usage, comfort level with mobile technology, and what mobile apps students have downloaded to use as educational resources. Following the design and development of the 4natomy mobile app, it was then distributed to first year medical students during the Neurological Disorders Learning Block. After the final exam for the learning block first year medical students were asked to complete a post-survey, consisting of questions developed based on the TAM about the mobile app. Additionally the final group interview sessions with first year medical students was conducted in order to determine the beneficial components of the app, features that could be eliminated or included and overall improvements that would be desirable for future iterations of the 4natomy mobile app.

The group interviews with second year medical students, the app development process, the post-survey, and group interview sessions with second year medical students
described above will be presented in chapters 2, 3, 4 and 5, respectively, and will be written as individual manuscripts. The title and aims of each manuscript are listed as follows:

Chapter 2: Assessing Medical Student’s Perspective on Mobile Devices and Apps in an Integrated Curriculum

Aim: To conduct group interviews with second year medical students in order to assess the current usage and comfort with mobile technology within an integrated medical curriculum.

One of the goals for this research was to create a mobile app that was novel in both function and content distribution. Due to the lack of literature on mobile technology usage by first and second year medical students, the first series of group interviews aimed to determine the following: 1) what mobile devices medical students use; 2) what self-assigned comfort level they had towards mobile device hardware and software; 3) what mobile apps they had downloaded to use as educational resources; and 4) what features of these apps were perceived to be beneficial to the user.

Chapter 3: Development of Anatomy an Integrated Anatomy Mobile App for iOS
Aim: To create a novel anatomical mobile app based on the spinal cord for the Apple iPad device reflecting the feedback gathered from the second year medical student group interviews.

Development of mobile apps for iOS is a booming market in the technology field. As of July 2014, there were over 1.25 million mobile apps available on The App Store, with as many as 60,000 apps added to the store each month (Adjust, 2014). Even as the Apple App Store is saturated with mobile apps there is currently no app that integrates the four anatomical sub-disciplines (i.e., gross anatomy, histology, embryology and neuroanatomy) into a single resource, which led to the need for development of this novel mobile app. Data from the group interviews directed the development of the mobile app prototype over the summer of 2014. The Anatomy mobile app was completed by a hired computer science student and the project lead to prior to the start of the Neurological Disorders Learning Block in January 2015.

Chapter 4: Medical Student Acceptance of an Anatomical Mobile App Based on the Technology Acceptance Model

Aim: To quantify the level of user acceptance of a novel anatomical mobile app based on the Technology Acceptance Model in order to better understand how integrated educational resources can be effectively implemented into integrated medical curricula for medical students prior to Step 1 of the United States Medical Licensing Examination (USMLE).
The purpose of this study was to investigate the usage and acceptance by first year medical students of a novel mobile app developed for iOS within an integrated medical curriculum. The current literature about mobile apps utilized by medical students is focused on third and fourth year students or residency education. There is no current literature about mobile apps created specifically for first and second year medical students during their respective years of school. There is also no current literature about mobile apps created based on an integrated medical curriculum. Based on the theoretical research model, the following research questions and associated hypotheses were tested:

**Research Question 1:** What relationship will perceived ease of use have with perceived near-term usefulness, perceived long-term usefulness, perceived enjoyment, and behavioral intention?

**Hypothesis 1:** Perceived ease of use positively affects perceived near-term usefulness of the mobile app.

**Hypothesis 2:** Perceived ease of use positively affects perceived long-term usefulness of the mobile app.

**Hypothesis 3:** Perceived ease of use positively affects perceived enjoyment of the mobile app.

**Hypothesis 4:** Perceived ease of use positively affects behavioral intention towards use of the mobile app.

**Research Question 2:** What relationship will perceived near-term usefulness have with behavior intention?
**Hypothesis 5:** Perceived near-term usefulness positively effects behavioral intention towards use of the mobile app.

**Research Question 3:** What relationship will perceived long-term usefulness have with perceived near-term usefulness and behavioral intention?

**Hypothesis 6:** Perceived long-term usefulness positively effects perceived near-term usefulness of the mobile app.

**Hypothesis 7:** Perceived long-term usefulness positively effects behavioral intention towards use of the mobile app.

**Research Question 4:** What relationship will personal innovativeness have with perceived long-term usefulness, perceived ease of use and behavioral intention?

**Hypothesis 8:** Personal innovativeness positively effects perceived long-term usefulness of the mobile app.

**Hypothesis 9:** Personal innovativeness positively effects perceived ease of use of the mobile app.

**Hypothesis 10:** Personal innovativeness positively effects behavioral intention of the mobile app.

**Research Question 5:** What relationship will perceived enjoyment have with behavioral intention?
**Hypothesis 11:** Perceived enjoyment positively effects behavioral intention of the mobile app.

**Research Question 6:** What relationship will behavioral intention have with actual usage of the mobile app?

**Hypothesis 12:** There is a positive relationship between behavioral intention to use the 4natomy mobile app and the actual usage of the app.

**Research Question 7:** What relationship will user acceptance have with anatomy exam scores?

**Hypothesis 13:** There is a positive relationship between students with high levels of acceptance of the 4natomy mobile app based on the TAM and scores on anatomy specific exam questions.

**Chapter 5: Assessing Medical Student’s Final Perspective on the 4natomy Mobile App**

**Aim:** To conduct a group interview with first year medical students that used the 4natomy app in order to assess desired improvements for future iterations of the app.

Following distribution of any mobile app, the developers responsible for the creation and maintenance of the app often solicit users for valuable feedback on all aspects of the app. This app was distributed through an enterprise release in order to limit those who could obtain and use to app to only medical students within OSU-COM. Due
to the control of this type of distribution method, direct feedback was obtained from individual users in person through a final series of group interviews. This information provided by the students will aid in the design, development and distribution of future 4anatomy mobile app versions.

1.8: Significance and Future Directions

Investments made in establishing new curricula and the development of curricular resources can be time consuming and financially exhaustive. Educational resource prototypes created with design, development, distribution, and user feedback in mind aid in the determination of future investments for universities. Recruiting medical students to download, use, and provide feedback for the mobile app will prove an invaluable source of information to focus the continued development of mobile educational technology.

This study provides data on the preferences and perceptions of second year medical students towards mobile technology and mobile apps. The first integrated anatomical mobile app for iOS was developed with a focus on the spinal cord following group interviews with second year medical students about their use of mobile technology. Quantitative data measuring the acceptance and usage of the novel anatomy mobile app by first year medical students was assessed based on the TAM. First year medical students that utilized the mobile app provided qualitative data on which features to improve and what content to include in future integrated mobile resources. The long-term goal of this research project is to provide medical universities with data on user
acceptance of mobile educational resources in order to aid in future curricular content and related financial decisions.

1.9: Conclusion

The time allotted and the methods used for teaching the anatomy sub-disciplines within higher education has gone through multiple changes over the past century. The decrease in time for teaching gross anatomy, embryology, histology, and neuroanatomy, along with the continual advances made in technologies used by students, is directing the new generation of higher-level educators to create and implement new pedagogical methods. Multiple medical schools have created and implemented alternative teaching methodologies such as computer assisted learning modules, interactive anatomical computer programs (Bryner et al., 2008; McNulty et al., 2009; Nowinski et al., 2009; Petersson et al., 2009), m-learning PDA learning projects (Davies et al., 2012), and the creation of virtual microscopy libraries with annotated digital slides (Triola & Holloway, 2011). While other medical schools have provided students with mobile devices such as iPads, which allows students to find resources on their own through mobile apps available on the Apple App Store (Comstock, 2013; George et al., 2013).

As Drake et al. (2014) found in their recently conducted survey, medical schools are rapidly transitioning their curricular infrastructure to follow an integrated curricular model. As medical curricula transition to an integrated systems-based approach, students must adapt their learning and study habits to accommodate this pedagogical model. Medical educators can potentially assist students in this transition and potentially make
the studying process more efficient by developing and providing educational resources that integrates the curricular content. Unfortunately, the current deficit within the higher education sector for medical students is m-learning technology that can teach the anatomical sub-disciplines in an integrated, interactive, and intuitive way. Due to the fact that an integrated anatomical educational resource does not currently exist, one main focus of this study is to develop and distribute an integrated anatomy resource for medical students to use during the relevant integrated medical learning block. Based on the perceived difficulty by anatomy faculty and students of the nervous system (Bryner et al., 2008), the content of the mobile app for this project focuses on the spinal cord. Assessment of the novel anatomical mobile resource through the TAM provides a quantitative measure that will aid in determining the overall acceptance and usage of the mobile app by first year medical students. The data gathered from the TAM can benefit the future development of mobile resources for medical students. The user feedback from first year medical students that utilized the app provides data on the features that can be improved, new content to be added, and how the mobile app should expand in future versions.
Chapter 2: Assessing Medical Student’s Perspective on Mobile Devices and Apps in an Integrated Curriculum

2.1 Introduction

The decreased amount of time devoted in medical curricula to the traditional didactic teaching of the anatomical sciences between the years 1955-2009 (Drake, McBride, Lachman & Pawlina, 2009) is one reason that medical educators began developing computer-based anatomy resources. Petersson, Sinkvist, Wang and Smedby, (2009) developed an interactive web-based three-dimensional (3D) learning tool for medical students to provide instruction on the major vessels of the body. Bryner, Saddawi-Konefka and Gest, (2008) developed online modules to provide medical students with additional resources to master concepts such as the autonomic nervous system, lobes of the cerebral cortex, and cranial nerves. Nowinski et al. (2009) developed a computerized and mobile-based digital brain atlas application to provide self-assessment of cerebral and vascular anatomy by students. Triola and Holloway (2011) developed an open source virtual microscopy based on the Google Maps Application Program Interface (API) for students and faculty to annotate slides. However, as Lewis, Burnett, Tunstall and Abrahams, (2014) detailed, very little research has been carried out
to evaluate the effectiveness of utilizing tablets on medical education and even less research on the effectiveness of tablets on anatomy education.

Mobile apps and mobile learning (m-learning) modules are being created and distributed directly through local networks or indirectly through digital marketplaces like Apple’s App Store to students of various educational levels. These learning resources vary in their target market, from specific high-level medical concentrations [e.g., *The Utilization of the iOS Platform to Create LearnENT: An Interactive Educational App in Otolaryngology- Head and Neck Surgery and Use of Mobile Learning Module Improves Skills in Chest Tube Insertion* (Davis et al., 2012; Kohlert, Scherer, Kherani & McLean, 2012)] to massive appeal for undergraduate, graduate and health professional students (e.g., *Essential Anatomy*, created by 3D4Medical and *Netter’s Anatomy Atlas*, created by Elsevier).

Previous studies have focused on the reactions of medical students to various educational resources following use within clinical settings or measuring their mobile technology usage. Unfortunately, the majority of these studies were conducted with medical students in their third year or beyond. Mobile devices such as smartphones were found to be nearly ubiquitous within the medical field; with 79% of medical students and 74.9% junior physicians surveyed in the United Kingdom (UK) reported owning a smartphone (Payne, Wharrad, & Watts, 2012). Tablet computers are also rapidly growing within the medical field. A study conducted by Sclafani, Tirrell, and Franko (2013), through the Accreditation Council for Graduate Medical Education (ACGME), surveyed participants in various residency and fellowship programs. The survey, which was
originally conducted in December 2011, found that 40% of respondents used a tablet, with Apple’s iPad being the most popular.

Due to the increased adoption rate of mobile devices, researchers have recently begun to develop mobile resources for medical residents and fellows. Tews, Brennan, Begaz, and Treat (2011) created instructional videos to be viewed on iPod touches by fourth-year medical students in the Emergency Department prior to patient encounters in order to improve patient care presentations. Davis et al. (2012) developed a video to demonstrate proper chest tube insertion, which was viewed by residents, medical students, and United States (U.S.) Army Forward Surgical Team members on iPod touches prior to performing the procedure. These videos were developed in order to improve student scoring on the skills checklist. Davies et al. (2012) distributed Personal Digital Assistants (PDAs) to participating third to fifth year medical students pre-loaded with various resources. Usage monitoring, focus groups, and surveys were conducted with the students in order to understand how they used the technology. The feedback provided by students following the study included positive remarks such as “I used it principally for making reference on the wards and I use the anatomy quite a lot when we are in the theaters” or “(Using it) reinforced key points at point of need (p. 4)”. Students also had negative feedback in regards to the PDAs, such as “… I found it quite hard to carry it around with me all the time or “I just wonder if there is actually something which is more intuitive – with less extra effort – it might be more useful”. Davies et al. (2012) argues that based on the feedback provided by the medical students, adopting a smartphone platform may be advantageous due to the consistent software and powerful
hardware compared to PDAs. Tanaka, Hawrylyshyn & Macario (2012) developed digital teaching resources on iPads for residents within an orthopedic rotation, while the control group used the traditional printed material. Students utilizing the digital resources rated the overall teaching quality of the rotation higher than the control group.

The mobile educational resources provided to first and second year medical students by their institution can vary based on the medical school. For instance, the University of California Irvine School of Medicine has provided students in each medical class with iPads preloaded with course notes, textbooks, and podcasts of lectures. The school has reported that the first class to utilize the iPads in their “iMedEd” initiative scored an average of 23% higher on the Step 1 United States Medical Licensing Exam (USMLE) compared to previous classes despite similar Grade Point Average (GPA) and Medical College Admissions Test (MCAT) scores (Comstock, 2013). One main purpose of introducing iPads into the Lead.Serve.Inspire (LSI) curriculum (i.e., the name of the integrated medical curriculum) at The Ohio State University College of Medicine (OSU-COM) was to increase student engagement with the material, the instructors, and their fellow students. The iPads provided are open to customization due to the large number of mobile apps and other resources available to the students (Geier, 2013). The studies discussed previously and numerous others focus on the creation and distribution of resources to medical students in their third year or beyond. Few studies have investigated mobile educational resources that were developed for medical students in their first and second years, in which the “basic science” instruction traditionally occurs prior to the Step 1 USMLE.
As there continues to be a decrease in contact hours with medical students, specifically within anatomy sub-disciplines (Drake, McBride & Pawlina, 2014), resources dedicated to the creation of new educational resources are also limited (Davies et al., 2012). By understanding what mobile resources medical students have discovered, downloaded, and used on their mobile devices, content creators can develop resources that contain features of the highest-demand by users and resources that even users that are the least comfortable with mobile devices will use. An investigation into how second-year medical students utilized mobile technology throughout the first year of an integrated medical curriculum provides valuable data for the creation of future resources. These group interview sessions conducted with second-year medical students provides feedback directly from students who discovered various mobile apps on Apple’s App Store independently or via “word of mouth” from their medical student peers. Information collected in these group interview sessions also aided in the development of an integrated anatomical mobile app, created specifically for first-year medical students, as well as the design and implementation of future mobile educational resources. The aims and hypothesis of the current study were as follows:

- **Aim 1**: To identify what mobile devices 1st and 2nd medical students own and use while studying and to quantify their comfort level with using mobile devices.
- **Aim 2**: To determine what mobile apps 1st and 2nd medical students download and use while studying.
• **Aim 3**: To determine what features of educational mobile apps are of the highest demand by 1st and 2nd medical students.

• **Hypothesis 1**: There is a positive relationship between self-reported comfort level with mobile devices and the number of apps downloaded for studying by second year medical students.

2.2 Methods

All second year medical students at The OSU-COM were invited through email to participate in a group interview at various times between July 2014 and October 2014. Convenience sampling was used to select the participants. Each medical student chose from a list of pre-determined group interview times that would best fit their personal schedules. The sizes for group interview sessions varied from 1 to 8 students. Students were given a copy of the consent form in the original email, as well as given a physical copy to read over and sign prior to the beginning of the group interview session. Consent was obtained in accordance with the Institutional Review Board (IRB# 2014B0202) of The Ohio State University. The students were handed a series of pre-determined questions (see Appendix A) to answer individually for the first 5-10 minutes of the session. The remaining 10-20 minutes of the group interview involved a group discussion of the answers written by each student. Audio recordings of each group interview session were made for accuracy and retained for verification of student answers. The only facilitator of each group interview was the lead of the study, Derek Harmon.
2.3 Data Analysis

Qualitative analysis was conducted for each question of the group interview sessions, with answers coded and entered into SPSS for analysis. Frequency distributions were created for each research question and descriptive statistics were analyzed to calculate the mean comfort level and mean number of mobile apps downloaded. Correlational analysis was conducted to compare student’s self-reported comfort level with mobile technology and the number of mobile apps downloaded for studying.

2.4 Results

A total of 59 medical students (30.26% of the second year medical class) participated in the group interview sessions throughout the four months. A frequency distribution was conducted to analyze the portable electronic devices owned by second-year medical students. The majority of participants in the group interviews (98.3%) reported owning a smartphone, an iPad (issued by the Ohio State University College of Medicine), and a laptop computer, with only one student reporting to not own a smartphone. Table 1 shows the brands of smartphones owned by the second year medical students.
Table 1. Smartphone brands owned by second-year medical students (n= 59). N/A for this table refers to the one student that did not own a smartphone.

<table>
<thead>
<tr>
<th>Smartphone Brands</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple iPhone</td>
<td>74.6%</td>
</tr>
<tr>
<td>Android</td>
<td>10.2%</td>
</tr>
<tr>
<td>Not Indicated</td>
<td>13.6%</td>
</tr>
<tr>
<td>N/A</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

A frequency distribution was conducted to analyze the self-reported comfort levels for second year medical students using mobile devices, along with the mean comfort level (Figure 5). A total of 38 medical students (64.4%) rated their comfort level as “very comfortable” with ratings of 9 and 10, while 21 medical students (35.6%) rated their comfort level as “moderately comfortable” with ratings of 7 and 8. The mean comfort level of the group was 8.81, with a standard deviation of 1.06.
Figure 5. Self-reported comfort level with mobile device usage. Measured on a 1 (very uncomfortable) - 10 (very comfortable) scale.

A frequency distribution was conducted to analyze the portable electronic devices used by students while studying (Figure 6). The majority of medical students (84.7%) that participated in the group interview sessions reported using multiple mobile devices when studying for curricular block exams, with the largest group (64.4%) using their iPads and laptop computers. The second largest group of students (20.3%) reported using their laptops, iPads, and smartphones throughout the course of studying.
A frequency distribution was conducted in order to analyze the percentage of students that downloaded zero, one, or multiple mobile apps on their mobile devices to use as study resources. The results of the distribution are located in Table 2. The majority of second year medical students (78%) that participated in the group interview sessions reported downloading multiple mobile apps to their mobile devices to aid in studying. Only 5.1% of students reported not downloading any mobile apps to use as study resources. Figure 7 shows a frequency distribution of the total number of apps downloaded by students, with the average number of apps downloaded equal to 3.03.
Table 2. Number of apps downloaded on mobile devices for studying by students (n=59).

<table>
<thead>
<tr>
<th>Number of Apps</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.1</td>
</tr>
<tr>
<td>1</td>
<td>16.9</td>
</tr>
<tr>
<td>≥2</td>
<td>78.0</td>
</tr>
</tbody>
</table>

Figure 7. Frequency distribution of the number of apps downloaded by students (n=59).
A total of 48 different mobile apps were mentioned by the medical students when asked to list the mobile apps they had downloaded on their mobile devices for studying during their first year of medical school. A complete list of the downloaded mobile apps is located in Appendix B. From the 48 mobile apps listed, 9 mobile apps were identified as anatomy specific apps. The anatomy specific mobile apps are listed in Table 3. The most commonly downloaded app by second year medical students was *Essential Anatomy* with 40 downloads (67.8%).

