Building a Medical App: Approach, Infrastructure, and Challenges of Developing a Congenital Heart Defects App for Educational Purposes

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Abstract

Mobile software application (apps) have exploded in popularity since 2008, when Apple’s App Store opened and have become increasingly present in medical education and medical practice. As evidence of educators realizing the potential apps have for educating students, the University of Arizona has created a department called the Office of Instruction and Assessment (OIA), which has a programming team that is committed to assisting faculty in the design, development and implementation of apps for University of Arizona Students. Congenital heart defects are the most common type of birth defect in the United States, affecting nearly 1% of, or about 40,000, births per year. There are complex three-dimensional relationships involved in many of the congenital heart defects that may be difficult for students to fully understand through the traditional method of reading and looking at two-dimensional diagrams. The principle goal of this project was to participate in the design and development of an educational mobile app that allows the user to interactively rotate digital 3D models of hearts with congenital heart defects. Multiple approaches to developing an educational medical app were explored including utilizing basic app-building programs that do not require computer coding or programming, paying a for-profit company to develop an app, and collaborating with a larger educational institution that has the resources available for developing an app and has a potential use for the app. This thesis aims to describe the resources available to develop an educational app, the major factors that determine the best approach for app development and the challenges associated with each approach. Through the case example of developing “Heart Defects” with the Office of Instruction and Assessment at the University of Arizona and publishing the app on the Apple App Store it was determined that the major factors guiding the approach to app development are complexity of the app, computer programming experience of the individual planning to develop an app, and having access to a larger institution with the ability to develop apps and the institution having a perceived benefit from developing the app.
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Introduction

Background

There is no doubt that mobile software applications (apps) have exploded in popularity since July 10, 2008 when Apple’s App Store for iOS opened. As of June 8, 2015 there have been 1.4 million apps published and over 100 billion app downloads from the Apple App store. These apps have penetrated almost every realm of human culture including medical education and medical practice. As of July 2013 Apple App Store listed 20,000 medical apps.

There is widespread belief in the medical community that mobile apps have the potential to expand clinical practice. In an article entitled “Mobile Applications in Dermatology” published in JAMA Dermatology in November 2013 it was noted that “the widespread variety and popularity of mobile apps demonstrate a great potential to expand the practice and delivery of dermatologic care” 2. Not surprisingly, mobile apps have also become increasingly relevant in medical education. In an article published in Clinical Anatomy in April 2014 entitled “complementing anatomy education using three-dimensional anatomy mobile software applications on tablet computers” it was noted that “3D anatomy applications serve as a useful learning tool when used in conjunction with existing teaching setups” 3. Medical schools are recognizing the potential of medical apps and in fact some schools such as the University of Arizona College of Medicine – Tucson provide iPads to incoming medical students. As evidence of educators realizing the potential apps have for educating students, the University of Arizona has created a department called the Office of Instruction and Assessment (OIA), which has a programming team that is committed to assisting faculty in the design, development and implementation of apps for University of Arizona Students.

Aims/goals/hypotheses

The principle goal of this project was to participate in the design and development of an educational mobile app that allows the user to interactively rotate digital 3D models of hearts with congenital heart defects. The intention was for the app
to be used as an educational tool for medical students studying congenital heart defects during the first year of medical school at the University of Arizona College of Medicine – Phoenix.

Also, part of this project included the goal to describe the resources that are available and the basic approaches of creating a medical app. Notably, the landscape of developing a medical app will be explored as it relates to multiple entities such as for-profit app-developing companies, free online app-building websites, educational institutions, and individual computer programmers.

Another goal of the project was to examine the proportion of medical apps that are associated with a named healthcare professional or institution and whether this has an impact on the popularity of the app or the users perception of the credibility of the app’s content.

It was predicted that the app could become a useful resource that students will use while learning about CHDs in the first year of medical school at the University of Arizona College of Medicine – Phoenix and potentially at other medical schools as well. It was also predicted that resident physicians, cardiologists, and families affected by congenital heart disease might use the app.

