Promoting adherence to daily PEFR measurement by college students with asthma

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introduction
“Assessing and monitoring asthma is an important component of asthma care. Asthma is highly variable over time, therapy may need to be adjusted. Self-management requires repetition and reinforcement.”

*Expert Panel Report: Guidelines for the Diagnosis and Management of Asthma, 2007*
DEFINITION

As defined by the National Heart, Lung, and Blood Institute (NLHBI)

“Asthma is a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role. In susceptible individuals, this inflammation causes recurrent episodes of coughing (particularly at night or early in the morning), wheezing, breathlessness, and chest tightness. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment” (NAEPP, 2007).

It is characterized by the interplay between an underlying inflammation, airway obstruction and hyperresponsiveness causing variable and recurrent symptoms. The interactions between these conditions can be further explained by the adjoining illustration adapted from the NHLBI report.

PREVALENCE

It is reported to be the most common chronic illness affecting children (Cordaro & Wamboldt, 2009). Over 20 million people in the US are affected by asthma in general, and nearly 9.1% (6.7 million) children as estimated by the 2007 National Health Information Survey. A study reported the total financial burden of asthma on healthcare to be $16.1 billion in 2004 (Shegog & Sockrider, 2010).

COMPONENTS OF CARE

As per the 2007 NAEPP guidelines, treatment for asthma focuses on controlling symptoms, reducing airflow limitations and preventing exacerbations.

The guidelines provide these four key components of asthma care.

1. Assessing and Monitoring Asthma Severity and Asthma Control

2. Education for a Partnership in Care

3. Control of Environmental Factors and Comorbid Conditions That Affect Asthma

4. Medications
A stepwise approach is then used for managing asthma. In order to initiate or control therapy asthma is classified on the basis of severity.

- Intermittent
- Persistent
  - Mild
  - Moderate
  - Severe

The Expert Panel Report recommends daily peak-flow monitoring for patients with:

- Moderate or severe persistent asthma
- History of severe exacerbations
- Poor perception of airway obstruction
- Worsening asthma

Monitoring peak-flow by patients may help assess asthma control but self-management requires repetition and reinforcement (NAEPP, 2007).

According to the NAEPP guidelines, asthma is highly variable and periodic monitoring can be achieved by instructing patients to monitor their asthma control through symptoms or peak flow meters.

**CLASSIFICATION**

**ASTHMA MONITORING**
Traditionally, asthma has been associated with younger children, however, researchers (Fedele, 2009) state that there is high prevalence of asthma in older children and young adults yet they remain an understudied population. The paper refers to a number of studies indicating that college students with asthma demonstrate more school absenteeism and may struggle more with unemployment in comparison to their peers.

Further, the researchers explore the effects of childhood onset asthma on the health related quality of life (HRQOL) in college students. Their findings have revealed that students with asthma are at a risk of diminished quality of life due to higher levels of illness uncertainty and lower scores on social functioning.

Studies indicate deficiencies in knowledge of asthma self-care in university settings (Reece, 2002). In this study, researchers developed a 42 point Asthma Severity / Management Survey (AS/MS) based on symptoms, treatments and pattern of seeking healthcare among other things. The researchers discovered discrepancies in the self-assessed severity of asthma by college students versus the actual severity based on the AS/MS scoring.

When researchers assessed asthma’s impact on a student’s life,
it was found that greater severity was associated with lower perceived health and self-confidence but higher stress and difficulty in coping with asthma care.

PHYSICAL AND ENVIRONMENTAL CHALLENGES

Young college students with asthma need to monitor their condition as asthma has shown to cause remodeling of the airways and can lead to pulmonary decline if untreated or undertreated. Therefore they are recommended to continuously monitor lung function even when asymptomatic (Cordaro & Wamboldt, 2009).

In addition, it has been reported (Painter, 2009) that environmental conditions in colleges such as dormitory environments may trigger attacks, increasing parental concern about their children moving away from home.

College years are marked by transitional social and academic demands and for students with a chronic illness it can put added pressure (Fedele, 2009). Therefore, it is important to investigate issues related to adherence and self-care practices in college students with asthma.
adherence

01.3.1 Adherence means making sure that the medication and other regimes are followed.
A literature review has revealed a repetitive common thread related to adherence issues specifically with adolescent population (Cordaro & Wamboldt, 2009; Kumar & Gershwin, 2006; Shegog & Sockrider, 2010; Shrimali, 2011; Yang, Sylva, & Lunt, 2010).

SUPPORT

Management of a chronic illness especially for children requires a strong presence of a support group which may include parents, siblings and other family members | friends, classmates and other peers | clinicians, nurses, teachers and other caregivers

MOTIVATION

There are two typical types of medications prescribed to asthma patients – everyday management medications and emergency rescue medications. The everyday management medications do not show any immediate results as they are preventive measures. Adolescents are more likely to over utilize rescue medications as they provide quick, instant relief. However, this tendency could worsen their asthma or lead to other complications.