Table 3. Anatomy specific mobile apps downloaded mentioned by medical students (n=59).

<table>
<thead>
<tr>
<th>Anatomy Mobile Apps</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential Anatomy</td>
<td>40</td>
</tr>
<tr>
<td>Netter’s Anatomy</td>
<td>3</td>
</tr>
<tr>
<td>Go Anatomy</td>
<td>1</td>
</tr>
<tr>
<td>Visual Anatomy</td>
<td>2</td>
</tr>
<tr>
<td>Brain and Nervous System</td>
<td>4</td>
</tr>
<tr>
<td>Human Anatomy Atlas by Visible Body</td>
<td>2</td>
</tr>
<tr>
<td>Visible Body Muscles</td>
<td>1</td>
</tr>
<tr>
<td>iMuscle2</td>
<td>2</td>
</tr>
<tr>
<td>Pathoma</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>57</strong></td>
</tr>
</tbody>
</table>

Based on the anatomy specific apps identified, Table 4 describes the number of anatomy apps that each student reported to download and use while studying over the course of their first year in medical school. Over three quarters of the second year medical students (78.0%) that participated in the group interview sessions reported to
downloading at least one anatomy specific mobile app.

Table 4. Percent of medical students that downloaded between 0-3 anatomy mobile apps (n=59).

<table>
<thead>
<tr>
<th>Number of Anatomy Apps</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>22.0</td>
</tr>
<tr>
<td>1</td>
<td>62.7</td>
</tr>
<tr>
<td>2</td>
<td>11.9</td>
</tr>
<tr>
<td>3</td>
<td>3.4</td>
</tr>
</tbody>
</table>

A frequency distribution was conducted in order to analyze which anatomy sub-disciplines the second year medical students downloaded mobile apps in an effort to aid in studying (Figure 8). The majority of second year medical students (52.6%) only downloaded a gross anatomy specific app, while 13 students (22.0%) of students reported downloading an app(s) that aided in gross anatomy and neuroanatomy.

Students were asked to list the features of mobile educational apps that were most beneficial to their learning. The features were analyzed through a frequency distribution located in Table 5. A large majority of students (71.2%) listed 3D models as a beneficial feature of anatomy mobile apps. Nearly one-half of the second year medical students (49.2%) also listed detailed textual information as an important feature. The total number in the frequency column is 102 due to the fact that many students indicated multiple desirable app features. Appendix C has the list of all combinations of app features listed by the second year medical students.
Figure 8. Anatomy sub-discipline specific mobile app downloads by medical students (n=59). N/A for this figure refers to no anatomy apps downloaded.

Table 5. Beneficial features of educational mobile apps indicated by medical students (n=59).

<table>
<thead>
<tr>
<th>App Features</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>29</td>
</tr>
<tr>
<td>3D Models</td>
<td>42</td>
</tr>
<tr>
<td>Video</td>
<td>8</td>
</tr>
<tr>
<td>Audio</td>
<td>10</td>
</tr>
<tr>
<td>Images</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>102</strong></td>
</tr>
</tbody>
</table>
A frequency distribution was conducted in order to analyze the final group interview question about the intention of second year medical students to utilize an integrated mobile app (Figure 9). A total of 58 second year medical students (98.3%) answered yes to the question.

Figure 9. Medical student responses to using an integrated anatomy mobile app (n=59).

A Spearman’s rank-order correlation was conducted in order to determine if there was a relationship between the self-reported comfort level of using mobile devices and
the number of apps downloaded by second year medical students. The results from the
correlational analysis are in Table 6. The r value for this correlation is .193, with a p-
value of .072, which means that there is not a statistically significant relationship between
comfort level and number of apps downloaded by second year medical students.

Table 6. Relationship between comfort level and number of apps downloaded of 2\textsuperscript{nd} year
medical students.

<table>
<thead>
<tr>
<th>Comfort Level</th>
<th>Correlation Coefficient</th>
<th>Comfort Level</th>
<th>Number of Apps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation Coefficient 1.000</td>
<td></td>
<td>.193</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tailed)</td>
<td></td>
<td>.072</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>59</td>
<td>59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Apps</th>
<th>Correlation Coefficient .193</th>
<th>Number of Apps 1.000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation Coefficient .193</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tailed) .072</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N 59</td>
<td>59</td>
</tr>
</tbody>
</table>

2.5 Discussion

Mobile devices are now a ubiquitous form of technology for students within
higher education, with most students owning more than one device. Apple iPads and
other tablets are hybrid devices between laptop computers and mobile phones. The
powerful hardware within tablets allows for streaming of HD video and manipulation of
interactive 3D models without a decrease in functionality. The creation of a digital
marketplace (e.g., Apple App Store) in which users can search and read reviews, as well
as watch previews prior to purchasing and downloading mobile apps has changed the way educators can reach students and how students can potentially learn.

Following the group interview sessions, the qualitative and quantitative data collected provides adequate information to assess the original aims of the study.

- **Aim 1:** To identify what mobile devices medical students own and use while studying and to quantify their comfort level with using mobile devices.

Based on the responses from the group interview sessions, the vast majority of medical students interviewed at the OSU-COM own multiple mobile devices. All students that participated (n=59) own a laptop and OSU-COM issued iPad, while 98.3% of the students also own a smartphone of some sort. The percent of medical students that own a smartphone in the current study greatly exceeds the percent of medical students surveyed in a previous study conducted by Payne et al., (2012). More specifically, a greater percentage of students in this study (74.6%) own an Apple iPhone compared to the students in the Payne, Wharrad, and Watts (2012) study (56.6%). The high percentage of Apple iPhone ownership is consistent with recent sales data of Apple iPhones, in which over 74 million iPhones were sold in the fourth quarter of 2014 alone (Statista, 2015), larger than any other smartphone model. As the average age of students for the OSU-COM class of 2014 was 23 years old (“Entering Class of 2014”, 2014), this data confirms the report by Nielsen (2014) in which the largest demographic of smartphone ownership is the 18-24 year old (85%) and 25-43 year old (86%) groups.
The majority of second year medical students in this study reported to be “very comfortable” with using mobile devices in their everyday life and while studying. A mean score of 8.81 on a 1 (very uncomfortable) to 10 (very comfortable) scale indicates that students are familiar with the mobile devices that they use each day. The majority of participating medical students (84.7%) reported to using multiple mobile devices while studying for their examinations. The most common combination of devices used was laptops and iPads (64.4%), followed by students using their laptops, iPads, and smartphones (20.3%). The comfort levels and number of devices used while studying indicates that the students utilize mobile devices on a consistent basis and have discovered tools to use on these devices.

By identifying what mobile devices medical students own and use, as well as quantifying their comfort with using those devices, content creators and medical curriculum developers are able to allocate the appropriate resources towards creating effective and easy to use mobile educational content.

- **Aim 2:** To determine what mobile apps medical students download and use while studying.

The number of second year medical students that searched and downloaded mobile apps for general studying and, more specifically, to study anatomy related content (94.9% and 78%, respectively) illustrates how independently driven these students are to find digital resources. Two of the most commonly downloaded anatomy specific mobile
apps reported in this study were consistent with two of the apps highlighted by Lewis et al. (2014) in their assessment of useful anatomy mobile software for tablets, *Essential Anatomy* (by 3D4Medical) and the *Visible Body Collection*. Responses from students indicates that gross anatomy was the anatomical sub-discipline in which the majority of students (74.6%) downloaded at least one app to use as a supplemental resource, 22% of students downloaded a neuroanatomy related mobile app, 3.4% of students downloaded any histology mobile app and 0% of students downloaded any embryology related mobile apps.

There were 48 different mobile apps listed by the students that could be classified as “study aiding apps”. As shown in Figure 7, the average number of apps downloaded by second year medical students is 3.03 apps with one student reporting to have downloaded 9 different mobile apps, while only three students (5.1%) downloaded 0 mobile apps. From the 48 total apps downloaded, 9 apps were identified as anatomy specific and 78% of the second year medical students involved in the group interview sessions reported downloading anatomy specific mobile apps.

The large number of apps downloaded by students to use while studying in addition to the positive relationship between the number of apps downloaded and comfort level with mobile devices, suggests that students will search and discover mobile resources on their own. By identifying the mobile apps that students are currently downloading, medical administrators and educators can determine how students are utilizing the mobile devices and invest in the creation and distribution of resources that effectively and accurately supplement the content within the medical curriculum. Based
on these results, it is recommended that medical schools identify what mobile apps medical students download and use for studying different basic science disciplines prior to developing mobile resources.

- **Aim 3:** To determine what features of educational mobile apps are of the highest demand for medical students.

Based on the responses from the group interview sessions, the majority of students (71.2%) have a preference towards anatomical mobile apps that contain 3D models. Students also have a strong preference towards anatomy mobile apps with detailed text descriptions (49.2%). Many students prefer apps that contain multiple features, for instance apps with text and 3D models (23.7%), as well as apps with text and high-resolution images (10.2%) being the largest combinations (see Appendix C). The process of learning gross anatomy requires spatial understanding of the body (Vorstenbosch et al., 2013), which may explain the results in which gross anatomy apps that contain 3D models are the most commonly downloaded. *Essential Anatomy* is a mobile app based on a 3D model skeleton in which tissue layers can be applied and removed and was the most commonly downloaded mobile app (67.8%) by the second year medical students.

Following the completion of the first year of two within an integrated medical curriculum, the second year medical students were asked about their intention to use an integrated anatomical mobile app if one ever became available to download. The
response from the students was nearly unanimous (98.3%) in favor of utilizing an integrated anatomical mobile app. As there is no current integrated resource available, this is the first investigation into the demand by medical students. Based on these results, it is recommended that medical schools develop mobile resources that are integrated and contain major multimedia features including 3D models, videos, images, audio, and detailed text descriptions.

As part of the group interview process, students described how they prepare themselves for each comprehensive exam in an integrated learning block. Throughout the 8-16 weeks allotted for a learning block one or more instructors from each discipline (e.g., anatomy, physiology, pharmacology, etc.) lectures, provides notes, and assigns detailed reading assignments to students. Approximately one or two weeks prior to the final examination students collect all of their notes, textbooks, and other educational resources used throughout the learning block and begin to “connect the dots” between each discipline. Students noted during the interviews that the curriculum is integrated to the extent that all of the material is based on the same organ system, but it is their responsibility to see how the pieces from each discipline is integrated within that particular organ system. Based on the responses from the second year medical students, creators of educational anatomy resources need to consider the design and development of future mobile apps and other mobile resources that reflect the curricular arrangement of integrated medical schools.
2.6 Limitations

There are limitations to this study, with the largest limitation being that these group interview sessions only focused on one class of medical students from the same year and the same medical school, all conducted at the same period of time. A second limitation is that The OSU-COM provides medical students with iPads, which limits the ability to compare the results of this study to other medical students that are not provided iPads or other mobile technology. The small sample size is another limitation when attempting to make comparisons to the larger population of medical students. One reason for the small sample size could be due to the fact that the majority of the group interview sessions were held over the summer while many students were conducting research or working out of town. There is potential for bias as the students that participated in the group interview sessions have a prior teacher-student relationship with the interviewer, which could lead students to respond differently than if there was a neutral interviewer. Another limitation is the self-reporting style of a group interview sessions. Students were asked to rate themselves in regards to comfort level and to recall all the mobile apps they had downloaded and used to study over the previous year. In the future, it is suggested that group interviews be held over a longer period of time, as well as holding them exclusively throughout the traditional school year.

2.7 Conclusions

The results from this investigation demonstrate that medical students almost exclusively own and use mobile technology throughout their first two years of medical
school. Mobile devices now provide students with nearly endless access to various categories of mobile apps, and due to this, the majority of medical students will likely seek out and download mobile apps that can potentially assist in the learning and retention of basic science knowledge. Gross anatomy is a discipline within the medical curriculum in which the majority of medical students have downloaded at least one app to aid their studying. Though it is not clear whether this is due to the decrease amount of contact hours in anatomy, or the large amount of gross anatomy content that is taught within medical curricula. Future studies should assess if there is any relationship between the number of contact hours in gross anatomy and the number of gross anatomy resources downloaded by medical students. The most commonly downloaded app by students at The OSU-COM was *Essential Anatomy*, which utilizes high-quality 3D models with detailed text descriptions of the body tissues. Both features were rated the most beneficial components for educational anatomy mobile apps. Due to the integrated curriculum for The OSU-COM, 98.3% of the participating second year medical students (n=59) indicated their interest in using an integrated anatomical mobile app created specifically for the curriculum.

There are few current studies that have investigated mobile device usage, mobile apps downloaded, and features within educational apps of high demand by first and second year medical students. The results from this study provide further insight into how medical students utilize mobile technology. The hope is that the information attained from these group interviews with second year medical students can be used in the future development of mobile educational resources within medical curricula. Further study is
recommended for educational resources designed for mobile devices, as well as mobile resources designed specifically for integrated medical curricula. Based on the responses from the group interviews, second year medical students noted that they personally must integrate the content from each individual discipline prior the final examination. As there is currently no integrated resource provided to medical students, there is a need for the development and assessment of an integrated anatomy mobile resource for medical students.
3.1 Introduction

Apple’s App Store opened to the public on June 10, 2008 and, from that point forward, the way users would interact with their mobile devices forever changed. This digital marketplace quickly expanded to all of Apple’s mobile devices beginning simultaneously with the iPhone and iPod touch. Then on April 3, 2010, Apple released their first tablet computer, the iPad. The increased screen size (i.e., 9.7” vs. 3.5”) and processing power compared to the iPhone allowed developers to create mobile apps that display larger high-quality images, interactive three-dimensional (3D) models, and high-definition videos. Since 2007, approximately 825 million iPhones and iPads have been sold (Statista, 2015), all of which run iOperating System (iOS) (i.e., The App Store).

Due to the large number of individuals that own iOS devices, a continual increase in mobile app development has occurred. As of October 20, 2014, The App Store surpassed the milestone of 85 billion apps downloaded to mobile devices (Perez, 2014). Based on an assessment in January 2015, there were 1.4 million mobile apps available on The App Store for the iPhone and iPad, with over 60,000 new apps being added each month (Adjust, 2014; Monaghan, 2015). There are currently 725,000 iPad specific apps out of the 1.4 million total apps available on The App Store, which further emphasizes the
demand by users for apps that take advantage of the large screen size and powerful processor. Based on the reported $10 billion paid to developers in 2014, there appears to be no end in sight for developers creating mobile apps for iOS. According to Apple’s own records, the iOS ecosystem has created 627,000 jobs in the United States alone (Monaghan, 2015).

As anatomy education has seen a continual decline in contact hours within medical curricula and many medical schools have or are beginning to transition to an integrated systems-based curriculum (Drake, 2014), the need for efficient and integrated anatomy resources are high. Mobile apps have the potential to efficiently and effectively teach anatomical content, while still providing spatial understanding of the human body through manipulation of 3D anatomical models. Through mobile devices like the iPad, developers can create educational anatomy apps that present the anatomical information through various pedagogical methods such as detailed text descriptions, interactive 3-D models, high-resolution images, animations, and videos. As Lewis, Burnett, Tunstall, and Abrahams (2014) discovered, very little research has been carried out to evaluate the effectiveness of utilizing tablets on medical education and even less research on the effectiveness of tablets on anatomy education. Their study collected information and gave detailed descriptions of the current gross anatomy mobile apps for the iPad that utilize 3-D models.

Based on the results from group interviews conducted with second year medical students (see Chapter 2), medical students utilize multiple mobile devices while studying and are very comfortable while using mobile technology. Gross anatomy is the discipline
in which medical students download the most apps and students prefer anatomy mobile apps that utilize multiple media components to convey information (e.g., 3D models, detailed text, video, audio, and images). Based on these responses from the second year medical students and the increasing number of medical schools transitioning to an integrated curriculum (Drake, 2014), there is demand for the development and evaluation of an anatomy mobile app that integrates the four anatomy sub-disciplines (i.e., gross anatomy, embryology, histology, and neuroanatomy) into a single mobile app. The purpose of this chapter is to describe the process of designing, developing, and implementing a novel mobile app, which was used as an educational resource by first year medical students. Information from this chapter and the next chapter will aid in the future development of mobile educational resources for professional students.

3.2 Background

The educational field is viewed as an early adopter of technological advances and is known for allocating a large amount of resources on new technologies with the goal of improving the teaching and learning process (Vimu, Sherimon, & Krishnan, 2011). Due to the rapid expansion of iPad sales and educational potential many professional, undergraduate, and early childhood institutions began implementing these mobile devices into their curriculum. The Ohio State University College of Medicine (OSU-COM) initiated the iPad program in the fall of 2013 to incoming first year medical students and, upon entering their third year, medical students exchanged their full-size iPads for iPad minis prior to clinical rotations (Geier, 2013). Stanford University and Yale University
are other prominent medical schools that incorporated iPads within their medical curriculum beginning in the fall of 2010 (Gallegos, 2013). The Warren Alpert Medical School (AMS) of Brown University required first year medical students to purchase iPads prior to entering school. AMS instituted problem-based learning (PBL) small groups with second year medical students utilizing the iPad (George et al., 2013). However medical schools are not the only programs that have incorporated iPads. Indiana University-Purdue University Indianapolis (IUPUI) implemented iPads into numerous undergraduate courses as supplemental learning tools within the classroom (Rossing, Miller, Cecil, & Stamper, 2012). Mang and Wardley (2012) introduced iPads into three undergraduate courses over the summer of 2011 in order to test the viability of using tablets in post-secondary education.

The ways in which mobile devices have been utilized in education vary depending on: 1) how specific the discipline is (e.g. third grade math class vs. undergraduate courses vs. orthopedic rotations); 2) how novel the devices were at the time of use; and 3) the resources available to produce the mobile apps. Kiger et al. (2012) conducted a study which implemented iPod touches pre-loaded with numerous mathematics apps created by various companies that were available on The App Store into an experimental group of two third-grade math classes to be used for teaching fractions. The control group of this study was two separate third-grade classes that were taught fractions through the traditional methods of “Everyday Mathematics” and flashcards. The results from their study showed a statistically significant difference between the experimental classrooms compared to the control classrooms on a post-
intervention multiplication exam. Risconscente (2012) described a repeated measure cross-over designed study in which a mobile app *Motion Math* was created specifically to be tested with fifth grade students in order to strengthen children’s understanding of fractions, proportions, and percentages. This mobile app was created by Stanford University graduate students and was immediately tested with a single elementary school. This method differs from the study conducted by Kiger et al. (2012) in that only a single mobile app was used as the independent variable for testing purposes (Risconscente, 2012), while Kiger et al., provided iPod touches pre-loaded with multiple math apps.

