8-2016

A Feasibility Study of Just-in-Time Asthma Self-Management Intervention

Phillip Charles Scruggs
University of Tennessee, Knoxville, pscrugg2@vols.utk.edu

To the Graduate Council:

I am submitting herewith a thesis written by Phillip Charles Scruggs entitled "A Feasibility Study of Just-in-Time Asthma Self-Management Intervention." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biomedical Engineering.

Xueping Li, Major Professor

We have read this thesis and recommend its acceptance:

Lee Martin, Jindong Tan

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

A Feasibility Study of Just-in-Time Asthma Self-Management Intervention

A Thesis Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Phillip Charles Scruggs

August 2016

Acknowledgements

I would like to express my sincere gratitude to Professor Xueping Li for his continuous support throughout my Masters studies and related research, for his deep commitment to each of his students, and for his advice over the past several years. I would also like to express my gratitude to my parents, coaches, and other individuals who have helped to push me to reach new limits in all aspects of my life.

Tell me and I forget, teach me and I may remember, involve me and I learn.

– Benjamin Franklin

Abstract

Quality asthma care requires not only an initial diagnosis, but long term follow up care and education on long term control. Preventable symptoms continue to reduce the quality of life for chronic asthma sufferers and place an unnecessary burden on emergency services and the health care system at large. A mobile health (mHealth) solution is proposed to effectively improve outcomes for patients while ultimately reducing the overall burden of mismanagement on the healthcare system as a whole. The Just-in-Time Asthma Self-Management and Intervention (JASMIN) system provides a way for a patient or user to track, self-manage, and interact with his/her overall treatment plan and empowers the patient or user to take charge of his/her long term asthma control. The JASMIN system incorporates both hardware and software components in the form of a mobile hardware device and an internet-based application. A portable device designated Prototype1 was developed to meet the requirements to be utilized by a target population of young children and adolescents who might not own smartphones or mobile devices. An additional web based application was also developed for users including adolescents and adults. The device, Prototype1, incorporated a peak flow meter, push buttons, GPS location, particulate matter, temperature, humidity, and light sensors, as well as the associated hardware required for a real time connection to a network. Such a device enabled a pilot project in which real time data collection would be possible for users without smartphones or other similar services. The web application component of the JASMIN system would enable users including children, parents, teachers, as well as healthcare practitioners a system that could act as a record of adverse events associated with asthma, a digital journal that is

updated automatically, as well as a resource for intervention as the need arises. Such a system may address persistent problems associated with improving care for chronic asthma sufferers by addressing the needs of being real time, having information on managing symptoms when that information needs to be presented, and provides a way for users to intervene and manage their symptoms when not in the presence of healthcare professionals.

Table of Contents

List of Tables

List of Figures

List of Attachments

Chapter 1: Introduction

Asthma has been determined to be one of the leading chronic childhood diseases, affecting 6.8 million children in the US according to Brown, Disler et al. (2011). Asthma symptoms are initiated by a variety of factors, and the progression of the disease has been well studied. However, often times symptoms propagate and become worse due to inaction of the patient or mismanagement of symptoms. Asthma has a broad list of contributing factors, and reducing asthma morbidity requires asthma management that effectively addresses the full context of a person's life instead of just clinical management alone (Brown, Disler et al. 2011). While traditional management techniques for both adults and children, including written action plans, medication regimens, and monitoring of peak expiratory flow rates have resulted in improvements to care, asthma prevalence, morbidity, and related costs have not decreased (Davis and Herman 2011). Caregivers and asthma suffers are typically aware of asthma symptoms; however, overall long-term treatment plans or action plans often go unnoticed and are generally not well tolerated. Several studies have shown that many asthma patients who had difficulty in following action plans on a daily basis had low compliance to medication regimens (Finkelstein and Friedman 2000). The consequences of mismanagement are staggering and result in children who exhibit higher rates of morbidity and enter the cycle of becoming frequent users of emergency department services. Poorly controlled asthma results in 14 million missed school days each year (Herman, Garble et al. 2010). Furthermore, fewer than 1 in 2 children with asthma get an asthma action plan, and 1 in 5 children with asthma resort to an emergency department for care, resulting in substantial economic costs (National Institutes of Health 2007). The

overall estimated burden of asthma in terms of overall healthcare expenditures has been valued at $1443.00 per patient for each additional step up in asthma severity on the Asthma Control Questionnaire (ACQ) (Sullivan, Ghushchyan et al. 2016). Much of this disability and disruption of daily lives is unnecessary because effective treatments for asthma are available.

Teaching children and younger patients about the self-management of their asthma symptoms has become a major focus so that they may achieve greater success rates with asthma treatments over time. Studies have demonstrated that an individualized, home-based intervention can enhance adherence to the daily use of inhaled steroids in children with asthma (Bartlett, Lukk et al. 2002). By educating these children early, they grow into adults who manage and control their asthma symptoms and reduce the burden of asthma that accounts for so much social and economic cost. A recent [2/29/2016] search of the Apple iTunes app store yielded several hundred asthma related applications. Unfortunately, many applications lack the specificity and validity necessary to adequately address asthma symptoms. Additional programs that have demonstrated success in increasing education about asthma and how to manage symptoms include *Okay with Asthma* ™ (OKWA) which is a program designed for children between seven to eleven years old with diagnosed asthma to promote children's psychosocial adaptation. OKWA was based on a Biobehavioral family model (BFM) with children assuming self-care with assistance from peers, family, his/her healthcare team, and involved adults. OKWA demonstrated improved knowledge and attitude toward chronic illness at one and two weeks post intervention (Wyatt, Li et al. 2013).

Traditionally, prescribed asthma management plans attempt to alleviate the problem of

mismanaged asthma symptoms. Such plans can range from non-written instructions provided by a caregiver to a detailed written plan that is intended to be carried and followed whenever symptoms or a peak flow measurement indicate. Peak flow values are a measurement taken by a device that the patient blows into. It is a measurement of a person's maximum speed of expiration. This value correlates to the degree of contraction of the patient's airway and thus the degree of obstruction that results in symptoms. Written plans typically include instructions or aims including

- How often a regular inhaled steroid medication should be taken
- When to increase the dose of inhaled steroid medication in response to a deterioration
- When to take oral medication
- When to seek urgent medical aid in response to a further deterioration in either symptoms or peak flow

Unfortunately, despite the time and effort that caregivers spend creating a written plan, morbidity and mortality related to asthma persists in spite of substantial advances in the management and understanding of the disease. Children continue to end up in emergency rooms across the country despite having some knowledge of how to manage their symptoms. One method to help address the problem of improper management are Biobehavioral family models (BFM) which have shown in the past to allow children to assume self-care with assistance from peers, family, the health care team, and involved adults. Such models demonstrated improved knowledge and attitude toward chronic illness at 1 and 2 weeks post intervention (Wyatt and Hauenstein 2008). However, even with the help of nearby peers, family, and involved adults, reviews have stated that when

considering written vs. non-written plans, that the written plans appear to have no consistent effectiveness over that of a non-written plan and that electronic monitoring of medication use can and should be used to provide the most reliable and accurate measure of adherence (Toelle and Ram 2004). Another downside of the written plans is their "one-way" and "downward" focus which unintentionally disempowers patients. Only when real time data including symptoms, medication usage, and the result of treatment will we be able to target our educational programs at the components of asthma management that lead to the greatest improvement in health outcomes (Toelle and Ram 2004).

Attempts have been made to utilize new technologies when creating personally controlled management systems. These systems contain devices that record data that has been shown to lead to adverse symptoms if not managed correctly and also contain self-management plans. There have been a growing number of studies that show that when compared to no intervention (i.e. standard care) self-management approaches lead to benefits for participants in knowledge, performance of self-management behavior, self-efficacy, and overall health.

In order to achieve population improvements, a system must first be effective for individual patients who utilize it and have high reach, wide adoption, and proven long term changes among patients. mHealth technologies provide a way to meet these objectives, but healthcare providers have been slow to adopt them because there was a dearth of evidence that direct-to-consumer mHealth tools were effective or provided accurate disease recommendations (Himes and Weitzman 2016).

Chapter 2: Purpose of the Study

Healthy living starts in our homes, schools, workplaces, neighborhoods, and communities. Just-in-Time Asthma Self-Management Intervention (JASMIN) for Children aims to build upon the success of previous efforts for improving asthma control in each of these environments. Previous studies, such as Okay with Asthma (OKWA), demonstrated that children relate well to stories about asthma and that educational topics can be injected into these stories. The computer-based program also led to improved attitude about having chronic asthma (Wyatt, Li et al. 2013). An enhanced version of the OKWA Biobehavioral family model will include real-time asthma geospatial information, seasonal patterns, and social media to enable just-in –time learning and self-management. The proposed enhanced Biobehavioral family model encompasses environmental, physiological, and behavioral factors associated with (or risks for) asthma that enables users to establish and gain new insights into determinants of asthma and strategies for self-management. This model also aims to help identify and improve the social determinants that are so vital to overall public health (ODPHP 2016).

2.1 Specific Aims

Specific Aim 1: Promote adherence to peak flow monitoring using an electronic meter for self-management through innovative mobile health enhanced intervention.

Hypothesis 1: Children in the mobile health intervention group will demonstrate greater adherence to peak flow monitoring and greater gains in managing symptoms than children in the standard care control group who will utilize the current standard of care non-electronic version of a peak flow meter.

Specific Aim 2: Enhance asthma health outcomes through geospatial intelligence models (events are limited in distribution, or more likely to occur in some areas rather than other areas based on information) and social media based predictive models. This will be measured by a question and answer system that indicates whether a participant took action based on a recommendation and the result after that decision.

Hypothesis 2: The mobile health intervention group will have greater improved health outcomes (fewer asthma episodes, lower overall healthcare and emergency care utilization, and fewer missed school and parent work days directly attributed to asthma) as reported by parents compared to the standard of care control group.

Specific Aim 3: Improve the quality of life for children with asthma

Hypothesis 3: The mobile health intervention group parents and caregivers will report higher asthma quality of life scores (such as the physical health of the child, activity of the child and family, and emotional health of the child and family) compared to the standard care control group.

Specific Aim 4: Work as a Health Impact Assessment device to review needed, proposed, and existing strategies for improving asthma outcomes, and change existing social policies for their likely impact on health, and meet the standards set in the Office of Disease Prevention and Health Promotion's Healthy People 2020 as an evaluation device.

Hypothesis 4: Use of the JASMIN device will help determine if strategies to address self-management in the mobile health intervention group also lead to improvements in other areas of social determinants of Health.

Chapter 3: Literature Review

A thorough literature review was conducted in order to gain insights and understanding of the current discussion about asthma, self-management models, and mobile health applications. These topics are closely related and are discussed through this section. An explanation on how this particular study can extend existing literature is also provided. Search terms included *mobile health, asthma, m-health, self-management model, and real time health monitoring*. Some other areas that were examined include the *cost benefits to society by reducing the length of hospital stays related to asthma* and *improved outcomes in life due to reduced burden of disease*.

3.1 Mobile Health

Mobile health technology (mHealth) is a term used to describe the practice of medicine and public assistance supported by mobile devices as defined by Lin, Chen et al. (2002) and encompasses a broad variety of emerging technologies that leverage portable devices and networks to reduce the cost and improve the quality and delivery of healthcare. mHealth applications currently exist in six broad categories: Public Health Research, Primary Care, Emergency Care, Chronic Condition Care, Information and Self-Help, and System Efficiency Improvement (West 2014). Health care providers need effective methods to encourage health care consumers to improve lifestyle habits and to improve their self-management of chronic diseases. mHealth devices have the potential to transform the delivery and receipt of health messages and can help to increase the amount of information, encouragement, and support that can be conveyed to health care consumers. mHealth technologies include mobile phones, smartphones, personal digital assistants,

enterprise digital assistants, portable media players, handheld video game consoles, tablets, and other portable computers; however, smartphones and tablets have become the primary means of delivery. Projections estimate that over 50 billion devices will connect to the internet over the next 10 years, generating a 40-fold increase in the current amount of global personal data being stored on servers (Barrett, Humblet et al. 2013). These devices acquire and transfer data in a variety of ways, but the most common transmission of the health-related data is made via wireless and cloud-based networks (Lin, Chen et al. 2002). The rapid progress of portable and wearable sensors and reductions in their cost has led to the development of additional sensors for detecting different bio-physiological signals and has created new ways to interact with the body. These sensors are often integrated into existing smartphones and other portable hardware that are increasingly affordable and portable. These factors have contributed to many people carrying these devices with them wherever they go. This allows mHealth solutions to be delivered when the intervention is needed most and not gain the attention of the mobile health consumer when his/her attention is not necessary. For example, a person experiencing symptoms related to asthma could access an emergency action plan during the exacerbation itself rather than long before or after the exacerbation. When coupled with the additional economic savings in terms of specialized human resources, patients receive more accurate and comfortable care while healthcare service providers, receive decreased variability in healthcare administration, and decreased costs associated with healthcare delivery.