**Significance**

In this thesis we explore the approaches, infrastructure and challenges of building a medical app and use an app designed by the authors as a framework example. The app designed as part of this project is an educational app that allows the user to interactively rotate digital 3D models of hearts with congenital heart defects. The app was developed with the intention of using it as an educational tool that first year medical students can utilize while studying congenital heart defects during the Cardio-Pulmonary-Renal component of the curriculum at the University of Arizona College of Medicine – Phoenix.

An important question is why was the subject of congenital heart defects chosen for the content of an educational app. Many factors make congenital heart defects an
ideal subject to be included in an educational app. The Centers for Disease Control and Prevention (CDC) reports that “congenital heart defects are the most common type of birth defect in the United States” and estimates that they affect nearly 1% of, or about 40,000, births per year. The most common type of congenital heart defect is ventricular septal defect. The incidence of severe congenital heart defects that require expert cardiologic care is around 2.5 to 3 per 1000 live births. Considering the CDC report stating that the prevalence of some mild types of congenital hearts defects has been increasing, it is clear that congenital heart defects will continue to be an important issue affecting our society. Hospital costs associated with congenital heart defects in the United States in 2004 were estimated at $1.4 billion. A study in 2000 estimated there to be 850,000 adults living with a congenital heart defect and another study estimated that 20% to 30% of people with a congenital heart defect have a coexisting illness or disability. All of these studies help to stress the importance of individuals in the healthcare field needing to have an understanding of congenital heart defects.

Also, there are complex three-dimensional relationships involved in many of the congenital heart defects that are difficult for students to fully grasp through the traditional method of reading and looking at two-dimensional diagrams. Through my mentor, Dr. Randy Richardson, there were available 3D digital models of hearts with congenital heart defects that were created from CT scans from actual patients. These digital models were believed to possess high educational value because they have a color-coded scheme in which the major chambers of the heart and vessels are each represented with a particular color. This makes it easy for the viewer to understand the anatomy of the heart in a 3D model and be able to understand the variations of anatomy in models with a particular congenital heart defect. These models are fully rotatable and allow the user to interact with the model in a dynamic way, being able to explore all the connections of the heart and trace the flow of blood through all the structures. Congenital heart defects is an important subject that is both clinically relevant and highly tested on medical exams such as the United States Medical Licensing Exam (USMLE).
**Materials and Methods:**

This project began with the idea of creating an educational app on congenital heart defects (CHDs) using existing 3D digital heart models but with very little to no plan for the approach that would be used to develop the app. This created a situation in which multiple approaches to developing a medical app would need to be explored. It should be noted that the exploration of the potential approaches of developing a medical app was attempted by Alex Stoker, a first year medical student at the University of Arizona College of Medicine – Phoenix at the start of the project.

Before beginning the process of developing a congenital heart defects app I met with Randy Richardson, who is a radiologist at St. Joseph’s Hospital and medical Center in Phoenix, AZ. Dr. Richardson had created a series of digital 3D heart models from CT scans of actual patients with congenital heart defects, and therefore show real variation in human anatomy. It should be noted that these models use a color-coordinated scheme to show the different structures of the heart. The models represent the space within the heart and its vessels rather than representing the heart muscle itself. This allows for visualization of where connections are within the heart and where blood can flow. It was the belief of Dr. Richardson and I that these models possessed great educational potential and would be ideal to use in an educational app.

The first approach taken to develop a congenital heart defects app was to use online programs that allow someone to create an app without needing to perform any computer programming or requiring knowledge of computer science. These types of programs allow someone to create an app by offering a series of boxes that the user can put text into and organize a navigation system between the series of boxes. It was quickly realized however that these types of programs do not allow one to create apps with complex features such as displaying a 3D heart models while allowing the user to rotate the model. Due to the limiting features of these types of app-creating programs it was determined that this approach would not allow for our concept of a congenital heart defect app to be created. This phase of the project lasted from January 2013 to February 2013.
After it was determined that the app I aimed to develop was relatively complex and would not be feasible to independently develop, I turned to the next approach. This approach was to pay a for-profit company with experience creating apps to develop the app. This approach entails coming up with a rough blueprint of the app including the number of pages that can be navigated to and all the features to be included in the app. This information is then presented to the company so that they can give an estimate for what the app will cost. I researched several companies and decided that Vuria Creative Technologies was the company that would be able to adequately develop the app at the cheapest price. They quoted a price of $10,000. Since this project was being conducted to fulfill the requirement of the Scholarly Project component of the curriculum at the University of Arizona College of Medicine – Phoenix and I was not given any significant source of funding I realized I was not able to pay the fees of a private company to develop the app and would have to pursue alternative means of developing the app. This phase of the project lasted from February 2013-March 2013.