Mayfield, Ohara, and O’Sullivan (2012) conducted a study examining the effects of using an iPad-based dissection manual during gross anatomy laboratory instruction on the learner’s perception of anatomy dissection. The iPad-based manual contained the same step-by-step dissection instructions as the paper version and the same digital images found in the paper version, as well as videos clips and images of relevant material found in the previous day’s lecture. Three dissection tables served as the experimental group and utilized the iPads, while three dissection tables served as the control group and used the traditional dissection materials (i.e., *Grant’s Atlas of Anatomy* and *Netter’s Atlas of Human Anatomy*). Researchers found that students who used the iPad-based laboratory manual were both observed and self-reported to be more engaged, achieved more objectives for each lab, and spent more time on task during the dissection compared to the control group of students.

Teri et al. (2013) conducted a study in which a mobile app (i.e., *NutriBiochem*) was specifically designed for nursing students enrolled in Biochemistry and Metabolism
II at the University of Guelph-Humber in the fall of 2012 and the winter of 2013. This app was created through a collaborative project between the Department of Human Health & Nutritional Services and the School of Computer Science both at the University of Guelph. While the app was created specifically for two undergraduate courses at the University of Guelph, it was designed for most undergraduate courses that cover human metabolism and nutrition. Following development within the university, the app was made available on Apple’s App Store, as well as for Android and Blackberry devices. Results from the study found that over half of the class accessed the app at least once, with the most common mobile device used being smart phones. Students with a higher level of comfort towards technology were more likely to utilize the app compared to lower comfort level individuals. Over 75% of the students agreed that NutriBiochem was a useful learning tool for both courses. Teri et al. (2013) concluded the study by describing how the use of mobile apps in education and science education have shown to be: “effective in enhancing students’ learning experience, relevant and important as an emergent method of learning given modern pressures facing higher education, and met with positive student attitudes and perceptions in terms of adopting and using such technology for educational purposes (p.134).”

Kohlert, Scherer, Kherani, and McLean (2012) created an iOS app called LearnENT, which is an educational app to aid in creating a standardized experience in otolaryngology head and neck surgery (OTOHNS) for medical students at the University of Ottawa. The app provides students with simple text-based learning modules, links to peer-reviewed references, instructional videos, and interactive quizzes providing
feedback to students. Davis et al. (2012) developed a short video demonstrating the proper procedure for chest tube insertion and divided healthcare trainees (e.g., residents, medical students, and U.S. Army Forward Surgical Team Members) into an experimental group that viewed the video on iPod touches and a control group that received no instruction. The experimental group scored significantly better on the skills checklist for chest tube insertion compared to the control group (p<.001). Tanaka, Hawrylyshyn & Macario (2012) developed digital teaching resources on iPads for residents within an orthopedic rotation. The study aimed to compare scores on staff evaluations of overall teaching quality following the first six months in which the residents received all curricular information printed in a binder with scores on staff evaluations in the final six months when residents received the same curricular information on iPads. The overall teaching rating improved from the “before intervention” stage to the “post intervention” stage.

The previous studies discussed have illustrated the various methods in which mobile devices, mobile apps, and mobile learning have been used in education. From early childhood education to medical resident rotations, learning with mobile technology is rapidly growing. Based on the large number of mobile apps available on Apple’s App Store, as well as the Google Play Store users have the ability to seek out and download apps they believe could be beneficial to their learning. Potential downfalls of this “seek and download” method is the fact that students are unable to verify that these apps are teaching the material to the appropriate level of specificity and/or unable to verify that the information is accurate. Unless the instructor recommends specific mobile apps and/or is
directly involved in the creation of educational mobile apps, the student is at risk of purchasing a resource that may not be beneficial and may be potentially detrimental to their learning. The mobile app created for this project, *Anatomy*, was created in order to reflect The OSU-COM integrated curriculum and was created by a content expert in the anatomy field. The features within the mobile app were created to reflect group interview responses by second year medical students (Chapter 2) in regards to other anatomy apps they have downloaded and what specific multimedia features they desire in mobile educational apps.

3.3 Methods

The proposal for creating the *Anatomy* mobile app was first submitted to the Department of Computer Science and Engineering’s (CSE) Capstone Design Course (CSE 5911). The Capstone Design Course is a required course for CSE undergraduate students, which provides real-world experience working with public or private businesses in designing, developing, and trouble-shooting information technology (IT) or information systems (IS) projects. The Capstone Design Course is divided into five major sections based on the student’s career interests: 1) Software Applications; 2) Game Design and Development; 3) Computer Animation; 4) Knowledge-Based Systems; and 5) Information Systems. The app project proposal was accepted to the Software Applications Section of the Capstone Design Course for the summer 2014 semester. After being accepted by the CSE department, five undergraduate students chose the *Anatomy* mobile app as the Capstone project they wished to work on for the semester.
Beginning in the summer semester of 2014, the five CSE student development team and the project manager met to discuss the concept and justification for the mobile app, the basic design and user interface of the app, and to distribute the initial anatomy content to the developers. The six members of the project met weekly and occasionally bi-weekly to keep up-to-date on the progress of the project, to brainstorm ways to implement new features or content of the app and to make the decisions on components that would be integral during the 10 weeks allotted for the project. A general layout for the initial integration of the app created by the CSE students is shown in Figure 10.
The development of iOS mobile apps requires a Mac computer with a version of Apple’s integrated development environment (IDE), Xcode (Apple Inc., Cupertino, California). Xcode is the program in which developers edit code and have access to all iOS properties and the User Interface library. Built into Xcode is an iOS mobile device simulator, which allows the developer to test their code on a simulated iPhone, iPod touch, or iPad device. A recent feature added to Xcode is the storyboard function, which allows for a visual layout to the coding, as well as some “drag and drop” functionality. The Capstone Design students had access to Mac computers within the CSE computer
labs and one of the students owned an iPad, which was used for testing the app on the actual device.

Due to the short period of time within the summer semester at The Ohio State, the Capstone group was unable to complete the app, but was able to make a functioning prototype, which was estimated to be approximately 60-70% complete. The prototype was able to display the basic layout of the mobile app and allowed for a visual representation of the original concept. Screenshots from the prototype are shown in Figures 11-13. The CSE students presented the prototype of the Anatomy mobile app at their final presentation. The prototype version of the app developed during the Capstone Course served as the framework on which the final app was developed.
Figure 11. Screenshot of 4natomy prototype index.
Figure 12. Screenshot of 4natomy prototype neuroanatomy home page.
Figure 13. Screenshot of 4natomy gross anatomy home page.
Following the Capstone Design Course, a job posting was sent out to all CSE undergraduate students, looking for a student interested in being hired to complete development of this iOS mobile app. At approximately the time the job posting was sent to the CSE Department, a second recruitment email was sent to the Advanced Computing Center for the Arts and Design (ACCAD) Department. The recruitment email was intended to hire an animator who could collaborate on the project in order to make a series of spinal cord tract animations for the neuroanatomy section of the mobile app. Shortly after sending both emails, one CSE undergraduate student and one post-graduate ACCAD student were hired.

The hired CSE undergraduate student and the project manager met numerous times a week over the course of 10 weeks beginning in November 2014. Features in the Anatomy mobile app were created in order to reflect the responses of second year medical students in the mobile device group interview study discussed in chapter 2. Four 3-D spinal cord models (i.e., cervical, thoracic, lumbar, and sacral) with the most commonly taught spinal cord tracts were created to provide interactive high-resolution images for the students. The thoracic spinal cord image is displayed in Figure 14.
Collaboration between the animator recruited from the ACCAD Department and the project lead led to the creation of nine spinal cord tract animations (i.e., five afferent and four efferent) using the 3-D spinal cord models. Two screenshots from the *Lateral Corticospinal Tract* animation are in Figure 15.
Figure 15. Screenshots from the lateral corticospinal tract animation in the 4natomy mobile app.
A spinal cord prosection demonstration video was created for the gross anatomy section of the mobile app, with a screenshot of the video in Figure 16. The novel feature of this mobile app is the integration between the anatomy sub-disciplines. Figure 17 shows an example of the integration, with the user tapping the ventral horn of gray matter while in the gross anatomy section, followed by clicking the “embryo” button in the popover and then the “histo” button in the popover. The licensing division of the Health Science Library at The Ohio State University approved all images used in the Anatomy mobile app, as this was not a profitable project and the app was not publicly released. All images used were properly cited within the app. Collaboration between the mobile developer and the anatomy content expert led to creation of the final version of the mobile app for distribution during the Neurological Disorders Learning Block of the first year medical curriculum at The OSU-COM.
Figure 16. Still image from the spinal cord prosection demonstration in the 4natomy mobile app.
Figure 17. Series of screenshot images displaying the integration of the 4natomy mobile app, gross anatomy (top left), embryology (top right) and histology (bottom).
The final version of the mobile app was distributed to all first year medical students through an “enterprise release” method. This allows for mobile apps to be distributed within a closed network and not made available to the general public through The App Store. The distribution was done through a company called Crashlytics and their modular mobile platform called Fabric (Twitter Inc., San Francisco, California). This application allows developers to upload a finished mobile app to Crashlytics’ servers. A link was sent through the Fabric application to all first year OSU-COM medical students, which provided the download instructions. The students were also provided with download instructions through an email, as well as through a video, which walked them through how to use the mobile app.

Fabric by Crashlytics, in addition to providing an enterprise distribution system, also provides data analytics on total number of users that have downloaded and used the mobile app, how many users have used the app each day, and the average length of time spent using the app. Through Fabric’s web-based dashboard, the app developer is able to monitor the number of daily users of the app and which of those users are new, the number of monthly active users, the number of crash-free users, how many sessions were conducted on the app that day, and the average length of usage for the session. An example of the daily email sent by Crashlytics is displayed in Figure 18 and an example of the web-based dashboard is in Figure 19.
Figure 18. Example of daily email report for the 4natomy mobile app sent by Crashlytics.

Figure 19. Crashlytics web-based dashboard providing data analytics on the 4natomy mobile app. The top chart displays median session length and the bottom chart displays time in app per user, with the peaks representing times.
3.4 Conclusions

The utilization of mobile technology in education continues to grow as mobile devices become more ubiquitous within the general population. Past concerns of mobile devices having small screen sizes, slow processors, and lack of consistent and strong connectivity (Cronje and El-Hussein, 2010; Gupta and Koo, 2010) have been alleviated by technology companies creating larger, more powerful, and constantly connected devices. M-learning has been implemented and researched in all levels of education from third-grade classrooms to medical residents utilizing PDAs, smartphones, and tablet computers.

The cost of mobile apps can vary widely based on the size of the app, what features are built within the app and the amount of server space that may be needed for storage. The estimated cost of an iOS app built by a small firm is anywhere between $50,000-150,000 or more (Yarmosh, 2015). This estimated cost does not take into account the cost of hiring content creators that can develop animations, 3D models and edit videos. The high cost can be a deterrent for many medical school administrators from pursuing the development of mobile resources. The development of the Anatomy mobile app was completed at a low overall cost (approximately $2,500) due to the collaborations between the project lead, the CSE department and the ACCAD department at The Ohio State University. These collaborations do not only serve the Anatomy department courses for which the mobile resource is developed, but provides CSE students with valuable experience in developing software in the iOS environment, which is the most popular
mobile operating system. ACCAD students also benefit from these collaborations by expanding their portfolio and gaining experience with creating assets for clients.

As the sales of mobile devices and mobile apps continues to grow, the need for intuitive, interactive, and content specific educational mobile apps is also growing. The creation and investigation into the effectiveness of integrated anatomy mobile resources is needed due to the decrease in contact hours for anatomy sub-disciplines (Drake et al., 2009) and the increase in the number of medical schools adopting integrated curricula (Drake et al., 2014). 4natomy is the first mobile anatomy resource that was created with the four anatomy sub-disciplines (i.e., gross anatomy, histology, embryology and neuroanatomy) integrated into a single mobile app. This integrated mobile app prototype was distributed to first year medical students during the Neurological Disorders Learning Block in order to measure the level of user acceptance, motivation to use and the effectiveness of this novel resource. Data collected to measure these constructs was based on the TAM and the results will be investigated in the following chapter. The 4natomy mobile app was a collaborative effort between the Division of Anatomy, the Computer Science and Engineering Department, and the Advanced Computing Center for the Arts and Design Department at The Ohio State University- Columbus Campus.
Chapter 4: Medical Student Acceptance of an Anatomical Mobile App Based on the Technology Acceptance Model

4.1 Introduction

The introduction of the iPhone in 2007 and the iPad in 2010 by Apple led to record sale figures, with 825 million iPhone and iPads sold since 2007 (Statista, 2015), and to the explosive growth in the entire smartphone market. During 2014 alone, smartphone sales globally passed the one billion devices mark, with Apple shipping the most phones in the fourth quarter of 2014 (Lunden, 2015). As of the first fiscal quarter in 2015, over 285 million iPads in total have been sold worldwide, with over 21 million iPads sold in Q1 2015 alone (Figure 20) (Statista, 2015). The largest demographic of mobile device ownership is the 18-24 year old (85%) and 25-43 year old (86%) groups (Nielsen, 2014). The information technology (IT) and information systems (IS) of mobile devices today allow for constant connection to email, the Internet, and numerous mobile apps via data and Wi-Fi networks. These constantly connected devices led to the creation of the first major mobile marketplace (The App Store) by Apple in 2008, which provided a centralized location for developers to distribute their mobile apps to the public. This started a revolution in the technology sector in which mobile app companies created applications, which were used by millions of people and have been acquired for billions
of dollars (e.g., Instagram and WhatsApp; $1 billion and $19 billion, respectively) (Olson, 2014; Raice & Ante, 2012).

The rapid growth in sales of mobile devices has also occurred in the educational field, with many professional, undergraduate, and early childhood institutions implementing the technology into their curriculum. Numerous medical universities have been quick to implement iPads within their curriculum in order to decrease paper printing, provide easy access to journals, and allow students to utilize these devices as education resources through educational mobile apps (Gallegos, 2013). Examples of
prominent medical schools that have implemented iPads are: Brown University-Alpert Medical School, University of California Irvine School of Medicine, Stanford University College of Medicine, George Washington School of Medicine, University of Minnesota-Duluth Medical School, Ohio State University College of Medicine, University of Central Florida College of Medicine, Yale University College of Medicine, Georgetown University School of Medicine, and Dartmouth University-Geisel School of Medicine (Dolan, 2011).

Some of the mobile resources available to students in higher education were created through their university. For instance, the LearnENT mobile app created by Kohlert, Scherer, Kherani, and McLean (2012) allowed medical students to have a standardized experience in otolaryngology head and neck surgery at the University of Ottawa. NutriBiochem was a mobile app designed by Teri et al. (2013) to serve as an educational resource to students enrolled in Biochemistry and Metabolism II at the University of Guelph-Humber. Davis et al. (2012) developed video demonstrations on the proper procedure for chest tube insertion to be viewed on iPod touches by various medical personnel and students at University of Miami. The studies discussed are just a few examples of mobile devices and the resources created for those devices have been studied in higher education.

The majority of studies that investigate mobile device usage and the effectiveness of resources for medical students focus on students in their third year of medical school or beyond. There are few studies that have investigated mobile device usage and mobile
resources created specifically for students in the first and second years of medical school, which is when the “basic science” education traditionally occurs. The purpose of this study was to investigate the usage and acceptance by first year medical students of a novel mobile app developed for iOperating System (iOS) within an integrated medical curriculum. The usage and acceptance of the novel 4natomy mobile app was investigated through the Technology Acceptance Model (TAM). 4natomy was the first mobile app created that integrates the four anatomy sub-disciplines (i.e., gross anatomy, embryology, histology, and neuroanatomy) into a single mobile resource. This was also the first study to investigate medical student acceptance and usage of a mobile app created to be used throughout an associated Neurological Disorders Learning Block in the first year medical curriculum at The Ohio State University College of Medicine (OSU-COM). Finally, this was the first study that utilized the TAM to investigate acceptance of a mobile educational resource by medical students.

4.2 Theoretical Background

The TAM was first proposed by Davis (1986) as a way to explain user acceptance of information technology (IT) and information systems (IS) and since that time has become a dominant model to investigate factors that effect the acceptance of technology by users (Maranguinc & Granic, 2014). The original TAM was developed as a successor to the Theory of Reasoned Action (TRA), which was developed by Ajzen and Fishbein (1980) (Figure 21). The TRA was developed to predict and understand people’s beliefs and attitudes. In their model, Ajzen and Fishbein argued that a person’s behavior could be
determined by considering their prior intentions, as well as the beliefs a person would have for a given behavior (Davis, 1989). Ajzen added a new element to the TRA, which is the concept of perceived behavioral control, and with the addition of this concept the Theory of Planned Behavior (TPB) was created (Ajzen, 1985). The main function of the TPB was to measure an individual’s intention to perform a given behavior. The TRA and the TPB were useful models in predicting and explaining actual behaviors by individuals, though they did have limitations particularly in attempting to apply them within specific contexts like user acceptance of IT and IS. This limitation led Davis (1986) to propose the TAM.

Figure 21. Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980).

Throughout the initial development of the TAM Davis reviewed information technology and human factors that related to technology adoption in organizations
(Davis, 1989). Following this literature review, Davis proposed the initial version of the TAM, which focused on two distinct beliefs, perceived usefulness (PU) and perceived ease of use (PEOU), as constructs to predict a user’s attitude toward use of a system. The individual’s attitude toward using the system and PU would directly influence the behavioral intention (BI) to use the system. Finally, the individual’s BI to use a system directly affected the actual use of the system, with use defined by Davis as “an individual’s actual direct usage of the given system in the context of his or her job” (Davis, 1989, p. 320). Figure 22 represents the original TAM proposed by Davis in 1986.

Figure 22. Original Technology Acceptance Model (TAM) (Davis, 1986).

Perceived usefulness is defined as “the degree to which an individual believes that using a particular system would enhance his or her job performance” (Davis, 1989, p. 320).
320). PU influences an individual’s attitude towards adopting a new technology based on the belief that the technology will positively affect job performance. PU directly affects BI to adopt and use a new technology because people develop intentions towards the use of devices that are believed to increase performance related rewards. Perceived ease of use is defined as “the degree to which an individual believes that using a particular system would be free of physical and mental effort” (Davis, 1989, p. 320). In Davis’ (1989) model, PEOU will directly affect an individual’s attitude toward using and the perceived usefulness of the technology. Davis argues:

> Given that a non-trivial fraction of a user’s total job content is devoted to physically using the system per se, if the user becomes more productive in that fraction of his or her job via greater ease of use, then he or she becomes more productive overall (Davis, 1986, p. 26).

Due to the causal relationship that links attitude to behavioral intention to actual use, the TAM implies that a positive attitude towards a system (or software) leads to a stronger intention toward using that system, while a negative attitude would lead to a weak intention toward use. The investigation conducted by Davis, in which the original TAM was proposed, evaluated user acceptance of substituting videotape presentations for hands-on interaction by 40 Masters of Business Administration (MBA) students.