Smartphone and tablet applications have been used in the past to capture, monitor, analyze, process, and transmit health-based information, and research demonstrates how the devices can be utilized to help facilitate health-behavior change. For example, mobile applications

can be used to monitor and improve medication adherence by providing daily logs and reminders (Dayer, Heldenbrand et al. 2013). One review, entitled The Effectiveness of Mobile-Health Technology-Based Health Behavior Change or Disease Management Interventions for Health Care Customers by Free, Phillips et al. (2013), considered the effectiveness of mobile technology interventions delivered to healthcare customers. Researchers identified 75 controlled studies of mHealth interventions delivered to health care consumers for a variety of diseases including HIV, smoking cessation, and diabetes control. These studies showed that the use of text messages helped improve the adherence to antiretroviral therapy among HIV-positive patients, increase the success of smoking cessation efforts, and encourage physical activity for diabetic patients resulting is improved diabetes control (Free, Phillips et al. 2013). The study also suggested that there is evidence of short-term benefits for interventions regarding asthma control.

While mHealth technologies support new methods for improving many aspects of healthcare, there have been questions regarding standardization of assessments, evaluating interventions, and reshaping evidence using mHealth. Future implementations of mHealth technologies should ensure that the magnitude of improvement to care and deliverables can be measured accurately and compared to existing standards in order to demonstrate whether or not such implementations are worthwhile to pursue. When sensors are available to track symptoms, they provide more detailed and timely information than is found in a typical EHR and avoid inherent errors involved with self-reporting events (Barrett, Humblet et al. 2013). These potential benefits establish a precedent to develop sensors and devices that measure and report symptoms associated with chronic disease.

3.2 Adolescent and Child Users of mHealth Technologies

Children and adolescent users present several challenges to mHealth deployment including limited access to smartphones, tablets, and other devices that can reliably connect to the internet. However, these individuals may benefit most from mHealth resources as many barriers exist to them receiving information and support due to lack of income, transportation, or insurance coverage (Wesley and Fizur 2015). In one study involving mobile applications in the support of chronic disease management, adolescent users noted a variety of difficulties during the trial. Barriers to using the applications consistently included forgetting the smartphone and thus being unable to make an entry, forgetting to make entries at all, or feeling unwell. Additional difficulties included the usability of the apps themselves. Some were easy to navigate by all users, while others required sophisticated skills to operate. Children and adolescents are a very heterogeneous group and a large variability exists with regard to the developmental level of patients and users in this group. This creates challenges when developing specific applications that cater to the different developmental level of younger users. Given the limits of patient self-report, especially among younger patients, attention should focus on integrating new technologies that connect to the applications and report vital statistics (Wesley and Fizur 2015). Children also face difficulties consistently using smartphones and tablets due to restrictions placed by school or parents. Such restrictions are necessary for the productivity and academic performance of the child according to End, Worthman et al. (2010), however, these rules could prevent a child from taking full advantage of a mobile application. In order for younger users to take full advantage of m-Health opportunities he/she needs to be able to access and/or record health events when those events occur.

3.3 Real Time Data Analysis

Real time data acquisition has the ability to help design more effective asthma action plans, programs, and improve compliance with recommendations. mHealth presents an opportunity to obtain data related to a subject's physiological condition without time intensive traditional measurement visits. This enables studies to be completed in a quicker timeframe and also allows for real-time predictive modeling. Such data from real-time models can help with selective acquisition of measurements and interventions, especially when the factors measured are not of equal expense (Kumar, Nilsen et al. 2013).

Real Time Data Acquisition can also help improve the accuracy of self-reported symptoms associated with chronic disease. Studies indicate that compliance and accuracy of self-assessment is questionable at best. One study performed by Verschelden et al. (1996) in particular indicated that reliance on self-reporting Peak Expiratory Flow (PEF) values in a daily journal tend to be inaccurate. Through the study, participants were asked to record his/her PEF values in a daily diary. The peak flow meter that participants used showed the PEF value on a LCD screen. Participants in the study were not notified at the beginning that the peak flow meter that they were using was also recording the PEF measurements as well as displaying the value on a screen for the participant to write down in a diary. While diary records indicated that entries were made 54% of the time, the meters themselves recorded that only 44% of the values taken and then written were actually acquired from the peak flow meter itself. Through the use of the nondisclosed tracker the data indicated that the 20 study participants fabricated 425 values over the duration of the three-month study. The study also noted that the values that participants wrote down only corresponded to the stored values 90% of the time. This study indicates that the compliance with daily

peak expiratory flow assessments is generally poor in chronic stable asthmatic subjects assessed on two visits separated by a three-month period and that a substantial quantity of values were invented (Verschelden, Cartier et al. 1996). Future iterations of diary type apps must consider some type of data validation feature in order to ensure that the data being collected is consistent, valid, and usable for the evaluation of the user's physical condition.

Real time data acquisition also presents an opportunity to predict and model where environmental pollutants might have a negative health effect on asthma patients. When asthma programs are developed, both indoor and outdoor environmental exposures should be considered (CDC 2001). Exposures including environmental tobacco smoke, building materials, and antigens from pets can be present in both residential and nonresidential indoor settings, such as child care centers or schools (CDC 2001). Outdoor exposures contribute to asthma morbidity and include pollutants such as ozone, particulate matter, nitrogen oxides, sulfur dioxide, and other outdoor antigens e.g. pollen (CDC 2001). Such a variety of substances can make it difficult to pinpoint specifically which exposures a asthma sufferer is sensitive to. Reliable data from the time and location at which symptoms occur can help to narrow the list. Unfortunately, many patients do not record when and where negative symptoms occur and the manual tracking of events is tedious even for the most motivated patients. Disjointed and incomplete tracking of symptoms does little to help local health officials understand the causes and particular locations where symptoms are occurring.

In one study, a product called the Asthmapolis sensor, which attaches to asthma metered-dose inhalers, helps to address many of the problems associated with traditional manual

tracking of symptoms and record keeping of adverse symptoms. The device passively captures the time and GPS coordinates of inhaler use by communicating with a smartphone or other Bluetooth enabled device. The device records each time that an inhaler is depressed and transmits the applicable data. The data is stored on a remote server and, through the use of a web based application, allows a user to access to many analytical features. The presentation of the data in tables and graphs helps clarify relationships between controller medication adherence and asthma exacerbation events while creating a data feedback loop that helped improve adherence (Barrett, Humblet et al. 2013). Participants who used the Asthmapolis sensor experienced reduced asthma symptoms and improved control and awareness over a 4-month period (Barrett, Humblet et al. 2013). Real time data acquisition not only offers more reliable information about a patient's adherence to medication regimens and routines but also enables real time analysis that can be used for predictive models that might help warn of future symptoms.

3.4 Self-Management Models

Common barriers to self-management include a lack of awareness, physical symptoms, transportation, and the cost/lack of insurance coverage (Jerant, Friederichs-Fitzwater et al. 2005). While self-management models provide a way to address each of these issues, they can involve a complex sequence of effects including formulating a plan, determining steps to achieve the goals outlined in the plan, overcoming barriers through planned steps, and receiving positive feedback when goals are achieved. Creators expect the models to change patients' behavior by increasing self-efficacy and knowledge which, in turn, should lead to better disease control through better patient outcomes and reduced utilization of health care services. Such a variety of possible sequences and assumptions gives self-management

models multiple objectives and multiple endpoints for evaluation. The main objective, however, remains to change patients' behavior (Pearson, Mattke et al. 2007). A variety of initiatives exist and have been completed in regards to asthma management on a personal and regional level. The CDC's Controlling Asthma in American Cities Project intended to create inner-city laboratories where culturally appropriate, integrated methods would improve the health with children with asthma. However, self-management training was also a primary concern (Herman, Garble et al. 2010). Other desired outcomes included assessing the effectiveness of a comprehensive, community-based collaborative approach in achieving population-based outcomes.

Self-management interventions have been studied for efficacy in asthma patients. Such programs can fall into several categories including social learning, cognitive behavioral models, or educational models expanded to incorporate other components such as social support, exercise, or practical tasks (Newman, Steed et al. 2004). A review of studies indicates that "a self-care regimen, a characteristic of active patient self-management, can reduce mortality and disability, improve quality of life, and reduce health care costs" (Jerant, Friederichs-Fitzwater et al. 2005). Active self-management in itself has therapeutic value; as higher adherence is associated with improved health outcomes despite the effectiveness of the treatments given. The steps of visualizing a personal health-related goal, developing a self-care regimen to make an incremental step towards that goal, and sticking with and revising the regimen as needed is often as or more important than the specifics of the goal or regimen (Jerant, Friederichs-Fitzwater et al. 2005). "Developing programs to promote active self-management and determining the mechanisms by which they influence outcomes should become a high priority" (Jerant, Friederichs-Fitzwater et

al. 2005). The handling of core chronic illnesses self-management tasks and skills by active and passive self-managers is different and has a bearing on outcomes. Commonly used behavior change techniques included providing feedback on performance, goal setting, information on the consequences of a continued behavior, tailoring, prompting of self-monitoring of behavior, and identifying ways of overcoming barriers.

One common complaint of mHealth and self-management models regards a user's limited interactions with a doctor. However, studies show no difference in outcomes when users are instructed by lay rather than by professional tutors (Barlow, Wright et al. 2002). This indicates that information could potentially be transmitted to individuals through electronic means via trained educators or electronic documents and games rather than through medical professionals who lack the time or motivation to explain the same repetitive steps to patients exhibiting similar symptoms.

3.5 Directly Observed Treatment

Directly Observed Treatment has its roots in managing tuberculosis outbreaks; however, similar principles have been proposed for managing other chronic diseases. Between 1995 and 2005, Directly Observed Treatment (DOT) expanded through 190 countries in an effort to combat the communicable disease tuberculosis. The application of DOT regimens has begun to be applied to other chronic diseases as a method to improve outcomes and reduce the burden on the healthcare system at large. A 2005 study in the journal American Family Physician by Miller (2005) examined the effects of a DOT treatment performed at school for the provision of inhaled corticosteroids on asthma severity in urban children with mild to severe persistent asthma . 180 children aged three to seven were divided into two

separate groups. One group was the school based group where medications were provided by the school in a DOT manner. The other group was the usual-care group (medications not given through the school). The school nurse was in charge of administering medication to the school based children. Assessments of the two groups were performed on a monthly basis and the main outcome measure was the number of symptom-free days.

Results from the study indicated that children in the school-based care group had more symptom-free days during the winter months and missed fewer days of school than children in the usual-care group. School based programs providing inhaled corticosteroids on school days significantly improved symptoms, quality of life, and absenteeism in urban children with asthma (Miller 2005).

3.6 Architecture of Healthcare Monitoring Systems

Existing mHealth applications operate in environments that combine physical hardware including sensors, actuators, displays, smart computing devices, and networks with related software, services, interfaces, and humans that all interact, sense, and communicate with one another. The structure of health-monitoring systems on mobile devices may be introduced as a three-level architecture containing a physical layer of data acquisition, mobile device-server communication, and an application layer for data processing and visualization.