After realizing that I did not possess the technical skills to develop a complex app on my own and did not have the appropriate funding to have the app professionally developed I realized that I would need a larger institution with a potential use for an educational congenital heart defects app to take an interest in the project. This is when I discovered the Office of Instruction and Assessment (OIA), which is an entity within the University of Arizona and is designed to serve the role of creating technologies to aide in teaching University of Arizona students. The OIA has experience creating online Independent Learning Modules (ILMs) and apps, mainly for University of Arizona professors. After learning that the OIA had developed apps before including one that was used by medical students at the University of Arizona College of Medicine- Tucson during their anatomy course, I knew there could be potential interest in developing a congenital heart defects app. I began by contacting Michael Griffith in March 2013, who at the time was the associate director of biomedical communications at the University of Arizona. I then attended the Mobile Matters Symposium at the University of Arizona on March 29th, 2013, where I learned about past projects and apps developed by the
Office of Instruction and Assessment as well as discussed the idea for the congenital heart defects app with several individuals in the department. I then began the formal proposal for the development of the app by writing up the goals of the project as well as a description of the concept of the app along with the digital heart models which were saved in “.mov” format. The project was presented to the approving committee at the Office of Instruction and Assessment in April 2014 and was approved as it met the conditions of being developed with the intention of benefiting University of Arizona medical students and was being developed under my mentor, Dr. Randy Richardson, who holds the position of being a University of Arizona Instructor.

I then met with Michael Griffith in June of 2013 to discuss the overall aim of the project, brainstorm the conceptual model of the app, discuss ways to maximize the educational value in the app, and begin designing the layout of the app. From June 2013 to July 2013 I wrote the script for the app and designed the layout. This involved choosing the appropriate digital 3D models to represent the congenital heart defects to be included in the app. The congenital heart defects chosen to be included in the app were ventricular septal defect (VSD), atrial septal defect (ASD), total anomalous pulmonary venous return, coarctation of the aorta, patent ductus arteriosus (PDA), pulmonary stenosis, Tetralogy of Fallot, transposition of the great arteries, truncus arteriosus, and hypoplastic left heart syndrome. For each of these conditions, a “chapter” was designated in the app and in each of these chapters three sections were written. For example in the tetralogy of Fallot chapter, there is an “explore” section where the user can freely rotate a 3D digital heart model that was constructed from an actual CT scan of a patient with tetralogy of Fallot and read a description of the condition. There is also a “review” section where the user can see a list of the key facts associated with tetralogy of Fallot in a bullet point format. Lastly, there is a “test” section, where the user can read a multiple-choice question and then can click a button to reveal the correct answer and a description. There is also an “orientation” chapter where the user can look at a model of a normal heart to become familiar with the color scheme used to represent the structures of the heart and to review fetal heart
circulation, which is an important concept related to congenital heart defects. Alex Stoker wrote and organized all of the text with the digital heart models from June 2013 to July 2013, essentially creating a “blueprint” of the app and then presented that to Michael Griffith and Timmy Garrabrant, a programmer working for the Office of Instruction and Assessment, in July 2013.

In the fall of 2013 an early demo-version of the app was completed and made available to view on a webpage. After the app was viewable on a webpage I began getting feedback from content experts, namely Dr. Brigham Willis, MD who is a pediatric cardiovascular ICU physician and Dr. Randy Richardson, MD who is a pediatric radiologist. I received feedback from Dr. Willis and Dr. Richardson and sent edits to Timmy Garrabrant in the Fall of 2013 to update the app posted on the webpage (chd.biocom.arizona.edu).