Since 1986 there has been extensive research conducted on the TAM. Maranguinc and Granic (2014) conducted a comprehensive literature review of TAM studies between 1986 and 2013. Through detailed reading and analysis, 85 studies were identified and
reviewed. The constructs used for these studies varied based on the organizational setting and how contextually relevant the variables were to the particular hardware or software of interest. For instance, a study that utilized the TAM for measuring usage and acceptance of an online disability evaluation system by physicians included the constructs organizational readiness, perceived compatibility and technical readiness. The TAM has been studied in the private sector investigating adoption of e-mail (Gefen & Straub, 1997), microcomputer usage, (Igbaria, Guimaraes, & Davis 1995), user intention to adopt wireless technology (Yen, Wu, Cheng, & Huang, 2010), consumer intention to use e-books (Tsai, 2012), and consumer acceptance of mobile apps (Yang, 2013), among many other examples. The TAM has also been utilized in the educational field to study student acceptance of e-learning (Park, 2009), student acceptance of m-learning (Liu, Li, & Carlsson 2010; Park, Nam, & Cha 2012), intention of blue collar workers to use a web-based learning system (Calisir, Gumussoy, Bayraktaroglu, & Karaali, 2014), and user acceptance of YouTube for procedural learning tasks (Lee & Lehto, 2013).

The original TAM has been widely used in IS and IT research, but over time has drawn criticism due to the lack of components that can provide a broader view and better explanation of system adoption (Legris, Ingham, & Collerette, 2003). The TAM is a robust model to predict behavioral intention when use of the system is voluntary, in which the user’s motivation to use a system is maintained by their goals (Lee & Lehto, 2013; Rawstorne, Jayasuriya, & Caputi 1998). Venkatesh, Speier, and Morris (2002) integrated aspects from the motivational model with the TAM. Their new model brought in the constructs of intrinsic and extrinsic motivation to be combined with the constructs
of PU and PEOU. Schunk, Pintrich, and Meece (2008) described intrinsic motivation as the motivation to engage in an activity for its own sake, where in task participation of the activity itself is the reward. Schunk et al. (2008) described extrinsic motivation as the motivation to engage in an activity because of the anticipated outcomes, for example improved job performance, promotions, and improved test scores. In order to integrate the two models, Venkatesh et al. (2002) discussed how both extrinsic motivation and PU were both emphasizing an individual’s personal gains based on use of the technology and, thus, combined both constructs into PU. The TAM has no construct measuring intrinsic motivation and the motivational model has no construct related to PEOU, thus the new model proposed by Venkatesh et al. (2002) contains both constructs. Lee et al. (2005) took the original TAM and integrated the motivational perspective discussed by Venkatesh et al. (2002) by including perceived enjoyment (PE) as the intrinsic motivational construct. Figure 23 depicts the updated model by Lee, Cheung, and Chen (2005) along with results from their study, which assessed the acceptance of an Internet based learning medium by undergraduate students at a university in Hong Kong.
Results from the study conducted by Lee et al. (2005) indicated that perceived usefulness had a significant direct effect on attitude ($\beta = 0.39, t = 7.41$) and behavioral intention ($\beta = 0.19, t = 3.31$). Perceived enjoyment had a significant direct effect on attitude ($\beta = 0.53, t = 9.53$) and behavioral intention ($\beta = 0.17, t = 2.63$). Perceived ease of use had a significant direct effect on perceived usefulness ($\beta = 0.51, t = 8.63$) and on behavioral intention ($\beta = 0.52, t = 9.08$). Attitude had a significant direct effect on behavioral intention ($\beta = 0.35, t = 4.54$). The only hypothesis not supported in the study was the effect of perceived ease of use on attitude. The results from this study provides
support for utilizing the TAM in measuring acceptance of internet-based learning mediums by undergraduate students at the university in Hong Kong.

Liu et al. (2010) utilized the TAM to investigate the key motivating factors for students to adopt m-learning. The original TAM proposed by Davis (1989) was altered for the study to include three different constructs, namely near-term usefulness, long-term usefulness, and personal innovativeness. Liu et al. (2010) subdivided the original construct of PU into two more specific constructs near-term and long-term usefulness due to criticisms of PU being too broadly based. From the literature review, Liu et al. (2010) found near-term and long-term to both have significant impact on intentions to use IT. Chiu and Wang (2008) discussed that an educational system can simultaneously have near-term and long-term usefulness for students. Improved learning performance, effectiveness, and productivity represent students’ perceived near-term usefulness, while graduating, obtaining a job, or the passing of distant qualifying exams are examples of perceived long-term usefulness. Both perceived near-term and long-term usefulness have been shown to be significant predictors of student’s behavioral intention (Chiu & Wang, 2008).

Liu et al. (2010) introduced personal innovativeness as a new construct into the updated TAM presented. Personal innovativeness within an IS context is described as an individuals’ willingness to adopt new technology. Based on prior research, the construct of personal innovativeness has shown to be a significant predictor of perceived ease of use (Lu et al., 2005; Serenko, 2008; Yi, Jackson, Park & Probst, 2006) and behavioral intention (Crespo & Rodriguez, 2008; Taylor, 2007). Personal innovativeness describes
individuals who are nicknamed “early adopters” (Agarwal & Prasad, 1998). These individuals are more likely to perceive new technology as easy to use and to have stronger intentions to use the technology. Figure 24 depicts the updated model by Liu et al. (2010) with the results from the study, which assessed the acceptance and adoption of m-learning technology by undergraduate students in Zhejiang Normal University in China.

![Diagram of the updated TAM research model](image)

Figure 24. Results from the updated TAM research model (Liu et al., 2010).

Results from the study conducted by Liu et al. (2010) indicate that perceived long-term usefulness had a significant direct effect on behavioral intention ($\beta = 0.356$, $p<0.001$) and perceived near term usefulness ($\beta = 0.694$, $p<0.001$). Perceived near term
usefulness had a significant direct effect on behavioral intention ($\beta=0.306, p<0.001$). Personal innovativeness had a significant on perceived ease of use ($\beta=0.537, p<0.001$) and behavioral intention ($\beta=0.233, p<0.001$). Perceived ease of use had no significant effect on near-term usefulness ($\beta=0.054, p>0.05$) or on behavioral intention ($\beta=0.063, p>0.05$). Liu et al. (2010) discovered that the proposed model in the study of m-learning adoption explained 60.8% of the variance in behavioral intention.

The original TAM developed by Davis (1989) measured the effect of perceived usefulness and perceived ease of use on attitude and behavioral intention. The updated TAM presented by Lee et al. (2005) transitioned the model towards educational research by adding perceived enjoyment as a construct to measure intrinsic motivation of students. The TAM presented by Liu et al. (2010) removed the construct of attitude and divided perceived usefulness into two sub-divisions (i.e., near-term usefulness and long-term usefulness), which were able to measure behavioral intention to adopt a new pedagogy based on the student’s perceived near and long-term usefulness of the system. The theoretical research model for this current study was developed (Figure 25) based on the previous literature and research conducted utilizing the TAM specifically on educational research.
Figure 25. Theoretical research model for the current study. Key: H= Hypothesis.
4.2.2 Research Questions and Hypotheses

**Research Question 1:** What relationship will perceived ease of use have with perceived near-term usefulness, perceived long-term usefulness, perceived enjoyment, and behavioral intention?

PEOU of early m-learning products were negative due to complaints of low processing power, small screen size, lack of consistent connectivity, and reduced input capabilities (Cronje & El-Hussein, 2010; Gupta & Koo, 2001; Vinu et al., 2011). New m-learning hardware like the iPad have largely eliminated the concerns originally vocalized about m-learning. Due to the large population of iDevice owners, as well as the continual increase in usage of mobile devices in daily life, there will likely be a low barrier to overcome in use of a new mobile app.

Perceived ease of use was one of the two original constructs first proposed by Davis (1989) within the TAM. PEOU has been shown to predict intention to use of new systems (Davis, 1989; Venkatesh et al., 2002), as well as predicting perceived usefulness and perceived enjoyment of IS (Lee et al., 2005; Yuanquan, Jiayin & Huaying, 2008). Based on TAM and m-learning literature, the following hypotheses based on PEOU are proposed:
**H1:** Perceived ease of use positively affects perceived near-term usefulness of the mobile app.

**H2:** Perceived ease of use positively affects perceived long-term usefulness of the mobile app.

**H3:** Perceived ease of use positively affects perceived enjoyment of the mobile app.

**H4:** Perceived ease of use positively affects behavioral intention towards use of the mobile app.

**Research Question 2:** What relationship will perceived near-term usefulness have with behavior intention?

The original TAM proposed by Davis (1989) had PU as only a single construct. Over time the construct PU drew criticism due to being too broadly based. Chau (1996) originally argued that PU should be separated into two separate constructs (i.e., perceived near-term and perceived long-term usefulness) and found that each had significant impact on the intention to use IT. Liu et al. (2010) studied the two separate PU constructs and found near-term usefulness to be a strong predictor for intention to use. A mobile app that is believed to have near-term usefulness by students should be shown to improve learning performance, effectiveness, and productivity for the content with which the app is developed. Near-term usefulness has been shown to predict
intention to use new systems (Chau, 1996; Liu et al., 2010). Based on the previous studies of near-term usefulness with the TAM, the following hypothesis is proposed:

**H5:** Perceived near-term usefulness positively effects behavioral intention towards use of the mobile app.

**Research Question 3:** What relationship will perceived long-term usefulness have with perceived near-term usefulness and behavioral intention?

Liu et al. (2010) studied the two separate PU constructs and found long-term usefulness to be a strong predictor for intention to use. In a study conducted by Cole, Bergin, and Whittaker (2008), usefulness was defined as “student’s perception that the task will be useful to meet some future goal” (p. 613). They found that if students do not recognize the usefulness of a course and the exams associated with the course, then both the effort towards the course and test would suffer.

Examples of long-term usefulness within the educational field and more specifically medical education are graduating, getting a job, or passing distant qualifying exams. Innovations of educational IS will benefit students in their long-term careers. When a new system or technology complies with a student’s view of usefulness, they will be more likely to accept the technology. Based on previous studies on long-term usefulness within the TAM, the following hypotheses are proposed:
**H6:** Perceived long-term usefulness positively affects perceived near-term usefulness of the mobile app.

**H7:** Perceived long-term usefulness positively affects behavioral intention towards use of the mobile app.

**Research Question 4:** What relationship will personal innovativeness have with perceived long-term usefulness, perceived ease of use, and behavioral intention?

Personal innovativeness in IS and IT research refers to individuals that are most likely to adopt innovative information technology earlier than others (Agarwal & Prasad, 1998). Lu, Yao, and Yu (2005) found that personal innovativeness showed a significant positive impact upon perceived usefulness and perceived ease of use for adoption of wireless internet services via mobile technology. Liu et al. (2010) also found personal innovativeness to have a significant positive relationship to perceived ease of use, perceived long-term usefulness, and behavioral intention to use.

Based on the literature related to personal innovativeness, it is expected that the medical students that are innovative learners will develop positive beliefs and become the forerunners in usage of the Anatomy mobile app. Based on the previous studies on personal innovativeness, the following hypotheses are proposed:

**H8:** Personal innovativeness positively effects perceived long-term usefulness of the mobile app.
**H9:** Personal innovativeness positively effects perceived ease of use of the mobile app.

**H10:** Personal innovativeness positively effects behavioral intention of the mobile app.

**Research Question 5:** What relationship will perceived enjoyment have with behavioral intention?

The original TAM lacked a construct to measure intrinsic motivation of the user to accept new technology. In 2005, Lee et al. combined the original TAM with the motivational model in order to assess whether the intrinsic and extrinsic motivation of the user had any relationship to actual acceptance and behavioral intention to use the technology. The construct perceived enjoyment was created as a measure of intrinsic motivation. Perceived enjoyment was defined as “the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated” (Lee et al., 2005, p. 5). In the context of this study perceived enjoyment will be measuring the extent to which using the 4anatomy mobile app is perceived as enjoyable to use in its own right.

Lee et al. (2005) found that perceived enjoyment had a statistically significant relationship to behavioral intention to use the technology. Based on the literature related to intrinsic motivation, it is expected that medical students that perceive the 4anatomy
mobile app to be enjoyable will be more likely to show intention to use the same technology in the future. Based on the literature, the following hypothesis is proposed:

**H11:** Perceived enjoyment positively affects behavioral intention of the mobile app.

**Research Question 6:** What relationship will behavioral intention have with actual usage of the mobile app?

A significant number of previous studies have shown a significant relationship between behavioral intention and actual usage (Davis, 1989; Hung & Chang, 2005; Koeszegi, Vetschera & Kersten, 2004; Szajna, 1996; Taylor & Todd, 1995; Taylor & Todd, 1995; Venkatesh & Davis, 1996). Based on the previous research studies listed, the following hypothesis is proposed:

**H12:** There is a positive relationship between behavioral intention to use the 4natomy mobile app and the actual usage of the app.

**Research Question 7:** What relationship will user acceptance have with anatomy exam scores?
Increased utilization of technology related learning tools has been associated with improved learning and knowledge assessment of anatomy (Petersson et al., 2009). As McNulty et al. (2009) found in a six-year study of computer-aided instruction in a gross anatomy course, students that utilized the computer-aided instruction had significantly higher course grades compared to students that never accessed the new technology. In 2011, Triola and Holloway developed an interactive virtual microscopy computer application to replace the physical histology lab. The results showed that, on average, the students that used the virtual microscopy system scored higher on exam scores compared to medical students that did not have the system the prior year.

The final hypothesis of this study has not been conducted in previous TAM studies and does not extend to the theoretical model. Due to the testing of a novel educational resource used during a medical learning block, the research question was developed in an attempt to measure any relationship between acceptance of the 4natomy mobile app and anatomy specific exam question scores:

**H13**: There is a positive relationship between students with high levels of acceptance of the 4natomy mobile app based on the TAM and scores on anatomy specific exam questions.
4.3 Methods

4.3.1 Survey Instrument and Sample

The survey model for this study was a structured questionnaire, which consisted of two components. The first component gathered demographic information, such as gender and the number of times using the 4natomy mobile app, while the second component directly measured the constructs included in the research model. The six constructs of the model were measured using a seven-point Likert scale, which ranged from “strongly disagree” (1) to “strongly agree” (7). To ensure content validity, the survey instrument involved the adaptation of existing validated scales from previous studies. The six constructs and twenty-two indicators measuring the constructs were derived from the literature and carefully modified in order to meet the requirements of this specific study. The measures for perceived near-term usefulness (PNTU), perceived ease of use (PEOU), and behavioral intention (BI) were adapted from instruments developed by Davis (1989), Chau (1996) and Liu et al. (2010). The measures for personal innovativeness were developed based on the study of Agarwal and Prasad (1998) and the instrument developed by Liu et al. (2010). The measures for perceived long-term usefulness (PLTU) were adapted from instruments developed by Chau (1996) and Liu et al. (2010), while the measures for perceived enjoyment (PE) were adapted from the instrument developed by Lee et al. (2005) as shown in Appendix D. Multiple committee members, an administrator at The OSU-COM, and two doctoral students reviewed the developed instrument in order to ensure clarity and readability of the questions.
A convenience sample was used for this study, as all first year medical students own the required hardware (iPad) and the medical curriculum is integrated. All of The OSU-COM first year medical students of the 2014 entering class (i.e., expected to graduate in 2018) were invited to participate (n=195) by downloading the 4natomy mobile app during the Neurological Disorders Learning Block. First year medical students were asked to sign a consent form at the beginning of the learning block if they wished to participate in the study. By consenting, the medical students allowed their anatomy examination scores and medical college admissions test (MCAT) scores to be used for this study. Throughout the learning block, a total 106 first year medical students downloaded and opened the mobile app at least one time. Following the comprehensive exam at the end of the learning block, an email was sent to all first year medical students with a link to the survey at www.SurveyMonkey.com. Medical students were incentivized to participate in the study by offering entry into a randomized drawing of 8 gift cards for iTunes during the three-week window in which the survey was open. In the email, students were asked to click on the link provided in the email and to fill out the survey, which contained a total of 26 questions. The estimated time necessary to complete the survey was between 5-15 minutes. The survey remained open for the students to complete over a three week time period. From the 106 students that downloaded and opened the 4natomy mobile app on their personal OSU-COM issued iPads, 82 students completed the survey (77.36% of all first year students opened the app, 42.05% of all first year students completed the survey). Two of the survey responses from medical students had to be deleted due to no responses on the majority of the survey.
questions. Therefore responses from 80 completed surveys were analyzed for this study.

Table 7 summarizes the profile of the medical students in regards to gender, age, and usage of the 4natomy mobile app.

Table 7. Demographic information gathered from the survey of participating medical students (n=80).

<table>
<thead>
<tr>
<th>Item</th>
<th>Demographic</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
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<td>48.7</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>41</td>
<td>51.2</td>
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<tr>
<td></td>
<td>24-26</td>
<td>21</td>
<td>26.6</td>
</tr>
<tr>
<td></td>
<td>27-29</td>
<td>6</td>
<td>7.5</td>
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<td></td>
<td>&gt;30</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>4natomy App Total</td>
<td>1</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Times Used</td>
<td>1-3</td>
<td>45</td>
<td>56.3</td>
</tr>
<tr>
<td></td>
<td>3-5</td>
<td>18</td>
<td>22.5</td>
</tr>
<tr>
<td></td>
<td>&gt;5</td>
<td>9</td>
<td>11.3</td>
</tr>
</tbody>
</table>

*Note: One student’s age was unable to be obtained.

4.4 Data Analysis

Data collected from the survey questionnaire was collected and coded by an educational resource specialist in the Office of Evaluation, Curriculum Research & Development (OECRD) in The OSU-COM in order to de-identify the database. The de-identified data was first recorded in Microsoft Excel and then transferred to the IBM
Statistical Package for the Social Sciences (SPSS), Windows (Redmond, WA) version 22. Descriptive statistical analysis such as mean, standard deviation, frequency, percent, correlation, and reliability measures were conducted using SPSS. The data were then transferred to AMOS 22 for Windows in order to test the hypotheses by structural equation modeling (SEM).

Structural equation modeling is a method to provide quantitative tests to previously established theoretical models. The researcher hypothesizes the relationships between a set of variables and then empirically tests those relationships (Schumacker & Lomax, 2010). SEM is able to test various types of theoretical models through a combination of different statistical analyses including multiple regression, path analysis, and confirmatory factor analysis. There are two basic variables that are measured in SEM, specifically latent variables and observed variables. Latent variables, also known as constructs or factors, are not directly measured or observed. Latent variables are measured indirectly through a set of observed variables (or indicators), which are directly measured usually through tests or surveys (Schumacker & Lomax, 2010). The latent variables of this study are: behavioral intention (BI), perceived ease of use (PEOU), perceived enjoyment (PE), perceived long-term usefulness (PLTU), perceived near-term usefulness (PNTU), and personal innovativeness (PI).