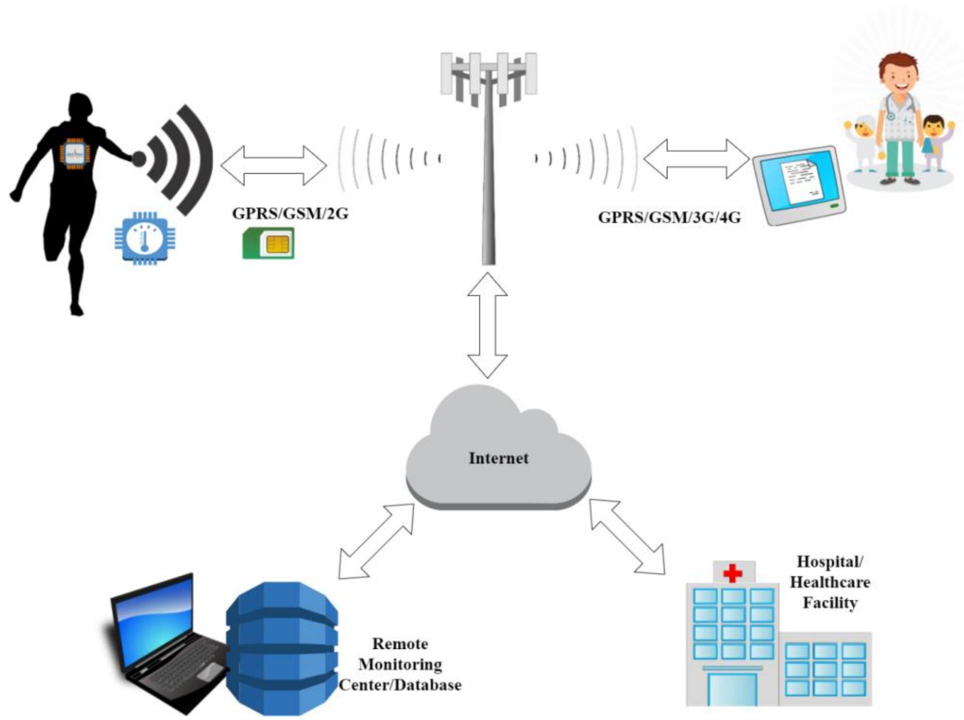


Figure 1: The overall architecture of a mHealth solution and its overall location in the healthcare system.

A variety of factors need to be considered when deploying wireless networks for mHealth services including input data, network topology, throughput, energy consumption, and radio transceiver range. Input data acquired from sensors located on or used by the person is acquired in a variety of ways and then transmitted. This data could represent ECG, heart rate, blood pressure, temperature, or a PEF measurement from the patient at a specific moment in time. A mobile device operates as a communication node for the connected sensors and sends the data to a server utilizing the existing cellular network. The Remote Monitoring Center / Database is used to store and analyze data. When needed, an alert can be sent to a healthcare provider. Healthcare providers may also access the system to monitor a patient's status. Other considerations include the reliability of the signal that is sent to the network from the mobile device and/or sensors.

3.7 Mobile Monitoring Solutions

One of the key component additions identified that existing mobile applications lacked was the need for the addition of an electronic monitoring device that was simple enough for young children to use. Such a hardware device would need to contain sensors that would accurately record data that could be analyzed and demonstrate whether specific aims 1-4 were accomplished. An electronic monitoring device would need to exhibit the following qualities in order to be utilized in the JASMIN program.

- Robust and Durable
- Low-Cost
- Reliable
- Small Size
- Long Battery Life

A review of state-of-the-art existing products that could be used to acquire data for such a study are shown in Figure 2.

3.8 Implications for Public Health

Previously, most data gathered by patients traveled straight to that person's doctor or research team, resulting in an improvement of care for only that particular individual. However, an information flow gathered from many data sources (patients) can be presented to many other individuals, resulting in a much larger positive impact on those users' decisions (McKenna 2013). Those users may include anyone from public health officials to general members of the public. One of the most well-known disease surveillance programs is ProMED-mail (Program for Monitoring Emerging Diseases) which is a program that maps emerging disease outbreaks on a map based on data

gathered from government reports and unofficial news articles. Newer versions of the program such as HealthMap utilize internet sources as well and passively scan social media networks for specific terms that are likely related to a potential outbreak. Such a concept could easily be transitioned to asthma care and other chronic conditions that are directly related to environmental triggers (common causes of increased symptoms). Real time data acquired from volunteered data is low cost and has the potential to identify potential danger zones or “hot spots” that other users may avoid. By clearly identifying these dynamic areas quickly and accurately, at risk populations can learn to avoid particular areas containing triggers that may exacerbate symptoms.

An additional company that is currently piloting real time data acquisition devices is Propeller Health (formerly Asthmapolis). This company is acquiring user data from small Bluetooth enabled buttons that are placed on top of rescue inhalers and record the time and date that medication was administered. Such a system is small, reliable, and only records data when the medication is administered. This relevant data can then be used by public health officials to indicate where potential problem areas are. For instance, certain areas of a city might have excess levels of a pollutant that is known to cause exacerbations of asthma symptoms in a select group of individuals, e.g. children under age 12. Public health officials using an electronic application could transmit information rapidly to those at risk individuals who are within the warning area and meet the criteria for a warning to be sent e.g. Children in the select area would receive a warning while adults utilizing the same application would not if there was evidence to show that children were being affected while adults were not.

Product Comparison

	Propeller	MySpiroo	SmartOne	AsthmaMD	Puff Minder	Care TRx
						
Company Name	Propeller Health	HealthUP	Medical International Research Smart One	Quest Products	Doser	CareTRx (Gecko)
Availablity	Demo Only	No	No	Yes	Yes	? NO
Bluetooth	Yes	YES	YES	NO	NO	YES- Bluetooth
GSM Capable	NO	NO	NO	NO	NO	NO
WIFI Capable	NO	NO	NO	NO	NO	NO
Phone Requirements	YES - Bluetooth	YES-Bluetooth	YES - Bluetooth	NO	NONE	YES- Bluetooth
Cost	Not Disclosed	Not Disclosed	Not Disclosed	$20.00	$40.00	Not Disclosed
Peak Flow Data	NO	YES	YES	Yes	NO	NO
Generic Button Press	Through App	Through App	Through App		NO	Through App
Pollution Sensor	NO	NO	NO	NO	NO	NO
Temp Sensor	NO	YES	NO	NO	NO	NO
Humidity Sensor	NO	YES	NO	NO	NO	NO
Integration with APP	iOS and Android	iOS	iOS and Android	NO	NO	iOS and Android
Internal Storage	-	-	-	NO	30 Days	Up to 400 recordings
Alarm	-	-	-	NO	Limited	NO
Cloud Direct	NO	NO	NO	NO	NO	NO
Cloud Functionality	YES w/Phone	YES w/Phone	YES w/Phone	MANUAL ADD	NO	YES w/Phone
Battery Life	18 Months	LongLife?	24 Months	-	12 Months	6-12 Months
LOCATION	YES w/Phone	YES w/Phone	YES w/Phone	NO	NO	YES w/Phone

Figure 2: A comparison of available devices that enable data acquisition of events and/or medication disbursement related to asthma symptomatology.

The devices listed in Figure 2 are all adequate for users who have smartphones, however, according to the Group Spéciale Mobile Association or the GSMA (2014) most children do not possess the cellular/wireless devices or smart phones that are required in order to facilitate constant and accurate tracking of the child's symptoms and medication use A device that integrates all of the features in Figure 3 is necessary in order to accomplish the overall goals established in Purpose of the Project section for users who do not possess a smartphone or other similar device. Since few state of the art devices met all of the requirements necessary for inclusion in the JASMIN system a prototype device was developed that would sufficiently meet the design criteria listed in the specific aims on page 5.

Certain sensors were determined to be necessary for a comprehensive device as determined by supporting studies. For instance, a pollution/dust sensor capable of identifying second-hand smoke was determined to be useful since children who are exposed to environmental tobacco smoke are at increased risk for adverse health consequences. According to McIntosh, Clark et al. (2009) even when parents of children with asthma were presented with evidence that the child was being harmed by his/her active smoking near the child initially he/she was still less likely to quit the habit of smoking next to the child unless presented with evidence throughout the course of the study that showed that he/she was smoking near the child and that it was causing harm. In order to truly improve a child's number of asthma exacerbations many factors including the habits of others located in proximity to the child must be considered.

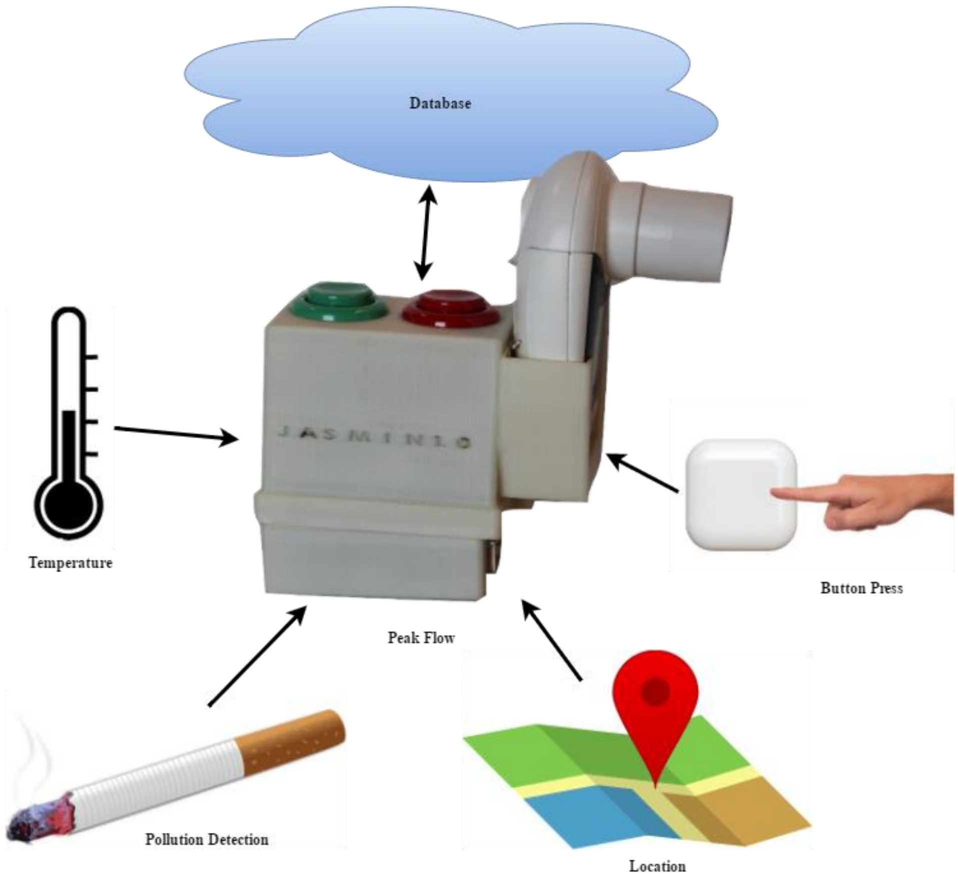


Figure 3: The necessary functions for Prototype1 to have in order to sufficiently meet the requirements of JASMIN.

Table 1:Typical handling of core chronic illness self-management tasks and skills by active and passive self-managers

Core Self-Management	Typical Handling by:	
	Passive self-managers	Active self-managers
Core self-management task		
Medical Management	Defer to HCP (Health Care Provider	Collaborative with HCPs
Role management	Feel compelled to relinquish values roles	Strive to maintain valued roles
Emotional management	Erratic, ineffectual	Conscious, regular use of coping strategies
Core self-management skills		
Problem solving	Chaotic, catastrophizes	Formal, careful process
Decision making	Made in haste and fear	Made after considering all options carefully
Resource utilization	Minimal to none	Expert in identifying and selecting support
Partnership with HCPs	Minimal to none	Highly developed
Action planning	Unfamiliar with process	Applied frequently
Self-tailoring	Minimal to none	Frequent

Note: Adapted from the Journal of Patient Education and Counseling: (Jerant, Friederichs-Fitzwater et al. 2005)

Chapter 4: Innovation: JASMIN

4.1 JASMIN

Today's self-management programs have moved away from a step-by-step education where educational content was delivered by healthcare professionals to an individualized approach that allows a patient to address needs and concerns when needed as defined by the patient. Construction of a real time mitigation project named Just-in-Time Asthma Self-Management (JASMIN) is aimed at alleviating the problems associated with previously existing "self-management support" programs. Previous attempts at self-management programs within mobile applications lacked reliable, comprehensive information about the condition and failed to effectively combine with the supportive tools necessary for self-management (Huckvale 2012). JASMIN is set up to allow evaluators to reasonably assess whether the program is accomplishing what it is intended to do based on many points. An electronic device referred to as Prototype1 has also been developed to send data to a cloud based application for parents, children, healthcare providers, and other caregivers to document, check in real time, and generate more accurate records of symptoms. Users of the JASMIN program will have access to different features shown in Table 4 located on page 38.