Then in January 2014 I presented the app to Dr. Elaine Niggemann, who is the Director of the Hematology/Cardiovascular & Pulmonology/Renal/Acid-Base Block at the University of Arizona College of Medicine – Phoenix, which is the component of the curriculum in which medical students learn about congenital heart defects. Dr. Niggemann was very interested in the app and using it as a tool that first year medical students can utilize as they are learning about congenital heart defects. I then presented the app to the Class of 2017 at the University of Arizona College of Medicine – Phoenix in their lecture hall a few days before their formal lecture on congenital heart defects in January 2013 so that they were able to access the online webpage version of the app and utilize its features as they studied CHDs. I received feedback from first year medical students who had used the app and continued to make edits in the spring and summer of 2014. After correcting typos and making some small edits to the online version of the app we began the process of making the app available on the Apple App Store. This portion of the project was conducted by Timmy Garrabrant who submitted the app to Apple. The app was approved by Apple and made available for free on the Apple App Store in October 2014 under the name “Heart Defects” with a copyright by the University of Arizona.
Results:

The outcome of this project is a fully functioning congenital heart defects educational app published on the Apple App Store. The app is called “Heart Defects” and can be found by searching “Heart Defects” on the Apple App Store. The app contains chapters on ventricular septal defect (VSD), atrial septal defect (ASD), total anomalous pulmonary venous return, coarctation of the aorta, patent ductus arteriosus (PDA), pulmonary stenosis, Tetralogy of Fallot, transposition of the great arteries, truncus arteriosus, and hypoplastic left heart syndrome. Each of these chapters has an interactive fully rotatable 3D model, which shows the corresponding congenital heart defect and real variation in human anatomy. An image of one of these models is shown in figure 1. One exception to this is the chapter on atrial septal defects, which actually uses two-dimensional CT images rather than 3D models to convey the anatomy involved. This is because the thin nature of the interatrial septum is not easily visualized in the models and is more appropriately visualized in 2D images.

In each of these chapters the user can read about the condition while rotating a 3D model with the touch of a finger and can explore the various connections within the heart and trace the flow of blood. All of the models are paired with a model of a normal heart so that when the user rotates a model with a congenital heart defect a normal heart will be displayed immediately adjacent and will rotate to maintain the same orientation between the normal heart model and the model with a congenital heart defect. This allows the user to more easily visualize the defect and see how it differs from the normal heart anatomy. An example of the “explore” section showing two paired heart models is shown in figure 2. Each of these chapters also has a “review” section where the user can see a list of all the major learning points relevant to that particular CHD in a bullet point format. An example of the review section is shown in figure 3. Each chapter also has a “test” section where the user can read a multiple-choice question and click on a button to reveal the correct answer and an explanation. An example of the “test” section is shown in figure 4. The user can easily navigate
between these three sections in each chapter by clicking on “explore”, “review” or “test” at the top of the screen.

Also available within the app is an orientation chapter, which allows the user to become familiar with the color scheme used in the app and look at a model of a normal heart. The models all show the superior vena cava, inferior vena cava and right atrium in teal, right ventricle in light purple, the pulmonary trunk and pulmonary arteries in dark blue, the pulmonary veins and left atrium in bright pink, the left ventricle in light pink (salmon colored), the aorta and major branches on the aortic arch in bright red, coronary arteries in tan, and surgical shunts shown in bright green. The orientation also reviews normal fetal cardiovascular circulation, which is an important concept relating to congenital heart defects. There is also a chapter that shows five different un-labeled models, which are used in other chapters of the app, and asks the user to identify all the congenital heart defects in the model. The user can then click on a button to reveal a list of the congenital heart defects present in that particular model. An example of one of the “mystery models” in this chapter is shown in figure 5. An example of the chapter menu, which allows navigation between chapters, is shown in figure 6.