The twenty-two items of the survey questionnaire (Appendix D) were the observed variables, which measured the six latent variables. The proposed model diagram, which shows the relationship between the observed and latent variables for this study, is displayed in Figure 26.
SEM analysis is conducted by first testing a measurement model, which specifies the relationship between observed variables and latent variables. Following verification of the measurement model, the structural model is tested. The structural model specifies the relationship among latent variables, which is predetermined by previous theoretical models (Schumacker & Lomax, 2010). A confirmatory factor analysis is conducted in order to test our measurement model. Confirmatory factor analysis follows a sequence of five steps or processes: 1) model specification; 2) model identification; 3) model estimation; 4) model testing; and 5) model modification. Following testing and verification of the measurement model, the hypotheses within the structural model are tested.
Figure 26. Theoretical proposed model for current study, with observed variables from Appendix D.
4.5 Results

4.5.1 Analysis of the Measurement Model

Model specification is the first of five steps or processes conducted in a confirmatory factor analysis. Model specification is the initial step due to the fact that it involves using all the relevant research, theories, and information to develop the theoretical model. This step requires the researcher to specify the model that will be confirmed. The information gathered from previous research determines the variables to be included in the model and which variables not to include (Schumacker & Lomax, 2010). This step was thoroughly examined in section 4.2 “Theoretical Background”. Following the model specification step, a series of measurement equations are developed that reflect the relationship between observed variables and the latent variables with which they are measuring. An example of one measurement equation for the latent variable personal innovativeness is listed below:

- \( PI_1 = \text{factor loading} \times \text{personal innovativeness} + \text{error} \)

Model identification is the second process in a confirmatory factor analysis. Model identification is required because SEM involves estimating unknown parameters (e.g., factor loadings and path coefficients) based on known parameters. A necessary condition for a model to be properly identified is the order condition, under which the number of free parameters (e.g., unknown value and hoping to estimate) to be estimated are less than or equal to the number of distinct values in the sample matrix. The formula to determine the number of distinct values in the sample matrix was \( p(p+1)/2 \), where \( p \) is
the number of observed variables. The value of $p$ in this study was 22, thus the number of
distinct values in the sample matrix was 253. Following calculation of the number of
distinct values in the sample matrix, the number of free parameters must be calculated to
determine if the proposed model is under-identified, just-identified, or over-identified.

The total sum of free parameters included in this study is 55. The Degrees of
freedom (df) in SEM is calculated by subtracting the total number of distinct values in the
sample matrix (253) by the number of free parameters (55), thus for the current study the
df equals 198. A positive degrees of freedom value indicates that the model is over-
identified, which is the preferred level of identification.

Model estimation is the third process in a confirmatory factor analysis. Following
the proper identification of the model, estimation of the unknown parameter values is
conducted. The most common estimation method in SEM is maximum likelihood (ML).
The goal of model estimation is to minimize the difference between the observed
covariance matrix (i.e., sample data) and the implied covariance matrices (i.e., theoretical
model).

Model testing is the fourth process in a confirmatory factor analysis. The output
data from the ML estimates indicates the factor loadings, measure error variances, and
selected fit indices. The selected fit indices are examined to determine how well the
observed data from the sample fits the theoretical model. Commonly used global (or
absolute) fit indices are: Chi-square to degrees of freedom ratio and root mean squared
error of approximation (RMSEA). Absolute fit indices measure the ability of the sample
data to fit the model. Relative fit indices compare the theoretical model to a baseline
model (i.e., null or independent model in which the model has no relationship among variables). Common relative fit indices reported are: comparative fit index (CFI), incremental fit index (IFI), tucker-lewis Index (TLI), and normed fit index (NFI) (Schumacker & Lomax, 2010).

Model modification (or respecification) is the fifth and final process in a confirmatory factor analysis. This step allows the researcher to make modifications to the initial model in order to achieve a better-fit following analysis of the global and relative fit indices. The modifications made to the model must be theoretically consistent and be replicated with new data (Schumacker & Lomax, 2010).

Construct validity of the measurement model was assessed through a confirmatory factor analysis, which determines whether the sample data provides empirical support for the theorized structure from the TAM. Construct validity was evaluated through an examination of convergent validity and discriminate validity. Convergent validity implies the extent to which the indicators of a latent variable that are theoretically related should correlate highly (Park, 2009; Park et al., 2012). Convergent validity is evident when: 1) all indicator factor loadings exceed .70; 2) composite reliability for each construct exceeds .70; and 3) average variance extracted (AVE) by each construct exceeds .50 (Fornell & Larcker, 1981). Discriminant validity indicates the extent to which a given concept is different from other constructs (Bagozzi, Yi & Phillips, 1991). Adequate discriminant validity can be confirmed if the square root of the AVE for each construct exceeds the correlation shared between the construct of interest and the other constructs in the model (Fornell & Larcker, 1981). Internal consistency was
assessed through measurement of Cronbach’s alpha, with the recommended cutoff value of 0.7 (Nunnally & Bernstein, 1994). The factor loadings, average variance extracted, composite reliability, and Cronbach’s alpha are listed in Table 8.
Table 8. Factor loadings, average variance extracted, composite reliability and Cronbach's alpha of observed variables.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>Factor Loadings</th>
<th>Average Variance Extracted (AVE)</th>
<th>Composite Reliability (CR)</th>
<th>Cronbach’s Alpha (α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Enjoyment (PE)</td>
<td>PE1</td>
<td>0.90</td>
<td>0.74</td>
<td>0.85</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>PE2</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Ease of Use (PEOU)</td>
<td>PEOU1</td>
<td>0.91</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEOU2</td>
<td>0.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEOU3</td>
<td>0.83</td>
<td>0.79</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>PEOU4</td>
<td>0.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEOU5</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Near-Term Usefulness (PNTU)</td>
<td>PNTU1</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU2</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU3</td>
<td>0.79</td>
<td>0.68</td>
<td>0.93</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>PNTU4</td>
<td>0.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU5</td>
<td>0.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU6</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Innovativeness (PI)</td>
<td>PI1</td>
<td>0.90</td>
<td></td>
<td>0.84</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>PI2</td>
<td>0.97</td>
<td></td>
<td></td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>PI3</td>
<td>0.89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Long-Term Usefulness (PLTU)</td>
<td>PLTU1</td>
<td>0.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLTU2</td>
<td>0.90</td>
<td>0.71</td>
<td>0.88</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>PLTU3</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavioral Intention (BI)</td>
<td>BI1</td>
<td>0.92</td>
<td></td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>BI2</td>
<td>0.81</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BI3</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The results show that all items fit their respective factor quite well. All factor loadings are above the threshold of 0.70, the average variance extracted values are all above 0.5, and all composite reliability values are above 0.8, which indicates good convergent validity. The Cronbach’s alpha values ranged from 0.84 to 0.95, which are all over the 0.7 level indicating good reliability.

 Discriminant validity of the measurement model was examined through comparisons of the square root of the AVE by each construct with the respective inter-construct correlations (Fornell & Larcker, 1981). As shown in Table 9 the square roots of AVE of all constructs (see bolded numbers on the diagonal) are greater than the correlation estimate with the other constructs. This indicates that each construct is more closely related to its own measures compared to those of the other constructs, and, therefore, discriminant validity is supported in this study.

Table 9. Mean, standard deviation, and estimated correlations among constructs. The bolded numbers represent the square roots of the average variance extracted (AVE) values for each construct.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Mean</th>
<th>SD</th>
<th>PE</th>
<th>PEOU</th>
<th>PNTU</th>
<th>PI</th>
<th>PLTU</th>
<th>BI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>5.46</td>
<td>1.26</td>
<td>0.863</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>5.52</td>
<td>1.29</td>
<td>0.652</td>
<td>0.890</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNTU</td>
<td>5.58</td>
<td>1.15</td>
<td>0.841</td>
<td>0.467</td>
<td>0.822</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>5.04</td>
<td>1.51</td>
<td>0.273</td>
<td>0.048</td>
<td>0.401</td>
<td>0.918</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLTU</td>
<td>5.50</td>
<td>1.16</td>
<td>0.847</td>
<td>0.502</td>
<td>0.805</td>
<td>0.408</td>
<td>0.844</td>
<td></td>
</tr>
<tr>
<td>BI</td>
<td>5.75</td>
<td>1.17</td>
<td>0.849</td>
<td>0.553</td>
<td>0.812</td>
<td>0.412</td>
<td>0.826</td>
<td>0.855</td>
</tr>
</tbody>
</table>
The overall fit of the measurement model was assessed through a confirmatory factor analysis (Figure 27) with the fit being interpreted with commonly used fit indices.

Figure 27. Confirmatory Factor Analysis of Proposed Model.
Table 10 reports the statistics of the chi-square to degrees of freedom ratio ($\chi^2$/df), the normed fit index (NFI), root mean squared error of approximation (RMSEA), the comparative fit index (CFI), the incremental fit index (IFI), and tucker-lewis Index (TLI). Following the traditional recommendations for model fit indices, this model is a fairly good fit. The results from the measurement model demonstrate an acceptable fit between the observed sample data and the measurement model based on the various fit indices.

<table>
<thead>
<tr>
<th>Model fit indices</th>
<th>$\chi^2$/df</th>
<th>RMSEA</th>
<th>NFI</th>
<th>CFI</th>
<th>IFI</th>
<th>TLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtained Value</td>
<td>1.436</td>
<td>0.074</td>
<td>0.884</td>
<td>0.961</td>
<td>0.962</td>
<td>0.946</td>
</tr>
<tr>
<td>Recommended Value</td>
<td>&lt;3</td>
<td>&lt;0.08</td>
<td>&gt;0.9</td>
<td>&gt;0.9</td>
<td>&gt;0.9</td>
<td>&gt;0.9</td>
</tr>
</tbody>
</table>

4.5.2 Analysis of the Structural Model

Following acceptance of the measurement model, the structural model was tested. The proposed hypotheses were tested within the context of the structural model by analyzing the relationships between latent variables. Figure 28 gives a graphical description of the results including the standardized beta coefficients or the standardized regressions weights ($\beta$), the critical ratio (t-value), and the total variance explained for each latent variable.
Contrast to the expectations of this study, perceived ease of use had no significant
effect on perceived near-term usefulness (PEOU \(\rightarrow\) PNTU, \(\beta= -.05, p = .409\)) and
behavioral intention (PEOU \(\rightarrow\) BI, \(\beta= .10, p = .598\)), which indicates that hypotheses 1
and 4 are not supported. Consistent with hypotheses 2 and 3, perceived ease of use has a
significant effect on perceived long-term usefulness (PEOU \(\rightarrow\) PLTU, \(\beta= .50, p < .001\))
and perceived enjoyment (PEOU \(\rightarrow\) PE, \(\beta= .65, p < .001\)). Personal innovativeness had no
significant effect on perceived ease of use (PI \(\rightarrow\) PEOU, \(\beta= .06, p = .571\)) indicating that
hypothesis 9 is not supported. However, personal innovativeness did have a significant
effect on long-term usefulness (PI \(\rightarrow\) PLTU, \(\beta= .21, p = .007\)) and behavioral intention (PI
\(\rightarrow\) BI, \(\beta= .20, p = .036\)), thus supporting hypotheses 8 and 10. Perceived long-term
usefulness had a significant effect on perceived near-term usefulness (PLTU \(\rightarrow\) PNTU, \(\beta=
1.03, p < .001\)) supporting hypothesis 6, but did not have a significant effect on
behavioral intention (PLTU \(\rightarrow\) BI, \(\beta= .47, p = .695\)), which indicates a lack of support for
hypothesis 7. Perceived near-term usefulness and perceived enjoyment did not have a
significant effect on behavioral intention (PNTU \(\rightarrow\) BI, \(\beta= .07, p = .873\)) and (PE \(\rightarrow\) BI, \(\beta=
.33, p = .165\)), indicating that hypotheses 5 and 11 are not supported. The results are
presented in Table 11.
Figure 28. Results of structural equation model analysis. Key: *p<0.05 but > .01, **p<0.01 but >.001, and ***p<0.001.
Table 11. Beta coefficients, t-values and results of hypotheses from structural equation model analysis. Key: *p<0.05 but > .01, **p<0.01 but >.001, and ***p<0.001.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H1) PEOU → PNTU</td>
<td>-.05</td>
<td>-.753</td>
<td>Not Supported</td>
</tr>
<tr>
<td>(H2) PEOU → PLTU</td>
<td>.50</td>
<td>4.047***</td>
<td>Supported</td>
</tr>
<tr>
<td>(H3) PEOU → PE</td>
<td>.65</td>
<td>6.043***</td>
<td>Supported</td>
</tr>
<tr>
<td>(H4) PEOU → BI</td>
<td>.10</td>
<td>.748</td>
<td>Not Supported</td>
</tr>
<tr>
<td>(H9) PI → PEOU</td>
<td>.06</td>
<td>.507</td>
<td>Not Supported</td>
</tr>
<tr>
<td>(H8) PI → PLTU</td>
<td>.21</td>
<td>2.685**</td>
<td>Supported</td>
</tr>
<tr>
<td>(H10) PI → BI</td>
<td>.20</td>
<td>2.558*</td>
<td>Supported</td>
</tr>
<tr>
<td>(H6) PLTU → PNTU</td>
<td>1.03</td>
<td>6.847***</td>
<td>Supported</td>
</tr>
<tr>
<td>(H7) PLTU → BI</td>
<td>.47</td>
<td>.245</td>
<td>Not Supported</td>
</tr>
<tr>
<td>(H5) PNTU → BI</td>
<td>.07</td>
<td>.038</td>
<td>Not Supported</td>
</tr>
<tr>
<td>(H4) PE → BI</td>
<td>.33</td>
<td>1.475</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>

4.5.3 Modification of the Structural Model

Following assessment of the model fit for the originally proposed measurement and structural models, the β (i.e., standardized beta coefficient) value for the effect of perceived long-term usefulness on perceived near-term usefulness and the R² were both greater than one, which indicates the presence of a Heywood case. Heywood cases are improper solutions in structural equation modeling in which standardized values exceed 1.0 (Schumacker & Lomax, 2010). One solution proposed by Schumacker & Lomax (2010) to resolve the error associated with Heywood cases is to rescale observed variables to create a more linear relationship. Perceived near-term usefulness and perceived long-term usefulness were combined into a single latent variable perceived
usefulness in order to complete rescaling of the model. Tables 12 and 13 present the confirmed reliability and construct validity, while Table 14 shows the confirmed model fit indices for the modified model. Each model fit indices measurement exceeded the minimum value, with the exception of the NFI (0.893 < 0.9). As noted by To, Liao, Chiang, Shih & Chang (2008) values for NFI above 0.8 are considered adequate for model fit.
Table 12. Factor loadings, average variance extracted, composite reliability and Cronbach’s alpha of observed variables for modified model. Created by rescaling observed variables.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Indicators</th>
<th>Factor Loadings</th>
<th>Average Variance Extracted (AVE)</th>
<th>Composite Reliability (CR)</th>
<th>Cronbach’s Alpha (α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Enjoyment (PE)</td>
<td>PE1</td>
<td>0.93</td>
<td>0.74</td>
<td>0.85</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>PE2</td>
<td>0.81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Ease of Use (PEOU)</td>
<td>PEOU1</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEOU2</td>
<td>0.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEOU3</td>
<td>0.84</td>
<td>0.79</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>PEOU4</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PEOU5</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Usefulness (PU)</td>
<td>PNTU1</td>
<td>0.89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU2</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU3</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU4</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PNTU5</td>
<td>0.74</td>
<td>0.69</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>PNTU6</td>
<td>0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLTU1</td>
<td>0.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLTU2</td>
<td>0.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PLTU3</td>
<td>0.91</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal Innovativeness (PI)</td>
<td>PI1</td>
<td>0.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PI2</td>
<td>0.98</td>
<td>0.84</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>PI3</td>
<td>0.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavioral Intention (BI)</td>
<td>BI1</td>
<td>0.90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BI2</td>
<td>0.82</td>
<td>0.73</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>BI3</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 13. Mean, standard deviation and estimated correlations among constructs for modified model. The bolded numbers represent the square roots of the average variance extracted (AVE) values for each construct.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Mean</th>
<th>SD</th>
<th>PE</th>
<th>PEOU</th>
<th>PNTU</th>
<th>PI</th>
<th>BI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>5.46</td>
<td>1.26</td>
<td>0.859</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>5.52</td>
<td>1.29</td>
<td>0.651</td>
<td>0.890</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PU</td>
<td>5.55</td>
<td>1.15</td>
<td>0.847</td>
<td>0.482</td>
<td>0.830</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>5.04</td>
<td>1.51</td>
<td>0.277</td>
<td>0.052</td>
<td>0.401</td>
<td>0.919</td>
<td></td>
</tr>
<tr>
<td>BI</td>
<td>5.50</td>
<td>1.16</td>
<td>0.845</td>
<td>0.583</td>
<td>0.815</td>
<td>0.467</td>
<td>0.853</td>
</tr>
</tbody>
</table>

Table 14. Model fit indices for modified measurement model.

<table>
<thead>
<tr>
<th>Model fit indices</th>
<th>( \chi^2/\text{df} )</th>
<th>RMSEA</th>
<th>NFI</th>
<th>CFI</th>
<th>IFI</th>
<th>TLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtained Value</td>
<td>1.493</td>
<td>0.079</td>
<td>0.873</td>
<td>0.953</td>
<td>0.954</td>
<td>0.939</td>
</tr>
<tr>
<td>Recommended Value</td>
<td>&lt;3</td>
<td>&lt;0.08</td>
<td>&gt;0.9</td>
<td>&gt;0.9</td>
<td>&gt;0.9</td>
<td>&gt;0.9</td>
</tr>
</tbody>
</table>

Figure 29 shows the modified model with perceived usefulness replacing both perceived near and long-term usefulness. (Note: The originally proposed hypotheses have been adjusted to reflect the modified model.) The standardized beta coefficients (\( \beta \)), the critical ratio (t-value), and the total variance explained for each latent variable are labeled accordingly. Modification of the model leads to new statistical results: Perceived ease of use had a significant effect on perceived enjoyment (PEOU \( \rightarrow \) PE, \( \beta = .65 \), \( p < .001 \)), perceived usefulness (PEOU \( \rightarrow \) PU, \( \beta = .50 \), \( p < .001 \)) and behavioral intention (PEOU \( \rightarrow \) BI, \( \beta = .19 \), \( p = .039 \)). Personal innovativeness has a significant effect on perceived
usefulness (PI $\rightarrow$ PU, $\beta = .21$, $p = .005$) and behavioral intention (PI $\rightarrow$ BI, $\beta = .15$, $p = .03$). Perceived usefulness had a significant effect on behavioral intention (PU $\rightarrow$ PLTU, $\beta = .71$, $p < .001$). Perceived enjoyment did not have a significant effect on behavioral intention (PE $\rightarrow$ BI, $\beta = .04$, $p = .818$) and personal innovativeness did not have a significant effect on perceived ease of use (PI $\rightarrow$ PEOU, $\beta = .07$, $p = .561$). The results with the adjusted hypotheses are presented in Table 15.

