End-user programming tool for creating custom health surveys with automatically generated reports

AN ABSTRACT OF THE PROJECT OF

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Online survey data collection is becoming popular because it provides benefits in cost, ease of
collecting and managing data, flexibility in format, and access to a diverse population. Surveys
are often used for health studies such as Oregon State University's WAVE Project, which utilizes
the WavePipe system, a server enabling scientists to create studies, enroll subjects and their
mobile devices, collect data from the devices and surveys and view/export data for analysis.
This Master's project presents an enhancement that lets scientists provide feedback to study
subjects in response to their survey answers, thereby potentially helping to influence those
subjects' behavior. Scientists can import surveys into studies, select goal-settable questions
from the surveys and allow subjects to set goals on those questions. Surveys are sent and
responses collected over a period of time. The new sub-system automatically generates custom
reports for each subject by aggregating survey responses with the subject's goals. This way,
scientists are not only collecting survey data, but also educating the subjects by providing
feedback. An evaluation of the sub-system with a graduate student (representing the scientist
side of the system) and with subjects showed that it is both usable and understandable.

ACKNOWLEDGEMENTS

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1   Introduction

Online data collection is popular because it provides researchers with benefits in "reduced time, lowered cost, ease of data entry, format flexibility, ability to capture additional response-set information, and ability to access different population" [1].

In this thesis, the word 'subject' refers to a person who participates in one or more research studies, while 'scientist' refers to a researcher conducting the studies.

The use of surveys by scientists is usually unidirectional, as a source of data from subjects. Health scientists create and distribute surveys with the intention of collecting data to be later used for analysis. For example, scientists at Oregon State University (OSU) can conduct health studies that track subjects' nutritional and physical activities using a health-research dashboard called WavePipe [2]. Collecting daily diet information from subjects through online surveys is a part of the study. The existing system serves scientists by providing built-in surveys to choose from, while sending surveys to subjects. Unfortunately, a software developer's involvement (for changes in the code) is needed in order to change or add a survey. In addition, the system has lacked a means of automatically generating feedback to individual subjects. That is, as with many other studies, information flow has been unidirectional toward the scientists.

In contrast, this master's project investigates how it might be possible to enable scientists to generate custom feedback to study subjects in response to survey data, thereby facilitating bi-directional communication. The focus is on studies related to health and nutrition. By using surveys, scientists could benefit from collecting data, and subjects could benefit from receiving

feedback on survey responses, thereby contributing to subjects' learning and awareness about nutrition and physical health.

The new sub-system, called WavePipe Survey Reporter, achieves this goal through two specific enhancements. First, integrating the Qualtrics survey tool [3] [4] enables scientists to create and deploy custom surveys. Second, WavePipe Survey Reporter generates reports by aggregating Qualtrics survey responses for each subject over a period of time. In addition, the report includes three new parameters: *goal questions, scientist expectation and subject goals*. These parameters provide the linkage between what information the subjects provide and what information appears in feedback.

Specifically, '*goal questions*' are a subset of the actual Qualtrics survey questions that a scientist selects in order for them to be included in the report. For instance, a goal question might be "How many times did you eat vegetables today?" A '*scientist's expectation*' is the expectation of the scientist for each goal question in a survey. It is expressed in the form of three color ranges--red, orange and green—corresponding to negative, neutral, and positive feedback. These color ranges are non-negative, increasing and continuous. For instance, the scientist might consider eating vegetables 0 times to be negative (red), 1-3 to be neutral (orange), and 4 or more to be positive (green). A '*subject's goals*' is the goals that the subject sets for the goal questions at the beginning of the study. Each subject may set his or her own goals. For example, a certain subject might set a goal of eating vegetables at least 3 times per day.

The report generated for a subject includes goal questions, the average for the goal questions on survey responses collected over a period of time, color highlight over the average in red, orange or green depending on the range that the average falls under and the subject's goals for the goal questions.

The tool for creating surveys and generating reports was tested with a graduate student in health science. Through this evaluation, an important feedback was that the graduate student wanted to continue using the tool. Also, most of the other feedbacks about the tool were positive. In addition to this evaluation, the reports were also tested with 6 graduate students into health science studies. This evaluation showed that most of the students liked the report for its content, presentation, color choices for the ranges, etc.

WavePipe Survey Reporter is an end-user programming tool. "End-user programmers are people who write programs, but not as their primary job function. Instead, they must write programs in support of achieving their main goal, which is something else" [5]. 'Programs' in this context refers to writing computer code. According to this definition, health scientists in the WAVE project, who program WavePipe and its new survey reporter tool to conduct studies and analyze data, are end-user programmers.

Programs created by end-user programmers are "just small parts of the much larger contexts of their lives at work and at home". It is important to understand "how programming fits into end-users' everyday life" while designing tools for them [6].

Finally, [7] estimates that "90 million American workers" would have used computers in 2012, out of which "over 12 million workers" would have done "programming in a self-reporting sense". These factors have been instrumental in developing an end-user programming tool for health-scientists of the WAVE project that they could use to solve their work-related problems.

2   Related Work on Tools for Creating Surveys and Reports

Numerous tools exist for helping scientists and others to create surveys. Other tools existing for helping them to create reports. The WavePipe Survey Reporter appears to be the first tool that enables health scientists to automatically generate personalized reports to study subjects based on custom surveys.

Several tools exemplify the range of options that scientists have had for creating custom surveys. The authors in [8] state that "Developing forms, particularly surveys, is a common requirement of end users, and several tools have been developed to support this task". For example, Quask FormArtist (FA) [8] is an online-form development tool. It allows an end-user to design, deploy, notify, fetch data and analyze web forms. Neither FA nor any other tool discussed in the paper include the feature of automatic report generation that the WavePipe Survey Reporter includes.

Other similar tools include the following:

- CLICK (Component-based Lightweight Internet-application Construction Kit) [9] is a web-based application development tool that is targeted towards non-programmers. It focuses on creation of web application and provides Excel data export functionality.
- SURVEYMAN [10] provides scientists with a domain-specific language to create surveys. It "applies static analysis, randomization and dynamic analysis for locating survey errors and ensure the quality of responses".

- The Questionnaire Programming Language (QPL) system [11] allows the author to create web-surveys. This system provides real-time summary statistics report for each question in a survey.

- Topsl [12] is another domain-specific language that "provides a layer of abstraction and allows programmers to express surveys clearly without having to write non-domain-specific code while still being able to write surveys with novel control-flow elements".

- SurveyMonkey [13] is a popular web-survey tool that provides many survey related features like creating and designing surveys, distributing surveys, collecting responses and reporting. SurveyMonkey allows an author to view/share/export data and create customized reports from responses intended to be shared with other scientists and not subjects.

- Formsite [14] is a web-based survey tool that provides almost the same features that SurveyMonkey [13] provides. The reports generated in Formsite are also meant for other scientists and not subjects.

- Instant.ly [15], SurveyGizmo [16], SocialSci [17] and LimeSurvey [18] are also web survey tools that have limited features for reporting back to scientists.