An additional educational tool now exists for medical students at the University of Arizona College of Medicine – Phoenix to gain a better understanding of the complexities of congenital heart defects. The class of 2017 and the class of 2018 were presented with the app when they learned about congenital heart defects and were given the opportunity to utilize the app to compliment their education. The app is also available on the Apple App Store so it is available for any medical student, resident physician, attending physician, or interested individual to download the app for free to help them gain a better understanding of congenital heart defects. A screen shot of the description of the app “Heart Defects” on the Apple App Store is shown in figure 7.

Another result of this project is a better understanding of the infrastructure and potential approaches available for someone to create an educational medical app. The different approaches that were explored in the development of an educational medical app are summarized the flowchart depicted in figure 8.
Figure 1. Image of one of the digital 3D models used in the “heart defects” app, which was created from a CT of an actual patient and shows real variation in human anatomy. All the models in the app use the same color-scheme to represent the different structures of the heart. This model shows a normal heart and is used as a reference when studying the various congenital heart defects included in the app.
Figure 2. Screen shot of the “explore” section of the chapter on Tetralogy of Fallot in the app “Heart Defects”. The heart model on the left is of a heart with Tetralogy of Fallot while the model on the right is a model of a normal heart. Touching the screen with a finger allows the user to rotate the models. Both models will simultaneously rotate and remain in the same orientation in order for the user to easily compare anatomy between the two hearts.
Tetralogy of Fallot Review

- Congenital heart defect that has four cardinal features
  1. Pulmonary stenosis
  2. Ventricular septal defect
  3. Right ventricular hypertrophy
  4. Overriding aorta
- All 4 features result from anterosuperior displacement of the infundibular septum during cardiac development
- Heart is often enlarged and on x-ray may appear “boot-shaped” due to right ventricular hypertrophy
- Most common cause of cyanotic heart disease (50% to 70% of all cyanotic CHDs)
- Severity of pulmonary stenosis is the most important determinant for prognosis
  o If pulmonary stenosis is mild, the abnormality may resemble an isolated VSD with left-to-right shunting
  o If pulmonary stenosis is severe there is reduced blood delivery to the lungs via the pulmonary artery causing right-sided pressures to increase. If RV pressure exceeds LV pressure, there will be a right-to-left shunt, causing cyanosis
- Patients will experience hypoxic spells and learn to squat to improve symptoms. By squatting, the femoral arteries are compressed and total peripheral resistance increases. This causes more blood to be pumped through the pulmonic valve for oxygenation in the lungs and less through the aortic valve
- Systolic murmur is heard along the left sternal border
- Environmental risks for development of Tetralogy of Fallot include maternal diabetes, maternal phenylketonuria, and retinoic acids
- Associated with DiGeorge syndrome

Figure 3. Screen shot of the “review” section of the chapter on Tetralogy of Fallot in the app “Heart Defects”. This section of the chapter allows one to quickly review the key facts relevant to Tetralogy of Fallot.
**Which of the following is not one of the cardinal features of Tetralogy of Fallot?**

A. Pulmonary stenosis  
B. Ventricular septal defect  
C. Right ventricular hypertrophy  
D. Overriding aorta  
E. Hypoplastic right ventricle

**Answer E.**

The four cardinal features that make up Tetralogy of Fallot are pulmonary stenosis, VSD, overriding aorta, and right ventricular hypertrophy. The right ventricle is hypertrophied and not hypoplastic, giving the heart the classic “boot-shaped” appearance.