Table 15. Beta coefficients, t-values, and results of hypotheses from structural equation model analysis of modified model once observed variables were rescaled. Key: *$p<0.05$ but $>.01$, **$p<0.01$ but $>.001$, and ***$p<0.001$.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>$\beta$ Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H1) PEOU $\rightarrow$ PU</td>
<td>.50</td>
<td>4.715***</td>
<td>Supported</td>
</tr>
<tr>
<td>(H3) PEOU $\rightarrow$ PE</td>
<td>.65</td>
<td>6.193***</td>
<td>Supported</td>
</tr>
<tr>
<td>(H4) PEOU $\rightarrow$ BI</td>
<td>.19</td>
<td>2.065*</td>
<td>Supported</td>
</tr>
<tr>
<td>(H5) PU $\rightarrow$ BI</td>
<td>.71</td>
<td>4.831***</td>
<td>Supported</td>
</tr>
<tr>
<td>(H9) PI $\rightarrow$ PEOU</td>
<td>.07</td>
<td>.582</td>
<td>Not Supported</td>
</tr>
<tr>
<td>(H8) PI $\rightarrow$ PU</td>
<td>.21</td>
<td>2.800**</td>
<td>Supported</td>
</tr>
<tr>
<td>(H10) PI $\rightarrow$ BI</td>
<td>.15</td>
<td>2.166*</td>
<td>Supported</td>
</tr>
<tr>
<td>(H4) PE $\rightarrow$ BI</td>
<td>.04</td>
<td>.230</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>
Figure 29. Results of the structural equation model analysis for the modified model created by rescaling the observed variables. Key: *p<0.05 but > .01, **p<0.01 but >.001, and ***p<0.001.
Modification of the original model alleviated the Heywood case that was initially present, as indicated by the $\beta$ and the $R^2$ values for perceived usefulness below one. The modification of this model was theoretically sound as perceived usefulness was the original construct used by Davis (1989) and has been a consistently tested construct for the majority of TAM studies.

The relationship between the behavioral intention and the actual usage of the *Anatomy* mobile app by the medical students was analyzed by first creating a variable of the average for all three behavioral intention responses. As both variables (i.e., $BIAvg$ and $AppUsage$) are ordinal, a bivariate correlational analysis was conducted. The Spearman’s rho correlational coefficient data is presented in Table 16. The correlation between behavioral intention and app usage was statistically significant ($\rho = .243$, $p<.05$), and, thus, hypothesis 12 was supported.

Table 16. Relationship between behavioral intention ($BIAvg$) and app usage ($AppUsage$).

<table>
<thead>
<tr>
<th></th>
<th>AppUsage</th>
<th>BIAvg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation Coefficient</td>
<td>1.000</td>
<td>.243*</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td>.</td>
<td>.015</td>
</tr>
<tr>
<td>N</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Correlation Coefficient</th>
<th>1.000</th>
<th>.243*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AppUsage</td>
<td>Sig. (1-tailed)</td>
<td>.015</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (1-tailed).
The final hypothesis was tested by creating two variables, specifically *AnatomyScores* and *Acceptance*. *AnatomyScores* is the sum of the four spinal cord anatomy specific questions from the Neurological Disorders Learning Block comprehensive final exam and *Acceptance* is the average score from each survey response (i.e., observed variables). The descriptive statistics for these two variables are displayed in Table 17. As both of these variables are ordinal, a bivariate correlational analysis was conducted. The Spearman’s rho correlational coefficient data is presented in Table 18. The Spearman’s rho correlational coefficient value was 0.099 with a p-value = .190, and thus this outcome signifies that hypothesis 13 is not supported.

Table 17. Descriptive statistics for anatomy scores and acceptance.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AnatomyScores</td>
<td>80</td>
<td>1.00</td>
<td>4.00</td>
<td>3.3500</td>
<td>.78111</td>
</tr>
<tr>
<td>Acceptance</td>
<td>80</td>
<td>2.82</td>
<td>6.91</td>
<td>5.4932</td>
<td>.87041</td>
</tr>
</tbody>
</table>
Table 18. Relationship between acceptance and anatomy scores.

<table>
<thead>
<tr>
<th></th>
<th>AnatomyScores</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>1.000</td>
<td>.099</td>
</tr>
<tr>
<td>Coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td>.190</td>
</tr>
<tr>
<td>N</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

4.6 Discussion

To better understand factors that lead to the adoption and usage of educational mobile apps by medical students, the aim of this study was to identify and measure the constructs that influenced the student’s intention to use an integrated mobile app. Based on previous studies that measured the factors which influenced the usage and acceptance of new IT and IS programs or systems [e.g., Davis (1989), Lee et al., (2005), Liu et al., (2010)] the TAM was the theoretical framework for the study. Investigation of these factors has significant implications for future educational initiatives that require substantial investments prior to implementation.

The results of the present research study support the conclusion that the TAM accurately represented the data collected based on the fit indices analyzed. As found in previous literature on which this study was based, the general structural model was shown to be helpful in explaining student’s behavioral intention to use a novel mobile app. All hypotheses related to the original TAM proposed by Davis (1989) are supported.
in this study. The results in this study are also supported by the previous studies on the application of the TAM to e-learning (Lee et al., 2005) and m-learning (Liu et al., 2010). The results specify three significant motivators of anatomy mobile app acceptance and intention to use, which are: 1) perceived usefulness; 2) perceive ease of use; and 3) personal innovativeness.

Perceived usefulness was found to be the strongest determinant of behavioral intention, which is consistent with the idea that perceived usefulness is a measure of extrinsic motivation of the user (Venkatesh et al., 2002). This relationship is consistent throughout the vast majority of TAM studies (Li et al., 2008). Due to the Heywood case in this study, perceived near-term and long-term usefulness were combined into the single perceived usefulness construct. Future TAM studies that measure perceived near-term and long-term usefulness must be aware of the possibility of Heywood cases and adjust the constructs accordingly. Based on the significant causal relationship between perceived usefulness and behavioral intention in this study, medical students must believe that a voluntary educational resource will potentially improve their understanding, decrease the amount of mental strain, and provide the greatest potential of increasing examination scores for them to utilize that resource. The significant affect of perceived usefulness on behavioral intention in this study indicates the importance of designing and developing mobile educational resources for medical students of high perceived.

Perceived ease of use was found to be a significant determinant for behavioral intention of the anatomy mobile app usage by medical students. These findings are consistent with some previous studies (Legris et al., 2003; Yuanquan et al., 2008). Based
on the results of this study, medical students must believe that a resource is easy to use and easy to understand, otherwise they will quickly be deterred and likely not use the product in the future. This phenomenon has led companies like Apple and Google to develop user interface (UI) guidelines. These guidelines ensure consistent UI designs, which the user has become accustomed to throughout everyday use of the mobile hardware and software. One indirect function of the TAM is to serve as a usability test for new software prior to wide spread distribution. The questions within the TAM survey pertaining to perceived ease of use measure the usability of the software and, thus, the individual’s intention to use the resource in the future.

Personal innovativeness was found to be a significant determinant of behavioral intention of the Anatomy mobile app usage by medical students. Consistent with previous studies (Liu et al., 2010; Taylor, 2007), innovative learners would be more likely to hold positive beliefs towards new IT and IS and, thus, be more inclined to use an integrated anatomy mobile app. This information suggests that when developing new mobile educational resources, it may be an effective strategy to test the resource first with individuals who have been identified as “innovative users”. Together, perceived ease of use, perceived usefulness, personal innovativeness, and perceived enjoyment accounted for 81.0% of the variance in behavioral intention, which indicates that these three variables are good measures of behavioral intention.

This TAM study also found significant effects between other constructs similar to previous educational studies that utilized the TAM. For instance, in the present study personal innovativeness had a statistically significant effect on perceived usefulness,
which was also found to be statistically significant in the study conducted by Liu et al. (2010). The present study also found perceived ease of use to have a statistically significant effect on perceived usefulness and perceived enjoyment, which was also found to be statistically significant in the study conducted by Lee et al. (2005).

The significant effect of perceived ease of use on perceived usefulness in this study indicates that resources that are intuitive and easy to use are more likely to be viewed as useful in the learning process by medical students. Similarly, students who perceive themselves as innovative individuals are more likely to perceive a resource as useful due to the content and design, without the burden of learning new software.

The students reported the number of times they used the app throughout the course of their studying for the Neurological Disorders Learning Block (Table 7). The results indicate that 90% of the students that downloaded the app and completed a survey (n=80), used it more than one time throughout the learning block and over one-third of the students used the app more than three times (33.8%). This amount of usage suggests that students were motivated to use the app and found the app to be a viable resource while learning about the spinal cord. The significant positive relationship between behavioral intention and app usage indicates that students who submitted higher rated responses on behavioral intention questions also used the app more often. The study did not find a statistically significant relationship between overall acceptance of the 4anatomy mobile app and scores on the four spinal cord anatomy questions on the final exam.

While this may indicate that using the app does not improve examination scores, it may also be that 4 exam questions are not sufficient to see any effect with only 80 students.
Further development and testing with control and experimental groups is recommended to determine if this type of mobile resource can impact educational outcomes.

4.7 Limitations

There are limitations associated with this study, the first being the relatively small sample size when attempting to make comparisons to the larger population nationally of medical students. While the percentage of students that downloaded the app and filled out the survey was large (77.36%), 80 medical students is a smaller subset of all medical students currently enrolled in an integrated medical school. The current study was unable to account for student ability when analyzing the relationship between acceptance of the 4anatomy mobile app and scores on the four spinal cord related anatomy questions. Future versions of the study should use MCAT scores to account for student ability prior to assessing any relationship between acceptance of a mobile resource and exam scores. Future versions of the study should analyze the relationship between actual usage of the mobile app and the anatomy scores by students. These future studies should choose a subject matter that will have a larger number of test questions for students to answer.

Another limitation of the study was the low amount of analytical data built into the mobile app. Finally, future versions of the app should have meticulous analytical measures built into the app in order to measure length of page views, number of buttons pressed, etc. There is potential for bias as the students that downloaded the mobile app and completed the survey have a prior teacher-student relationship with the individual conducting the study.
4.8 Conclusions

This is the first study that utilized the TAM to measure the acceptance and behavioral intention towards the use of a novel educational mobile app by medical students. The TAM used in this study provided insights into how high-level professional students perceive a mobile educational resource developed to reflect their curriculum. The traditionally measured TAM constructs, including perceived usefulness and perceived ease of use, were found to be significant motivators to behavioral intention, which is consistent with previous TAM studies [e.g., Davis (1989), Lee & Lehto (2013)]. A more recently developed and tested construct, personal innovativeness was also found to be a significant motivator towards behavioral intention in this study. The model used in this study explained 81% of the variance in behavioral intention, which provides support for the applicability of the TAM for this study.

The educational resource for this study was developed specifically for the Apple iPad. The medical students in the current study are provided the same Apple iPad model running the same version of Apple’s mobile software (iOS), which allowed for the resource to be accessed by the entire class of first year medical students. Due to the popularity and consistency of Apple’s hardware and software, the students were able to quickly understand the UI of the mobile app and, thus, could focus on the educational benefit of the resource. As more mobile educational resources are developed to function on mobile phones and tablet computers, it is of practical interest to first identify the mobile operating system and hardware that the majority of students who the resource is
being developed for currently use. Following the selection of the mobile OS that the resource will be developed, a prototype version should be created for testing. Testing a prototype version of a mobile resource through the TAM will provide valuable data on the user’s perception towards the usefulness, ease of use, and their overall intention to use the resource in the course of their learning.

The results from this study provide insight into both the demand for integrated anatomical mobile resources by medical students, as well as the viability of using the TAM to assess the level of acceptance and usage intention of educational mobile resources. Based on the responses from the second chapter of this research, there was a need to develop and assess if medical students would accept and use an integrated anatomy mobile app. The main features within the 4natomy mobile app were developed based on the features of highest demand by second year medical students in the group interviews.

As indicated by the results of the 4natomy mobile app testing through the TAM, medical students in a medical school that distributes mobile devices and utilizes an integrated curriculum accepted a novel mobile app that integrates the four anatomical sub-disciplines (i.e., gross anatomy, histology, embryology, and neuroanatomy). The TAM utilized in this study indicates that if first year medical students believe that they are personally innovative and that a mobile resources is useful and easy to use, then these students have a strong determinant towards the intention to use that resource. These results suggest that with the development of future mobile resources, these three constructs (i.e., perceived usefulness, perceived ease of use, and personal innovativeness)
must be addressed in the early stages of development in order to improve the likelihood of medical students adopting and using the mobile resource. The results from this study are limited to acceptance of an integrated anatomy mobile app by first year medical students in an integrated curriculum at the OSU-COM. As personal innovativeness was a positive determinant for medical student’s intention to use the mobile app future studies should attempt to determine which medical students consider themselves to be personally innovative by conducting a pre-survey. As acceptance of a novel resource must occur not only among the student body, but faculty must also believe the resource to be useful, assessment of faculty acceptance should also be considered in future studies. Future studies should also identify students of various academic levels based on medical college admission test (MCAT) scores and previous anatomy block exam scores (if applicable based on an integrated curriculum). By determining the various academic levels of students prior to distribution of the mobile resource, the researcher can assess if the resource is benefiting, hindering or providing a neutral effect to students of various academic levels. Future studies should assess acceptance and usage of an integrated anatomy app at multiple medical schools that also utilize an integrated systems based curriculum. Future studies should also attempt to measure acceptance of the integrated anatomy mobile app in other higher educational fields such as dental schools or other disciplines in which integrated resources are relevant. Future studies should also assess how medical students in their third year or beyond accept this technology while in their clinical rotations or residencies. It is recommended in future studies to continue assessment of an integrated anatomy mobile app by creating an expanded mobile app that
includes all anatomy related content for an entire learning block. Finally, future studies should look at how different groups of students (e.g., elementary, high school, undergraduate, etc.) accept and use mobile educational resources.

4.8.1 Key Findings

Research Question 1: What relationship will perceived ease of use have with perceived near-term usefulness, perceived long-term usefulness, perceived enjoyment, and behavioral intention?

H1: Perceived ease of use positively effects perceived near-term usefulness of the mobile app.

H2: Perceived ease of use positively effects perceived long-term usefulness of the mobile app.

H3: Perceived ease of use positively effects perceived enjoyment of the mobile app.

H4: Perceived ease of use positively effects behavioral intention towards use of the mobile app.
Table 19. Chapter 4 Hypotheses 1-4 results.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEOU → PNTU</td>
<td>-.05</td>
<td>-.753</td>
<td>Not Supported</td>
</tr>
<tr>
<td>PEOU → PLTU</td>
<td>.50</td>
<td>4.047***</td>
<td>Supported</td>
</tr>
<tr>
<td>PEOU → PE</td>
<td>.65</td>
<td>6.043***</td>
<td>Supported</td>
</tr>
<tr>
<td>PEOU → BI</td>
<td>.10</td>
<td>.748</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>

Key: ***p<0.001.

**Research Question 2:** What relationship will perceived near-term usefulness have with behavior intention?

**H5:** Perceived near-term usefulness positively affects behavioral intention towards use of the mobile app.

Table 20. Chapter 4 Hypothesis 5 results.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNTU → BI</td>
<td>.07</td>
<td>.038</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>

Not statistically significant (p=.873).

**Research Question 3:** What relationship will perceived long-term usefulness have with perceived near-term usefulness and behavioral intention?

**H6:** Perceived long-term usefulness positively affects perceived near-term usefulness of the mobile app.
**H7:** Perceived long-term usefulness positively affects behavioral intention towards use of the mobile app.

Table 21. Chapter 4 Hypotheses 6-7 results.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLTU→PNTU</td>
<td>1.03</td>
<td>6.847***</td>
<td>Supported</td>
</tr>
<tr>
<td>PLTU→BI</td>
<td>.47</td>
<td>.245</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>

Key: ***p<0.001.

**Research Question 4:** What relationship will personal innovativeness have with perceived long-term usefulness, perceived ease of use, and behavioral intention?

**H8:** Personal innovativeness positively affects perceived long-term usefulness of the mobile app.

**H9:** Personal innovativeness positively affects perceived ease of use of the mobile app.

**H10:** Personal innovativeness positively affects behavioral intention of the mobile app.

Table 22. Chapter 4 Hypotheses 8-10 results.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI→PLTU</td>
<td>.21</td>
<td>2.865**</td>
<td>Supported</td>
</tr>
<tr>
<td>PI→PEOU</td>
<td>.06</td>
<td>.507</td>
<td>Not Supported</td>
</tr>
<tr>
<td>PI→BI</td>
<td>.20</td>
<td>2.558*</td>
<td>Supported</td>
</tr>
</tbody>
</table>

Key: *p<0.05 but >.01, **p<0.01 but >.001.
**Research Question 5:** What relationship will perceived enjoyment have with behavioral intention?

**H11:** Perceived enjoyment positively affects behavioral intention of the mobile app.

Table 23. Chapter 4 Hypothesis 11 results.

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE → BI</td>
<td>.33</td>
<td>1.475</td>
<td>Not Supported</td>
</tr>
</tbody>
</table>

Not statistically significant (p= .165).

**Research Question 6:** What relationship will behavioral intention have with actual usage of the mobile app?

**H12:** There is a positive relationship between behavioral intention to use the *Anatomy* mobile app and the actual usage of the app.
Table 24. Chapter 4 Hypothesis 12 results.

<table>
<thead>
<tr>
<th></th>
<th>AppUsage</th>
<th>BIAvg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation</td>
<td>1.000</td>
<td>.243*</td>
</tr>
<tr>
<td>Coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td>.</td>
<td>.015</td>
</tr>
<tr>
<td>N</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (1-tailed).

**Research Question 7:** What relationship will user acceptance have with anatomy exam scores?

**H13:** There is a positive relationship between students with high levels of acceptance of the *anatomy* mobile app based on the TAM and scores on anatomy specific exam questions.
Table 25. Chapter 4 Hypothesis 13 results.

<table>
<thead>
<tr>
<th></th>
<th>AnatomyScores</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AnatomyScores</td>
<td>Correlation</td>
<td>.999</td>
</tr>
<tr>
<td></td>
<td>Coefficient</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tailed)</td>
<td>.190</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>80</td>
</tr>
<tr>
<td>Acceptance</td>
<td>Correlation</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Coefficient</td>
<td>.099</td>
</tr>
<tr>
<td></td>
<td>Sig. (1-tailed)</td>
<td>.190</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>80</td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (1-tailed).

Table 26. Results of hypotheses for modified model

<table>
<thead>
<tr>
<th>Hypothesized Path</th>
<th>β Coefficient</th>
<th>t-value</th>
<th>Result of Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEOU→PU</td>
<td>.50</td>
<td>4.715***</td>
<td>Supported</td>
</tr>
<tr>
<td>PEOU→PE</td>
<td>.65</td>
<td>6.193***</td>
<td>Supported</td>
</tr>
<tr>
<td>PEOU→BI</td>
<td>.19</td>
<td>2.065*</td>
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Key: *p<0.05 but > .01, **p<0.01 but >.001, and ***p<0.001.
Chapter 5: Assessing Medical Student’s Final Perspective on the 4natomy Mobile App

5.1 Introduction

The creation of mobile educational resources has occurred at various educational levels from early childhood education (Kiger, Herro, & Prunty, 2012) to high-level professional schools (George et al., 2013). The mobile resources that have been studied in previous research were developed independently by private companies (Lewis, Burnett, Tunstall & Abrahams, 2014) or specifically by the investigator of the study in order to investigate the effectiveness of the resource (Davis et al., 2012; Tanaka, Hawrylyshyn & Macario, 2012; Teri et al., 2013; Tews, Brennan, Begaz, & Treat, 2011). The feedback provided by the users in research studies investigating mobile resources enables content creators to quickly implement the requested changes in order to improve future versions of the resource.

Teri et al. (2013) received positive and negative feedback about their mobile app (i.e., NutriBiochem) from students that used the app. For example, some students found the app to be easy to use and it provided convenient and accessible material, while others found the app lacking adequate depth of content and that at times it was “glitchy”. Recommendations for future NutriBiochem app development are based on the direct
feedback provided by the students that utilized the mobile app and updated future version plan to correct the errors.