MONITORING

Chronic conditions like asthma require constant monitoring and self-management in order to recognize changing symptoms and adjust medications accordingly. For example, peak flow meters are used to monitor a patient’s lung function to develop an asthma action plan that places a patient in a green zone (doing fine), yellow zone (some problems) or red zone (dangerous symptoms). This constant need for monitoring with possible family involvement may lead to negative feelings of nagging, babying etc. in adolescents.

SELF-IMAGE

Adolescents have been reported to hide their condition from peers as they may be viewed as being weak. In addition, they may ignore or not report symptoms due to reported coping strategies like “toughing up” or “sucking it up” to avoid the guilt they may feel for letting others down. Adolescents with asthma reportedly have a bleaker outlook towards future health and have decreased ability to participate in strenuous exercise, playing music or hanging out with friends.

TRIGGER AVOIDANCE

Some common desired activities or objects (pets, outdoors, exercise) may in fact be triggers for an asthma attack in specific patients. Identification and avoidance of such triggers is a key measure in self-management and adolescents may have problems in adhering to these measures.
existing solutions
“There is some additional software and a cable to download and graph the flows.

I did not purchase or use these extra items, but I like the idea that they are available.”

An Amazon Review on the Piko-1 Electronic Peak Flow Meter, January 2011
Existing solutions have been classified into four different categories.

**DEFINITION**

The first of these categories termed “Reminder Aids” refers to any device or equipment designed to remind users to take their medications on time.

**PRODUCT EXAMPLES**

Some of the products that fall within this criterion are day-of-the-week pill boxes with either manual or automatic dispensing.

Organizations like the Healthcare Compliance Packaging Council encourage incorporating compliance friendliness into pill packaging itself. Ecoslide RX is an example of one such product.
Gadgets such as watches and key chains to the more sophisticated GlowCaps by Vitality are available on the market today.

THE ELECTRONIC ADVANTAGE

Electronic devices can prove helpful in improving adherence. Vitality, for example, on their website (Vitality, 2010) states that in its recent tests, participants using GlowCaps achieved 86% adherence over a 3 month period which is substantially higher than the 50% average.

Studies (Helen et al., 2002) have also shown that median overall adherence to peak flow monitoring was as high as 89% over a 72 week period when the patients relied on electronic monitoring.
activity tracking devices

DEFINITION

The second category is termed “Activity Tracking Devices” and it refers to any device or equipment designed to keep track of a user’s daily activities through sensors like accelerometers used in pedometers.

Pedometers keep a count of the number of steps taken or distance traveled. Most often these devices need to be physically attached to the user by some means. Some of the more advanced devices offer ways to store the readings and chart progress over time.

02.2.1 UP (top)  
02.2.2 New Balance NB639 (top right)  
02.2.3 FitBit (right)  
02.2.4 MotoActv (far right)
PRODUCT EXAMPLES

There are many inexpensive pedometers available on the market. Nike+iPod Sport Kit, introduced in 2006, is an advanced pedometer that allows users to attach the sensor to their compatible Nike shoes. The readings from this device are synced with Apple devices like the iPod or iPhone, or a Nike+ Sportband.

Apart from workout metrics, other devices like the FitBit, introduced in 2008, allows users to also track their quality of sleep. Users have to clip the device into a wristband when in sleep mode. UP by Jawbone is a similar wristband style device that pairs with a user’s iPhone and keeps track of their activity, sleep patterns and diet. It has a built-in vibrator that can be set to remind the user to get up and move every user-defined period of time. On their product website (Jawbone, 2012), the creators claim that simply tracking activity may increase activity by 26%.

Some of the other notable examples include New Balance NB639 Earphones, MotoActv Wristwatch and the Striiv keychain that donates money based on activity.

THE ASTHMA LINK

A study (Firrincieli, 2005) examined the physical activity levels in young children using accelerometers. The study showed that children with a history of asthma or wheezing showed decreased levels of physical activity and the difference was most significant in cases of prolonged or sustained activity. Even people with exercise induced asthma symptoms are advised (More, 2011) to exercise lightly as it may help with their asthma.
modern asthma solutions

DEFINITION

The third category termed “Modern Asthma Solutions” refers to any recent device or equipment designed to monitor, control or treat asthma. These devices with the help of today’s computing technologies prove to be an improvement over its predecessors. Some of them are readily available on the market, while others are still under development.

A GPS-enabled inhaler (CNET, 2009) has been recently prototyped. It may help detect zones of high-risk for asthma patients by analyzing locations of where an inhaler has been used.

Similarly, a Bluetooth and IR enabled inhaler (Engadget, 2009) has been developed to provide reminders, track use of the inhaler and share those readings with health care providers.

ADVANCED INHALERS

In 2004, researchers from the University of Pennsylvania (Bogen, 2004) developed an electronic adherence monitor for Advair Diskus, a dry powder inhaler. This adherence monitor demonstrated the capability to reliably and cost effectively record the time and date of up to 300 dose deliveries.

02.3.1 PiKo (right)
02.3.2 Vitalograph (far right)

ADVANCED PEAK FLOW METERS

Moving beyond mechanical peak flow meters, in the early 2000s, electronic peak flow meters like Microlife and nSpire Piko became commercially available.

In 2003, Piko-1 was recognized as the Best Over-the-Counter and Self Care Product at the US Medical Design Excellence Awards.
These devices can be connected to a computer over a serial connection. Recently, the UK-based company Vitalograph has made its electronic peak flow meter with Bluetooth commercially available but, currently it is only sold in bulk volumes aimed primarily at researchers.

**OTHER ADVANCEMENTS**

In 2009, researchers at University of California, Berkeley (Seto, 2009) demonstrated the use of an on-body wireless system consisting of motion sensors, meter for air particulate matter, and GPS receiver all connected to a tablet style base station. This system allowed for personal and community level interventions for exacerbations based on environmental conditions and physical activity.

At the Georgia Institute of Technology, researchers (Yun, 2010) introduced technology probes into households with an asthmatic child to investigate the needs and desires of participants in real-world settings. Their system consisted of indoor and outdoor air quality reporting, electronic peak flow monitoring, and a web-based data application. They noted that the participants could use a combination of such technologies for better asthma self-management.
asthma web and smartphone apps
DEFINITION

The last category termed “Asthma Web and Smartphone Apps” refers to any web based or mobile application designed to monitor asthma and promote self-management.

APPLICATION EXAMPLES

In the previous chapter, researchers at Georgia Institute of Technology used Salud!, a web-based health data recording application in their study. This application allows users to track personal health information and provides visualization and analytical tools to promote self-management (Medynskiy & Mynatt, 2010). It can be found on Apple App Store and Android markets and even allows users to input data using text messaging.

Some of the other common examples of mobile applications in the Apple or Android markets are AsthmaMD, Asthma Journal, Asthma-Charter to name a few. These apps allow users to track their peak flow readings, triggers, medications, high risk locations or weather conditions. AsthmaMD in particular, also requests users to participate anonymously by sharing their data with researchers.

Another web-based application concept, by designer Perry Chan (Chan, 2011), takes the notion of sharing data further by building a social network for asthmatics to share their health information and motivate each other to improve adherence.
identifying components
It is essential to keep track of certain activities. This involves knowing the frequency, location and time when these activities may have been performed.

KEY ACTIVITIES

In case of asthma patients, the key activities that need monitoring are:

- Peak flow readings
- Use of controller medication
- Use of rescue medication
- Visits to high risk locations
- Triggers
- Occurrence of an asthma attack
- Environmental conditions like temperature and humidity
- Exercise and physical activity
03.1.1 Identifying Components: Activity Recognition
When the data is collected and processed the end result needs to be presented to the end user in a coherent manner.

However, it is also important to note that there are several stakeholders may need access to this information while respecting the privacy of the user.

Although, the user maintains the control over the information, sharing its visibility with other stakeholders like medical professionals, for example, may be critical.

DATA CHARACTERISTICS

- Access
- Visibility
- Control
- Privacy

STAKEHOLDERS

- User
- Parents and Family
- Peers
- Primary Care Physician
- Emergency Responses
03.2.1 Identifying Components: Information Access
In order to collect data about frequency of use, location or other relevant parameters, a number of sensors may be needed.

These sensors may be embedded in the device or the environment depending on the requirement.

Some of the potential sensors and meters needed to detect the key asthma activities are listed below.

**METERS AND SENSORS**

- Accelerometer
- Gyroscope
- Pedometer
- Pressure sensor
- Temperature sensor
- Humidity sensor
- Touch sensor
- GPS receiver
- RFID tags
- Microphone
- Camera
- Skin Galvanic Response
- Particulate Matter Meter
03.3.1 Identifying Components: Sensors
As mentioned earlier, sensors and meters may be embedded into a device or the environment.

INTEGRATED DEVICES

A sensor may be embedded into an existing device already being used by the user. The advantage is that some of these devices have some sensors built-in which could now be used for dual purposes.

- Tablet
- Smartphone
- Gaming Console
- Physical Activity Tracker
- Music Player
- Television

DEDICATED DEVICES

A dedicated device is created to serve a specific function. There is a lot more flexibility in terms of design opportunities for such a device. Depending on its purpose and use, its characteristics may vary.

- Ambient
- Wearable
- Combination
03.4.1 Identifying Components: Devices
user networks
“You don’t have to figure out asthma treatment on your own. An important step in asthma care is assembling your treatment team, and each member will help ensure you get the best possible asthma care.”

Who’s on Your Asthma Treatment Team?, EverydayHealth.com, August 2010
building your network

04.1.1 User Networks
Managing and maintaining control over a chronic condition like asthma is challenging for an individual and frequently requires a team effort. There are several parameters that may affect an individual’s condition and building a network of support around these parameters is crucial.

This location-oriented user network model has been created using a host of references. The nested Pediatric Asthma Initiative model on the bottom right of this page is an example of one such reference. It was developed at the Georgia Institute of Technology’s Health Systems Institute and is built on different “Ecological levels” (HSI, 2009).

**HOME**

The home network includes an individual’s family, friends and roommates that provide care and support at the home level. For college students, their housing arrangements on campus also form a part of this network.

**SCHOOL**

College students generally spend a lot of their time on college campuses. Apart from classes, students may also participate in recreational and leisure activities, attend social gatherings and get daily meals here.

**PRIMARY CARE**

Individuals with severe to moderate asthma may need to schedule frequent visits with a primary care physician. Students may have access to such physicians at the on-campus health centers. A primary care physician may also recommend pulmonologists, otolaryngologists and other specialists depending upon the severity of asthma (EverydayHealth.com, 2010).

**ENVIRONMENT**

Many asthma triggers may be dependent on environmental conditions like temperature, humidity, climate or pollution. Individuals may need to modify their lifestyle and living conditions accordingly.

**HOSPITAL**

During an asthma attack, emergency services like hospital EDs, ambulances and paramedics may form a critical part of the network to reduce the risk of fatalities.
mood boards for inspiration
“Words fail miserably when trying to translate design concepts.

A picture is worth a thousand words, and mood boards are a great tool to create that picture.”

*Why Mood Boards Matter, Webdesignerdepot.com, December 2008*
one of those bags there's credit card, which wasn't fixed out on a bedroom.
Before developing design concepts, mood boards were created using magazines and web searches to inspire creativity. Firstly the home environment was explored for opportunities.

For college students, this may comprise of dormitory housing provided by universities and roommates may also play a big role in this setting. College dorm rooms are often depicted as messy, cluttered spaces. Furniture and other home accessories designed for college students tend to focus on bright colors and bold prints. Convenience, space and cost considerations are a high priority. Study tables, lamps, large storage bins, twin/full sized beds, small room appliances are characteristic of this demographic.
school
Secondly, the college atmosphere was explored. The primary references for this category included college magazines, newsletters and alumni magazines. A deep sense of community stewardship, ambition, camaraderie and alma mater loyalty were key emotions expressed through these magazines. Athletic and social events were given a high priority.

Group activities showed a strong presence through pictures of study groups, student communities, athletic teams, cheering at athletic events, commencement ceremonies and ‘hanging out’. Students and their interactions with electronic gadgets like cellphones, laptop computers, headphones, gaming consoles was apparent which is discussed in the next section.
gadgets
Students and their interactions with electronic gadgets were apparent in the mood boards.

Small gadgets may be used as reminder aids. This mood board focused on the form of such commercially available small gadgets. Such devices included keychain objects, desk objects, wall mounted objects and hand-held objects. The main body shell was most often made of injection molded plastics in neutral colors like black, white, silver or gray. Many featured LED or LCD screen depending on their function. Body or contrast-colored buttons were found on most of these gadgets. Some even featured novelty forms inspired by pop culture references like Star Wars.
bags and accessories
College students were depicted carrying backpacks, large hand bags, cross body purses, messenger bags or gym bags. Accessories such as all-in-one wristlets, ID holders, lanyards and carabiners were also popular with students.

Accessories from youthful brands such as Vera Bradley were widely used and backpacks from brands such as Swissgear, High Sierra, The North Face and Patagonia were common. Bags and accessories designed for women featured bold, bright colors and floral or patterned prints. On the other hand, bags for men were monochrome or featured a bold accent color. They maintained a strong outdoorsy feel with several pockets, loops and net compartments.
fitness

Planks are a great way to build core strength, and they won’t strain your neck.

ARRIVED AWAY

A new way of working up a sweat outdoors:
There’s no need to store your stuff. Tote all those must-haves—without weighing down your pockets—with these smart accessories.
As described previously in the Activity Tracking Devices section, it is important for asthma sufferers to perform some daily physical activity for maintaining healthy lung function.

This mood board looked at prevalent fitness gear including apparel, electronic gadgetry, shoes and other accessories. Apparel showed monochrome pieces with aggressive lines that contoured and shaped the body. Bold, bright colors, and color block patterns were popular. Fabrics were sweat-absorbing and form fitting providing support and minimal intrusion. Accessories were made hands-free using different techniques like straps, buckles, clips, loops, hooks and wristbands to achieve this quality. They were all designed to enhance user performance.
preliminary concepts
“Cluster related ideas into themes. Consider the relationship between them and look for patterns.

You can group and re-group the data in different ways to help you identify opportunities.”

Human Centered Design Methods Toolkit, HCDConnect.org, April 2012
After understanding the problem at hand, reviewing literature findings, benchmarking existing solutions and gaining contextual background information; the next step is to build on this information and find design opportunities.

In order to achieve this, it is important to reflect upon previous findings and use it as a basis for exploring concepts. Several concept ideas may eventually fall under a common theme. It is necessary to find that commonality between concepts and subsequently create themes that envelope a body of concepts.

When developing concepts for college students with asthma six such themes were created which are shown alongside. These themes may comprise of several different individual concepts. For example, in the theme wrist watches and other wearables; apart from a wrist watch other wearable arm bands, ankle bands, chest bands also fall under this category.

These themes and their background inspirations are explained in the next few pages.
06.1.1 The six preliminary concepts or themes developed as possible solutions:

- Inhaler cases
- Earphones or headphones
- Wrist watches or other wearables
- At-home reminders
- Buckles or clip-ons
- Keychains or lanyards
BUCKLES OR CLIP ONS

Objects that can be attached to the user through buckles and clips fall under this category. Being hands-free is an important characteristic recognized by developing the fitness mood board.

This theme opens the doors to various different form considerations that allow for easy clipping techniques. Belt buckles, hooks, loops and other clips all belong to this theme.

INHALER CASES

Asthma patients are generally prescribed two types of inhalers – controller inhalers and rescue inhalers.

Controller inhalers are used on a regular basis as prescribed even when asymptomatic. Keeping track of such inhaler use could help improve adherence.

Rescue inhalers are used during an acute exacerbation. Keeping a record of rescue inhaler use may help track the frequency and location of an asthma attack.

Inhalers may come in different shapes and sizes dependign on the manufacturer specifications. However, designing cases enhanced with sensors may help track their use.
EARPHONES OR HEADPHONES

Mood boards for school life and gadgets showed a strong connection between college students and music. Headphones like Beats by Dr. Dre were popular with this demographic. Products like the New Balance earphones featured earlier were designed with music and fitness in mind. Heart monitors and/or pedometers could be integrated within the earphones used by students.

WRISTWATCHES OR OTHER WEARABLES

The fitness mood board examined various gadgets used while working out. A key characteristic in these products was the hands-free attribute.

Several types of arm bands are available for cell phones and music players while MotoActv is an example of recently launched wrist watch-music player. This theme includes concepts that may be worn with the help of straps by a user while working out.

AT-HOME REMINDERS

The home mood board demonstrated that a student’s room in a dormitory most often features a study space which includes a desk and work chair.

Apart from the desk, several other places around the home like bathroom mirrors, bedroom doors and refrigerators may be used to display reminder information at and around the home.

KEYCHAINS OR LANYARDS

The mood board depicting school life showed student’s commonly using lanyards to carry their college ID and keys among other things.

The bags and accessories mood board showed some of the all-in-one wristlets popular among college girls. In addition, backpacks feature plenty of loops to facilitate carabiner attachment.
“Develop empathy and connect emotionally with the people you are designing for, in order to understand the problems and realities of their lives.

You’ll need to think about where and how your solution will be used or experienced.”
recognizing user needs

After initial concepts have been developed it is important to start assess these concepts on different parameters developed from understanding user needs, technical feasibility and other considerations. This helps develop a set of design criteria. As a first step towards developing such criteria, it was necessary to observe and recognize the user needs.

ONLINE SURVEY

In order to gain user insight, first an approval from the Institutional Review Board was obtained. An online survey was conducted and participants over 18 years were invited to participate. In addition, it was essential for these participants to be currently enrolled at a college or university and living away from their family home. All the participants self-reported that they had been diagnosed with asthma. Seven completed responses were considered and other fourteen partially completed responses were ignored.

Findings show that over 52% participants have in the past or presently use a web and / or smartphone application to monitor their relevant daily activities. Most of the participants were rarely prescribed hence carried a controller inhaler with them. Most of them were prescribed some kind of rescue inhaler, however, only about 28% always carried it with them.

The most significant finding was the significantly low use of the peak flow meter. Only one participant had received an asthma action plan. Lastly, while over 57% participants remained neutral about the currently available asthma management options, the same percentage would like to see more asthma-related accessories (inhaler cases, travel packs, exercise monitors) to help manage their condition.

I check my peak flow readings regularly

52

07.1.1 Survey question and results
CAMPUS OBSERVATIONS

In addition to the survey, campus wide observations were made to gain a better understanding of college student behavior. Several people were observed using earphones and headphones while walking, studying, working out and eating on campus. Lanyards were popular and commonly held college IDs, keys, flash drives and coupon cards.

Other badge holders with retractable cords and belt clips were as commonly observed. As depicted in the mood boards, all-in-one wristlets were very common among college girls. Like lanyards, they included a key ring to hold a host of objects.

Other commonly observed objects were carabiners on backpacks or lanyards used for similar purposes. Some observed examples are shown below.

07.1.2 (Clockwise starting from top left) Earphones used by a student, lanyards for sale, badge holder with belt buckle, wristlets at the recreation center, wristlets for sale, wristlet hooked to a backpack
The next essential step of the process is to construct a technology matrix with potential features and their associated characteristics. Such a matrix can be used to recognize the most relevant and feasible features that need to be included in order to optimize the functionality of the final concept.

### UNDERSTANDING THE MATRIX

The columns of the matrix represent each potential feature that can be included in the concept. Background research helps provide a list of such potential features.

On the other hand, the rows of the matrix represent a characteristic property. This associated
characteristic may be beneficial or detrimental. The final selection of features depends upon the number of desirable and undesirable characteristics associated with each feature.

In this matrix, undesirable characteristics are shown as red elements, desirable characteristics are shown as green elements, and neutral characteristics are shown in white. The blue columns are the final selected features, in this case - Peak flow meter readings and activity tracking.

UNDERSTANDING THE FEATURES

Most of the features like considered in the matrix are directly related to asthma management. Features like GPS, Weather Alerts and Activity Tracking have shown some significance and they can provide important information such as temperature, humidity, location and physical activity levels.

Last two features, music and flash drive, have no direct connection but are nice-to-have and can be easily integrated into the device.

UNDERSTANDING THE CHARACTERISTICS

Some features require a certain characteristic such as a screen in order to be usable while for others such a characteristic may not be an essential requirement to function.

WiFi, 3G, Bluetooth and Infrared offer different commonly used modes of communication between devices. Some features may need an alert mechanism with visual, tactile or auditory feedback to remind the user.

Relevancy refers to the significance of the contribution made by the inclusion of this feature. Place of use and frequency of use try to estimate when and where the device may be used. Uncertainty of use increases the undesirability of a characteristic.

Finally, prototyping feasibility estimates the ease of integrating each feature in the final concept.

RESULT

The top two features were selected based on the number of desirable characteristics and feature relevancy.
In the end, a set of design criteria were established by assimilating and learning from previously gathered body of knowledge. These criteria would form the basis for concept selection and evolution when we begin converging ideas. They can be described as follows.

**PROVIDE DAILY REMINDERS**

Our goal to achieve improved adherence levels can be achieved if the device can serve as a reminder aid by providing timely visual, tactile or auditory alerts to the user.

**SEAMLESS INTEGRATION**

College students are juggling their academic and social lives while managing a chronic health condition. Any successful solution provided needs to seamlessly blend in with everyday rather than increase their burden.

**PEAK FLOW AND ACTIVITY TRACKING**

Using the technology matrix we have determined that peak flow meter readings and tracking of physical activity are key features that need to be implemented to optimize the functionality of the concept.

**FUNCTIONAL FORM AND STYLING**

The form and styling of the device needs to reflect its function and environment of use. Mood boards helped determine that the device should embody a neutral base color with bright, boldly colored, contour accent lines.

**HIGH LEVEL OF PRIVACY**

Survey indicated that although a user’s friends and peers may know of their condition, the user did not wish to share this socially. Therefore, the device should incorporate a level of privacy and abstraction to respect their choice.
07.3.1 Different design criteria that have been established to form the basis for future iterations.
converging ideas
“Evaluating outcomes is important to the learning cycle.

A good assessment of a solution provides an opportunity for reflection that will inform the direction and goals for the next round of designs.”
08.1.1 Concepts selected using design criteria

evaluation of concepts

TOP THREE CONCEPTS

SELECTED CONCEPTS

These selected concepts will be evolved further in the next round of iterations and testing.

- Buckles or clip ons
- Earphones or Headphones
- Keychains or Lanyards

ELIMINATED CONCEPTS

These eliminated concepts did not sufficiently satisfy the previously established design criteria.

- Inhaler Cases
- Wristwatches or other wearables
- At-home Reminders
UNDERSTANDING THE EVALUATION TABLE

The evaluation table provides a summary of how the concepts were judged and subsequently eliminated.

The columns indicate each theme or concept category while each row examines the fulfillment of an existing design criterion. When a criterion is fulfilled the cell color is green. On the other hand, if it does not satisfy the requirement the cell color is red.

The selected concepts satisfy all the design criteria and are thus highlighted in blue.

ELIMINATION OF INHALER CASES

The inhaler case concept did not meet the requirement for seamless integration as the survey indicated that the users did not carry an inhaler with them at all times.

It also violated the peak flow and activity requirement as it may not be possible to get an activity reading if the case is with the user for most of the time.

ELIMINATION OF WEARABLES

The concept of a watch or other wearables also did not meet the requirement for seamless integration. The user may feel like wearing different types of watches or would not like to feel the compulsion to wear one particular watch for all occasions. Other wearables that are strapped to the body may also get uncomfortable if worn at all times.

ELIMINATION OF AT-HOME REMINDERS

At-home reminders are designed for the home environment and not for mobility. Mobility is a key characteristic for tracking of physical activity. Without this attribute the at-home reminders fail to perform this function.

College students may be required to share their accommodation and housing with other roommates and peers who may or may not be aware of their condition. Introducing a device into this environment may not provide the required level of privacy.
The selected concepts were taken to the next level of development. Extracting richer information from these concepts would be possible by creating study models. Such study models can help provide the scale of a product.

When interviewing potential users, these study models quickly and easily communicate the idea behind the concept and ensure that both the designer and the user are on the same page.

These study models were not used to embody the final form of a concept or idea, instead they were used to test and demonstrate its size or function.
KEYCHAIN OBJECT

A study model for an object to be placed on a keychain or a lanyard was created by using a key ring, and wrapping foam around it.

EARPHONES

The next study model was created by wrapping foam around the microphone of an old pair of earphones.

BELT BUCKLE

The belt buckle of an existing small sized pedometer was used as a study model to demonstrate the third concept.
08.3.1 Keychain object was the most preferred solution followed by earphones and belt buckle.
Once the study models were ready, ten college students who represent the potential users and/or peers judged each of these concepts. They were asked which of these objects would they choose to use given their preferences and experience with physical activity trackers or pedometers, earphones and keychains.

A keychain object was voted as the most preferred concept and was viewed to be the most convenient of all three. Most students believed the keychain object to be the something they would carry with them at all times.

As the most preferred option, a keychain object would be refined in the next stages of the process.

“These are great! I find them very convenient and I take it everywhere.”

“I usually carry my earphones with me but I know few people who don’t”

“I have used them while working out; I feel other girls may not like to use them.”
“All things in nature have a shape, that is to say, a form, an outward semblance, that tells us what they are, that distinguishes them from ourselves and from each other.”

*The tall office building artistically considered, Louis H. Sullivan, March 1896*
It was determined that a keychain object was the most preferred solution among the three finalized concepts. In the next stage of the design process steps were taken to estimate the form of such an object.

The ability to attach this device to a keychain is an important characteristic. The ability to communicate with a peak flow meter requires an easily accessible infrared port. Taking cues from a peak flow meter cradle it is possible to create some forms with a recess to hold the peak flow meter.

Also, it is possible to incorporate a carabiner-like loop that can open by pushing in one side. As some people did prefer using buckles, it can also be integrated into the form of the object. Some sketches and subsequent white models were made out of sine foam for further testing.
09.1.1 Models and sketches
user preferences 2.0
Once again, college students, being the potential users and/or peers were asked about their preferences for the final form of a plausible keychain object.

VOTING FOR THE FINAL FORM
The white models previously created with sine foam were judged by the students. Different shapes and sizes were laid out in front of them, along with their sketches and each student voted for their favorite form. The form that received the most number of votes is shown on the left page.

VOTERS" THOUGHTS
The students did not appreciate the recess for an infrared port featured in some of the models.

The selected form has an inline infrared port and smooth curves. A couple of the voters liked the smallest form because of its size and mentioned that they would have liked to see smaller and sleeker objects.

LIMITATIONS
During the prototyping stage, it is important to mention that certain limitations arise due to feasibility and time constraints. Although, an effort is made to achieve both high fidelity and high volume, designers need to find the middle ground. When several models need to be built, the level of detail incorporated into each model is low. White models offer an adequate level of detail for such purposes.
After the most preferred form was determined, then next step of form refinement followed. In order to refine the form it is necessary to first replicate the original form using computer aids.

**SOLIDWORKS MODEL**

In order to better understand the form and add details, a 3D model was built using Solidworks. This model helped understand the proportions of the object. Solidworks also laid the foundation in understanding the manufacturing and assembly considerations and material choices.

Modeling in Solidworks also made it possible to export the objects to a 3D printer and build prototypes to scale.

09.3.1 Form evolution (below)
09.3.2 Renderings of different models (right)
LESSONS FROM THE FIRST MODEL

The first model built and exported from Solidworks consisted of two LED lights on either side of the object for depicting physical activity. When examining the form from a manufacturing point of view these LED lights seemed excessive and were eliminated.

The original peak flow meter also uses a single button operation which turns the unit on or off along with the infrared transceiver. This operation would be incorporated into our device.

A single button would be used to scroll through the different modes - ON, PEAK FLOW, PHYSICAL and OFF therefore using the screen to show peak flow readings and physical activity.

CHANGES IN SUBSEQUENT MODELS

In the subsequent models, efforts were made to reduce the overall size of the object. The Solidworks model was created using parametrically derived equations. This increased the ease of form manipulations and development of potential configurations i.e. making it shorter, thicker or wider if needed while maintaining the overall form of the object.

The last refinement made the form more organic yet maintained the parametric relations. This was achieved by building it four parts instead of two halves - top and bottom panels and two side panels that snap in from either side.

This arrangement draws parallels with the stylistic cues derived from the bags and accessories, and fitness mood boards.
building a proof of concept
“Testing an actual model is far more informative than all the imagination you can muster. Identifying weaknesses becomes easy when you can test the actual device in real terms.

There are always surprises when you test the device.”

*Why Prototypes are Important, iFPfrontline.com, January 2002*
A working prototype was built to demonstrate the feasibility of the device and its sequence of use.

**FUNDAMENTALS**

PiKo-1 is the peak flow meter model by nSpire Health. It is one of the most common and widely used peak flow meters on the market. It uses a bidirectional port to communicate with its cradle that is connected to a computer by a USB. The computer runs their software called PikoNet to download and display the readings.

Depending on an individual’s age, height and asthma severity, their reading may fall under the green (good), yellow (caution) or red (danger) zones. This is shown by an arrow on the PiKo-1 screen.

An infrared receiver was used to intercept this communication. This infrared receiver was powered and run by an Arduino Diecimila unit.

Also connected to the unit are three LEDs - green, yellow and red which correspond to the previously mentioned green, yellow and red zones.

The whole circuit was labeled and assembled into sheets of corrugated cardboard.

**HOW IT WORKS**

The PiKo-1 unit and cradle communicate through infrared signals. When both the units are initiated and their infrared ports face each other information gets downloaded from the unit to the cradle. In order to
display this information the cradle is plugged into a computer. Our device intercepts this communication and uses the LEDs as a means to display the information.

This setup has been created for a single reading. If the device needs to store multiple readings, each past reading would be saved on a memory chip and multiple sets would be required. Ideally, our device should display past 30 readings. If the user consistently records one reading a day then they should, at a glance, get a picture of their lung function for nearly the past month.

Accelerometers are used in pedometers to convert change in acceleration into step count.
STEP 1. TURN ON THE UNIT

STEP 2. OBTAIN A READING

STEP 3. TURN ON THE RECEIVER

Instead of displaying the information as number of steps, the same information can be portrayed to the user as green, yellow, and red zones. This way the same hardware can be used to shuffle between the two modes on the actual unit. Therefore, a user can now visualize their peak flow meter and physical activity readings for the past one month.

SEQUENCE OF USE

Once the unit has been turned on, the user takes one deep breath in and exhales into the peak flow meter. The meter records the peak expiratory flow rate or the speed with which an individual can get air out of their lungs. It is used as an indication of airway obstruction.
Once a reading has been obtained, the individual can then turn on and initiate the receiver. While the infrared ports face other the transfer is initiated.

While the device is downloading the data, the indicator LED keeps blinking. Once the download is complete the unit lights up a green, yellow or red LED depending upon the information that has been received from the peak flow meter.

LIMITATIONS

The PiKo-1 unit communicates with the cradle using a proprietary infrared protocol. Several attempts were made to decode this protocol, however, at this time the protocol could not be recognized.

Some of the common protocols like the NEC, Sony, RC-5 and RC-6 were compared to the raw signal data picked up by the receiver, however, no match was found. A new library developed for the Arduino environment by Ken Shirriff (Shirriff, 2009) was used to receive and interpret the data.

Though the receiver can intercept the signal, the microprocessor does not interpret it. This is the reason why the LEDs cannot be made to light up according to the appropriate zone.

If the device were to be developed in association with the original manufacturer, this matter can be easily resolved.

10.1.2 Sequence of use
conclusion
The final product would be called PiKo+, a new addition to the nSpire Health line of products.

The screen essentially will be an array of multicolor surface mount LEDs. A tactile switch connected to a PCB will be used to control the unit.

The base is thicker and would make room for a surface mount IR tranceiver and a coin cell which is most commonly used to power similar devices.

The body would be made from injection molded plastic with metal rim inserts for the bezel, key ring and edges.
large key ring

single button

infrared port
future possibilities

We always strive to improve and build on what currently exists. Therefore, as we conclude this project there are few added possibilities for the future of systems like PiKo+ that have been proposed.

FORM DEVELOPMENT
The form has gone through several iterations, however, each new iteration brings with it a body of new knowledge and higher level of refinement.

More form refinements could focus on optimizing the design for manufacturing with due consideration to material choices.

ELECTRONICS
This project has touched base broadly on some the hardware and software requirements of this system. An in-depth study is needed before these products could be manufactured commercially.

MANUFACTURING
Key materials, method of assembly and components needed for the device have been identified. However, a comprehensive bill of materials would provide more accurate production cost estimates.

INFRARED PROTOCOLS
Access to the infrared protocols used by PiKo-1 would completely enhance the functionality of the working prototype. More experimentation and research could be undertaken in this matter to
recognize the protocol.

**BLUETOOTH**

Newer peak flow meters such as the ones currently developed by Vitalograph use Bluetooth technology to communicate instead of infrared or serial connections. When these meters become more commercially available it would be worthwhile to explore the possibilities offered. As most tablets, smartphones, and laptops come equipped with Bluetooth capabilities, PiKo+ could just as easily be connected with these devices for richer information.

Even before that happens, PiKo+ could be enhanced with added Bluetooth capabilities to leverage the immense benefits of using mobile apps.

**CHRONIC CONDITIONS**

Asthma is a chronic disease that requires continued care and management. Monitoring an individual’s lung function is an essential indicator of the severity.

However, there are many other prevalent chronic conditions like Type 2 Diabetes that too require periodic monitoring of health. Such a system can be extended to other chronic medical conditions.

11.2.1 The prototype showing the infrared receiver (left)  
11.2.2 Bluetooth module (top)


01.2 College Students

01.2.1 http://www.studentoncampus.com/on-campus/crazy-dorm-rooms/
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01.3 Adherence

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02.1 Reminder Aids

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02.2 Activity Tracking Devices

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02.3.2 http://www.vitalograph.com/images/products/enlarge/electronic_pfm_large.jpg
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02.4 Asthma Web and Smartphone Apps

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02.4.2 https://salud.cc.gatech.edu/welcome/

04.1 Building your Network

04.1.2 http://asthma.hsi.gatech.edu/overview/

011.1 Final Product Overview

011.1.1 http://www.batteriesinaflash.com/images/coincells/COMP-33_SANYO.jpg
011.1.1 http://i54.tinypic.com/ay58rb.jpg
011.1.1 http://www.vishay.com/docs/81211/tfdu6103.pdf