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**Figure 4.** Screen shot of the “test” section of the chapter on Tetralogy of Fallot in the app “Heart Defects”. This section allows the user to read a multiple-choice question testing one’s knowledge of Tetralogy of Fallot. The user can click on the reveal button to display the correct answer and an explanation.
**Figure 5.** Screen shot of the chapter “test your diagnostic skills” in the app “Heart Defects”. The user can rotate a “mystery model” alongside a normal heart to test their ability to identify all congenital heart defects in the model and then click on the “reveal” button to see a list of those defects present.
**Figure 6.** Screen shot showing the list of chapters displayed on a drop down menu in the app “Heart Defect”. This drop down menu appears on the left side of the screen when the user touches the list icon in the upper left hand corner.
Figure 7. A screen shot showing the app “Heart Defects” description on the Apple App Store. The app is available for free download. The description of the app names the individuals involved in the design of the app and displays the copyright under the University of Arizona name.
Figure 8. Flow Chart of the approaches to building a medical app. This chart reflects the experiences encountered by Alex Stoker during the development of the medical app “Heart Defects”.
Discussion:

Through the process of developing an educational medical app a number of important issues relating to app development were explored. Notably, the possible approaches to developing an app, the challenges associated with each of these approaches and the resources available for individuals who do not have computer-programming experience were explored.

As illustrated in the flowchart of the approaches to developing a medical app shown in figure 8, there are several key factors that determine what approach can feasibly be taken to turn an idea for an app into a fully functioning app. One of the most important factors in determining the approach to developing an app is the complexity of the app to be developed. There are a wide variety of features that have been included in medical apps including complex features like fully rotatable 3D models such as the ones utilized in “Heart Defects”, the app developed as part of this project. Complex features such as 3D models, paired objects, multi-layered graphics, or dynamic components require a higher level of computer programming skill and are not easily developed with online app-building platforms like iBuildapp or Conduit mobile app builder. These app building programs are designed for someone to create a very simple app without any computer programming skills. This option for app development is possible if the app to be developed only requires a very simple layout such as an organized series of text boxes. In order for me to develop a congenital heart defects app using this approach I would have only been able to create a series of chapters to read about each congenital heart defect and look at a two-dimensional image but would not have been able to incorporate any 3D heart models.

Another major factor in determining the app development approach is the level of experience with computer coding and programming of the developer. There are more complex app-building programs that allow one to utilize more complex features but they require the user to have a deeper level of computer programming knowledge. This approach is the cheapest approach to make a complex medical app, but also has the factor of being more time-consuming.
Another major factor in choosing an approach to develop an app is the level of funding available. I found that to properly develop a complex medical app by paying a professional company to develop the app one would need to invest roughly $10,000. Funding was a limiting factor for me as I explored approaches to developing apps and so I had to find an alternative means of developing the congenital heart defects app. The other approach I found to develop an app was to utilize a larger organization that has a potential beneficial use for the app. This approach is what ultimately led to the development of the congenital heart defects app and required several unique circumstances to all come together. Namely, I believe it was a somewhat unique situation that within the University of Arizona there was a division (the Office of Instruction and Assessment) devoted to creating technologies that would benefit University of Arizona students and had experience developing apps in the past. Also, an important component of this circumstance was that I was a University of Arizona medical student at the time, which gave me some credibility as a content expert but also helped because I possessed the perspective of knowing what type of app could be beneficial to medical students, a student population that the University of Arizona has a high degree of interest in helping succeed.

The most notable challenges encountered during the development of the congenital heart defects app were finding an entity willing to invest the time and money needed to convert my blueprint for the app into an actual fully-functioning app. As a student I did not have a significant amount of money to invest in the project and could not pay a company to develop the app, which is the approach most individuals without computer programming experience would take. By presenting the idea for the app to the Office of Instruction and Assessment and convincing them that the app could be useful for medical students, I was able to collaborate with a team of people who could develop the app from the computer programming aspect. Because the app was being developed by the University of Arizona to be used by University of Arizona students I did not need to provide any funding for the project, as the University of Arizona employed the team of programmers. Other challenges included making medical students aware of
the app so that they could utilize it. The most successful strategy proved to be working with Dr. Niggemann, the director of the Cardio-Pulmonary-Renal Block at the University of Arizona College of Medicine - Phoenix so that she could recommend that first year students studying congenital heart defects use the app to help them learn.