Davies et al. (2012) provided medical students in years 3-5 with personal digital assistants (PDAs) preloaded with numerous medical resources to be used during clinical rotations and studies. The feedback provided by students following the study included positive remarks such as “I used it principally for making reference on the wards and I use the anatomy quite a lot when we are in the theaters ” (p. 4) or “(Using it) reinforced key points at point of need” (p. 4). Students also had negative feedback in regards to the PDAs, such as “… I found it quite hard to carry it around with me all the time” (p. 6) or “I just wonder if there is actually something which is more intuitive – with less extra effort – it might be more useful” (p. 6). Davies et al. (2012) argues that based on the feedback provided by the medical students, adopting a smartphone platform may be advantageous due to the consistent software and powerful hardware compared to PDAs. George et al. (2013) introduced iPads into problem-based learning (PBL) sessions at the Warren Alpert Medical School (AMS) of Brown University. Students involved in the PBLs participated in focus groups and provided valuable feedback on the viability of using iPads within the sessions. Students commented that the iPads have the advantage of decreasing the amount of paper used, they provide easy searching for medical information, and allow for reviewing of class notes in real time. Disadvantages reported by the students are that the apps provided need better integration within the context of the PBLs and switching between different mobile apps was not easy.
There continues to be a decrease in contact hours with medical students, specifically within anatomy sub-disciplines (Drake, McBride & Pawlina, 2014), as well as limited resources dedicated to the creation of new educational resources (Davies et al., 2012). Feedback provided by previous m-learning studies focused on the hardware issues (e.g., small screen size, low processing power, and large body size) and software issues (e.g., glitchy, short battery life, and lack constant internet connectivity) associated with early mobile devices (Cronje & El-Hussein, 2010; Gupta & Koo, 2010; Huang, Kuo, Lin & Cheng, 2008). Many of the previous concerns of mobile devices have been addressed through the recent development of smartphones and tablet computers that have larger screens, faster processors, smaller sized casings and bodies, consistent software, and longer battery lives, as well as Wi-Fi and data networks (George et al., 2013; Melhuish & Falloon, 2010; Stirling & Birt, 2013).

The group interviews conducted in the current study with first year medical students provides feedback directly from students who used the 4natomy mobile app. Information collected in these group interviews will aid in the continued development and improvement of future versions of the 4natomy mobile app and other mobile medical resources.

5.1.1 Study Aims

- **Aim 1**: To determine if the 4natomy mobile app functioned as expected by the students and what features should be removed in future versions.
• **Aim 2:** To determine what features in the *4natomy* mobile app could be improved upon and what new features should be added in future versions.

• **Aim 3:** To determine if the *4natomy* mobile app should be expanded to include all anatomy related content within the Neurological Disorders Learning Block, as well as other integrated learning blocks.

5.2 Methods

All first year medical students at the Ohio State University College of Medicine (OSU-COM) who downloaded and used the app were invited through email to participate in a series of group interviews throughout a five-week period between April 2015 and May 2015. Convenience sampling was used to select the participants. The group interview sessions varied from 2-5 students involved. Consent was obtained in accordance with the Institutional Review Board (IRB# 2014B0202) of The Ohio State University. The students were handed a paper with six pre-determined questions (Appendix E) to answer individually for the first 5-10 minutes of the session. The remaining 10-20 minutes of the group interviews involved a group discussion of the answers written by each student. Audio recordings of each group interview session were made for accuracy and retained for verification of student answers. The only facilitator of each group interview session was the lead of the study (i.e., Derek Harmon).
5.3 Data Analysis

Qualitative analysis was conducted for each question of the group interview, with answers coded and entered into the statistical package for the social sciences (SPSS) for analysis. Frequency distributions were created for the appropriate research questions and the results are listed below.

5.4 Results

A total of 20 first year medical students (25% of those who completed the Technology Acceptance Model survey (n= 80), 18.9% of students that used the app (n = 106)) participated in the group interview sessions throughout the five-week period. A frequency distribution was conducted to determine if the app functioned as the students originally expected. Responses to each interview question are listed in Appendix F. Based on the group interview responses, 18 (90.0%) of the students reported that the app functioned as expected. One student responded with “N/A” to the first question because: “I had no expectations of the app before using it”. The one student that responded no to the first question indicated that “it was a little slow to start and not very new appearing”. Examples of extended responses to the first question by the students were:

- “Yes, it was much more detailed and comprehensive than I was expecting it to be.”

- “Yes, I would say so! I did not know what to think at first though. I did not think it would be as inclusive and all-encompassing as it is! Love that aspect.”
A frequency distribution was conducted to determine what components of the app students would like to see removed from future versions of the *4natomy* mobile app if any. All 20 (100%) students responded that none of the components should be removed.

Here are examples of some student’s extended responses to the second question:

- “Nothing removed. But if it comes to needing to focus on certain areas I think you could do away with the histology component - gross is vital!”

- “None! It would actually be great if you added more features on! (I don’t know if it might be possible to add in pharm/pathology or other aspects that are affecting anatomy).”

A frequency distribution was conducted to determine what components of the app students would like to see improved in future versions of the *4natomy* mobile app, if any. There were seven different responses by students that could be categorized, with Figure 30 displaying the frequency of responses. The most common response for improved components in future editions was “None” by 6 students. The other six improvements were: 1) more animations; 2) improving the interface/layout; 3) including self-assessment/quizzing; 4) more content; 5) close captioning to videos; and 6) more clinical correlations. Note that there are more than twenty responses as some students indicated multiple components. Here are examples of some student’s extended responses to the third question:

- “I would like to see the tracts have the words, 1st order, 2nd order, etc. added to the audio during the explanations.”

- Colors/highlighting of structures can be improved to be clearer and/or look more similar to cadavers.”
• “Would love to see it incorporate more animations in more systems.”

A frequency distribution was conducted to determine what new features students would like to see included in future versions of the 4natomy mobile app, if any. The ten new features students requested for future editions of the app are located in Figure 31. The most common responses for new features to add were: 1) a self-assessment/quiz
function (7 students); 2) increase and expand the amount of anatomy related content (6 students); and 3) clinical correlations to each anatomical sub-discipline (5 students). Note that there are more than twenty responses as some students indicated multiple features.

Here are examples of some student’s extended responses to the fourth question:

- “Quizzes, practice questions (ways to test knowledge) would be a great addition.”
- “Just expanded content. If you wanted you could add common pathology, but I don’t think it would be crucial.”
- “More clinical correlations maybe, so it can more of a one-stop shop for anatomy.”
A frequency distribution was conducted in order to analyze the fifth group interview question regarding whether the 4natomy mobile app should be expanded to cover all anatomy relevant material for each learning block at The OSU-COM. The student’s responses are shown in Figure 32, with 19 (95.0%) students responding “Yes” that the app should be expanded to include all anatomy related material for each learning block. One student did not respond to this question and thus appears as N/A in the figure. Here are examples of some student’s extended responses to the fifth question:
• “Absolutely. Doing so would be extremely helpful.”

• “Definitely!! This app was incredibly helpful as a medical student with the volume of info being given to us it was extremely helpful to have embryo, histo, neuro all tied together in one app. It was a tremendous help to me! Looking forward to seeing its development moving forward.”

• “Yes, it would definitely be a good resource to have each block anatomy all in the same app. Especially helpful for the connections made between different units.”

Figure 32. Medical student (n= 20) responses to expanding the 4natomy mobile app to cover all other integrated learning blocks at The OSU-COM.
The final aspect of the group interview sessions gave students the opportunity to write and discuss any other comments they had about the mobile app. Five of the twenty students had no comments, while the remaining students provided positive feedback and words of encouragement for future development. Here are examples of some student’s comments:

- “Loved the app! Very useful when studying for the final and lab exam!”
- “Would be interested to see how the app could be integrated into the classroom portion - I think this is a potential opportunity.”
- “Great job in putting this together. Consider integrating the information from pathoma in terms of pathology to make it clinically relevant.”
- “It was a great supplement and I think it could be expanded to be a serious teaching guide.”
- “I think the app was great overall with lots of potential benefits for students to learn anatomy in more comprehensive manner.”

5.5 Discussion

Individuals between 18-24 years old are the second largest demographic of smartphone ownership (85%), slightly behind 25-43 year olds (86%), based on the report by Nielsen (2014). The results from the previous study conducted in the second chapter of this paper indicate that the adoption rate of smartphones is much higher with 98.3% of participating medical students at The OSU-COM owning a smartphone. More medical schools are beginning to implement iPads within their curriculum due to the many advantages the iPads present to both medical students, residents, and beyond (Dolan, 2011; Robinson & Burk, 2013). As mobile device companies continue to improve the
processor speed, screen size, screen quality, hard drive space, and wireless accessibility, the demand for developing effective and efficient resources on these devices will remain high.

Each first year medical student at The OSU-COM receives an iPad upon beginning school, which made testing of a novel anatomical mobile app appropriate for this study. There is currently no published research investigating educational mobile apps developed as supplemental resources for an integrated medical curriculum. The data gathered from the group interview sessions following the implementation and usage of the 4natomy mobile app provides the necessary information to assess the original aims of the study.

- **Aim 1**: To determine if the 4natomy mobile app functioned as expected by the students and what features should be removed in future versions.

Based on the responses from the group interview sessions, the majority of medical students (90%) believe that the app functioned as they had originally expected, while one student described having “no” expectations at all when downloading the app. One student expected the app to be more polished in regards to the appearance and thought the app was a little slow sometimes when it was opened. The “yes” responses from the first group interview question can be explained by the fact that the students were provided with a clear description of the function and goals of the app and a video demonstration on the structural layout and interface of the mobile app prior to the release.
All of the medical students who participated in the group interviews agreed that none of the features provided by the 4natomy mobile app should be removed in future versions. An explanation for this is due to the fact that the 4natomy mobile app was developed based on the responses from the focus group conducted with second year medical students (Chapter 2). The app contains three-dimensional (3D) models of the spinal cord, animations/videos, detailed text descriptions, and high-resolution images, all of which were rated as beneficial components in educational anatomy mobile apps by second year medical students that participated in group interviews at The OSU-COM.

- **Aim 2:** To determine what features in the 4natomy mobile app could be improved upon and what new features should be added in future versions.

The student’s responses from the group interview sessions indicate six ways to improve the current version of the 4natomy mobile app for future development. The majority of students indicated that none of the components need improvement and function appropriately as they are currently. Five students requested for the anatomy content to be expanded, four students indicated the need for more clinically relevant correlations, and three students believe that more animations and videos would improve future versions of the app. The other improvements requested by the medical students were: 1) close captioning the videos/animations; 2) improving the appearance and interface; and 2) improving the self-assessment aspect of the mobile app. Some of these responses are consistent with the feedback in the study conducted by Teri et al. (2013),
with undergraduate students in that study requesting an increased amount of course related content.

Based on the responses of the first year medical students, three features were the most commonly suggested: specifically a formal self-assessment or quizzing function, an overall increase in the depth, and expansion to include all anatomy content and clinical correlations for each anatomical sub-discipline. The demand by students for relevant and challenging quizzes was also found as a result of the study conducted by Teri et al. (2013). The other features that were requested by a lower percentage of students were more animations, improved interface and layout, increasing user control and implementing more 3D models, increasing the number of landscape views, and implementing a voice control component.

Future versions of the 4natomy mobile app, as well as other mobile anatomy resources, should follow the recommendations and results from the group interviews in Chapter 2 and this chapter. The feedback provided by medical students indicates creating resources that contain multiple media formats, a comprehensive self-assessment component, expanding the app to include all anatomy related content within a learning block, and integrating clinically relevant cases to each anatomy sub-discipline.

- **Aim 3:** To determine if the 4natomy mobile app should be expanded to include all anatomy related content within the Neurological Disorders Learning Block, as well as other integrated learning blocks.
Based on the responses from students, the *Anatomy* mobile app should be expanded to include other anatomy related content in the Neurological Disorders Learning Block, as well as to other learning blocks. These results are consistent with the responses of the second year medical students in the previous group interview sessions (Chapter 2), where the demand was high for an integrated anatomy mobile app. Nearly all responses in regards to using the *Anatomy* integrated anatomy app and the expansion of the app to all anatomy relevant content was yes (98.3% and 95%, respectively).

The feedback gathered from the group interviews provides valuable information about expanding and improving the *Anatomy* mobile app, as well as the creation of other mobile resources. As this was the first mobile resource to integrate all four anatomy sub-disciplines (i.e., gross anatomy, histology, embryology, and neuroanatomy) into a mobile app for the iPad, feedback from students is important to determine what components to improve and features to add in future versions. Educators that want to create mobile educational resources can learn from the feedback provided by the first year medical students. Following the recommendations from both group interview sessions, effective mobile resources can be designed, developed, and implemented within medical curricula.

5.6 Limitations

There are limitations to this study, with the first being the relatively small sample size (n = 20) when attempting to make comparisons to the larger population of medical students. Another limitation is the fact that students who participated in the group interviews may be these users that held the app in a higher regard. There is potential for
bias in the group interview responses, as the medical students that participated knew that the project lead that was conducting the interviews created the mobile app. Another potential bias in this study is that the medical students that participated in the group interviews have a prior teacher-student relationship with the interviewer. In the future, it may be warranted to hold group interview sessions over a longer period of time or possibly allow the students to answer the questions anonymously online.

5.7 Conclusions

The responses from this study provided insight into medical student’s personal opinions on a novel mobile resource. The expectations held by the students prior to downloading the *4natomy* mobile app were predominately met, most likely due to the distribution of information about the purpose and how to use the app prior to the final release. The mobile app contained numerous multimedia components that were used to teach spinal cord information for the four anatomical sub-disciplines (i.e., gross anatomy, histology, embryology, and neuroanatomy). The results from the group interview sessions of second year medical students (Chapter 2) provided valuable information in regards to what components to include within the app. The ability of students to learn the anatomy through multiple mediums may explain the unanimous response of not removing any of the current components in future versions.

As this was a first version of a novel mobile app, there are components that can be improved, as well as new components that can be added. The expansion of the anatomy content, creation of more animations/videos, and inclusion of more clinical correlations
were the most frequently listed components to improve. Including a self-assessment or quiz feature, increasing the depth, and expanding to include all anatomy content, as well as including more clinically correlated examples, were the most common new features requested. As indicated by the components to improve, new features to include, and the response to the fifth question in the group interviews, students want the *Anatomy* mobile app to be expanded to include all anatomy relevant material for each learning block.

The results from this study provide insight into what components are desired and how to make mobile resources as attractive as possible for medical students. Furthermore based on the information gathered from second year medical students, the data collected in the TAM, and the responses in the final group interview sessions, students enrolled within medical schools that have an integrated curriculum want resources that effectively and efficiently supplement the material through an integrated approach.
Chapter 6: Conclusions and Future Recommendations

The current landscape of medical curricula in the United States is one of continual change and adaptation. The amount of contact hours for the anatomical sub-disciplines in medical schools, albeit low, has begun to level off from the results of the previous survey conducted by Drake et al. (2009), with the largest decrease in anatomy contact hours occurring between 1955-2009. Throughout the past two decades, medical curricula has begun to incorporate different educational programs in order to address the diverse learning styles of students, as well as incorporating competencies such as teamwork, leadership, and professionalism into their courses (Gregory, Lachman, Camp, Chen & Pawlina, 2009; Macpherson and Kenny, 2008; Youdas, Krause, Hellyer, Rindflesch & Hollman, 2013). Drake (2014) effectively summarized the current goals in medical curricula:

Some of the current reasons for making (curricular) changes, whether stated or unstated, are to reduce lecture hours, moving away from a teacher-centered approach towards a more student-centered approach, increase the time available for self-directed learning, reduce unnecessary redundancy between courses, provide less compartmentalized teaching and testing to promote topic integration.

The general trend that is being followed as medical schools make significant
curricular changes has been to move from an educational program consisting of discipline-based courses to an integrated curriculum or a mixed curriculum. (p. 258)

The results from the group interviews conducted with second year medical students indicates that medical students are highly comfortable with utilizing mobile technology in the process of their studying. This was evident by the large number and variety of mobile apps downloaded by the medical students throughout their first year of school. Gross anatomy is the anatomical sub-discipline in which medical students search for, download, and use the most of all the mobile apps. Mobile apps that utilized three-dimensional (3D) modeling and detailed text descriptions were determined to be the most highly sought-after of all educational mobile resources for learning anatomy. Due to the integrated curriculum for The Ohio State University College of Medicine (OSU-COM), 98.3% of the participating second year medical students (n = 59) indicated their interest in using an integrated anatomical mobile app created specifically for the curriculum. Second year medical students that participated in the group interviews indicated that it was their responsibility to integrate all curricular content taught by each discipline throughout an associated learning block prior to the comprehensive final examination. As there was no resource currently available that integrated any content within an integrated medical curriculum, this led to the development of a novel anatomical mobile app based on the spinal cord that integrates the four anatomy sub-disciplines (i.e., gross anatomy, histology, embryology, and neuroanatomy) into a single mobile resource.
The development of the *Anatomy* mobile app reflected the results from the second year medical student focus group sessions. This was the first mobile app to integrate the four anatomical sub-disciplines (i.e., gross anatomy, histology, embryology, and neuroanatomy) into a single resource. The app focused on the spinal cord and included features such as 3D model spinal cord slices within spinal tract animations, high-resolution images, cadaver prosection video demonstrations, and detailed text descriptions within each sub-discipline. Through collaborations with the computer science and engineering (CSE) department and the Advanced Computing Center for the Arts and Design (ACCAD) Department, this novel mobile app was made available to download for all first year medical students at The OSU-COM. The cost of mobile apps can vary widely based on the size of the app, what features are built within the app and the amount of server space that may be needed for storage. The estimated cost of an iOS app built by a small firm is anywhere between $50,000-150,000 or more (Yarmosh, 2015). This estimated cost does not take into account the cost of hiring content creators that can develop animations, 3D models and edit videos. The high cost can be a deterrent for many medical school administrators from pursuing the development of mobile resources. The development of the *Anatomy* mobile app was completed at a low overall cost (approximately $2,500) due to the collaborations between the project lead, the CSE department and the ACCAD department at The Ohio State University. These collaborations do not only serve the Anatomy departments for whom the mobile resource is developed, but provides CSE students with valuable experience in developing software in the iOS environment, which is the most popular mobile operating system. ACCAD
students also benefit from these collaborations by expanding their portfolio and gaining experience with creating assets for clients.

The results of the survey following the Neurological Disorders Learning Block provided evidence supporting the acceptance and behavioral intention of medical students towards the use of the 4natomy mobile app. The Technology Acceptance Model (TAM) was utilized in this study because of the validation and use of this model in previous studies [e.g., Davis (1989), Lee et al., (2005), and Liu et al., (2010)] in which new information technology (IT) and information systems (IS) programs are being implemented in private and public sectors. The TAM utilized in this study indicates that if first year medical students believe that they are personally innovative and that a mobile resource is useful and easy to use, then these students have a strong determinant towards the intention to use that resource. Following the results of the 4natomy mobile app testing through the TAM, medical students at a medical school that distributes mobile devices and utilizes an integrated curriculum accepted a novel mobile app that integrates the four anatomical sub-disciplines (i.e., gross anatomy, histology, embryology, and neuroanatomy). The responses to survey questions related to behavioral intention to using the mobile app had a significant relationship with actual usage of the app. While the results of the hypothesized relationship between user acceptance of the 4natomy mobile app and the anatomy scores was not statistically significant, future studies should be conducted utilizing more questions and controlling for student ability by including medical college admissions test (MCAT) scores in the analysis. While the results from this study are limited to acceptance of an integrated anatomy mobile app by first year
medical students in an integrated curriculum at the OSU-COM, this research study does expand the scope of mobile educational literature. This is the first study to utilize the TAM for an anatomical mobile app, as well as the first to utilize the TAM within a medical curriculum.