4.2 Self-Management Strategies

By acquiring data from a reliable digital source, one of the major sources of error, human recording error, is minimized within the system. When combined with the JASMIN web application, users can view data regarding specific health parameters. Integrated features in the application will allow medical professionals to use this data to evaluate patients and send instant feedback, while patients may use the application to remain motivated and to actively participate in their own care.

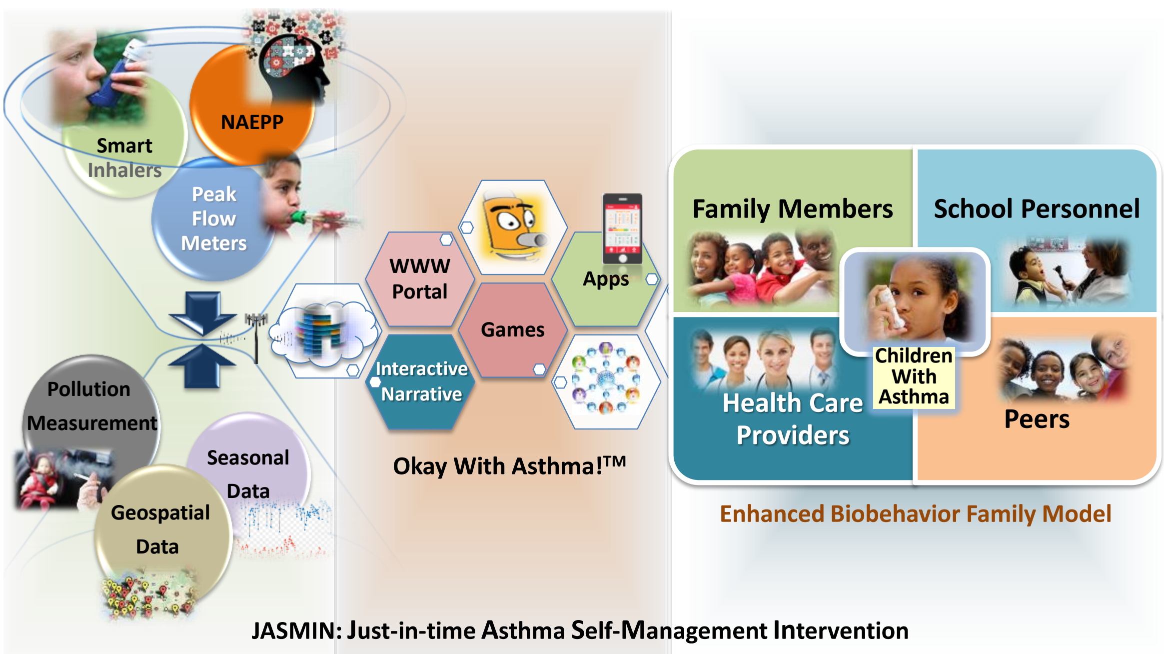


Figure 4: JASMIN Architecture - An overview of the areas that JASMIN addresses

Previous attempts at designing programs for self-management for asthma utilizing apps have failed to incorporate all the needs of the patient (Huckvale 2012). According to a study performed by Huckvale (2012), an app should contain the items that should be

addressed by a comprehensive asthma self-management education program which consist of the materials stated below.

- Basic Facts about the nature of the condition
- The nature of treatment: relievers and preventers
- Allergen and trigger avoidance
- How to use treatment
- Self-Monitoring and assessment skills
- The role of a written, personalized action plan
- Recognizing and responding appropriately to acute exacerbations
- Personalizing the definition of good asthma control

4.2 Electronic Self-Management Strategy

General areas where evidence supports a self-management program include the tracking and monitoring of active smoking, passive inhalation of secondary smoke, exposure to defined allergens, and reduction in obesity. Areas where limited evidence has been obtained to support a self-management program, but no comprehensive support exists, include exposure to pets, fungal allergens, cockroaches, air pollution, and vaccination against influenza. (Huckvale 2012) In order to develop the most effective program, evidence-backed areas for inclusion must be considered, while non-comprehensive supported measures can take a secondary role for inclusion.

Chapter 5: Research and Development of Prototype1

5.1 Development Goals

In order to achieve a program that:

- promotes adherence to peak flow monitoring using an electronic meter for self-management through innovative mobile health enhanced intervention
- enhances asthma health outcomes through geospatial intelligence models and social media based predictive models
- improves the quality of life for children with asthma
- works as a Health Impact Assessment device to review needed, proposed, and existing strategies for improving asthma outcomes

an analysis of existing devices was performed (see Figure 2). Due to the lack of availability of a device that would support all four specific aims, a new device was conceived.

5.2 Steps of Development

1) Consider alternative devices:
2) Form a list of attributes that prototype 1 should include (Table 2)
3) Develop Prototype1
    a. Comparison to existing devices
    b. Construction of Prototype1
4) Develop/Program functionality and description of capabilities
5) Upload code to microcontroller (Arduino) and demonstrate adaptability
6) Test to ensure data transmission via cellular network
7) Set up database to accept and organize data and show structure

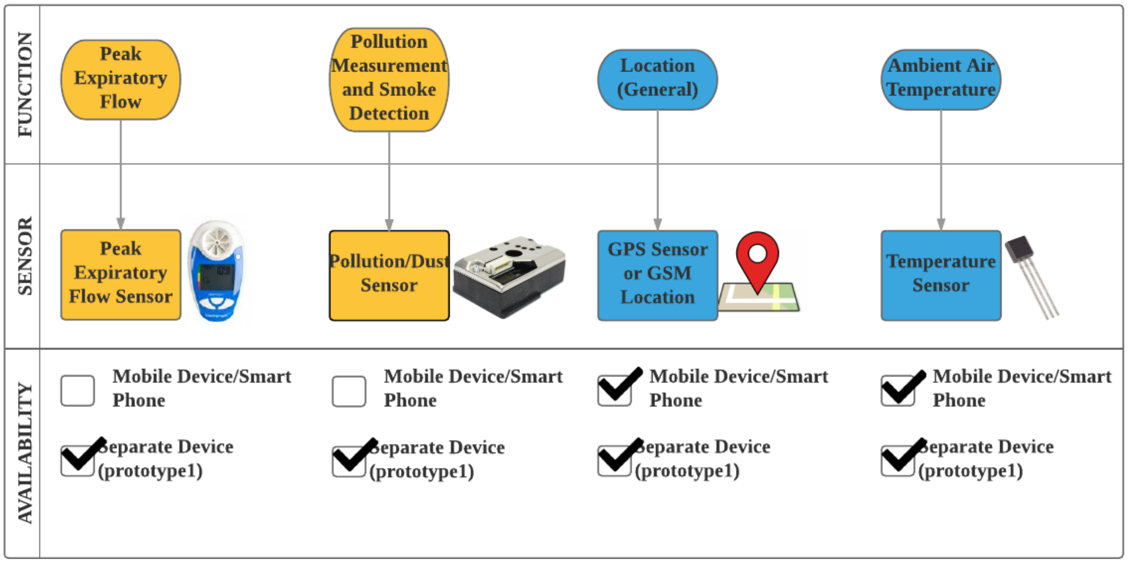


Figure 5: Block Diagram of Functionality necessary in the JASMIN system and the sensor availability among smartphones vs a separately developed device.

5.3 Prototype1 (JASMIN 1.0)

The JASMIN 1.0 is a real time data acquisition device that combines a reliable GSM connection with a peak flow meter and other additional sensors. The sensors chosen directly relate to asthma care, but could also be used by healthy individuals suffering from temporary airway inflammation caused by bronchitis, pneumonia, and colds. The JASMIN 1.0 device is designed to eliminate the effort that is typically involved with setting up a wireless sensor and allows the user to immediately begin using the device.

Other attempts have been made to utilize new technologies to create personally controlled management systems. Such systems typically consisted of a software component (app) and a hardware component such as a peak flow meter or other instrument. Many mobile health (mHealth) devices have attempted to address the problems associated with chronic disease management; however, the complexity of the devices requires a steep learning curve of its

own. This often leads to under or non-usage and a feeling of disempowerment for the user. In order to avoid this problem, components and design considerations were made for the overall JASMIN system while considering advice outlined in the Food and Drug Administration's (FDA) Human Factors in Medical Devices guidelines. For example, each button would have a specific function and users would receive feedback indicating what that function was through panels displaying information on both the prototype device and the application. If screens were considered for the device itself, it would be large and clearly visible in order to prevent misread information which could lead to incorrect medication administration on the basis of the misread information. Feedback from manipulating the device's sensors and buttons would be quick in order to facilitate the user's understanding while simple functions that only require a simple hardware solution should not rely on software, e.g., a stand-alone push button for a high priority, time-driven function (Sawyer 1996).

In order to facilitate an easy user experience and the most reliable network connection, a GSM or cellular based device should be set up prior to distribution to the user. State of the art hardware devices utilize several standardized communication protocols including Bluetooth and Wi-Fi, but very few utilize a GSM network or communicate directly to a server via existing cellular networks. In fact, all of the devices shown in Figure 2 rely on an additional mobile device to relay essential data to a server. Several iterations of prototype 1, which requires no additional hardware in order to send/receive data, were produced from each individual component shown in Figure 6. A justification for each sensor is included in the section entitled "Sensor Selection." Such a device would be easy to use and require little to no outside setup.

5.4 Data Transmission Considerations

The JASMIN device was designed for a specific community of young users who suffer from asthma. Existing devices are capable of connecting to Bluetooth-enabled smartphones. (See Figure 2) However, the majority of young children do not own or possess a smartphone a majority of time. Ages 10 to 12 years are the most common ages to first receive a mobile phone (GSMA 2014). This leaves a large share of children who would benefit from real time data acquisition yet, cannot do so due to a lack of a mobile phone or smartphone. A separate device must to be developed because a majority of young children do not possess cellphones and have limited access to smart devices (GSMA 2014).

A hard shell case was designed in order to facilitate the ease of use of the prototype. The case added durability and protection to the sensors inside and also improved the usability of the device. The prototype JASMIN 1.0 is a proof of concept that emphasizes ease of use and utilizes oversize buttons and a large case. Future prototypes including JASMIN 1.1 will emphasize portability and durability and contain smaller components and push buttons.

5.5 Components

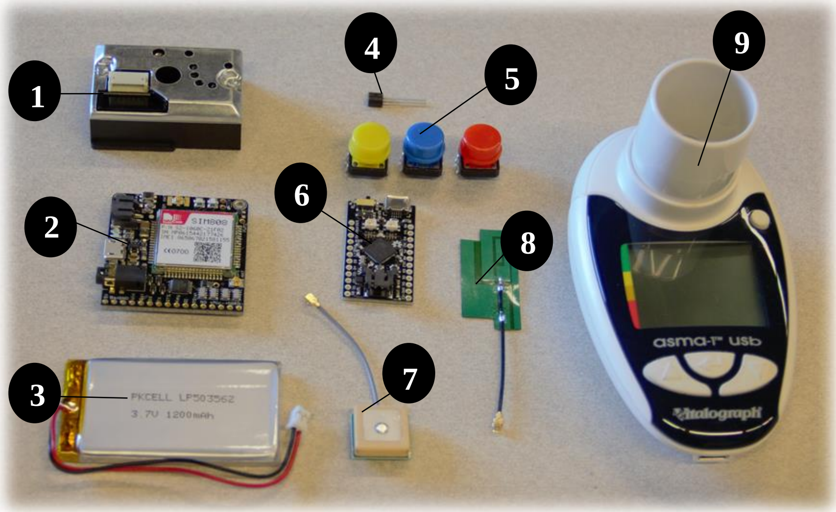


Figure 6: Components necessary in order to construct Prototype1.