A number of factors allowed the successful development of the congenital heart defects app. One of the most important factors was the interest that the Office of Instruction and Assessment at the University of Arizona and Michael Griffith, who ultimately put a programmer on the project, took in the project. One reason for this interest was the impression that the 3D heart models left when I presented the idea to Michael Griffith. The models are brightly colored and were saved in a format that allowed the user to rotate the models using a mouse on a desktop, which helped convey the educational potential that these models possess as most individuals found it exciting to explore the various orientations of the heart models.

I also believe that being a medical student gave me some additional credibility and contributed to people trusting me as someone who is responsible and could be relied upon in the app development process. The app was developed with a goal of creating something that would be utilized by medical students and not with the goal of making money, which allowed everyone involved to focus on the pure educational value of the app rather than trying to design something that would appeal to a wide audience base. Other factors that contributed to the success of the app were having interested content experts like Dr. Richardson and Dr. Willis and being able to collaborate with a wide range of people with different areas of expertise.

I also think it was important to publish the app on the Apple App Store with the copyright under the University of Arizona name and to also list the content experts that were involved, including Dr. Richardson and Alex Stoker who are associated with the University of Arizona College of Medicine – Phoenix, thereby giving additional credibility to the app. Another factor was being a student at the University of Arizona College of Medicine – Phoenix, which is a newer medical school, graduating its first class in 2011, where there is a culture of embracing the evolution of medical education and being
receptive to new ideas for educating medical students in the 21st century. This culture was important in having many individuals embracing the idea of using a medical app to educate medical students about congenital heart defects.

Another interesting aspect of medical apps that was explored as part of this project is the question of who creates medical apps and whether experts are involved in this process. In one article published in the journal of thoracic cardiovascular surgery in December 2013 the authors found that of the 379 medically-related apps only 6% were associated with a named medical professional, 15% with a publisher or professional society, and 63% with a user rating. The author goes on to say that this suggests inadequate input from the medical profession. I think one possible explanation for this is that many apps are created with the goal of making a profit and not necessarily with the pure intention of spreading medical knowledge and so many people who may not be experts on the subject are creating an app with the goal of making money.
Future Directions:

In order to further understand the utility of “Heart Defects”, the app developed as part of this project as an educational tool for medical students, it would be useful to conduct a study that compares preferences and outcomes of students learning about congenital heart defects through the “Heart Defects” app versus students learning about congenital heart defects through the traditional method of reading and looking at two-dimensional diagrams. For the app to be a successful teaching tool it should be both preferred by students as the method to learn about congenital heart defects and effective in educating medical students. It would be worthwhile to conduct a survey of medical students who used the app and their preferences and opinions on the 3D app versus the traditional learning method. It would also be worthwhile to evaluate student’s performance on exams that cover congenital heart defects, whether there is a significant difference between students who have used the app and students who only used the traditional method of learning about congenital heart defects. If it was shown that students had a deeper level of understanding of congenital heart defects and scored higher on exams it would make for a compelling argument to adopt more interactive medical apps into the curriculum at medical schools.

It would also be interesting to examine whether students, and practitioners look for the publisher name on apps they are using and how that impacts the level of trust they have in the information they are acquiring from the app.
Conclusions

I think one of the most important conclusions drawn from the process of developing an educational medical app while exploring the available resources and approaches of app development is that there is a growing emphasis on utilizing new technologies like mobile apps in educating medical students. I think the fact that the Office of Instruction and Assessment exists within the University of Arizona as a department dedicated to developing technologies that will aide students speaks to the current culture of higher education and the direction that medical education is headed. The current generation of medical students differs from previous generations in that they grew up with an intimate experience of computers, the Internet, and the world of smartphones. There are an increasing number of educational medical apps that are being utilized at medical schools to educate students and compliment what is being learned in the classroom and aide in clinical practice. I think in the coming decade, more and more apps will become embedded in medical school curriculums and become standard tools of practice for clinical medicine.

It should also be noted that there are a limited number of conclusions that can be drawn from this case example of creating an educational medical app, as there were a few unique circumstances that allowed for successful app development. The goal of this written thesis is to highlight the factors that were found to be important in successfully developing a medical app, the challenges encountered along the way, and the resources available for someone to develop an app.
References:


