12-2018

PHR: Patient Health Record

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University Honors Program Thesis/Capstone/Creative project

University of Nebraska at Omaha

Submitted by

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May 2018

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UNIVERSITY OF NEBRASKA AT OMAHA

HONORS THESIS/PROJECT/CREATIVE ACTIVITY ABSTRACT

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PROGRAM SIZE:	450+
THESIS:	REQUIRED
THESIS ISSUED:	PROGRAM

ABSTRACT OF THESIS:

The rapid development of information technology systems has expanded into multiple disciplines and results in systems that are limited by initial design and implementation: the Healthcare Information Technology (HIT) space is no different. The introduction of the Electronic Health Record (EHR) system has changed the way healthcare operates. Initial designs of these systems were focused on serving the needs of insurance companies and healthcare billing departments. Research shows that the design of EHR systems negatively impact provider-patient interactions and the care they receive. This capstone project capitalizes on the collaboration efforts between UNO and UNMC – by joining a research group at UNMC led by John Windle M.D. - tasked with “Optimizing the Electronic Health Record”. Their RO1 funded research has created an environment where my efforts and web development will be applied and directly benefit the efforts to innovate these HIT systems. The specific contributions of this project focus on the "After Visit Summary" page of the Patient Health Record (PHR) system at large. The development efforts for this research grant will continue in the future as the author has been offered employment by the research group starting in May of 2018.

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Introduction

Background

"Every once in a while, a new technology, an old problem, and a big idea turns into an innovation" –Dean Kamen. The focus of my capstone project stems from my interest in healthcare, technology, and medicine. Throughout my undergraduate career, I have devoted time and effort to understand the methods and practices incorporated in our healthcare system. With this in mind, I decided to pursue a degree in bioinformatics. After completing my first year in the program, I sought a degree that permitted free thought, idea generation, and innovation. The IT Innovation program at UNO offers students the chance to pursue creative ideas within a specific area of interest. This was the best of both worlds: an opportunity for me to pursue two bachelor's degrees, a journey to produce an innovation within the healthcare field, and the chance to continue my prerequisites to attend medical school. Fast forward two years, and I have reached my senior capstone course. My keen interest in precision medicine, healthcare, and information technology has created an environment where I can pursue an innovation in this field.

Year Journey

My journey towards an innovation within the healthcare space begins before both of the capstone courses. In June of 2017 I began contacting various experts and leaders in the healthcare information technology (HIT) space. My networking efforts began by reaching out to the following HIT experts: James Linder MD, Michael Dixon PhD, Dario Ghersi MD PhD, Paul H. Davis PhD. Of these efforts, I connected with Michael Dixon – the president and CEO of UNeMed. UNeMed is the technology transfer company for the University of Nebraska Medical

Center and Nebraska Medicine. Dr. Dixon was an incredible resource. We spoke on the phone at length about innovative ideas within HIT, the growth of the HIT space, and my potential capstone project ideas. This conversation was extremely valuable and the insight gained from his collaboration was worthwhile.

From this connection, Dr. Dixon introduced me to a variety of experts within the HIT field: Luis Lopez, Steve Kiene, John Windle MD, Kelly Emrick MD. I took advantage of Dr. Dixon's introduction and pursued each of these connections. After a variety of email conversations, phone interviews, and in-person meetings – I solidified a contact with Dr. John Windle at UNMC. Dr. Windle is a cardiologist that currently practices at UNMC. Furthermore, Dr. Windle has a keen interest in HIT and specifically the electronic health record (EHR) systems. We spoke at length about his history, my undergraduate degree, and our shared interest in HIT. I was given the chance to elaborate on my capstone project ideas and how I wanted to solve problems associated with HIT implementation into the patient doctor relationship. Following the discussion about my capstone project ideas, Dr. Windle humbly informed me about his interest in the same space and the project he was currently working on. From this moment on, I knew I had found the perfect HIT expert, mentor, and resource that I wanted to work with.

In 2014, Dr. Windle was awarded a 5 year multi-million dollar RO1 grant to pursue a project titled, "Optimizing the Electronic Health Record for Cardiac Care". Upon learning about his interest in research and his current projects, I was intrigued about the possibility that we could work together. For the next few weeks, Dr. Windle took the liberty of introducing me to his research team, showcasing me his working prototype, and showing me some presentation materials describing his current work. I was naive during these meetings because I was so

amazed by what he was showing me. First, I was dumbfounded that I found an expert and leader in the medical field that was working on a project that is my exact interest and aligned with preliminary prototypes of my senior capstone project. Second, I was reassured that the problem I identified for my capstone project was in fact genuine and authentic: the fact that a leader in the medical field was awarded a multi-million dollar RO1 grant to solve problems associated with HIT implementation for physicians was more than enough evidence. Third, Dr. Windle invited me to work with his team on my capstone project and foreshadowed his intentions of hiring me to work full-time on his research team in May of 2018. My feelings of excitement, pride, and relief are all an understatement. I gladly accepted his offer and began working with his team at the beginning of November.

The introduction of Dr. Windle into my senior capstone project has been exceptional. The opportunity to work with an industry leader on a project and idea that I was already developing is incredible. This is the perfect situation and opportunity for me to produce an innovation in the HIT space. Furthermore, the opportunity to work with him following my graduation from UNO is extraordinary. With this in mind, the entirety of my capstone project and development took a turn when Dr. Windle was added to the picture. It is important to note that this honors capstone report will incorporate the entirety of my work this year – before and after the introduction of Dr. Windle.

At the time of his introduction, Dr. Windle presented me with the chance to choose a project that will be my own to produce that will contribute to his larger work. With the help of his team, I have chosen to pursue a project that aims to do the following: optimize the electronic health record and patient health record by improving the after-visit summary page –

the place where users will go to figure out information about their healthcare visits. This page is crucial to solving the problem: acting as the portal for patients to answer their questions – and communicate concerns with their health provider. The remainder of this report will showcase the work behind my capstone project.

The Problem

As previously mentioned, the introduction of HIT systems into the practice of modern medicine has been received with mixed emotions from all types of caregivers (physicians, nurses, technicians, therapists) and patients. In fact, in a 2016 survey of over 17,000 physicians – 58.3% of physicians found that the "regulatory/paperwork" burdens were one of the major factors that physicians found least satisfying [1]. In addition, the ICD-10 coding system - which is an integral component of EHR systems - was noted by 42.5% of physicians that say it has "reduced/detracted" from their medical practice [1]. The initial design of EHR systems were aimed to benefit two groups, billing departments and insurance companies. With this in mind, there has been an underlying resentment of EHR systems since their introduction into medical practice.

Problem Definition

Although the EHR system may have been designed for an industry and not for the benefit of specific groups that would use it the most, one can still argue that the quality of medical practice is not affected. However, the data from a 2016 survey of practicing physicians tell a different story. The most astounding fact from this study is that, "72.1% of physicians stated their patient care was adversely affected by third party authorizations (EHR Design)" [1].

Furthermore, “54.4% stated that the EHR reduced efficiency, and 59.8% stated that the EHR reduced interaction” [1]. The data clearly shows that there is a problem with EHR applications in a medical setting. Moreover, the adoption-rate of commercial EHR systems is affected by a growing number of physicians using self-designed systems [2].

This data paints a descriptive picture of the expansive problem with HIT systems in medical practice. For physicians, these systems adversely affect their practice of medicine – making small tasks too complicated, creating an overwhelming amount of paperwork, and a dictated form of patient interaction based on the design of the EHR. A variety of personal interviews conducted with friends and family showcased the repercussions of this problem for physicians. Patients feel as though they are not adequately cared for, their concerns aren’t documented, and their medical care seems shortened by the required data entry for physicians/nurses dictated by the EHR. For patients, the pains and headaches caused for physicians is translated to their healthcare experience. This tension is widespread and well-documented. In addition to my personal market research, I was connected with Dr. John Windle at UNMC, and his remarks complimented my research and documented the real problem that exists. The most powerful evidence to document that the EHR systems in HIT are problematic is the funding of his RO1 grant titled “Optimizing the Electronic Health Record for Cardiac Care”. A multi-million-dollar five-year grant was awarded to a research group led by an experienced medical professional and Dr. Ann Fruhling – a leading HIT researcher in the field - to solve the usability problems and overall effectiveness of the EHR system. To conclude, the problem is well-documented and demonstrated.

The Solution

At first a solution to this problem sounds trivial – simply design a system that satisfies the users (caregivers and patients). However, the solution is much more complicated and arduous that it may seem. At the beginning of my first capstone course, I focused on developing an innovation that collected, analyzed, and notified patients and caregivers of a specific patient's condition. However, this idea was a massive undertaking and far too much work for the scope of this capstone project. I then focused on system that patients would use to manage their health data. I figured that the intricacies involved with a healthcare innovation would be far too profound for an undergraduate student to navigate and reach success (HIPAA, Hospital Adoption, Security of information, collaboration with practicing physicians). If an innovation within a healthcare setting would be too challenging to accomplish, then why not innovate outside of the healthcare setting?

I began to prototype a system that would cater to patients and their families. This system's main focus was on user experience, the design of the user interface and overall usability. If patients were more apt to interact with their health data and be informed about their health – then maybe this would translate to a more effective, optimized, and healthy healthcare experience.

The development of my innovative solution was catalyzed by the introduction of Dr. John Windle into my capstone project. His research grant focused on the exact ideas I was developing in my capstone courses. He showed me his medium-fidelity prototype that essentially echoed my aim to produce a patient centered health record. Following the introduction of Dr. Windle, my solution became a part of his larger research project. He intends

to optimize the entirety of the EHR system. The goal is to produce peer-reviewed research with best practices for EHR design backed by user testing and research methods that can be taken to major commercial EHR software companies. Thus, the integration of the best practices for EHR design can be implemented and percolated through commercial EHR software products to successfully optimize, innovate, and alleviate the problems caused by previous EHR systems.

Dr. Windle aims to optimize the EHR system by a timeline of milestones known as specific aims. The overall design of Dr. Windle's research can be summarized in figure 1. A majority of the research outlined in figure 1 has been completed. The current state of his research is in specific aim two, focusing on the design of the optimized EHR. Furthermore, Dr. Windle has incorporated another aim of his research which is to develop a patient health record (PHR) system into his work. My innovation will focus on the design of the PHR system. The PHR system acts as a vector for patients to communicate with their caregivers, to view important health information, and perform a variety of medical tasks that can be optimized through an HIT system. Most importantly, this PHR system needs to be user friendly. With this in mind, I will need to use the best design principles to prompt effective usability for all users. To begin, I will work to design different user experiences and interfaces for uses with low-computer self-efficacy. These system designs will be tested among these users.

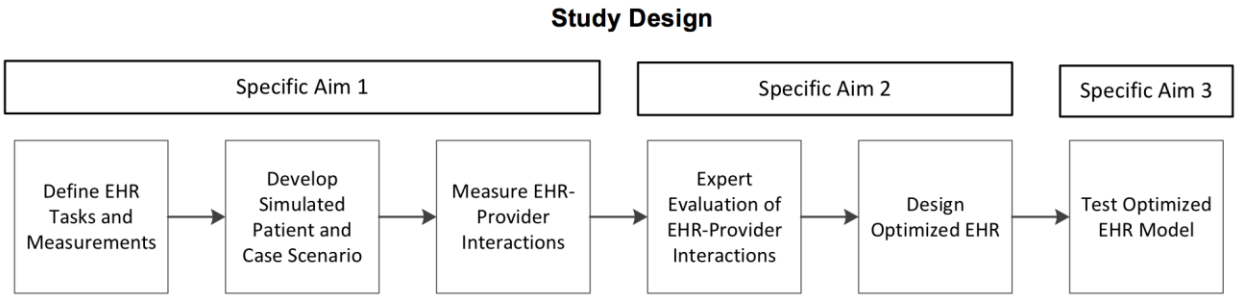

Figure 1: Study Design of Dr. Windle's Research [3]

Innovation Description

My innovation will focus on the design of the after visit summary module of the PHR system. The PHR system acts as a vector for patients to communicate with their caregivers, to view important health information, and perform a variety of medical tasks that can be optimized through an HIT system. Most importantly, this PHR system needs to be user friendly. With this in mind, I will need to use the best design principles to prompt effective usability for all users. To begin, I will work to design different user experiences and interfaces for uses with low- computer self-efficacy. These system designs will be tested among these users.

Overall, the entire PHR prototyped system is massive – containing different pages and modules. The contribution and focus of my honors capstone will be the after visit summary module. My introduction to his research team began in November of 2017. I was not a part of any technical development until mid-January of 2018. There were many technical barriers and hurdles in my introduction that caused this delay. In fact, much of my first sprint revolved around solving these barriers – which I will go into detail later in this report. Aside from the technical barriers – my development time was limited to the second capstone course which ran from January to April of 2018. In this time, it was clear that the after visit summary page would be an appropriate task for me to tackle – and to innovate according to my education and experience gained throughout my degree. The after visit summary page was undeveloped when I was introduced to the team – lending an appropriate realm for my contribution. In this page, I was able to collaborate with my research team on the design, features, and data shown to patients that will ultimately influence their healthcare experience. The information displayed

on the after visit summary page includes the following: medication information, diagnosis, provider information, and overall visit information.

Technical Specifications

The prototype for this PHR system has been partially developed by Dr. Windle and his team. For a project of this magnitude, the initial development environment and hurdles needed to be taken on by his professional staff. This prototype is developed according to software standards that are HIPAA compliant. This prototyped was initially wireframe produced using Sketch and then developed using Angular. Up until this project – I had never completed a web development project in Angular – so it was quite the task to accomplish! To store all of the data that is displayed on the PHR system, the developers for Dr. Windle's team use an Oracle Database. In addition, the web development utilizes Bootstrap – a responsive web development framework, and the database connection/storage uses Spring Boot. Web development code was written in HTML, CSS, and JavaScript.

ER and Data Flow Diagrams

As previously mentioned, the introduction of Dr. Windle into my senior capstone project has changed the course of my capstone at large. With this in mind, I had previously designed entity relationship and data flow diagrams for my personal project before the introduction of Dr. Windle. As such, I have both my own database design and the design of the database used in his development. The diagrams I have generated prior to the incorporation of Dr. Windle into my project are shown below in figures 2-5. It is important to note that these diagrams will not be implemented in the design of my innovation as my innovation has been focused on the user

design and user interface for patients and caregivers. There is much to be learned from my data flow and ER diagrams shown in figures 2-5 – taken as an outsider's design of the data flow. Then, figures 6-8 will showcase the ER diagram used for the PHR prototype with Dr. Windle. Figures 6-8 are partitioned for image quality.

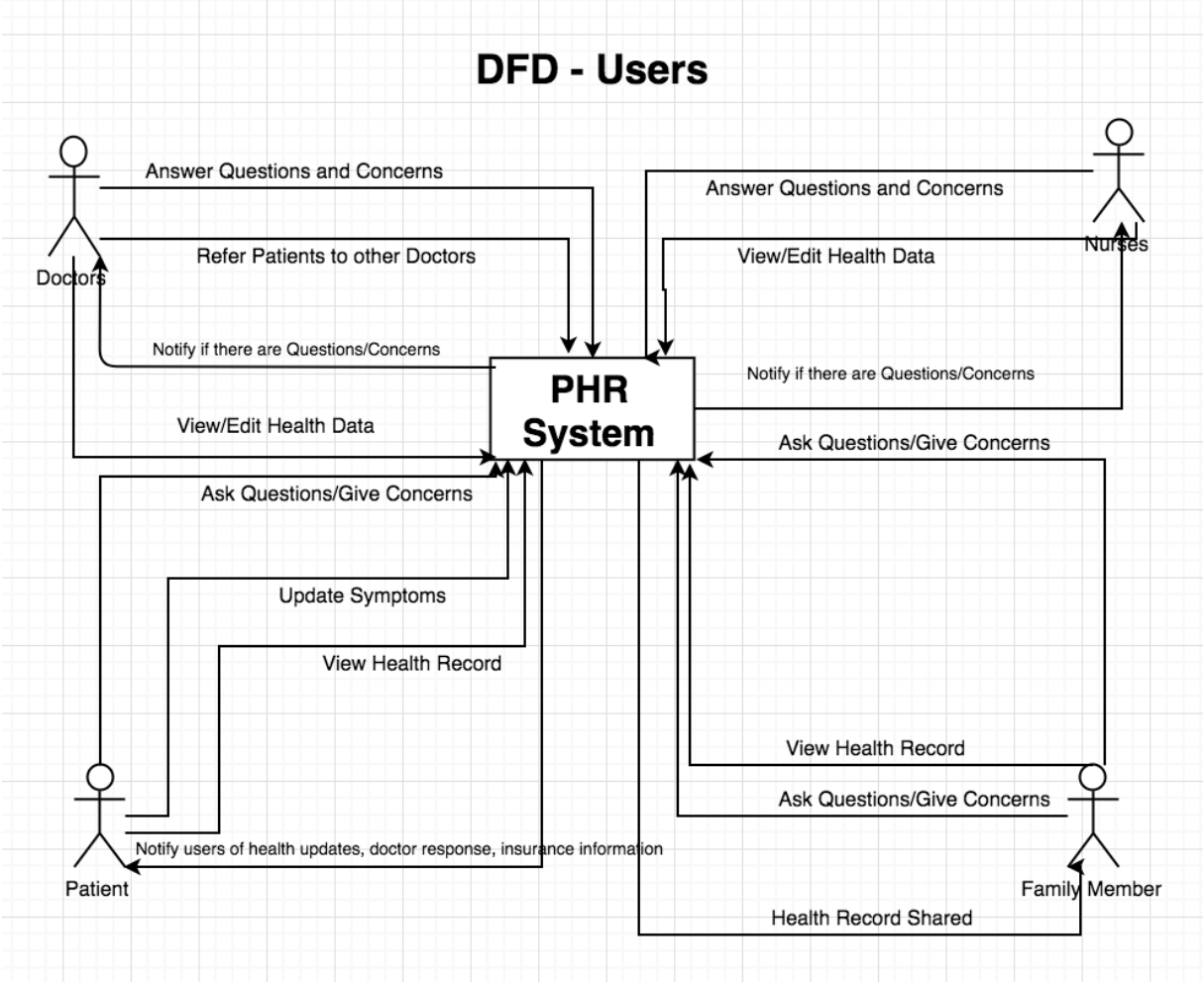

Figure 2: Users DFD

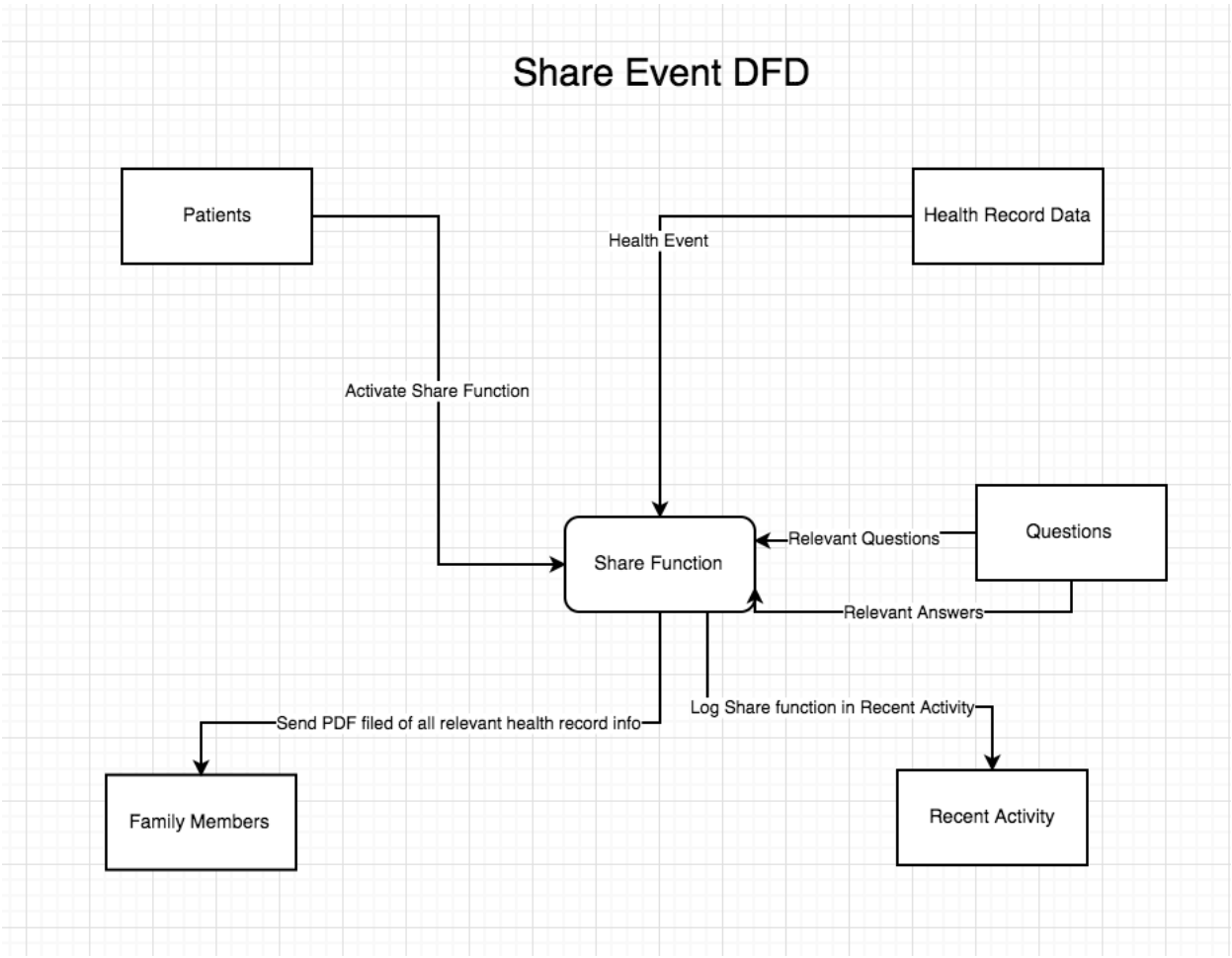

Figure 3: Data flow diagram of a Share Event

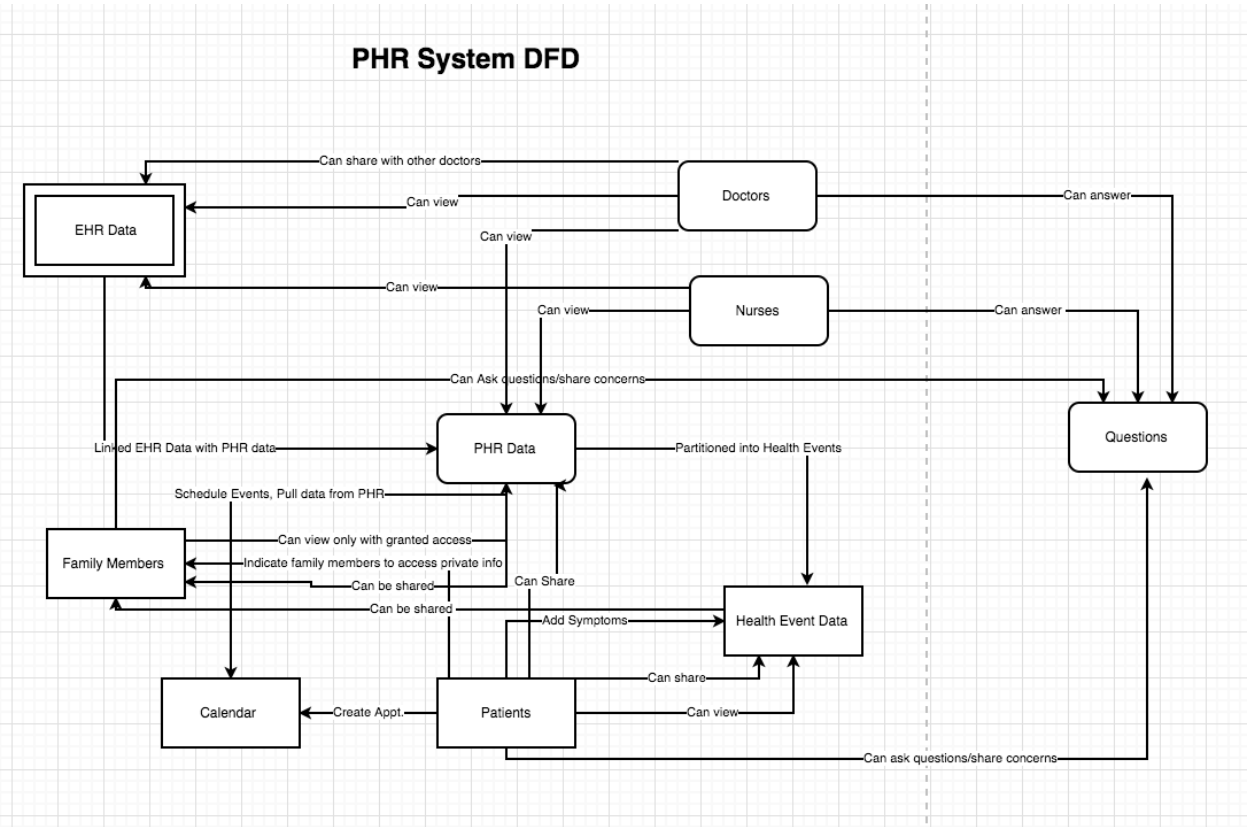

Figure 4: Data flow diagram of the PHR System

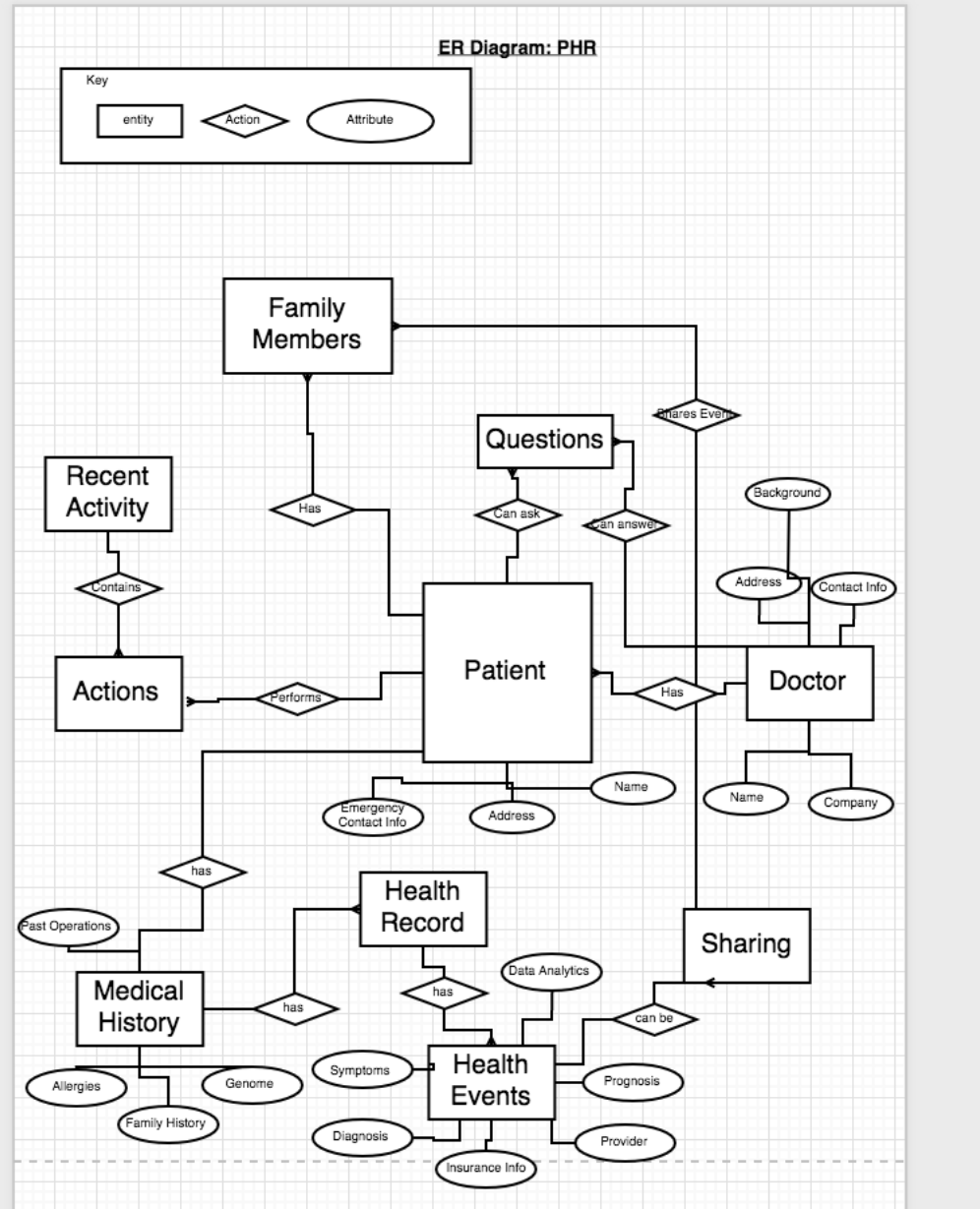

Figure 5: Entity Relationship Diagram of the PHR System

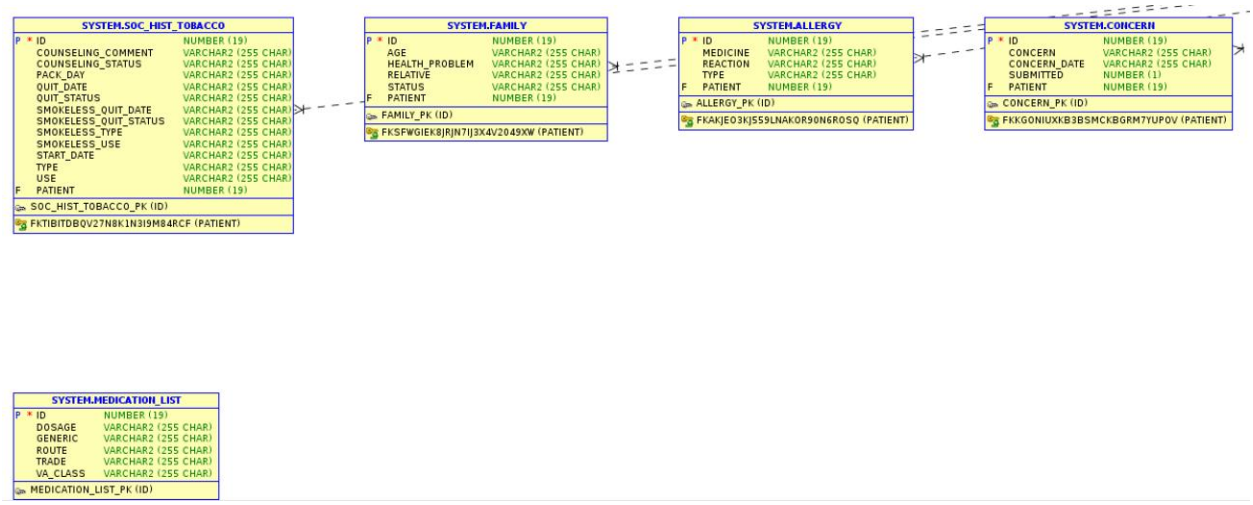

Figure 6: UNMC PHR Prototype ER diagram - part 1

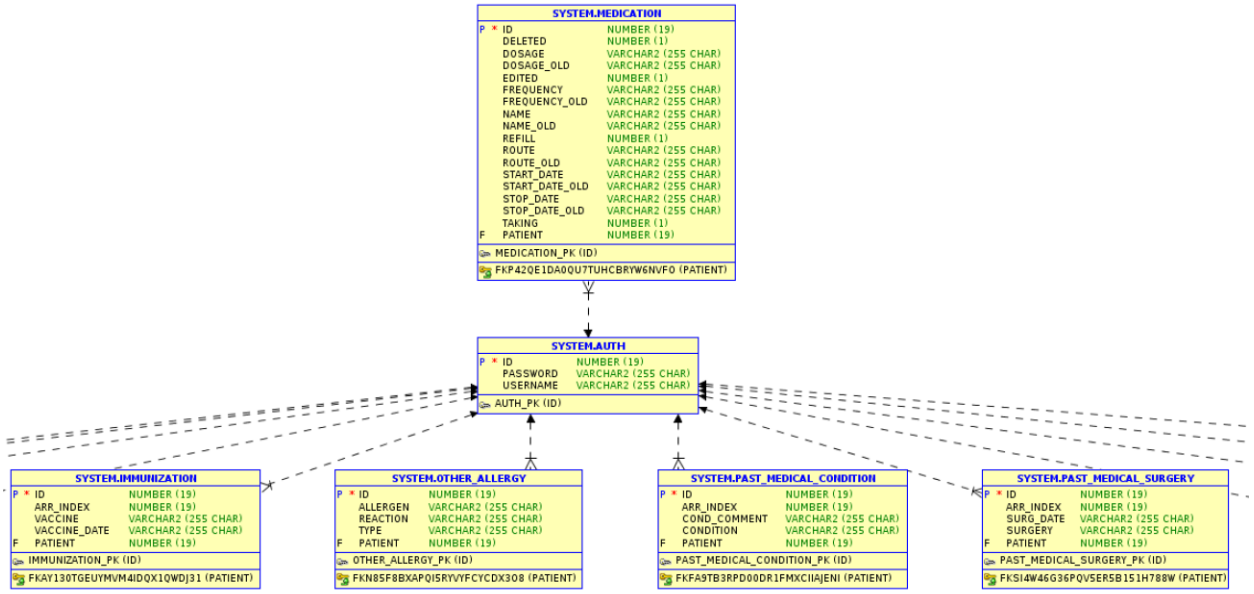

Figure 7: UNMC PHR Prototype ER diagram - part 2

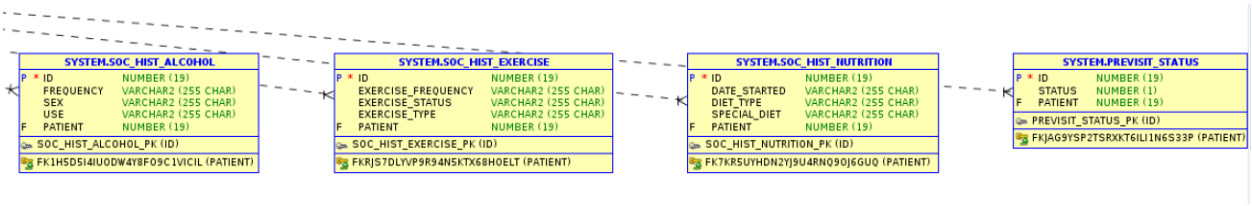

Figure 8: UNMC PHR Prototype ER Diagram - part 3

Figures 6-8 are taken from a larger ER diagram where they are assembled from left to right – figure 6, 7, 8, respectively. This ER diagram showcases the data stored and related to a previous medical visit in tables: PREVISIT_STATUS, SOC_HIST_NUTRITION, SOC_HIST_EXERCISE, SOC_HIST_ALCOHOL, PAST_MEDICAL_SURGERY, PAST_MEDICAL_CONDITION, OTHER_ALLERGY, IMMUNIZATION, SOC_HIST_TOBACCO, FAMILY, ALLERGY, CONCERN. The data stored in these tables are crucial to the PHR system. All of this information is important for the healthcare team to know. For example, if a patient has had a certain medical condition that required surgery – thus impacting the future of their care. The data stored in these tables is functional in the overall PHR system.

When figures 6-8 are compared with figure 5, it is clear that I was not far off when I was designing my ER diagram. Similar data tables like past medical history were included. In addition, I included a table containing a patient's genome information. The incorporation of a patient's genome information lends a future development of the PHR and EHR systems towards precision and personalized medicine.

Technical development

The timeline for this development effort can be observed in figure 9. Overall, the highlights of this development effort include two iterative cycles of development with user testing incorporated. This development chart was generated following the completion of my

capstone one course in the Fall of 2017. Following the development chart – I will specify the technical developments completed in my capstone two course in the Spring of 2018.

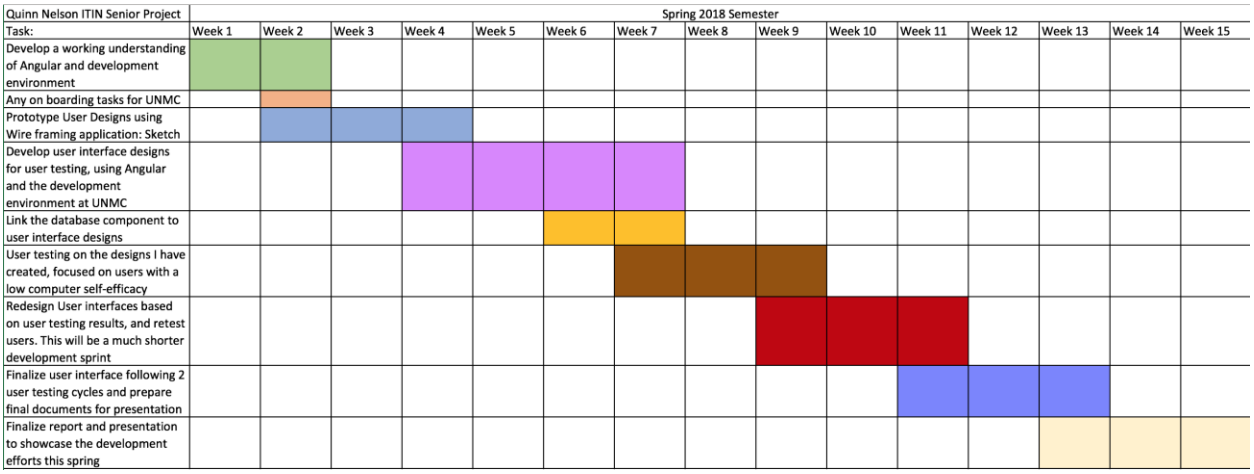

Figure 9: Gantt Chart of Development Timeline for the Spring 2018 semester

The majority of my technical development was completed in the IntelliJ Idea IDE - writing HTML, CSS, JavaScript, Java, and Angular code. Figure 10 showcases the IntelliJ Idea development environment. To complete my technical development, I also needed to deploy a Virtual Machine on my computer that housed the Oracle 12C database. This was accomplished with VirtualBox – a software that runs Virtual Machines on a Mac computer. This is shown in figure 11.

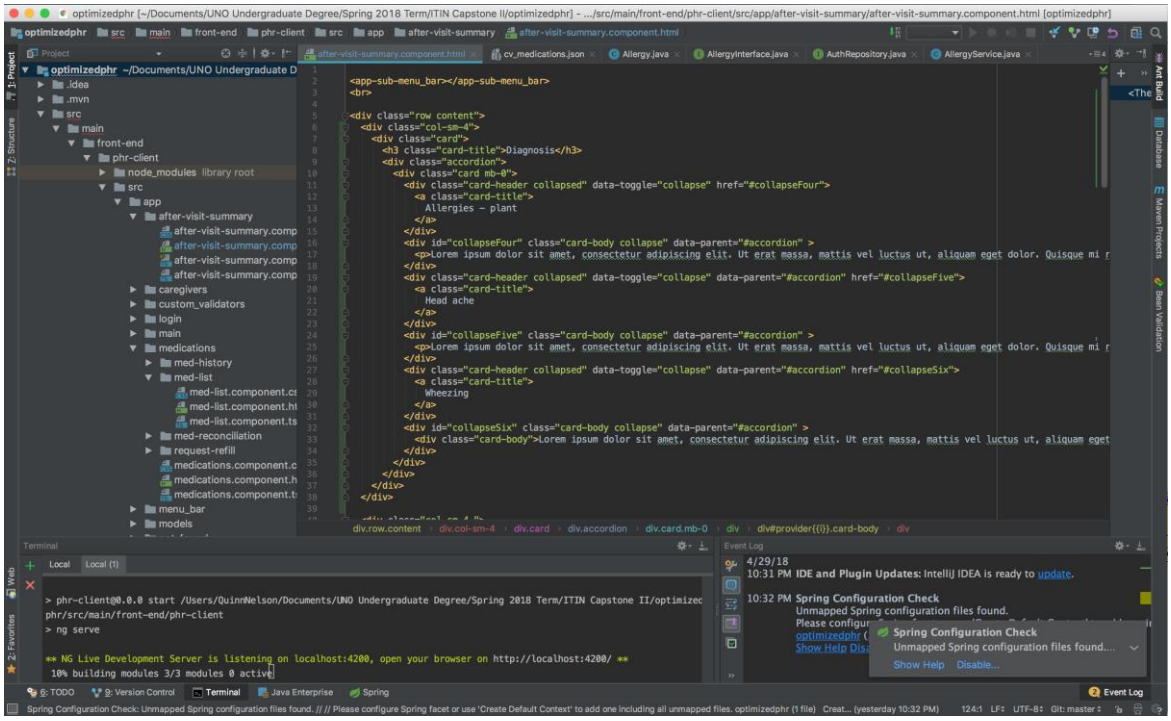

Figure 10: IntelliJ Idea IDE

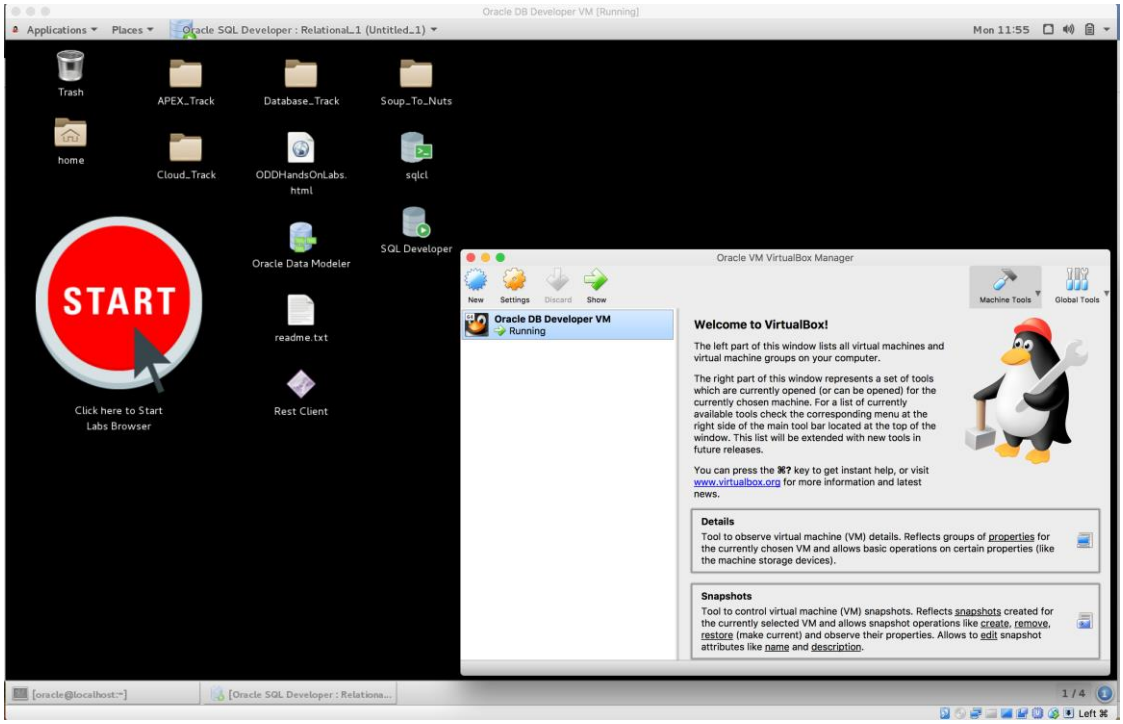

Figure 11: VirtualBox Oracle Virtual Machine (VM) running locally

The incorporation of these software for my local development took up the entirety of my first technical development sprint in capstone two. Once this environment was properly configured – I was able to embark on my web development journey.

Throughout my technical development in capstone two, I used the Agile software development framework. This framework utilizes sprints – where incremental tasks are planned out to manage the overall technical development of the project. As mentioned previously – sprint 1 encompassed the configuration of my development environment. Sprints two through five represented development efforts from February to April. These sprints developed the following webpages and software within the PHR prototype. This development is shown in figures 12-15.

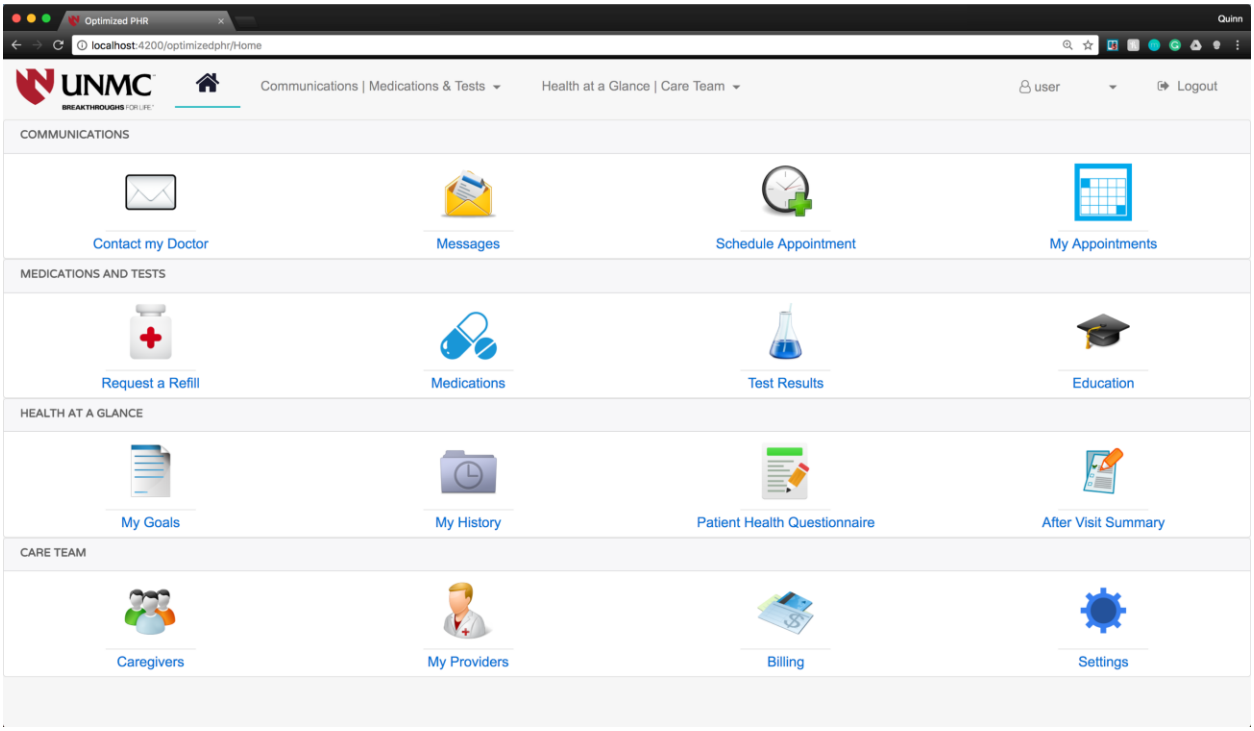

Figure 12: Home page of the PHR

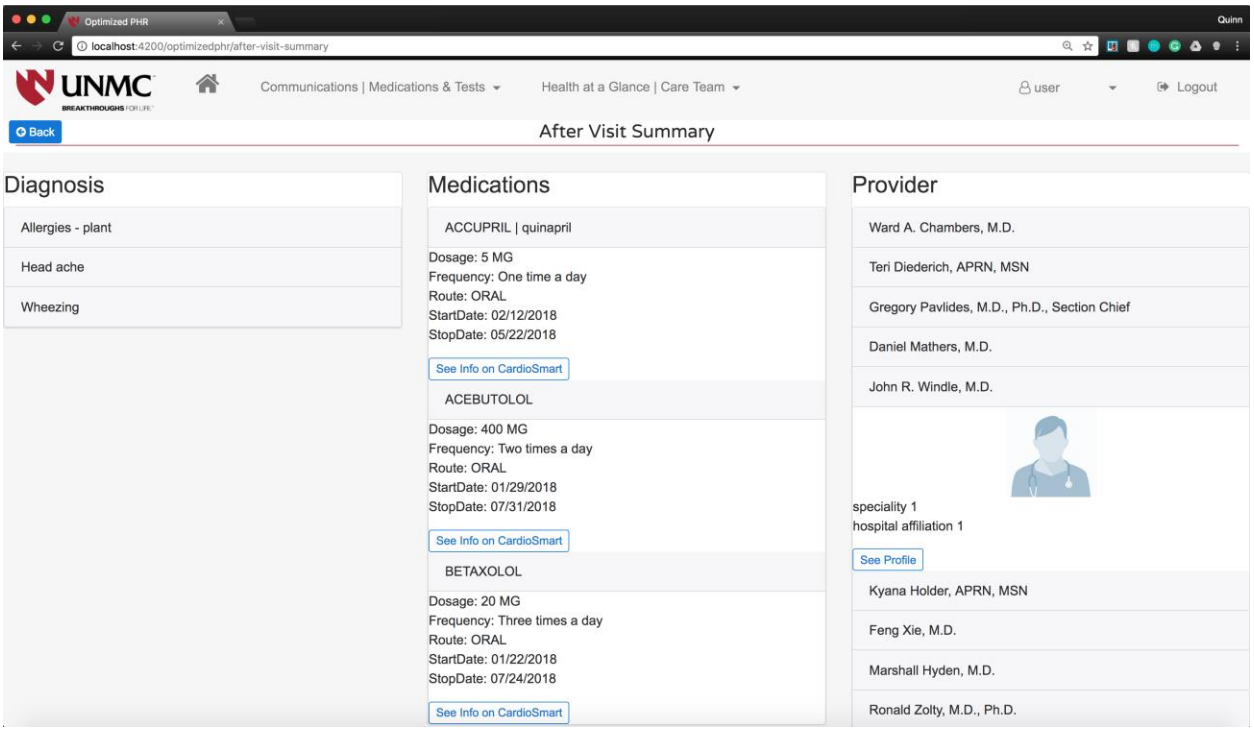

Figure 13: After Visit Summary Page – my specific development

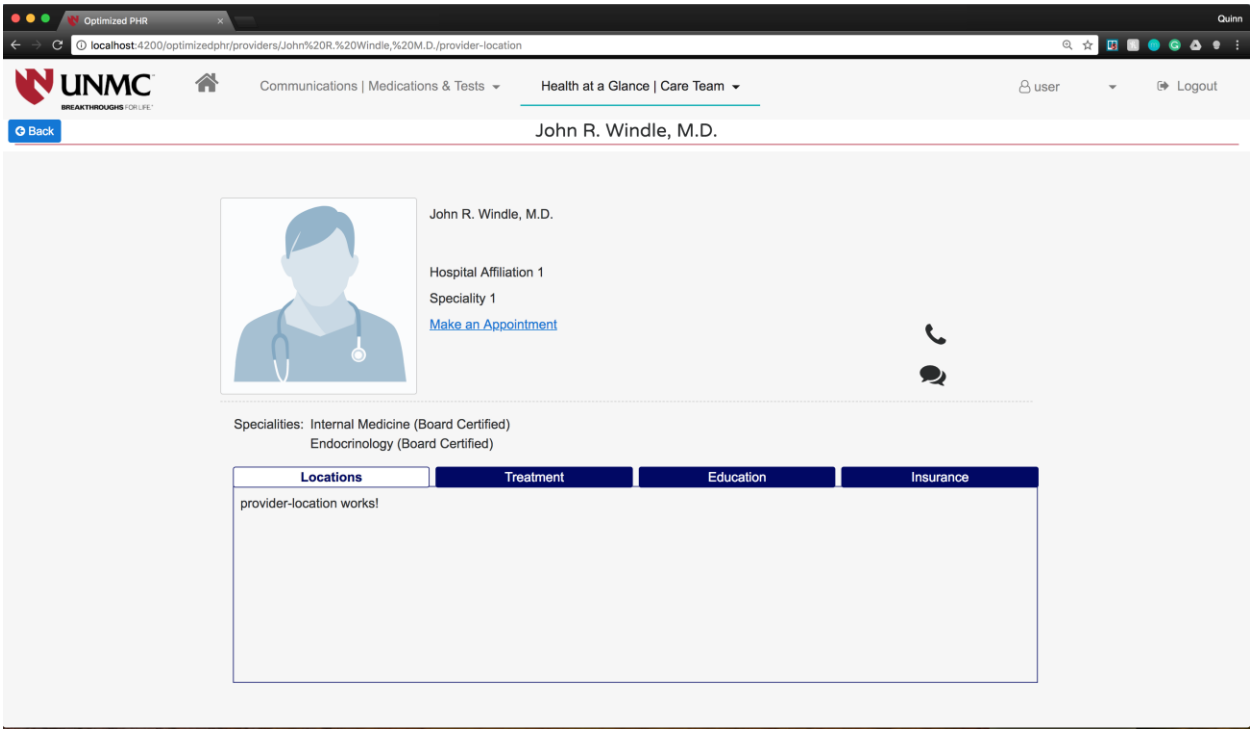

Figure 14: Provider page – linked to After Visit Summary

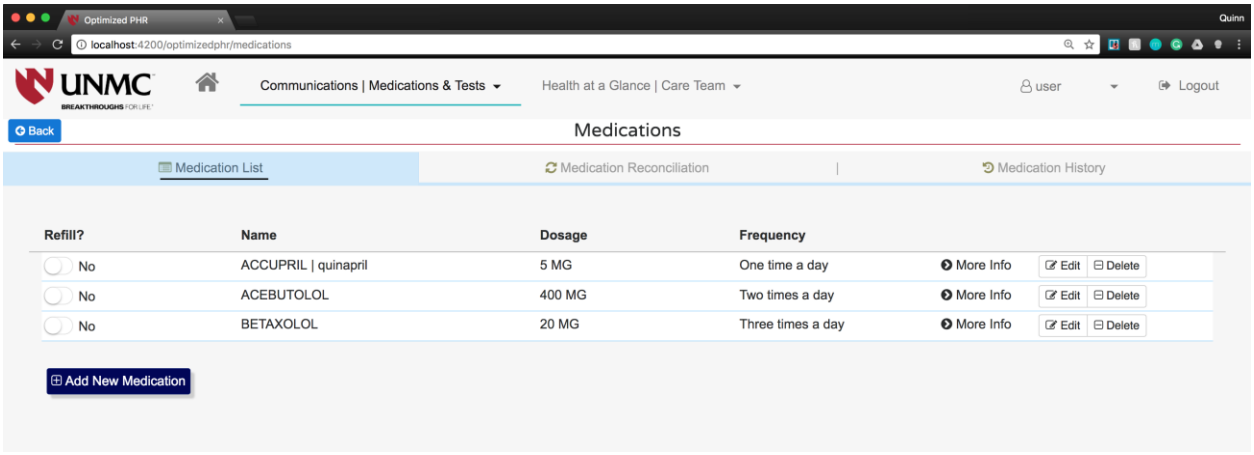

Figure 15: Medication Page – linked to After Visit Summary

Figure 12 showcases the home page of the PHR prototype. The module that I developed can be found on the lower right-hand corner – titled After Visit Summary. When clicking on the After Visit Summary icon – the user is brought to Figure 13 – the After Visit Summary page. This webpage was my specific development during my capstone project. The After Visit Summary page showcases diagnoses, medications, and their providers to patients – following a doctor's visit. Within each column – patients can interactively click to view more information about their diagnosis, medication, or provider. If a patient would like to learn more about their provider – they can click the "See Profile" button. This is then linked to figure 14 – the Provider Page. This page informs patients of their provider's qualifications, contact information, and insurance information – all vital information to patients in their healthcare experience. Furthermore, patients can explore medication information in figure 15 – the medication page. This page showcases the medication dosage, start/end date, the frequency, and the ability to edit or delete a medication. The pages developed create a system where patients can learn more about their healthcare, providers, and medical conditions at large. All in all, figures 12-15 showcase the technical development made during my capstone project.

The Consumer Market

The consumer market of this innovative project is two-fold. The direct consumer of this research is the commercial EHR software companies like Cerner, Epic, Meditech, CPSI, McKesson, and Medhost. As shown in figure 7 take from the "10 emerging EHR trends" published by Health Data Management, these companies account for 92% of the EHR software products in US facilities [2]. As previously stated, the goal of Dr. Windle's research grant and thus my project will be the adoption of best practices in EHR design by publishing this research. It is by this strategy that Dr. Windle aims to transform the HIT space with patient and physician focused EHR design practices in EHR software development. This consumer market has a demonstrated need as shown by statistics provided in the problem section of this report – physicians and patients both require a redesigned EHR system to benefit their practice of healthcare. It is vital to note that modern medicine has developed a dependency on commercial EHR systems. All of modern medicine relies on a computer record system that collates and relates data between users. The need for this product is widespread and constant because of the field's reliance on modern technology and information systems. Furthermore, the net worth of Cerner and Epic – the two-top grossing EHR companies, is 2.67 and 1.50 billion respectively [4]. This evaluation was done in 2013 and can provide a brief estimation of the amount of money in the HIT space. The healthcare industry in the United States is financially massive, as shown in figure 16.

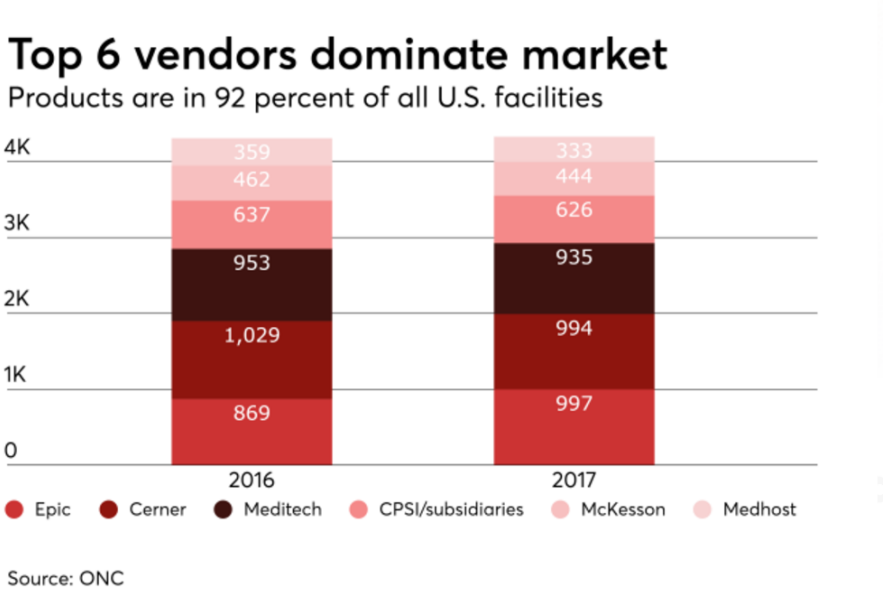

Figure 16: Top 6 vendors dominate market [2]

The Competition

A Crowded Field, Needing Direction

As shown in figure 16, the major competitors in the HIT space dominate the market. The field consists of some major players as outlined in the previous figure. Furthermore, 5 vendors – Epic, Allscripts, eClinicalWorks, NextGen, athenaHealth – have their systems "used by about 60% of doctors in 2016 and 2017" [2]. The intriguing part of this information is that despite the experience and permanence of these commercial software companies, physicians and patients still express their grief and tensions associated with EHR systems. The HIT field is crowded and saturated with large companies that have business with a majority of the market. This situation does not warrant a successful HIT startup company in most cases, however, there are exceptions. In order to produce an innovation in the HIT space, one would need a significant connection that could penetrate the politics associated with healthcare industries – this is the

exact reason why I contacted Dr. Windle and joined his team. Also, the prospective innovation would need to be demonstrated as more efficient and effective than its competitors. With this in mind, the model that Dr. Windle has proposed has a much higher chance of success and innovation adoption within the industry. By producing results in a research format as a published study – EHR software companies can adopt these best practices and push innovation in their development of their commercial software.

Information Pricing

Grant Information and Funding

This research is funded by an RO1 grant through the "Understanding Clinical Information Needs and Health Care Decision Making Process in the Context of Health IT" funding mechanism as an extension of the U.S. Department of Health and Human Services Agency for Healthcare Research and Quality (AHRQ) [5]. In total, this grant has been funded for $2,426,131 to Dr. Windle as the principal investigator at the University of Nebraska Medical Center. In addition, Dr. Fruhling – a professor at UNO – is a Co-PI on the grant. The dates of this project are listed as September 2, 2014 to August 31, 2019. The grant number for this research is the following: R01 HS022110.

Potential Pricing Structure and Business Model

Prior to the introduction of Dr. Windle, I had implemented the following business model and pricing structure in my fall 2017 capstone course. The business model is similar to that of AirBnB. As described in my oral presentation, the proposed business model would be to take

1% of every healthcare appointment that uses our system. Thus, with approximately 1.24 billion healthcare appointments and visits a year – a modest estimate that 10% of those appointments would use our system, resulting in 124 million appointments. The average healthcare appointment costs $200. At 1%, with $2 for every appointment, this innovative software system can aim to make 248 million dollars a year. Obviously, this estimate is far-fetched and not applicable to my current project. However – like any innovation project and startup company – a pricing structure and business model is important to postulate as development goes forward.

Honors Credit Justification

This project deserves honors credit for multiple reasons. As outlined in this report, the HIT space is expansive and saturated with companies that control an exceeding majority of the business opportunity. Thus – it was imperative for my project to find an influential figure to partner with in terms of development: an innovation in the HIT space without endorsement or partnership with an influential figure in the market would have been a wasted effort. The networking to connect and collaborate with Dr. Windle was all accomplished by myself. I was not pushed to reach out and set this collaboration up by any professor at UNO – I foresaw the troubles I would encounter at the end of my capstone project if I had not partnered with someone – and I executed this networking search eloquently. Dr. Windle was the perfect advisor, mentor, and collaborator for a capstone project of my interests. Over the course of this school year I have attended weekly research meetings at UNMC, collaborating with his research team. Moreover, I have spent countless mornings and hours at UNMC working with his development team. The web development efforts I have contributed for this capstone project will be used by this team and the PHR system. In retrospect, I have successfully contributed to

an innovation in the HIT space, collaborated with top HIT professionals, and secured employment with Dr. Windle for the Summer/Fall of 2018, and Spring of 2019. This is a dream opportunity that is a reward for my hard work and efforts put towards this project during my senior year at UNO. This capstone project, without a doubt, deserves honors credit – the efforts put forth in the last year go well above and beyond the high expectations of the IT Innovation Capstone Project courses. I have thoroughly enjoyed this project and the ability to collaborate with such an amazing research team at UNMC. I would like to acknowledge the mentorship and guidance of Dr. Doug Derrick, Dr. John Windle, Dr. Margeret Hall, and Dr. Lucy Morrison.

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