Table 2: A description of the components and sensors included in Figure 6.

#	Component Name	Sensor Description
1	Sharp GP2Y1010 Sensor	Pollution Detection (smoke)
2	Adafruit FONA 808	Cellular GSM + GPS sensor
3	Lithium Ion Polymer Battery	1200 mAh Battery
4	TMP36 Temperature Sensor	Measure Temp. (±1°C at +25°C)
5	Push Button	Used for Tactile feedback
6	Qduino Mini	ATmega32U4 Processor Board
7	GPS Antenna	GPS Antenna
8	Cellular Antenna	3dBi uFL Antenna
9	Asma-1 usb PEF Meter	Peak Flow Meter

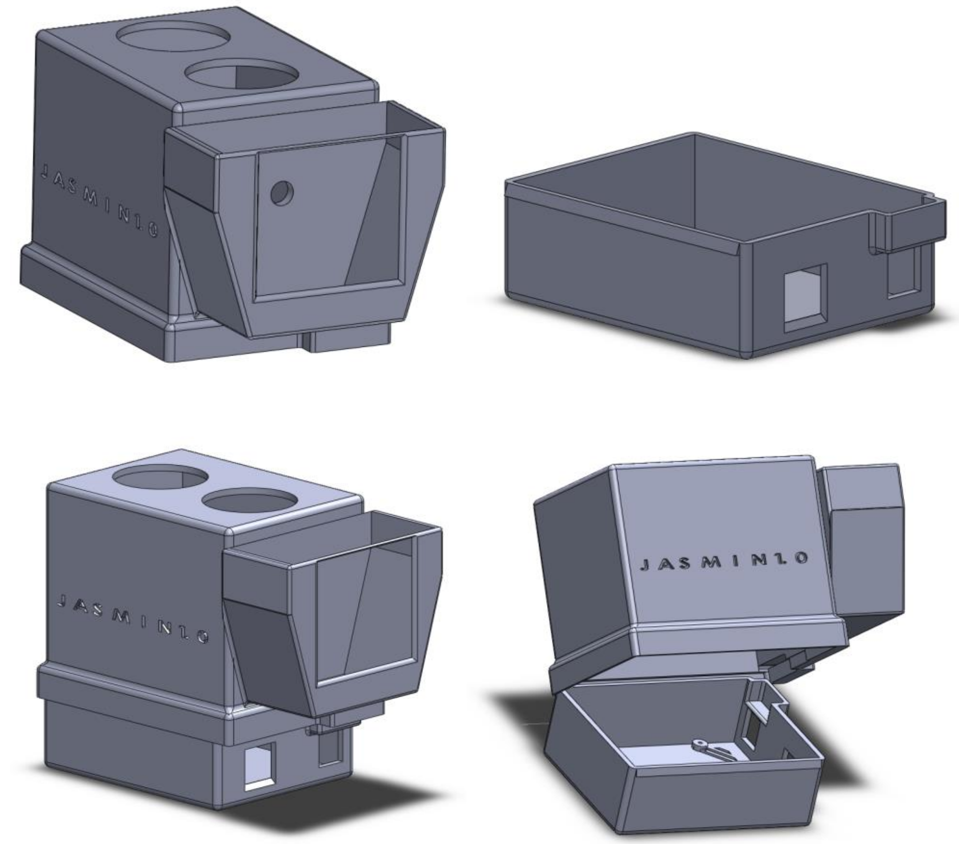


Figure 9: The concept of the latest iteration of Prototype1 called JASMIN 1.0.

5.6 Cross-Functional Flow Chart

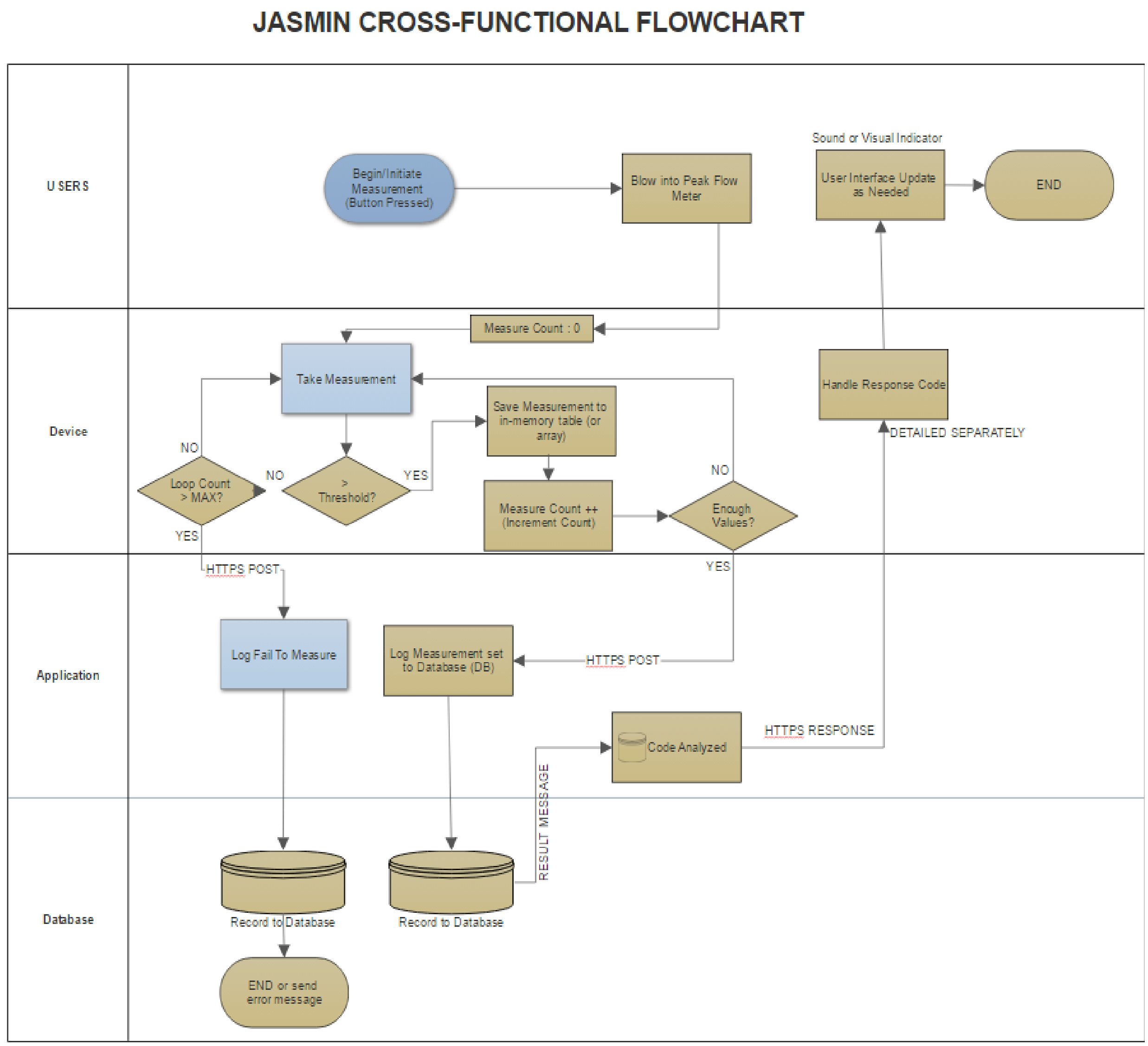


Figure 7: An overall chart demonstrating how each component of the JASMIN system interacts with each part. This diagram includes everything from inputs from the user all the way to what gets send and stored in a database.

5.7 Sensor and Other Component Selection

Peak Flow Meter

Peak expiratory flow (PEF) is a person's maximum speed of expiration and can be measured with a peak flow meter. A variety of devices exist to measure peak flow. One that was currently available was the Asma-1 usb PEF Meter. This peak flow meter was chosen due to its simple design and easy dis/reassembly.

Figure 8: The Peak Expiratory Flow meter was placed in front of a constant speed air source and the signal was analyzed during the prototype development.

Particulate Matter Sensor

Particulate matter (PM) pollution has been associated with asthma hospitalizations, emergency department visits, respiratory symptoms, and problems with pulmonary function (Lin, Chen et al. 2002). While both PM_{10} and $PM_{<2.5}$ are important, some studies have indicated that $PM_{10-2.5}$ showed stronger effects on asthma hospitalization than did studies only evaluating $PM_{2.5}$ and PM_{10} (Lin, Chen et al. 2002). A variety of particle

sensors that consider particulate matter in the air exist. The two general types of sensors include gravimetric and optical. Gravimetric sensors typically rely on weighing a filter after it has entrapped particulate material. Weight measurements taken before and after allows one to determine the concentration of particles in the air. Optical sensors are able to take measurements in real time. With these, sensors the aerosol particles are illuminated by a light beam and irradiate light onto a sensor. Recently adaptations of "dust sensors" have become available and increasingly used to measure PM pollution in the air (Cheng, Li et al. 2014). Several of these sensors have demonstrated a remarkably good agreement with commercially available instruments (Holstius 2014). However, it should be noted that the end users of these devices need to understand where data exclusion is required, as often little or no instructions on such matters are clearly defined by the sensor manufacturers (Williams, Kaufman et al. 2014). Many of these sensors rely on small resistors that heat air in order to draw it through the sensor body. PM sensors that have commonly appeared in literature are shown in Table 3. Example applications include general community monitoring and areas where a dense network or gradient with oversampling would provide high-quality estimates of spatiotemporally resolved concentrations of particulate matter (Holstius 2014).

Temperature and Humidity

A temperature and humidity sensor is considered due to the sensitivity to temperature and humidity that asthmatic patients face. Studies by Strauss, McFadden et al. (1978) have shown that symptoms can develop under a variety of conditions, including times when a patient is breathes in hot or cold air, especially during exertion, and when the air is particularly humid or dry. The cost, size, and dimensions of the DHT 11, which sells for

$1.08, or the DHT22, which sells for $3.09, allow each to make good fit in mobile projects.

Table 3: Commonly available "Dust" sensors capable of taking Particulate Matter Measurements.

Sensor	Sensor Type	Heat Element Present	Humidity (%)	Cost ($)
Shinyei PPD42NS	Optical	yes	< 80	11.95
Sharp GP2Y1010	Optical	no	-	12.00
Dylos	Optical	-	-	>500.00

Location

The use of a GSM module in the device can be utilized in order to get a general approximation of where the device itself is located. Each base station in a GSM network covers a small geographic area. The location of these towers can be utilized to provide a general location. A more accurate location coordinate can be acquired by using a GPS module inside of the device. However, GPS signals do not readily pass through structures, so there are limits to where a signal can be acquired while using a GPS module.

Light Sensor

A light sensor was used in order to help differentiate between environments. For example, a positive or good GPS signal combined with a high light value would indicate that a child is likely outside. Conversely a poor GPS signal combined with a low light value would indicate that a child is likely indoors. In either case, the GSM location would need to be utilized in order to determine the child or user’s approximate location. The

addition of the light sensor could help to determine if the child is indoors or out, which could be an important factor in determining the cause of an asthma exacerbation.

Push Buttons

Push Buttons were included on the device in order to facilitate ease of use in younger populations. This sensory input is one of the most basic functions learned at an early age.

Figure 9: Side and front views of Prototype1.

Chapter 6: The JASMIN Mobile Application

6.1 Target Market and Users

Table 4: An Overview of Functionality of Each User within the JASMIN application.