The responses from first year medical students in the final group interview sessions provided insight into future development of integrated anatomical mobile resources. The students emphasized the importance of expanding the anatomy content to cover more of the learning block, implementing more clinical case correlations into each sub-discipline (i.e., gross anatomy, histology, embryology, and neuroanatomy), and creating more animations/videos. Students would also like to see a self-assessment quizzing feature built into future versions of the app. Finally, the majority of the students want this integrated anatomical mobile app to include all anatomy related content within the Neurological Disorders Learning Block and to expand to other learning blocks within the OSU-COM curriculum.

The purpose of this study was to identify an educational resource that had a high demand by medical students and to develop a mobile resource (i.e., 4natomy) through collaborations with computer science and digital design students. After development to then test the viability and usability of the mobile app through a validated research model and collect feedback from the medical students that utilized the app in order to improve future versions of the resource. Utilizing the TAM in this study provided quantitative data on student perception’s towards and the actual usage of an educational mobile resource. The information gathered by the TAM in this study establishes a research framework to
assess the acceptance and usage of future educational resources by students within higher education, particularly medical school. There are few current studies that have investigated mobile device usage and no current studies investigating the acceptance and perception of mobile resources by first and second year medical students. The data gathered from this study illustrates the current landscape of mobile technology used by medical students within an integrated medical curriculum and what resources they prefer to use on those devices. The results from this study provide valuable data for the continued development of mobile educational resources, specifically within integrated medical curricula.

Limitations of this entire study must be addressed in an attempt to avoid them in future research. The group interview sessions with the second year medical students (Chapter 2) and the first year medical students (Chapter 5) have a limitation of small sample sizes. The small sample sizes limit the comparison of the responses to other medical students. Both group interview sessions were led by the project lead of this study, who serves as a teaching assistant for medical students. This relationship between the students and the instructor could have led to a potential bias in regards to the responses from the students. To avoid this bias in the future, group interviews should be led by a neutral party not directly involved in teaching the medical students. The results of the TAM from this study are limited to acceptance of an integrated anatomy mobile app by first year medical students in an integrated curriculum at The OSU-COM. Future studies should assess a mobile resource at multiple medical schools that utilize integrated curricula to determine if similar levels of acceptance occur.
The continued development of educational resources that allow medical students to learn anytime or anywhere will provide educators the potential opportunity to make a more meaningful and complete learning experience. As mobile technology continues to improve, medical students will search for and will expect to find more interactive and integrated resources. The creation of mobile educational resources by individuals directly involved in administering the medical curriculum provides consistency and relevance that is appreciated by students. Through the development of efficient and effective mobile resources, medical educators will be able to expand the amount of relevant content students can learn while maintaining the current amount of contact time. Prior to this study, no educational resource existed that integrated any discipline within a medical curriculum, forcing students to integrate the content themselves. This void led to the development of the Anatomy mobile app. While the app developed for the current study only focused on a small aspect of a larger learning block, the results indicate that students found the app to be useful and easy to use. The user feedback gathered from first year medical students that used the app provides support to expand the development of the app to include more anatomy content within a single learning block.

It is recommended that future studies expand the integrated anatomy resources to include all anatomy related content within other learning blocks. Future studies should assess acceptance and usage of an integrated anatomy app at multiple medical schools that also utilize an integrated systems based curriculum in place. Future studies should also identify students of various academic levels based on MCAT scores and previous anatomy block exam scores (if applicable based on an integrated curriculum).
determining the various academic levels of students prior to distribution of the mobile resource, the researcher can assess if the resource is benefiting, hindering or providing a neutral effect to students of various academic levels. Future studies should assess acceptance of the integrated anatomy mobile app in other higher educational fields, such as dental schools or other disciplines, in which integrated resources are relevant. Future studies should also assess how medical students in their third year or beyond accept this technology while in their clinical rotations or residencies. Implementation of a social media component to mobile resources, such as an intra-medical student network that allows students to collaborate and share features of the app seamlessly, should be assessed in future development. Also, mobile anatomy resources should be developed to run on other mobile operating systems such as Android and Windows, as well as other mobile devices including smartphones. It is also recommended to test new educational resource prototypes through the TAM prior to the commitment of large departmental resources on the full development, testing, and implementation.
References


166


Tews, M., Brennan, K., Begaz, T., & Treat, R. (2011). Medical student case presentation performance and perception when using mobile learning technology in the emergency department. *Medical Education Online, 16*, 1–7. doi:10.3402/meo.v16i0.7327


Appendix A: Second Year Medical Student Focus Group Questions

1. What portable electronic devices do you own?

2. On a scale of 1-10 (1 = very uncomfortable, 10 = very comfortable) how comfortable are you using portable electronic devices?

3. What portable electronic devices do you use to study?

4. What apps have you downloaded on your portable electronic device(s) to use as study aids?

5. Which if any anatomy sub-disciplines (Gross anatomy, Histology, Embryology or Neuroanatomy) have you downloaded apps specifically for?

6. What components of the apps downloaded for studying are most beneficial to you? (Text, 3-D models, video, audio, etc.)

7. Would you use an anatomy app that integrates the four sub-disciplines specifically designed for the medical curriculum?
Appendix B: Mobile Apps Downloaded by Second Year Medical Students at the OSU-COM

Adobe Reader
Anki Mobile Flashcards
Articulate Mobile Player
ASCVD Risk Estimator
Box
Brain and Nervous System Pro
DrawMD
Dropbox
ECG Cases
Epocrates
Essential Anatomy
Evernote
Firecracker
Go Anatomy
GoodNotes
GoodReader
Google Drive
Heart Murmur Pro
iBooks
iMuscle 2
Instant ECG (An Electrocardiogram Rhythms Interpretation Guide)
iTunes U
Kindle
Medscape
Micromedex Drug Interactions
Micromedex Drug Reference Essentials
Micromedex IV Compatibility
Netter’s Atlas
Notability
Appendix C: App Feature Combinations Listed by Second Year Medical Students

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<th>Combinations</th>
<th>Frequency</th>
<th>Percent</th>
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<td>3D Models</td>
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<td>27.1</td>
</tr>
<tr>
<td>Text &amp; 3D Models</td>
<td>14</td>
<td>23.7</td>
</tr>
<tr>
<td>Text &amp; Images</td>
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<td>10.2</td>
</tr>
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<td>Text</td>
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</tr>
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<td>3D &amp; Video</td>
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<td>5.1</td>
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</tr>
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<td>3D Models &amp; Audio</td>
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<td>5.1</td>
</tr>
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<td>Text, 3D Models, Video &amp; Audio</td>
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<td>1.7</td>
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<tr>
<td>Text, 3D &amp; Video</td>
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<td>Text, 3D &amp; Images</td>
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<td>3D &amp; Images</td>
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</tr>
<tr>
<td>Total</td>
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<td>100</td>
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</tbody>
</table>
Appendix D: Survey Instrument with Questions from the Technology Acceptance Model

1  2  3  4  5  6  7

Strongly                     Neutral                     Strongly
Disagree                     Agree

Near-Term Usefulness

1. I think using the mobile app can increase the efficiency of my studies and work within the corresponding learning block.
2. The mobile app was useful for my studies of the spinal cord.
3. I think using the mobile app can increase the effectiveness of my anatomy related studies.
4. I believe the content of the mobile app is informative.
5. The advantages of the mobile app outweigh the disadvantages.
6. Overall, I believe using the mobile app would be advantageous.

Long-Term Usefulness

1. Use of the mobile app would benefit me in future board examination questions based on the spinal cord.
2. Use of the mobile app increases my understanding of the spinal cord.
3. Use of the mobile app would improve my future retention of spinal cord anatomy.

Perceived Ease of Use

1. I think using the mobile app is easy.
2. My interaction with the mobile app is clear and understandable.
3. I find it easy to get the mobile app to do what I want it to do.
4. Interacting with the system does not require a lot of mental effort.
5. It is easy to become skillful at using the mobile app.

Perceived Enjoyment

1. I find using the mobile app to be enjoyable.
2. The think the mobile app was interesting.

Personal Innovativeness

1. I like to experiment with new technology.
2. If I hear about new technology, I look for ways to experiment with it.
3. Among my peers, I see myself as an early adopter of new technology.

Behavioral Intention

1. I would recommend others to use the mobile app.
2. I believe that when relevant, I would use the mobile app to assist in my future learning.
3. I would use a similar mobile app for other learning blocks.

Actual Usage

1. How many times did you use the 4natomy app?
   - 1
   - 1-3
   - 3-5
   - >5
Appendix E: First Year Medical Student Focus Group Questions

1. Did the app function as you originally expected it to?

2. What component(s) of the app if any, would you like to see removed in future editions of the app?

3. What component(s) of the app if any, would you like to see improved upon in future editions of the app?

4. What features would you like to see included in future editions of the app that are not in the current edition?

5. In your opinion, should the development of this app be increased in order to cover all anatomy relevant material for each learning block?

6. Other Comments?
Appendix F: Final Group Interview Responses

1. Did the app function as you originally expected it to?
   1. Yes
   2. “It did. I wanted an app that showed me zoomed in, and it did.”
   3. “It functioned well, just because it’s a first run I expected maybe a little more content.”
   4. “It was a little slow to start and not very “new” appearing.”
   5. Yes
   6. “Yes, it was much more detailed and comprehensive than I was expecting it to be.”
   7. Yes
   8. “N/A, I did not have any expectations before I had the app.”
   9. “For the most part yes. I expected more options to click on things to get more information in various formats such as a picture of embryology→what it forms.”
   10. “Yes, but I would’ve like to do less clicking (this may not be able to be fixed though).”
   11. “Yes, I would say so! I did not know what to think at first though. I did not think it would be as inclusive and all encompassing as it is! Love that aspect.”
   12. “Yes it did! In fact it far surpassed my expectations.”
   13. Yes!
   14. “Yes very nice app!”
   15. Yes
   16. “Yes, it was helpful for learning the spinal cord tracts, and the connections between histology, embryology and gross anatomy were helpful.”
   17. “Yes. Maybe was expecting more like essential anatomy.”
   18. “Yes, especially the 3D renderings and the structures.”
   19. Yes
   20. “Yes, intuitive as a whole.”
2. **What component(s) of the app if any, would you like to see removed in future editions of the app?**

1. “Nothing removed. But if it comes to needing to focus on certain areas I think you could do away with the histology component—gross is vital!”
2. None
3. None
4. None
5. “None!”
6. None
7. None
8. None
9. None
10. None
11. None
12. None
13. “Nothing that I can think of.”
14. Nothing
15. None
16. None
17. None
18. None
19. None
20. “None! It would actually be great if you added more features on! (I don’t know if it might be possible to add in pharm/pathology or other aspects that are affecting anatomy).”

3. **What component(s) of the app if any, would you like to see improved upon in future editions of the app?**

1. None
2. “Maybe the interface could be polished to look better.”
3. “Guidelines on what app has to offer. Quiz component where we can test what we learned.”
4. “Embryology seems to be the most complicated part of anatomy, so any other way to increase this material (animations, timeline of development) would be very helpful.”
5. None
6. “Some of the information still needs to be filled in.”
7. Layout
8. “Would love to see it incorporate more animations in more systems.”
9. “Add text to videos so you have auditory and visual learning. Expand embryology—there are great YouTube videos just the link even would be sufficient.”
10. “Colors/highlighting of structures can be improved to be clearer and/or look more similar to cadavers.”
11. “Less clicking to find each part (like histology). Make selections more user friendly/simple.”
12. “I would like to see the tracts have the words, 1st order, 2nd order, etc. added to the audio during the explanations.”
13. None
14. “Move the index button so it’s visible in the main neuroanatomy screen”
15. None!
16. “I would really like more clinical aspects incorporated – more examples.”
17. None
18. “The more interactive the components, the better—e.g. navigating easily among gross anatomy, imaging, histology, text, etc really helps to reinforce the concepts.”
19. “Include a function to allow zooming in on embedded images with gestures. Closed captioning for the tracts video. Ensure that screen orientation does not affect final viewing.”
20. “More clinical correlations.”

4. What features would you like to see included in future editions of the app that are not in the current edition?

1. “Sometimes viewing the app in other orientations limited the views in one orientation.”
2. “Would love to see more questions added to test my knowledge.”
3. “More content”
4. “An app for all of anatomy like this!”
5. “Maybe a quiz type feature that includes images/diagrams that need to be labeled to test student’s knowledge/help them review.”
6. “Quizzes, practice questions (ways to test knowledge) would be a great addition.”
7. “A video representation of embryogenesis could be nice.”
8. “Just expanded content.” “If you wanted you could add common pathology, but I don’t think it would be crucial.”
9. “Voice component to make the app more interactive and possibly a quiz feature. 3D rotation would be awesome as well.”

183
10. “Overlayed images of neuroanatomy and histology with the opportunity to highlight different tracts or apply different filters.”
11. “More detail to the tracts that they focus on with the step 1 exam could be a huge hit as well. I think that would be STT (Spinal Trigeminal Tract), CST (Corticospinal Tract) & Dorsal (Spinocerebellar) Tract.”
12. “Perhaps some common pathology/disease states that occur.
14. “More clinical correlations maybe, so it can more of a one-stop show for anatomy.”
15. “I would really like more blocks incorporated like MSK, cardio, endo, etc.”
16. N/A
17. “3D Navigation”
18. “More correlations to 2nd/3rd level questions, as commonly tested on practical exams.”
19. “Quiz function. Add video animations for embryology. Add slider bar for discrete time period?”
20. “If possible, describe the function of tracts in the videos. Could you put real gross anatomy pictures in addition to the computer generated images?”

5. In your opinion, should the development of this app be increased in order to cover all anatomy relevant material for each learning block?
   1. “Absolutely. Doing so would be extremely helpful.”
   2. Yes!
   3. Yes!
   4. Yes!
   5. “yes, I think seeing connections among gross anatomy and histology and the pictures were helpful.”
   6. Yes!
   7. “The videos of the tracts were very helpful. I think a similar concept following nerve/blood vessel paths could be very helpful [in future blocks].”
   8. “As long as it is done in a manner that is useful and time effective yes. For other anatomy [blocks] include imaging such as CT, MRI, PET and ultrasound in gross anatomy as well.”
9. “I would say yes only if it were organized in such a way that everything was easy to find with the increased volume of material.”

10. “Yes! I think an app like this for musculoskeletal medicine will be a huge hit! Additionally I can see this app being used for cardio and especially to help teach sympathetics and parasympathetics.”

11. “Yes, it would definitely be a good resource to have each block anatomy all in the same app. Especially helpful for the connections made between different units.”

12. Yes

13. Yes!

14. “Yes! It would be really helpful.”

15. Yes

16. Yes!

17. Yes

18. “Definitely!! This app was incredibly helpful as a medical student with the volume of info being given to us it was extremely helpful to have embryo, histo, neuro all tied together in one app. It was a tremendous help to me and thank you for putting it together for us!! Looking forward to seeing its development moving forward.”

19. Yes

20. No response on this question.

6. Other comments?

1. “Loved the app! Very useful when studying for the final and lab exam!”

2. “It was a great supplement and I think it could be expanded to be a serious teaching guide.”

3. “I really appreciated the embryo—we don’t go over that as frequently and the histology was very helpful.”

4. “It helped me visualize the 3D orientation better. I used this app for the spinal tract to see where each tract crossed and its spatial arrangement.”

5. “Thanks for everything Derek.”

6. “I think the app was great overall with lots of potential benefits for students to learn anatomy in more comprehensive manner.”

7. No comments

8. “The app was really helpful for reviewing multiple parts of the block. The definitions and explanations were clear and concise. A very good way to synthesize the material—Thanks!”

9. “Great job in putting this together. Consider integrating the information from pathoma in terms of pathology to make it clinically relevant.”
10. “I think adding sound/voice and 3D rotations would make this app go very far.”
11. No comments
12. No comments
13. “Would be interested to see how the app could be integrated into the classroom portion- I think this is a potential opportunity.”
14. None
15. None
16. “Just make sure all of the buttons link to what they’re supposed to. I remember clicking on text and being taken somewhere that didn’t make sense.”
17. “Loved the preview dissection videos in MSK, would be great to have that atlas and these videos accessible through the app.”
18. “Amazing work on developing an app for your dissertation. Congrats on graduating, thanks for everything!”
19. “Good luck! Thank you for all of your help!”
20. No comments
Appendix G: IRB Research Approval

Behavioral and Social Sciences Institutional Review Board

July 2, 2014

Protocol Number:  2014B0202
Protocol Title: USER ACCEPTANCE OF A NOVEL ANATOMICAL SCIENCES MOBILE APP FOR MEDICAL EDUCATION—AN EXTENSION OF THE TECHNOLOGY ACCEPTANCE MODEL, John Hile, Jennifer Barguny, Derek Shuman, Humed Informatics
Type of Review: Initial Review—Expanded
IRB Staff Contact: Jacob R. Sudduth
Phone: 614-292-0526
Email: jrs6@osu.edu

Dear Dr. Bolt,

The Behavioral and Social Sciences IRB APPROVED BY EXPEDITED REVIEW the above referenced research. The Board was able to provide expedited approval under 45 CFR 46.110(b)(1) because the research meets the applicability criteria and one or more categories of research eligible for expedited review, as indicated below.

Date of IRB Approval:  July 2, 2014
Date of IRB Approval Expiration:  July 2, 2015
Expedited Review Category:  6, 7

If applicable, informed consent and HIPAA research authorization must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. The IRB-approved consent form and process must be used. Changes in the research (e.g., recruitment procedures, advertisements, enrollment numbers, etc.) or informed consent process must be approved by the IRB before they are implemented (except where necessary to eliminate apparent immediate hazards to subjects).

This approval is valid for one year from the date of IRB review when approval is granted or modifications are required. The approval will no longer be in effect on the date listed above as the IRB expiration date. A Continuing Review application must be approved within this interval to avoid expiration of IRB approval and cessation of all research activities. A final report must be provided to the IRB and all records relating to the research (including signed consent forms) must be retained and available for audit for at least 3 years after the research has ended.

It is the responsibility of all investigators and research staff to promptly report to the IRB any serious, unexpected and related adverse events and potential unanticipated problems involving risks to subjects or others.

This approval is issued under The Ohio State University’s OHIRB Federalwide Assurance #00005378. All forms and procedures can be found on the OHIRB website: www.ohirb.osu.edu. Please feel free to contact the IRB staff contact listed above with any questions or concerns.

Michael Edwards, PhD, Chair
Behavioral and Social Sciences Institutional Review Board

Os-07-06 Exp Approval New CR
Version 05/18/10