JASMIN Core Functions	Health Providers	Parents/ Guardians	School Personnel	Peers	Children with Asthma
Review Asthma Action Plans	☑	☑	☑	-	☑
Modify Asthma Action Plan	☑	-	-	-	-
Notifications and Reminders	☑	☑	Limited	-	☑
Review adherence data and inhaler use data	☑	☑	Limited	Limited	☑
AQI data	☑	☑	☑	☑	☑
Asthma Map (Location)	☑	☑	Limited	Limited	☑
Track Adherence Data (PFM, Clicker/Sensor)	☑	☑	Limited	Limited	☑
Track Inhaler Data (Clicker/Sensor)	☑	☑	Limited	Limited	☑

The JASMIN app was designed to connect all the participants that are involved in a patient's healthcare decisions and support. Each user group of the app has a different interface that contains information relevant to that user. For instance, a medical practitioner or healthcare provider has the ability to modify a patient's asthma action plan. However, other users of the app do not have the ability to edit the action plan. This action is specifically relegated to the medical practitioner or medical provider.

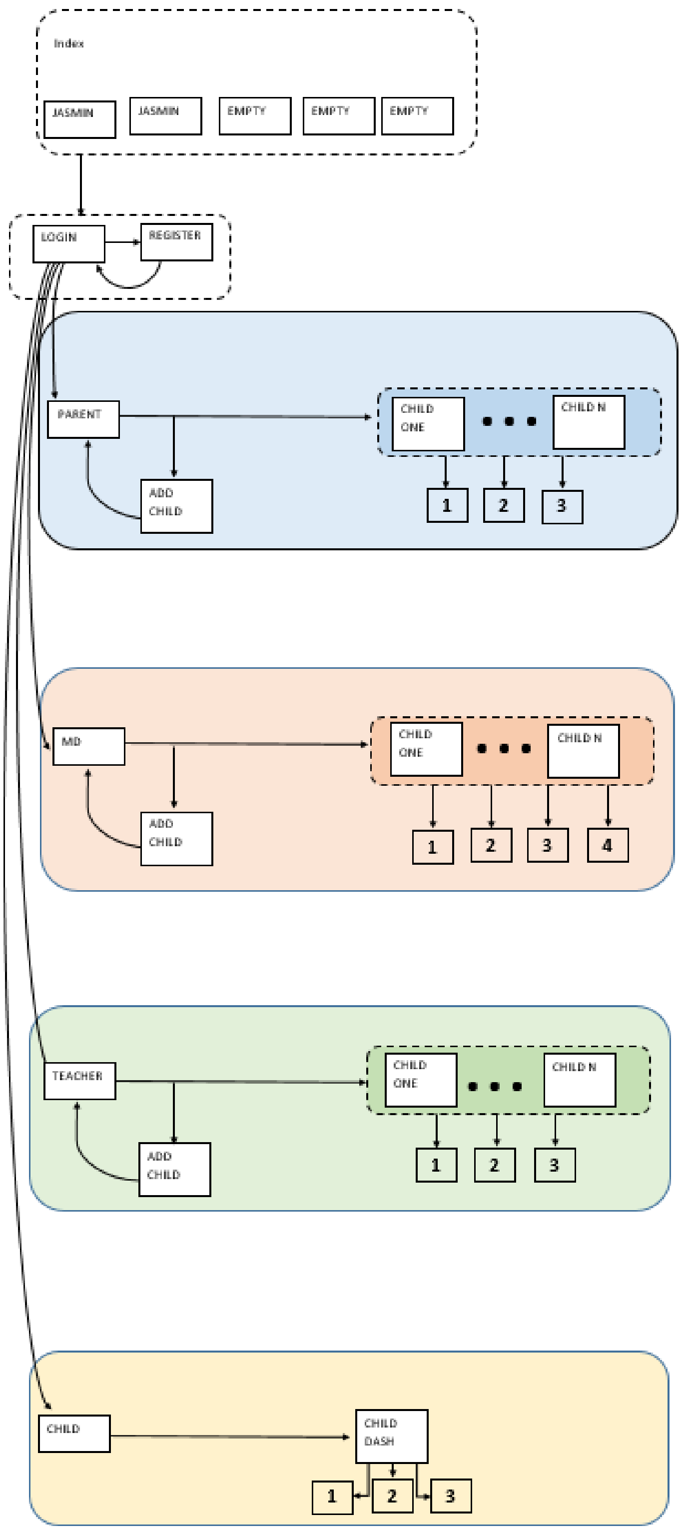
The JASMIN application UI development is shown in Figure 10 and 11 and includes the User Interface for all users including Child Users, Health Care Professionals, School Personnel and Parent/Guardians. Each of these groups has been addressed in order to increase the quality for all users. Some guidelines that direct the quality of health behavior apps has been developed by the National Institute of Health and Clinical Excellence (NICE) in the UK. The guidelines (NICE 2007) suggest the following shown below.

- Is the purpose of the app clear?
- Was the app developed in collaboration with the target group?
- Is the app easy to use and navigate?
- Does the app measure the user's initial motivation to change?
- Does the app demonstrate what successful behavior change and technique is?
- Does the app address maintenance and relapse concerns?
- How will efficacy and evaluation occur?
- Is there documentation available?
- Security?

Some of the other most common criticisms about the efficacy of apps meant to encourage health behavior change have been that certain segments of the population do not utilize smartphones or particular devices and that companies are vulnerable to particular vested interests, and that they have interoperability issues (the app works on one device, but not another). Steps were taken to ensure that all of these criticisms were considered and addressed as shown in initial sketches and wireframe mock up.

6.2 Initial Sketch and Mock-Up Diagram

Figure 10: The Overall layout of the JASMIN application.



1 ASTHMA HEAT MAP

- Google Maps
- Set up to Show "pins" where an asthma event occurred
- If there are many pins the area will light up in a heat map style
- Set by parameters such as 100 pins

2 PEAK FLOW USAGE | INHALER USAGE

- TABLE & CHART
- Shows Last 10 or 20 readings
- Shows Time and Date of Readings
- Simple Data Chart that that shows trends (Week, Month, Year, All Time)

3 Action Plan

- A displayed form that displays the instructions that are acquired from the MD's Edit Action Plan Page
- Boxes will appear on this in a way that looks good and is clear to the end user.

4 EDIT Action Plan

- Step by Step Additions or Edits that will show up under the Action Plan (#3) after submission (see edit action plan page)

Figure 10 Continued: The Overall layout of the JASMIN application.

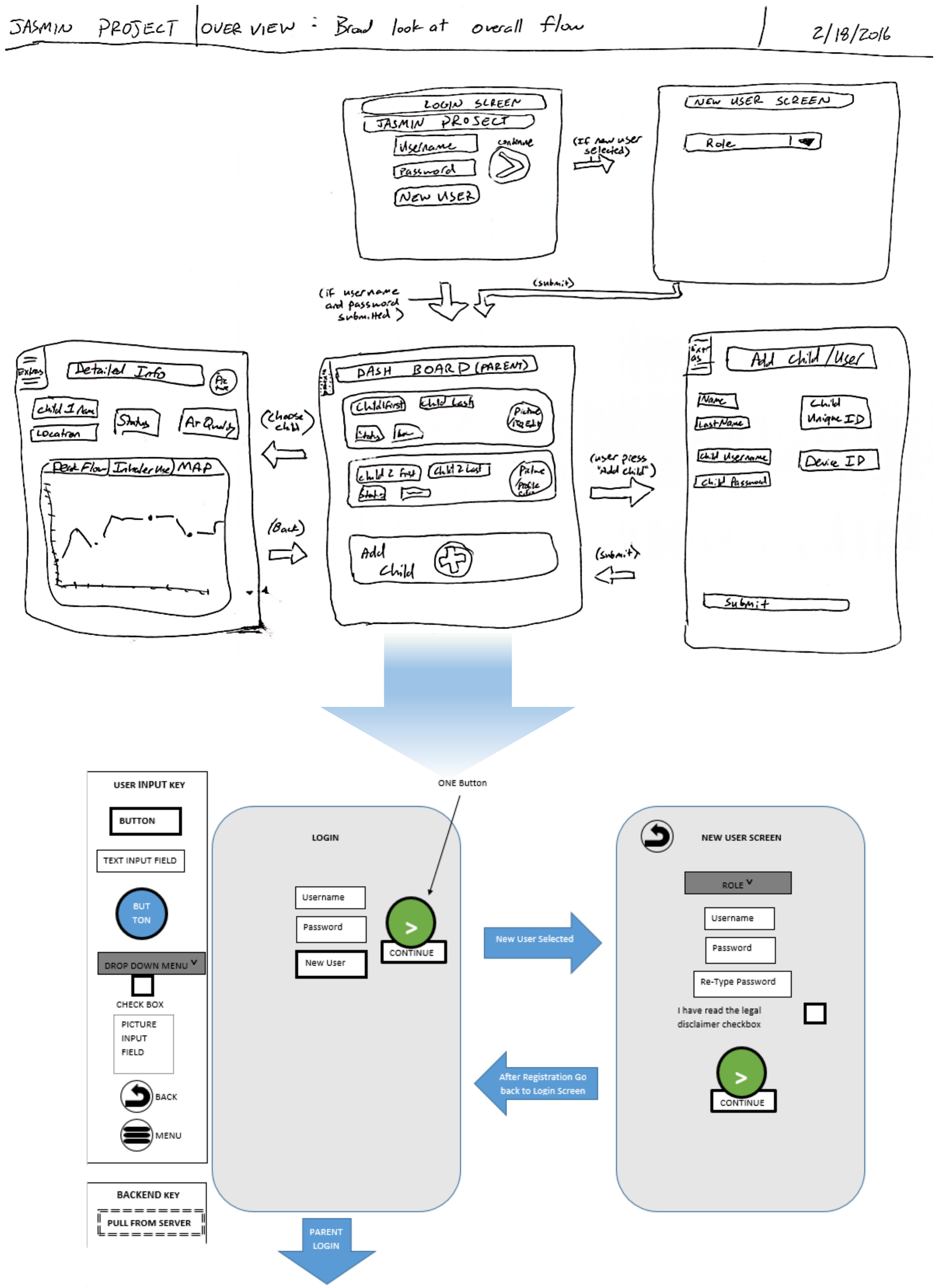


Figure 10 Continued: The Overall layout of the JASMIN application.

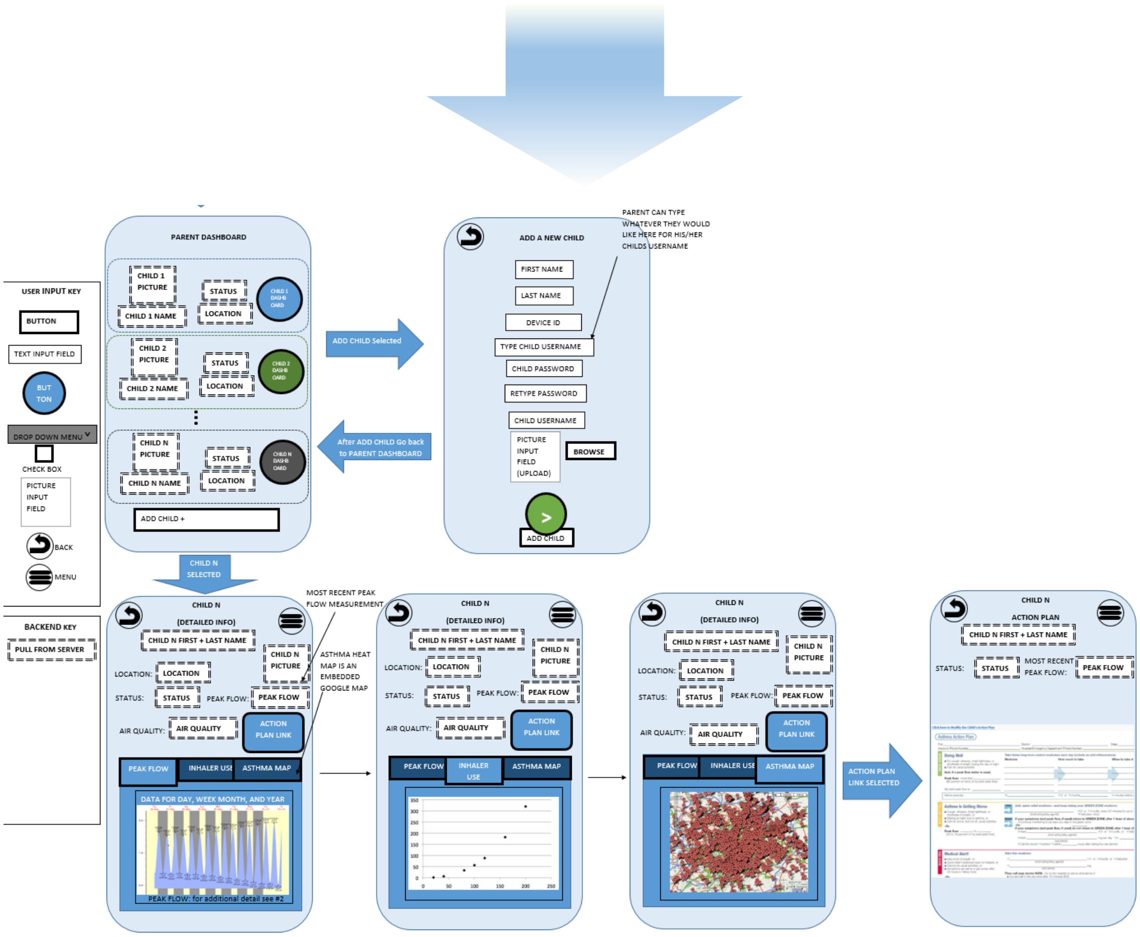


Figure 10 Continued: The Overall layout of the JASMIN application.

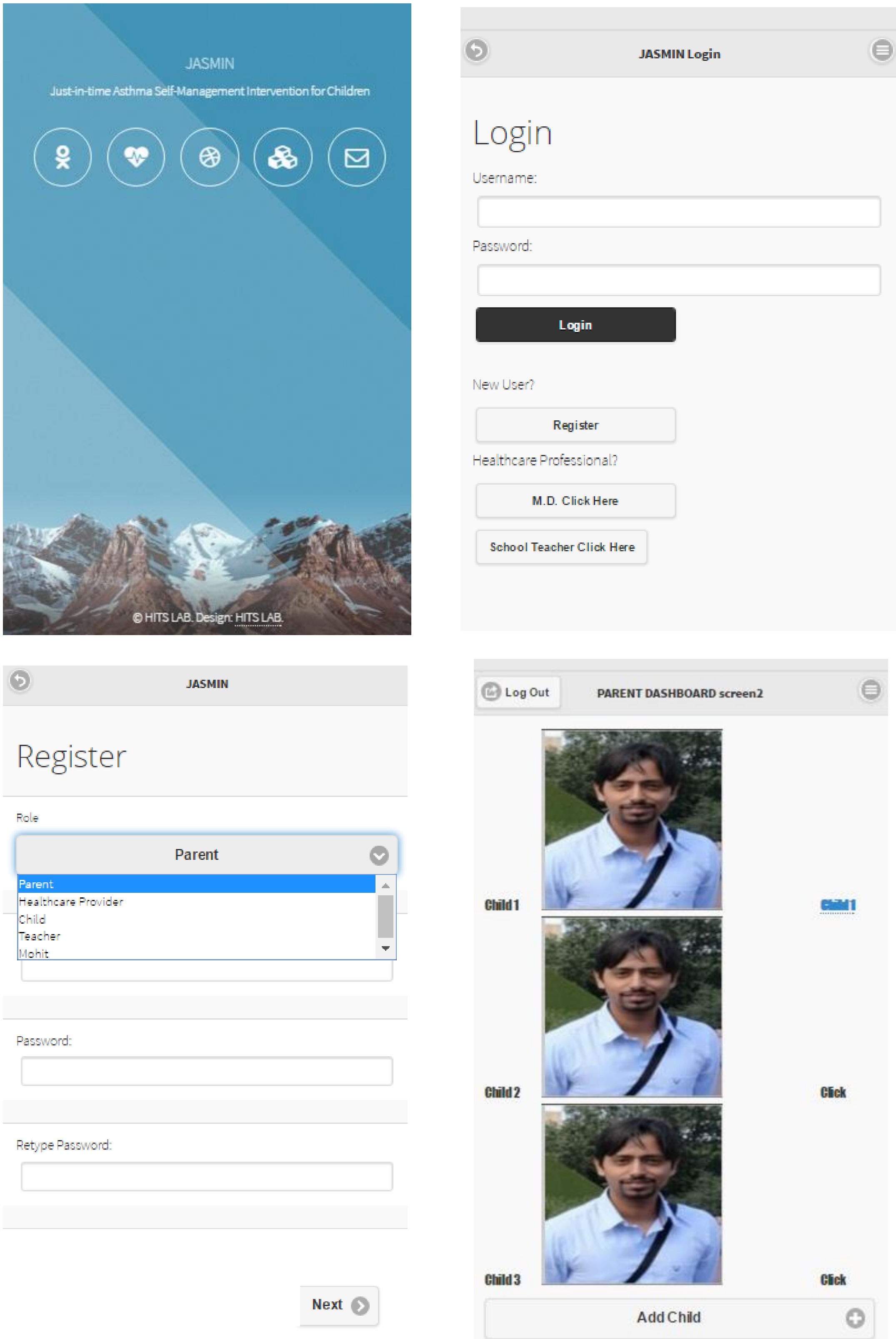


Figure 11: Proposed Screens for the Web Based Application

Chapter 7: Pilot Data

7.1 Database Information (What Gets Sent and How it is Displayed)

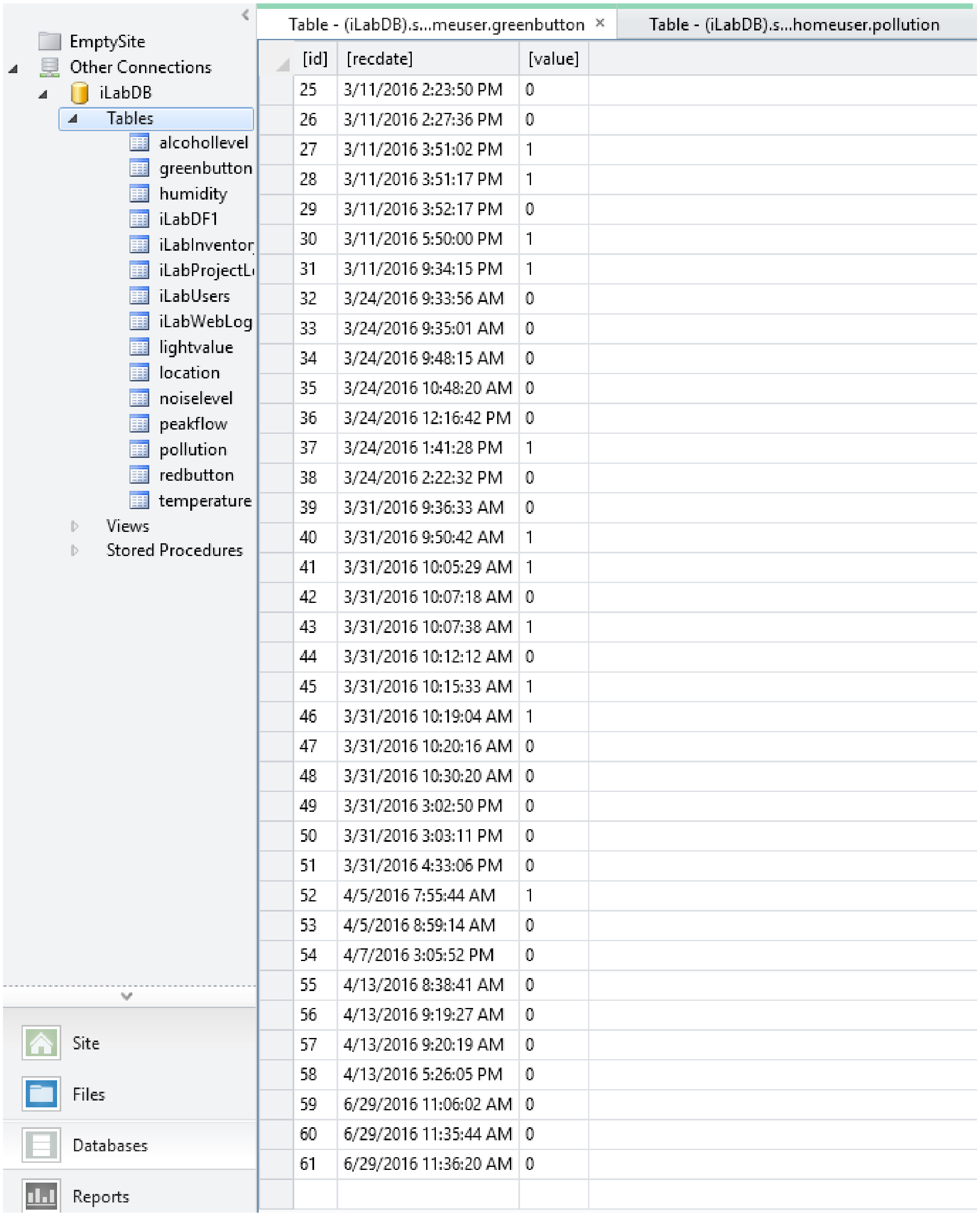
The program that is running on the Prototype1 device was set up to show what functions were operating when an event occurred. When connected to a screen, one can visualize what is going on with the device. For example, notice that there was a change in the level of pollution from a value of 0.62 to a value of 3291.16 in Figure 12. Such a rapid change in that value over the threshold initiates a sequence of events in which the device posts that data to the database. Notice a status of 200. This indicates that the value was successfully posted to the database. The device then resumes looping the program until another event occurs. Such an event could be a button press, a sudden change in temperature, or a peak flow measurement that is taking place.

Prototype1 ended up being quite versatile and possessed the ability to acquire and transmit the necessary information required for the overall system (Figure 5).

```
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
concentration of pollution = 1755.10

  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    The pollution is: 1755.10
        <--- ERROR
        ---> AT+HTTPINIT
        <--- OK
        ---> AT+HTTPPARA="CID"
        <--- OK
        ---> AT+HTTPPARA="UA"
        <--- OK
        ---> AT+HTTPPARA="URL"
        <--- OK
        ---> AT+HTTPPARA="CONTENT"
        <--- OK
        ---> AT+HTTPDATA=28,10000
        <--- DOWNLOAD
        <--- OK
        ---> AT+HTTPACTION=1
        <--- OK
Status: 601
Len: 0
        ---> AT+HTTPREAD
        <--- OK
        ---> AT+HTTPTERM
        <--- OK
0
concentration of pollution = 0.62

  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
concentration of pollution = 0.62

  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
concentration of pollution = 0.62

  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
  The RedButton state = 1  The Greenbutton state = 0  The Peak Flow value: 0    0
concentration of pollution = 0.62
```

Figure 12: A sample of the data displayed on the microcontroller that confirms a successful transmission of data to the database.

7.2 Database Display of Data



[id]	[recdate]	[value]
25	3/11/2016 2:23:50 PM	0
26	3/11/2016 2:27:36 PM	0
27	3/11/2016 3:51:02 PM	1
28	3/11/2016 3:51:17 PM	1
29	3/11/2016 3:52:17 PM	0
30	3/11/2016 5:50:00 PM	1
31	3/11/2016 9:34:15 PM	1
32	3/24/2016 9:33:56 AM	0
33	3/24/2016 9:35:01 AM	0
34	3/24/2016 9:48:15 AM	0
35	3/24/2016 10:48:20 AM	0
36	3/24/2016 12:16:42 PM	0
37	3/24/2016 1:41:28 PM	1
38	3/24/2016 2:22:32 PM	0
39	3/31/2016 9:36:33 AM	0
40	3/31/2016 9:50:42 AM	1
41	3/31/2016 10:05:29 AM	1
42	3/31/2016 10:07:18 AM	0
43	3/31/2016 10:07:38 AM	1
44	3/31/2016 10:12:12 AM	0
45	3/31/2016 10:15:33 AM	1
46	3/31/2016 10:19:04 AM	1
47	3/31/2016 10:20:16 AM	0
48	3/31/2016 10:30:20 AM	0
49	3/31/2016 3:02:50 PM	0
50	3/31/2016 3:03:11 PM	0
51	3/31/2016 4:33:06 PM	0
52	4/5/2016 7:55:44 AM	1
53	4/5/2016 8:59:14 AM	0
54	4/7/2016 3:05:52 PM	0
55	4/13/2016 8:38:41 AM	0
56	4/13/2016 9:19:27 AM	0
57	4/13/2016 9:20:19 AM	0
58	4/13/2016 5:26:05 PM	0
59	6/29/2016 11:06:02 AM	0
60	6/29/2016 11:35:44 AM	0
61	6/29/2016 11:36:20 AM	0

Figure 13: A sample display of data that has actually been sent to the database for analysis. The values shown above are for a simple push button switch located on the Prototype1 device.

7.3 Safety Considerations

Since both JASMIN's hardware and software components come in direct contact with inexperienced users, special precautions are necessary when deploying the product. The hardware must not cause any harm to the user while operating and the software must never make recommendations to a user that might put his or her health at risk. Safeguards must be built in to ensure that an erroneous piece of advice is not sent to a user that results directly in physical harm.

Chapter 8: Future Work

In order to evaluate the JASMIN program as a whole and evaluate its effectiveness, an exploratory study is proposed. The personalized, interactive iOS and Android compatible application (JASMIN) would be distributed to participants on Apple iPad devices. These iPads would be provided to participants in order to eliminate any cost barriers to participation. A 60 day study is proposed for patients with asthma ages 8-16 years old who have been prescribed at least one controller medication to assess if users engage in self-management behaviors. Users who do not have a smartphone that is compatible with the internet-based application or that was unable to be utilized throughout the day would also be assigned a Prototype1 device. Such a device would be able to be utilized at school and in other locations where a smartphone or other electronic device could be deemed a distraction and prohibited. Results from the short term study would evaluate whether or not medication adherence improved, asthma trigger avoidance skills improved, peak flow measurements were taken more often and understood to a greater extent, and electronic action plans were more closely adhered to than conventional paper action plans. Survey results at the beginning and end of the study would consider if the participants preferred smartphone/mobile applications to other methods that they previously received for asthma monitoring and education.

Other considerations when developing self-management models for an exploratory study would be to consider the national origin of the patient(s). Patients from one particular country might feel neglected in another based on prior experiences in healthcare facilities. For example, when working with Spanish-speaking individuals, some study

leaders noticed that patients felt neglected by the doctor or offered inferior care when they had a visit that was shorter than what they had experienced in their country of origin Lorig and Holman (2003). Designing applications that replace this important time spent with a physician could lead to dissatisfied patients. While the proposed exploratory study is to be based in Tennessee, there is no reason that it cannot be tailored to meet the needs of more specific communities within the U.S. and abroad.

Chapter 9: Discussion

By tracking where symptoms occur, pollutants and other contaminants that produce symptoms can be more readily targeted and more accurately mapped. While our goal is to more effectively manage asthma symptoms among specific patients the use of such data can be applied in a broader context to identify pollution hot spots in particular geographic areas or identify factors among a particular population. By combining the use of a peak-flow meter and environmental sensors with a smartphone app we believe that we can increase the adherence of patients using his/her prescribed action plan as well as reduce adverse symptoms due to asthma. Accurate collection of this data can also be helpful when addressing others' behaviors that contribute to uncontrolled asthma symptoms such as smoking cigarettes.

The development and testing of Prototype1 and the JASMIN system has the ability to improve many of the underlying issues surrounding chronic asthma care management on both an individual level and on a larger community-wide level. From medication adherence reminders to advice on what to while experiencing symptoms the JASMIN system presents a mHealth solution that after adequate testing has the potential to demonstrate real improvement in the lives of so many patients suffering from chronic asthma and ease the burden on caretakers.

References

Barlow, J., C. Wright, J. Sheasby, A. Turner and J. Hainsworth (2002). "Self-Management Approaches for People with Chronic Conditions: A Review." Patient Education and Counseling **48**(2002): 177-187.

Barrett, M., O. Humblet, R. Hiatt and N. Adler (2013). "Big Data and Disease Prevention." Big Data **1**(3): 168-175.

Bartlett, S. J., P. Lukk, A. Butz, F. Lampros-Klein and C. S. Rand (2002). "Enhancing Medication Adherence Among Inner-City Children with Asthma: Results from Pilot Studies." Journal of Asthma **39**(1): 47-54.

Brown, A., S. Disler, L. Burns, A. Carlson, A. Davis, C. Kurian, D. W. Jr. and K. Wilson (2011). "Family and Home Asthma Services across the Controlling Asthma in American Cities Project." Journal of Urban Health **88**(1): 100-112.

CDC (2001). Guide for State Health Agencies In the Development of ASthma Programs. U.S. Department of Health and Human Services.

Cheng, Y., X. Li, Z. Li, S. Jiang, Y. Li, J. Jia and X. Jiang (2014). AirCloud: A Cloud-based Air-Quality Monitoring System for Everyone. Conference on Embedded Network Sensor Systems, New York.

Davis, A. and E. Herman (2011). "Considerations and Challenges for Planning a Public Health Approach to Asthma." Journal of Urban Health **88**(1).

Dayer, L., S. Heldenbrand, P. Anderson, P. O. Gubbins and B. C. Martin (2013). "Smartphone Medication Adherence Apps: Potential Benefits to Patients and Providers." Journal of American Pharmaceutical Association **53**(2): 172-181.

End, C., S. Worthman, M. B. Mathews and K. Wetterau (2010). "Costly Cell Phones: The Impact of Cell Phone Rings on Academic Performance." Teaching of Psychology **37**(1): 55-57.

Finkelstein, J. and R. H. Friedman (2000). Telemedicine System to Support Asthma Self-Management. Information Technology Applications in Biomedicine. Arlington, VA, IEEE**:** 164-167.

Free, C., G. Phillips, L. Galli, L. Watson, L. Felix, P. Edwards, V. Patel and A. Haines (2013). "The Effectiveness of Mobile-Health Technology-Based Health Behaviour Change or Disease Management Interventions for Health Care Consumers: A Systematic Review." PLoS Med **10**(1).

GSMA, G. a. t. M. S. R. (2014). Children's Use of Mobile Phones. GSMA. Japan, NTT DOCOMO.

Herman, E., P. Garble and M. McGeehin (2010). "Assessing Community-Based Approaches to Asthma Control: The Controlling ASthma in American Cities Project." Journal of Urban Health **88**(1).

Himes, B. and E. Weitzman (2016). "Innovaitons in Health Information Technologies for Chronic Pulmonary Diseases." Respiratory Research **17**(38).

Holstius, D. (2014). Monitoring Particulate Matter with Commidity Hardware. Environmental Health Sciences, The University of California - Berkeley.

Huckvale, K., Mate Car, Cecily Morrison, Josip Car (2012). "Apps for Asthma Self-Managment: A Systematic Assessment of Content and Tools." BMC Medicine **10**(144).

Jerant, A. F., M. M. v. Friederichs-Fitzwater and M. Moore (2005). "Patients' Perceived Barriers to Active Self-Management of Chronic Conditions." Patient Education and Counseling **57**(2005): 300-307.

Kumar, S., W. J. Nilsen, A. Abernethy, A. Atienza, K. Patrick, M. Pavel, W. T. Riley, A. Shar, B. Spring, D. Spruijt-Metz, D. Hedeker, V. Honavar, R. Kravitz, R. C. Lefebvre, D. C. Mohr, S. A. Murphy, C. Quinn, V. Shusterman and D. Swendeman (2013). "Mobile Health Technology Evaluation: The mHelath Evidence Workshop." American Journal of Preventive Medicine **45**(2): 228-236.

Lin, M., Y. Chen, R. Burnett, P. Villeneuve and D. Krewski (2002). "The Influence of Ambient Coarse Particulate Matter on Asthma Hospitalization in Children: Case-Crossover and Time-Series Analyses." Environmental Health Perspective **110**: 575-581.

Lorig, K. R. and H. R. Holman (2003). "Self-Management Education: History, Definition, Outcomes, and Mechanisms." Annals of Behavioral Medicine **26**(1): 1-7.

McIntosh, N., N. Clark and W. Howatt "Reducing Tobacco Smoke in the Environment of the Child with Asthma: A Cotinine-Assisted, Minimal-Contact Intervention." Journal of Asthma **31**(6): 453-462.

McKenna, M. (2013). "The New Age of Medical Monitoring." Scientific American(308): 33-34.

Miller, K. E. (2005). "Value of School-Based Asthma Management Program." American Family Physician **71**(4): 790-794.

National Institutes of Health, N. H., Lung, and Blood Institute (2007). Expert Panel Report 3 (EPR-3)-Guidelines for the Diagnosis and Management of Asthma. NIH. U. S. D. o. H. a. H. Services. United States, U.S. Department of Health and Human Services.

Newman, S., L. Steed and K. Mulligan (2004). "Self-Management Interventions for Chronic Illness." Lancet **2004**(364): 1523-1537.

NICE (2007). Behavior Change: General Approaches. N. I. f. H. a. C. Excellence. United Kingdom.

ODPHP, O. o. D. P. a. H. P. (2016, 4/25/16). "Social Determinants of Health." 2020 Topics & Objectives Retrieved April 25, 2016, from https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health.

Pearson, M. L., S. Mattke, R. Shaw, M. S. Ridgely and S. H. Wiseman (2007). "Patient Self-Management Support Programs: An Evaluation." Agency for Healthcare Research and Quality.

Sawyer, D. (1996). An Introduction to Human Factors in Medical Devices. P. H. S. FDA, US Department of Health and Human Services, Center for Devices and Radiological Health. USA, Center for Devices and Radiological Health.

Strauss, R. H., E. R. McFadden, R. H. Ingram, E. C. Deal and J. J. Jaeger (1978). "Influence of Heat and Humidity on the Airway Obstruction Induced by Exercise in Asthma." The Journal of Clinical Investigation **61**(2): 433-440.

Sullivan, P., V. Ghushchyan, J. Campbell, G. Globe, B. Bender and D. Magid (2016). "Measuring the Cost of Poor Asthma Control and Exacerbations." Journal of Asthma.

Toelle, B. G. and F. S. Ram (2004). "Written Individualised Management Plans for Asthma in Children and Adults." Cochrane Database System Review **2**.

Verschelden, P., A. Cartier, J. L'Archeveque, C. Trudeau and J. Malo (1996). "Compliance with and Accuracy of Daily Self-Assessment of Peak Expiratory Flows (PEF) in Asthmatic Subjects over a Three Month Period." European Respiratory Journal **9**(5).

Wesley, K. M. and P. J. Fizur (2015). "A Review of Mobile Applications to Help Adolescent and Young Adult Cancer Patients." Adolescent Health, Medicine and Therapeutics **6**: 141-148.

West, K. L. (2014). mHealth: A Comprehensive and Contemporary Look at Emerging Technologies in Mobile Health In Depth Study/Overview, The University of Tennessee.

Williams, R., A. Kaufman, T. Hanley, J. Rice and S. Garvey (2014). Evaluation of Field-Deployed Low Cost PM Sensors. E. P. Agency, Office of Research and Development **R-14**.

Wyatt, T. H. and E. J. Hauenstein (2008). "Pilot Testing *Okay With Asthma*™: An Online Asthma Intervention for School-Age Children." The Journal of School Nursing **24**(3): 145-150.

Wyatt, T. H., X. Li, Y. Huang, R. Farmer, D. Reed and P. V. Burkhart (2013). "Developing an Interactive Story for Children with Asthma." Nursing Clinics of North America **48**(2): 271-285.

Vita

Phillip Charles Scruggs is a native Tennessean from Memphis, Tennessee. Born to the parents of Jerry L. Scruggs and Patricia A. Scruggs he has an older brother named Nathan Scruggs and a younger sister named Carmen Rose Scruggs. He completed high school at White Station High School and completed his Bachelors of Science in Biomedical Engineering at the University of Memphis, located in Memphis, TN. After completing an Internship at Wright Medical Technology as a Research and Development Intern he enrolled in the dual MBA and MS in Biomedical Engineering program at the University of Tennessee, Knoxville, and took an assistantship position under the guidance of Dr. Xueping Li in the Industrial Engineering Department. Phillip will graduate with his MBA and MS in Biomedical Engineering from the University of Tennessee - Knoxville in the summer of 2016.