- Google Consumer Surveys [19] is a web-survey tool used to answer business questions by asking "everyday-people – not just those who choose to participate in research panels". Scientists have to choose the target audience and type the question. The question is then displayed in online news, entertainment sites, etc. Reports are provided back to scientists. Also, the scientist doesn't get to choose the target audience. The

audience is automatically generated based on the criteria set.

- Qualtrics [3] [4] is an online survey tool that allows scientists to create and design surveys and analyze the results later. It creates custom reports viewable in its user interface. The reports can also be mailed to other scientists.

All of these tools, including the tools discussed in [20] have in common the limitation of not providing a means of generating reports back to subjects. In particular, none of them provides a means whereby the scientist or subject can specify expectations or goals for converting subjects' survey data into reports.

In addition, there are several tools for creating reports. Some of them are discussed as follows:

- Crystal Reports [21] is a tool that is used to create reports. It allows its users to "design and generate reports by pulling data from a wide range of data sources" [22].
- Tableau Software [23] [24] is a business intelligence and analytics software that allows its users to visualize and understand data from various data sources.
- IBM Cognos Report Studio [25] [26] is a powerful report tool that can generate reports that use both "textual and graphical formats to allow complex relationships to become quickly evident".
- [27] describes a tool that generates drilled-down reports from relational databases. The report supports pie-charts, bar charts, cross-tabbed reports, etc.
- [28] describes a surveillance and reporting system that "allows a user to monitor and

generate reports" from multiple sources. It allows users to configure reports from web-based control panel and the reports can be in the form of tables, graphs or charts. It also allows users to receive reports via email.

- A reporting tool that uses "Programming by Example" methodology is described in [29]. The tool consists of a user-interface where a user creates a sample report using example data from a relational database table. The tool "extracts the implied formatting rules" and interprets the rules to generate reports taking relational database tables as input.

- [30] describes a "pattern-directed" reporting tool that enable users to design reports using reusable report fragments. The tool retrieves data from SQL queries directed towards relational tables.

- Business Intelligence and Reporting Tools (BIRT) [31] [32] is a charting and reporting tool integrated with the Eclipse platforms. It provides APIs for creating data visualizations and reports that "can be embedded into rich client and web-applications, especially those based on Java and Java EE". The data can be supplied through many sources like databases, JDBC, XML, etc.

- GARP [33] is a tool that creates web reports based on relational databases (any DBMS supporting SQL queries through JDBC drivers). The final reports are JSP files formatted using XSL templates. The tool is targeted towards tacking the problems of constantly-changing database and the need to re-write past web reports.

- [34] introduces a document-driven approach to report generation wherein "the content of a report can be specified using a transformation language together with queries that

retrieve data from different databases". The report is exported as an SGML document that can further be saved into other formats.

- [35] describes a visual application called Table Presentation System (TPS) to "support visual programming for data transformation". Data transformation is the process of converting the layout of the data source to the layout of the report. TPS helps creating database reports without writing data transformation programs.

- [36] presents a custom-made medical data reporting tool used for "creating medical data models, extracting and filtering data from medical information system's database, and generating reports".

- JFreeChart [37] and JasperReports [38] are open-source Java reporting tools that allow visualization and reporting of data from many data sources. They provide libraries that can be used by Java developers to take advantage of reporting capabilities offered by professional reporting tools.

All of these tools have in common the limitation of not providing a means of creating custom surveys for data collection.

SuperTracker [39] [40] is a health reporting tool targeted towards educating people about nutrition and physical health. Unlike WavePipe Survey Reporter which sends subjects survey links for tracking daily activities, SuperTracker requires a user to log in every time to do the same. Also, SuperTracker does not generate reports containing the scientist's expectations. A

subject has to search for the ideal recommendations. Also, there is no way for a scientist to customize SuperTracker questions.

In addition, [41] reviews some nutrition/physical activity tracking mobile applications. None of the reviewed mobile applications support activity tracking through surveys.

3. Background: Limitations of WavePipe

The WAVE Project [2] is a group of health scientists and researchers at Oregon State University that are committed towards improving the health and lifestyle of athletic high school adolescents. WavePipe is a system that allows researchers in the WAVE Project to conduct health studies involving human subjects. The system allows scientists to create studies, enroll subjects and their mobile devices, collect data from the devices and surveys and view/export data for analysis. In short, it is a health-research dashboard to manage studies. The WavePipe Survey Reporter extends this existing WavePipe system.

3. 1. The need for enhanced survey capabilities

WAVE Project scientists often need to modify surveys delivered by WavePipe for operational adjustments, especially in community-based research. They need to add or remove or change the existing questions in the static survey present in the system and deploy the changes again in order to collect new data. So far, such changes have required a developer to manually change the questions according to the scientists' needs. Moreover, adding new surveys requires a developer to manually design and create surveys by writing code and deploy the new surveys into the server. During this process, a developer needs to understand the requirements, design, develop the feature and then finally test the system before it can be successfully deployed for the scientists' use. This is a very time-consuming process that would,

if continued, contribute to the need for retaining graduate students to make changes to the surveys in the future.

Since changing and adding new surveys are common requirements for the system, it would be more cost-effective for a developer to not be involved in the process, but to rather to provide a reusable, configurable tool that a scientist could use to create custom surveys for generating personalized reports. A finding by Hewlett-Packard suggests that "reuse can have a significant and largely positive effect on software development" [42]. A piece of code that is reused multiple times results in higher quality standards and reduces development time. The paper also suggests that "Because the product has already been created, tested, and documented, productivity increases because consumers of reusable products need to do less work". Thus, this master's project also aims at consuming existing reusable tools for developing WavePipe Survey Reporter.

3. 2.   The need for enhanced reporting capabilities

The WAVE project involves monitoring subjects by asking them to fill the same survey every day for a certain period of time. Giving subjects feedback about their survey data would be helpful because the purpose of the research project is to understand how to help children learn better lifestyle physical activities and healthy eating habits. Providing feedback to subjects might help to reinforce desirable behaviors and discourage undesirable behaviors. "The main task of any piece of software used for medical, or any other data analysis or processing – is to

create clearly formatted, well defined and readable reports" [36] [43] [44]. A study conducted on computer-tailored nutrition education concludes that "personalized dietary and psychological feedback is more likely to be read, remembered and seen as personally relevant compared to standard materials" [45]. Another study concluded that "computer-tailored nutrition information is a promising means of stimulating people to change their diet towards dietary recommendations" [46]. Another study concluded that their "tailored intervention led to more attention, involvement and cognitive processing than non-tailored intervention" at a family-level [47].

Unfortunately, none of the tools reviewed provide subjects with reports (Related Work, above). Therefore, there is a need to create a new reporting tool linked to survey responses.

Moreover, the health scientists on this project would also like subjects to set goals on certain survey questions before the study starts (subject goals). Once the study concludes and all the survey responses are collected, they would like subjects to see a comparison of the average of their response for each goal question and their goals. None of the current tools available allows subjects to set goals and receive reports comparing responses and goals.

These deficiencies in existing tools and the scientists' requirements have motivated us to develop the WavePipe Survey Reporter that tries to solve these problems.

4. Survey and reporting sub-system for WavePipe

To solve the problems mentioned in the previous sections, new features are provided in the WavePipe Survey Reporter. Because all faculty members at OSU have access to Qualtrics survey tool and they have used it in the past for managing online surveys, Qualtrics was the choice for integration with the WavePipe Survey Reporter and to bring all the data from Qualtrics into it, the Application Programming Interface (API) that Qualtrics provides was leveraged. This API gives developers the power to control every Qualtrics functionality through code. This made it possible to read surveys into the WavePipe Survey Reporter and display relevant Qualtrics survey-related information to the health scientists in a web user-interface. This would enable scientists to change surveys frequently and view the survey responses.

To deal with the need for individualized reporting, the WavePipe Survey Reporter also includes a feature that would allow health scientists to import an existing Qualtrics survey into WavePipe and then select a sub-set of the original questions along with the red, orange and green color ranges for the questions (goal questions). Once the questions are selected, the scientist could send email links to subjects clicking on which the subjects can set their own goals for those questions (subject's goals). Once the study finishes and all the Qualtrics responses have been brought to our system automatically (using Qualtrics API), another proposed feature would automatically aggregate survey responses for each subject and generate custom reports containing the average of the responses, the subject's goals along with the appropriate color highlighted over the average based on the range under which the average falls and the

subject's goals. These reports would then be sent to subjects by email.

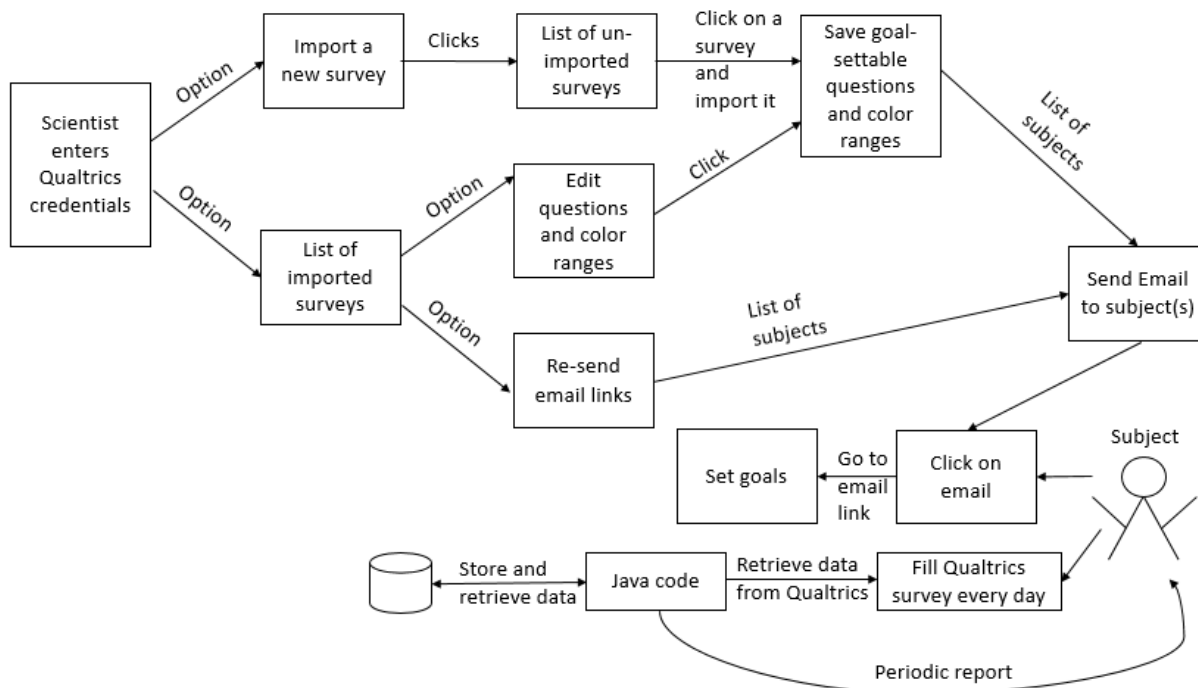The overall sequence of steps to generate customized reports is as shown in Figure 1 below.

Figure 1. Use case covering the WavePipe Survey Reporter

The following subsections describe the WavePipe Survey Reporter in detail.

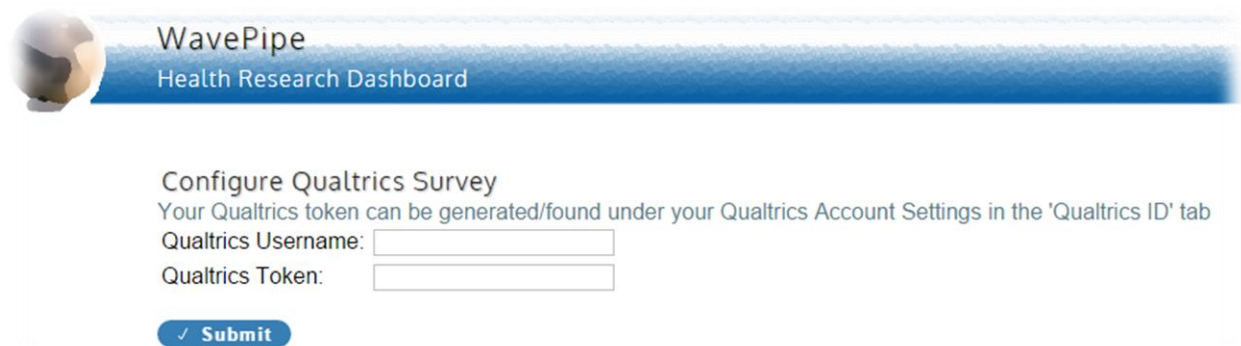### 4.1. Background: Process whereby a scientist sets up a study and a custom survey in existing systems

Health scientists of the WAVE research project at OSU currently use a health research dashboard WavePipe that helps them conduct studies. The dashboard allows them to configure studies, enroll subjects, send surveys that are built-into the application, assign mobile devices like Android phone, Fitbits etc., and collect & view data collected from the above media.

For the proposed features to work, a scientist first creates and configures a study on WavePipe. Once that is done, the next step is to enroll subjects by entering their names, email addresses, unique ID, etc. These features are already present in the current system.

Next, the scientist creates a survey for the study in Qualtrics, which is an existing 3rd party system external to WavePipe that provides custom survey-editing capabilities. The health researchers on the WAVE project preferred to integrate with existing system rather than have a new one implemented that they would have to learn to use. The survey serves two purposes in the WavePipe Survey Reporter: Firstly, the survey would be taken by registered subjects for a certain period of time. Secondly, the survey would be imported into WavePipe and goal questions are going to be used to periodically generate custom report for each subject based on their survey responses.

4.2.   New sub-system: Step-by-step process whereby a scientist imports and configures a custom survey

Once the survey is created on Qualtrics, the scientist goes to the study in WavePipe and clicks on a new option in the study menu called 'Configure Qualtrics Survey'. This option is used to import or edit Qualtrics surveys present in the scientist's Qualtrics account. Clicking on the option prompts the scientist to enter his/her Qualtrics credentials as shown in Figure 2.

Figure 2. Page to enter Qualtrics username and token

A Qualtrics credential consists of the Qualtrics username and token. The username is the same ID used to log in to Qualtrics. The token is a unique key (generated for each Qualtrics user) for interacting with the Qualtrics web services through API calls. Generating a token is a one-time task and requires the scientist to access his/her Qualtrics account and generate a token in the Account settings. An illustrated explanation to get the API token is provided by Qualtrics [48]. Once the scientist enters the username and token and clicks on 'Submit', one or

two options can be seen depending on whether the scientist is using the feature for the first

time for that particular study.

Assuming that the scientist is using the feature for the first time in the current study, the

dashboard prompts the scientist to import a survey from Qualtrics into the study. To do this,

the scientist clicks on the option displayed in Figure 3 below.
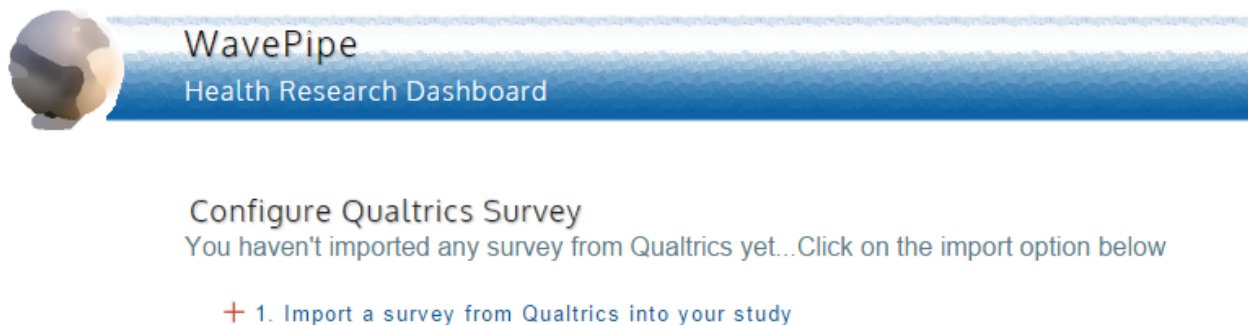
Figure 3. Main page for a first-time user of the feature

On clicking the option, Figure 4 displays the list of all surveys present in the scientist's

Qualtrics account that have not been registered in the dashboard yet.

Figure 4. List of un-imported surveys

The scientist clicks on the Qualtrics survey to be imported and registered with the study on WavePipe. On clicking on a survey for registration, a confirmation is asked from the scientist for the same. Confirming the action imports and registers the survey with that study.

The next step is for the scientist to decide the goal questions for the survey. Goal questions are items in the survey for which the scientist wants to specify what the subjects' answers ideally "should" be. For example, based on federal nutritional guidelines, the scientist might want to specify that a question about servings of vegetables is a goal question, and that

the ideal answer is in a certain range. To do that, the scientist clicks on the button 'Click here to decide the goal questions for the survey' as shown in Figure 5.
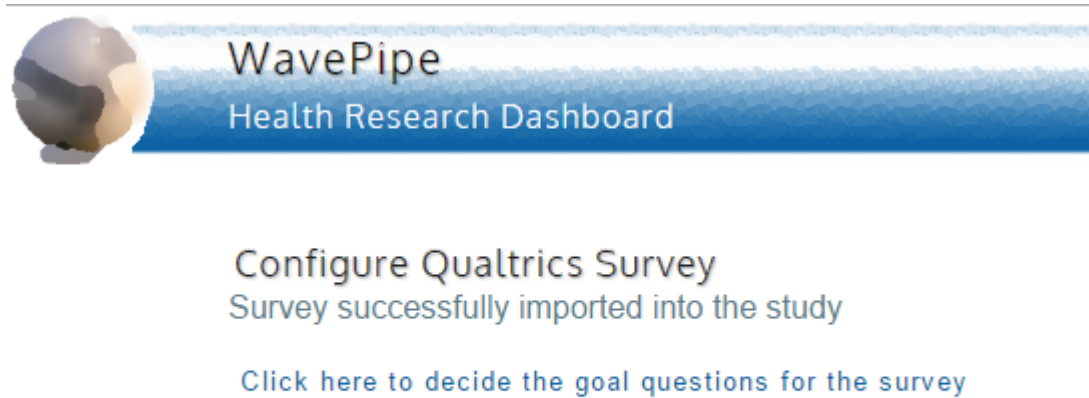
Figure 5. Instruction for scientists to decide and save the goal questions for the survey

Clicking on the button generates all the questions that were present in the survey as shown in Figure 6.

Figure 6. List of goal questions for the imported survey

A magnified image of the questions is presented in Figure 7 below.

Figure 7. Arrangement of goal questions and color ranges

As seen in Figure 7, each row is dedicated to a question. Checking a box next to a question includes the question in the list of goal questions. The 'Question' text area contains the exact text of the question that the scientist had typed while creating the survey on Qualtrics. The scientist can change the text of the question if he/she wants. Next to the question are three color ranges (red, orange and green) together called the 'scientist's expectations'. The purpose of these ranges will be discussed later. The color range always starts from 0 and ends at 'Infinity'. The scientist enters the end of 'Red' range in the textbox provided. The system automatically computes the value of the start of the 'Orange' range by incrementing the value of the end of 'Red' range by '0.1' and then displays it. The scientist similarly enters the end of 'Orange' range and the start of the 'Green' range gets computed and displayed automatically. 'Q3' in the figure illustrates the color ranges. This feature ensures that the color ranges are always continuous and increasing. There are validations in place to check for input anomalies including negative numbers. The scientist has to either enter all the color ranges for a question or leave them completely empty. The scientist cannot leave the color ranges for a question incomplete. Also, the system rounds-off any number to a 1-digit decimal number. This is to maintain uniformity in the scientist's input ranges.

The scientist may invite subjects to specify personal goals of their own for the goal questions, as well. Once the goal questions are checked and color ranges assigned, the scientist clicks on 'Save Questions' button at the bottom of the screen. On confirming the action, the questions are saved and the next step is to send email links to subjects for them to set their

own goals on these goal questions (subject goals). The scientist clicks on the button shown in Figure 8 below.
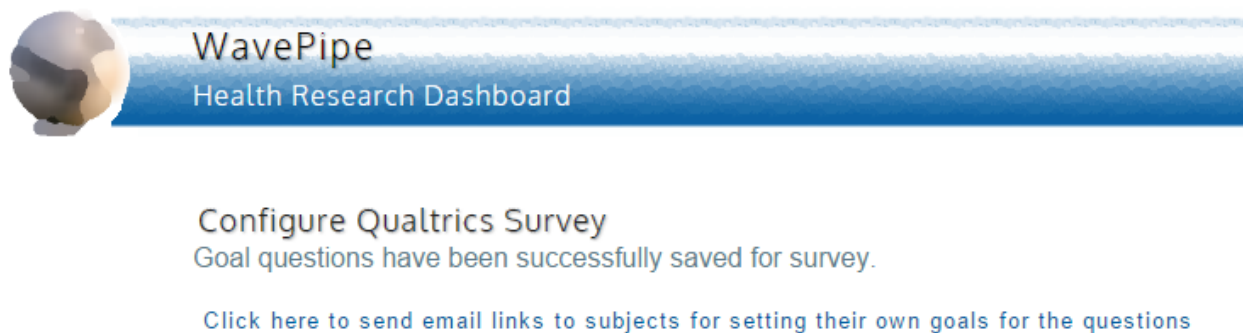
Figure 8. Instruction for scientists to send email links to subjects

The next screen lists the subjects registered in the study (represented in Figure 9). A 'Send Email' button is present next to each subject. Clicking on a button next to a subject sends an email to that subject.
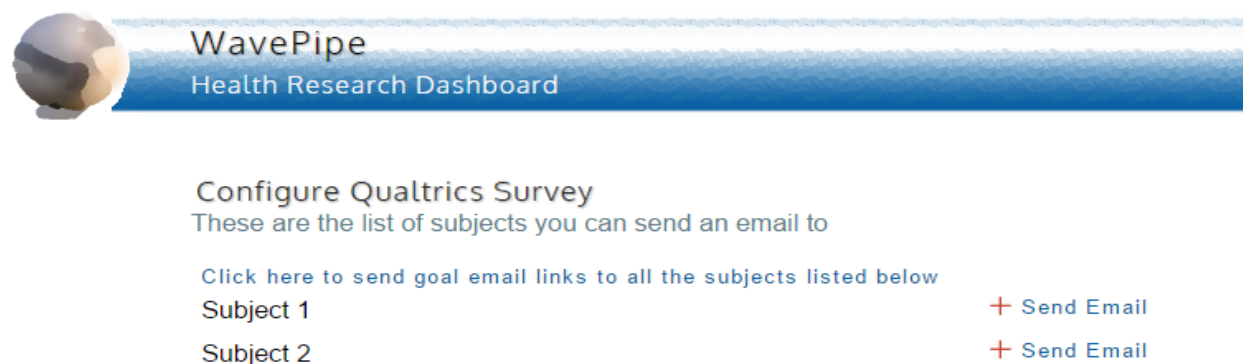
Figure 9. Sending email links to set subjects' goals

Assume that email links have been sent to some subjects. The scientist has now successfully configured a Qualtrics survey for the study.

Now consider a subject that receives an email from the system when the scientist clicks on 'Send Email' button next to the subject's name as described in Figure 9 above. The email contains a link that allows the subject to see the goal questions that the scientist had saved earlier. The user-interface for this page can be seen in Figure 10 below. Next to each question is a textbox in which the subject is expected to enter the goal to that question (subject's goal). The subject can either leave all the textboxes empty or enter a goal in all the textboxes. The boxes only accept positive integers.

For each question, please set your goals. You will get a periodic report comparing your tracked activities to the goals that you set now. If you don't fill any of the textboxes, you will not have set any goal

Question No.	Question	Goal
1	How many fruits did you have yesterday?	
2	How many times did you drink water yesterday?	

Click to submit your goals

Figure 10. Subject sets goals on the goal questions

Once the subject goals are saved, the study is ready to begin.

4.3. Step-by-step process whereby a scientist can modify a survey

Consider scenarios where the scientist wants to re-send email links to subjects, change the question text, reduce the number of questions or change the color ranges for an already imported and registered survey. To do that, the scientist again clicks on the 'Configure Qualtrics

Survey' option and enters the Qualtrics username and token as mentioned earlier. Now, in addition to the option of importing a new Qualtrics survey as seen earlier, the scientist sees one more option to edit a survey already imported as shown in Figure 11.

Figure 11. Menu after one/more Qualtrics surveys have been imported into the study

This new option contains the survey that the scientist just imported and registered.

The scientist clicks on the survey. The next screen contains two options as shown in Figure 12.
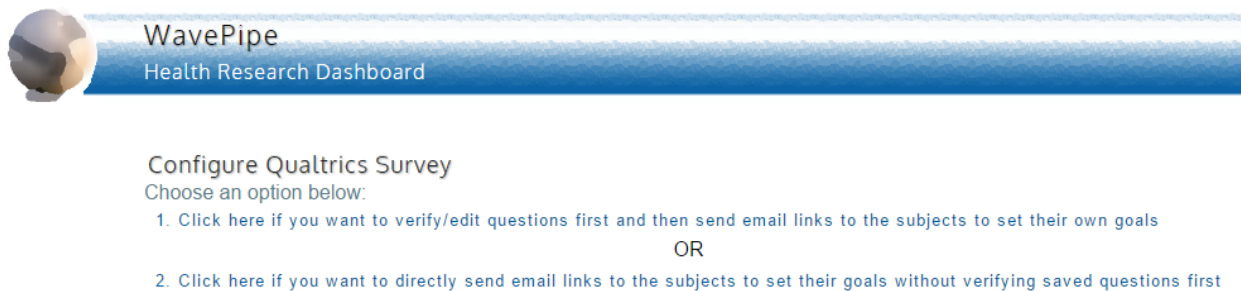
Figure 12. Options for changing the configuration on an imported survey

The first option allows the scientist to edit goal questions previously saved. Clicking on the option brings up the questions that the scientist had earlier saved. The scientist can change question text, color ranges or delete question(s) from this list and save the goal questions again. The screen looks exactly like the one shown in Figure 6 or 7.

After saving the questions, the scientist can re-send email links to subjects for them to set their goals on these questions now (subject goals) (same as Figure 9).

The second option is for the scenario when the scientist only wants to re-send email links to subjects without changing the goal questions (subject goals) (same as Figure 9). On clicking on this option, the scientist can see a list of registered subjects with a 'Send Email' button next to each. Clicking on a button sends an email to the subject thereby allowing that subject to set goals on the goal questions again. This is same as the feature to send email links to subjects and allowing them to set goals on the goal questions, as explained in the earlier section. This way, a subject can change their goals whenever needed.

4.4. Automated delivery of surveys, collection of responses, and generation of reports

The scientist collects survey responses from subjects through Qualtrics for a certain period of time. The scientist uses the Qualtrics system to send out surveys on whatever schedule is desired. Then, every night, the WavePipe Survey Reporter retrieves data from Qualtrics for each subject and saves it, using its API.

At a pre-defined time (currently, the 1st day of each month), the WavePipe Survey Reporter generates a consolidated custom report for each subject as follows. It first retrieves all survey responses of the subject for that survey for that particular period and the subject's goals. Next, it retrieves the list of saved goal questions. Then, for each of these questions, it checks the retrieved responses and computes the average. After doing this for all the questions, a report is constructed. The first column in the report contains the goal questions. The second column contains the calculated average for each question. In addition, the average is highlighted with a color. The color is computed based on where the average falls on the color range set by the scientist for each question (scientist's expectations). If the scientist does not set expectations from the questions, the averages do not get highlighted. The third column contains the subject's goals saved at the start of the study. This column is included in the report depending on whether the system database contains the subject's goals for that survey.

A sample custom report looks like Figure 13 below.

Hi,

Goal setting and self-monitoring are effective ways to help athletes achieve and maintain healthy lifestyles. Let's compare your tracked activities to the goals you've set:

Question	Your average	Your goal
I ate whole grain food (such as corn, whole oats, whole oatmeal, and brown rice) ____times in past 24 hr.	1.0/5.0	5.0
I ate whole fruit (such as apple, orange, banana; ½ cup raw or ¼ cup dried; not including 100% juice) ____times in past 24 hr.	3.0/4.0	4.0
I ate a vegetable (such as peas, carrot; 1cup raw or ½ cup cooked), including lettuces salad ____times in past 24 hr.	7.0/4.0	4.0
I ate a plant protein food (such as beans and nuts) ____times in past 24 hr.	3.0/1.0	1.0
I ate an animal protein food (such as egg and meat) ____times in past 24 hr.	6.0/2.0	2.0

■ - You do not meet the scientist's expectations

■ - You partly meet the scientist's expectations

■ - You fully meet the scientist's expectations

Thanks,
Wave-team.

Figure 13. A sample email report sent to a subject

The report also contains a personalized message on top of the report. The message changes according to the following rules shown in Figure 14 below.

	Survey Response present	Survey Response not present
Subject Goals Defined	Goal setting and self-monitoring are effective ways to help athletes achieve and maintain healthy lifestyles. Let's compare your tracked activities to the goals you've set.	Goal setting and self-monitoring are effective ways to help athletes achieve and maintain healthy lifestyles. You've set these goals a month ago. Let's start tracking your activities to work towards these goals!
Subject Goals Not Defined	Goal setting and self-monitoring are effective ways to help athletes achieve and maintain healthy lifestyles. Since you started tracking your activities, would you like to set goals today?	Goal setting and self-monitoring are effective ways to help athletes achieve and maintain healthy lifestyles. Would you like to start today?

Figure 14. Rules for personalized message

Once the report is generated, the report is sent in HTML format via email to the subjects. A copy of the report is also saved in the system for the scientist's reference.

After the study ends, the scientist may retrieve the data by logging into the dashboard and going to the study menu. The WavePipe Survey Reporter contains features to view/export Qualtrics survey responses, saved goal questions and expectations (color ranges), subject's goals and email reports sent to subjects. The data can be used for analyses.

5   Implementation Details

The system has been implemented entirely in Java as a dynamic web project. Since the WavePipe Survey Reporter is a part of WavePipe, its design and architecture is the same as well. The dashboard can be accessed using any browser that supports JavaScript. A scientist needs to have a valid login credential to access the dashboard.

The system was deployed as a web application using Apache Tomcat 7.0.42 (http://tomcat.apache.org/) as the servlet container on the server. Eclipse Java EE IDE was used to write the code. MySQL 5.6 (http://www.mysql.com/) was used as the relational database to support the system.

The Model-View-Controller architecture was followed to separate the behavior logic from the user-interface logic. It also helped to make the components loosely coupled. The *model* defines the data structure of the system. Data Access Objects (DAO) defined and written in Java were used to interact with the database. The code also used DataNucleus [49] [50], an abstraction on top of Java Data Objects (JDO) that helps in 'Object Persistence'. The *view* consists of HTML pages (containing JavaScript and CSS) embedded inside a Java Server Pages (JSP) page. The jQuery library [51] was used to make the web pages dynamic. The *controller* is a set of servlets that communicate with the model and view and pass messages between them. The following subsections explain the additional implementation details of the new features added to the system.

5.1.   Qualtrics survey integrated with the system

Health scientists in the WAVE project already used Qualtrics for other purposes, making it the natural choice for enhancing the WavePipe system with custom survey capabilities. Using it has made our system better and more flexible in two ways: Firstly, it removes the dependency on developers to create and deploy survey on behalf of scientists because Qualtrics is already used by scientists. It already provides a lot of features to create surveys that are attractive and useful. Secondly, its extensive API allows us to bring all data from Qualtrics to our system for scientists to have one central point to view/analyze all the data.

Qualtrics API version 2.4 has been used for developing our system functionality [48]. The API response is either in the form of JSON or XML. Jackson JSON processor [52] has been used for JSON parsing. JSON parsing is required for retrieving all the survey names present in the scientists' account and transmission of objects or information between the view and the controller throughout WavePipe. XPath is used to parse the Qualtrics XML response for the list of questions in a Qualtrics survey [53].
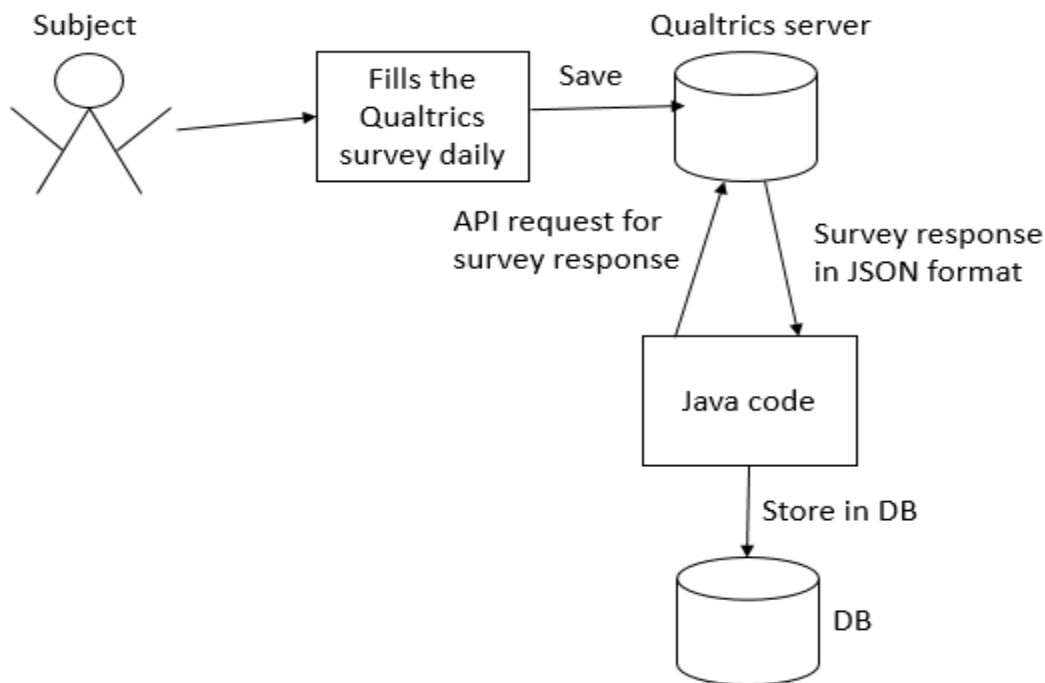
Figure 15. Interaction of the WavePipe Survey Reporter with Qualtrics server through its

5.2.   Setting color ranges for goal questions (scientist's expectations)

Coming up with a good user-interface for representing color ranges for goal questions

has been one of the most challenging parts of the WavePipe Survey Reporter. This is because of

the following reasons: Firstly, enabling a first-time user of the feature to understand the

purpose of color ranges and the way to use it is challenging. It is necessary to make the user-

interface design as meaningful and close to its real-world purpose as possible. Having the

ranges next to each other makes it easy for the user to understand the purpose (what is often

called "Juxtaposability" in the Cognitive Dimensions of user-interface design [54]). Secondly, it

is important to make the feature such that it is less error-prone. A set of color ranges (red,

orange and green) is error-prone if each sub-set range (individual color ranges) is non-

increasing, disjoint, incomplete, negative valued or differing in number precisions. To defend

against the possible errors, various validations (or checks) are present in the system that alert

the scientist against such input. The number of input have been minimized to only those values

that are absolutely necessary. For example: The first range always start with a '0' and the last

range always ends in 'Infinity'. Hence, the user is not asked to enter these values. The end of

range 1 (red) is taken as input from the user. This value is used to calculate the start of range 2

i.e. orange (value of the end of red range + 0.1). The computed value is immediately displayed

as the start of the orange range. Similarly, the user enters the end of the orange range and the

value of the start of range 3 (green) is calculate and displayed instantly. Using colors that have

commonly accepted meanings follows the "Closeness of Mapping" aspect of Cognitive

Dimensions [54] because it takes advantage of existing associations that people have with these

colors. This feature has been implemented using the event-handling functions that JavaScript

provides.

5.3.   Automated retrieval of survey responses every night and periodic custom report

The WavePipe Survey Reporter relies on the Cron job scheduler [55] to automatically

invoke the code used to perform the operations of retrieving survey responses of subjects from

Qualtrics every night and the generation of custom reports for each subject. These cron jobs

are installed on the server while deploying the application. It is easy to modify an already

installed cron in case of change in schedule. The cron job calls the appropriate script file on the

server that in turn, calls the appropriate Java code to do the work.
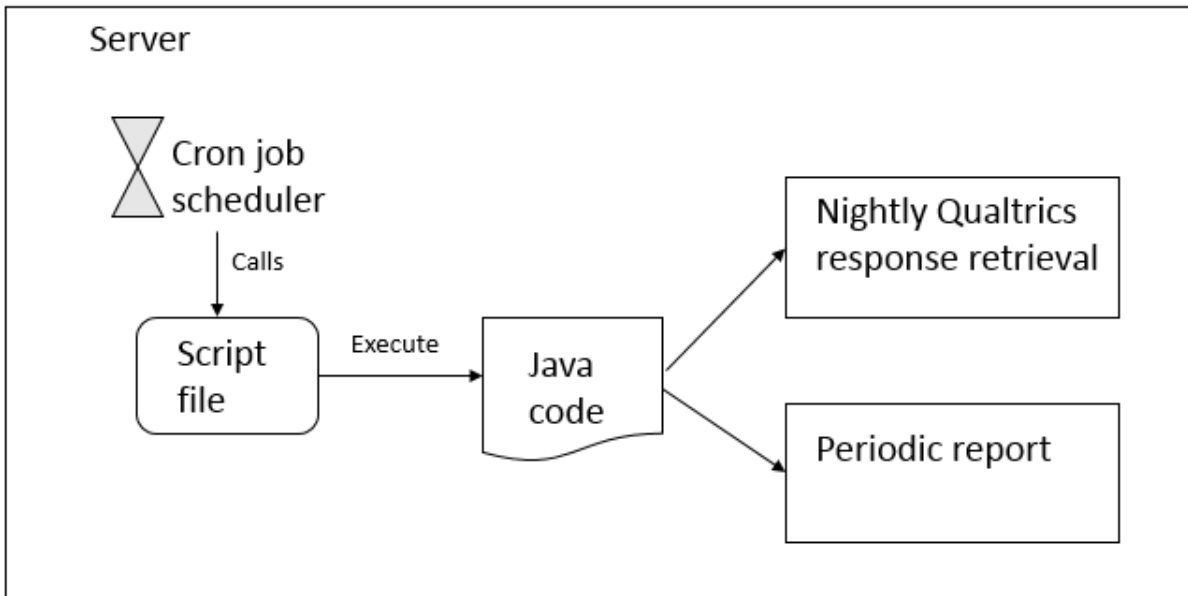
Figure 16. Functioning of a Cron job scheduler in the server

6   Evaluation

Two evaluations examined different aspects of the WavePipe Survey Reporter:

- ▪ Laboratory study evaluating how easily a novice scientist (a graduate student) could set up a survey in WavePipe Survey Reporter.

- ▪ Interviews evaluating how well health sciences graduate students could understand the reports generated by WavePipe Survey Reporter.

The subsections below describe these studies in detail.

6.1   Quantitative evaluation of the WavePipe Survey Reporter

The goal in this User Study was to evaluate the effectiveness and usability of the WavePipe Survey Reporter for a novice scientist, who was a graduate student from the College of Public Health and Human Sciences (CPHHS) at OSU and also a part of the WAVE team that uses our WavePipe system. The graduate student didn't have any experience in programming.

The study was designed to be completed in 45 minutes. The actual tasks needed the participant to assume the role of both a scientist and a subject. The participant was also encouraged to talk aloud while thinking and suggesting useful feedbacks for the system.

Filling out the consent form

At a pre-decided time in a laboratory, the participant was given a copy of the consent form to read. The participant was also made aware of a screen recorder running on the

computer throughout the duration of the study. Once the required consent was given, the study started.

Tutorial covering the features of the WavePipe Survey Reporter

The user was asked to do a tutorial task. The tutorial covered everything the participant needed to know for the actual tasks, below. At each step of the tutorial, the purpose of the current screen of the system and the function it performed were explained to the participant. The participant was given the freedom to interrupt and ask follow-up questions, if any. The tutorial finished in 27 minutes.

Actual task

The participant was given a task sheet containing the actual tasks and was required to finish all the tasks without any help from us.

The 1st task was to import and register a new Qualtrics survey called 'Mock Wave Survey'. The participant was asked to use a Qualtrics credential that were already fed into the system.

The 2nd task was to save 3 particular questions mentioned in the task sheet. These were the goal questions. The participant was also instructed to enter color ranges of choice for each question (scientist's expectations).

After saving the questions, the 3rd task was to send an email link to a subject already enrolled in the system under the study. The email link was for the subject to set goals on the questions.

A browser with that subject's email inbox was already open for the participant's convenience. The 4th task required the participant to pretend to be the subject and set goals on the questions.

For the 5th task, the participant was again asked to go back to the Qualtrics survey 'Mock Wave Survey', delete a particular question and save the questions, send an email link to the subject again and set goals on the new questions pretending to be the subject.

Feedback

The participant was asked to provide feedback to us by looking at 5 screenshots of the system that the participant encountered during the study. The five screenshots were:

- Screen 1 – The page where the scientist sets the goal questions (also containing the color ranges)

- Screen 2 – The page containing the list of registered subjects for the study and the 'Send Email' button next to each subject

- Screen 3 – The page for subjects to fill their goals on questions when they click on the email link

- Screen 4 – The main page where scientists see the options to 'Import a new survey' or 'Edit a survey that was already imported'

- Screen 5 – The screen when the scientist wants to edit a survey already imported. It contains two options: 'Verify/Edit a survey before sending email links to subjects' and 'Directly send email links to subjects without verifying the questions first'

Looking at each screenshot, the participant typed feedback the following questions:

- What aspects of this screen are particularly helpful or not helpful?

- What aspects of this screen are particularly easy or difficult to use?

- Are you confused by any portion of the screen?

- What aspects of this screen are particularly attractive or unattractive?

In addition to these questions, the participant answered two questions on the WavePipe Survey Reporter in general:

- Would you like to continue using the tool?

- Is there any other feature that you would like to see in this tool?

End

Finally, the participant was paid $15 for participating in the study and sharing feedback about the system. A confirmation of payment (signature and date) was collected from the participant.

Results and feedback of the study

The tasks were evaluated based on the accuracy of the participant and time taken to complete the tasks. The participant was able to finish all the tasks in 3 minutes without any mistakes. At no time during the tasks did the participant appear confused.

The following feedback was received from the participant for each question:

Q1. What aspects of this screen are particularly helpful or not helpful?

The participant found the explanation helpful to understand in most of the pages. In Screen 2, the participant suggested a feature to send emails to groups of subjects (i.e. study groups that the subjects are registered under). In Screen 5, the participant found the instructions too long to read and suggested shortening and simplifying them.

Q2. What aspects of this screen are particularly easy or difficult to use?

The participant found all the screens easy to use. For screen 3, the participant did not enter any comment.

About screen 1, the participant commented: "*The feature to choose questions was easy to use. It was easy to modify questions*". About screen 2, the participant commented: "*It was easy to understand and operate*".

Q3. Are you confused by any portion of the screen?

The participant's response was **'No'** for each of the screens.

Q4. What aspects of this screen are particularly attractive or unattractive?

For screen 1, the participant suggested adding more color to make the screen attractive. One suggestion was to have the red range input in red color, the orange range in orange color and the green range in green color.

As for the general questions on the WavePipe Survey Reporter, the following feedback was received:

Q1. Would you like to continue using the tool?

The participant answered **'Yes'** to this question.

Q2. Is there any other feature that you would like to see in this tool?

The participant suggested two features to add to this tool: Firstly, the participant wanted to be able to send emails to groups of subjects rather than individual subjects (already mentioned above). Secondly, the participant suggested using 'checkboxes' instead of 'Send Email' button next to each subject for sending email links.

Overall, based on the time it took for the participant to finish the tasks and the feedback received for the WavePipe Survey Reporter, and based on the fact that the graduate student is a novice scientist with less experience than the more senior scientists on the WAVE team, it is reasonable to expect that other scientists would be able to use WavePipe Survey Reporter quickly and correctly. Also, the fact that the participant wasn't confused by any aspect of the

tool and also expressed interest in using the tool again reinforces this confidence in the tool's usability.

6.2   Qualitative evaluation of the health report

The goal in this User Study was to evaluate a sample health report for its design, content and simplicity. The recruitment criteria was to consider graduate students from the College of Public Health and Human Sciences at OSU. 6 graduate students satisfying the above criteria were interviewed, of which 66.67% were female participants.

Mailing participants and consent form

The participants were first mailed the recruitment text approved by the Institutional Review Board (IRB) at OSU. Once the participants replied to the mail, the consent form was mailed to them. They gave their consent by replying to meet for the interview.

Interview

During the interview, the participants were first asked if they had any question about the study. Once any questions asked were answered, they were given a choice of one of the following: paper questionnaire, verbal interview, clicker-based study, online questionnaire hosted on Qualtrics. All the participant chose a paper questionnaire. In addition to the questionnaire, a sample report was also provided (for evaluation). There were 7 questions in the questionnaire out of which 4 questions required the participants to read and understand

the sample report provided. When the participants answered all the questions on the questionnaire, follow-up questions were asked for certain questions depending on the options that they marked. This process was followed for improvements and feedback about the report.

The participants' responses is discussed in 'Results and feedback of the study' section.

End

Finally, the participants were paid $25 per person for participating in the study and sharing feedback about the report. A confirmation of payment (signature and date) was also collected from them.

Results and feedback of the study

Let us consider the response of the 6 participants question-wise:

Q1. What is your job or year in school?

Figure 17: Participants' year in school
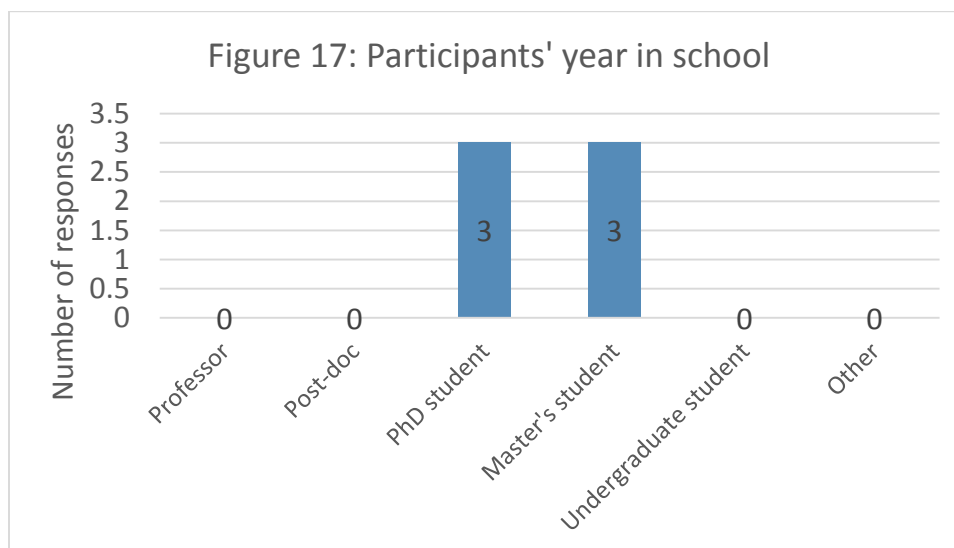
As seen in the Figure 17, the students recruited were graduate students at OSU.

Q2. What is your field or major?

Figure 18: Participants' major
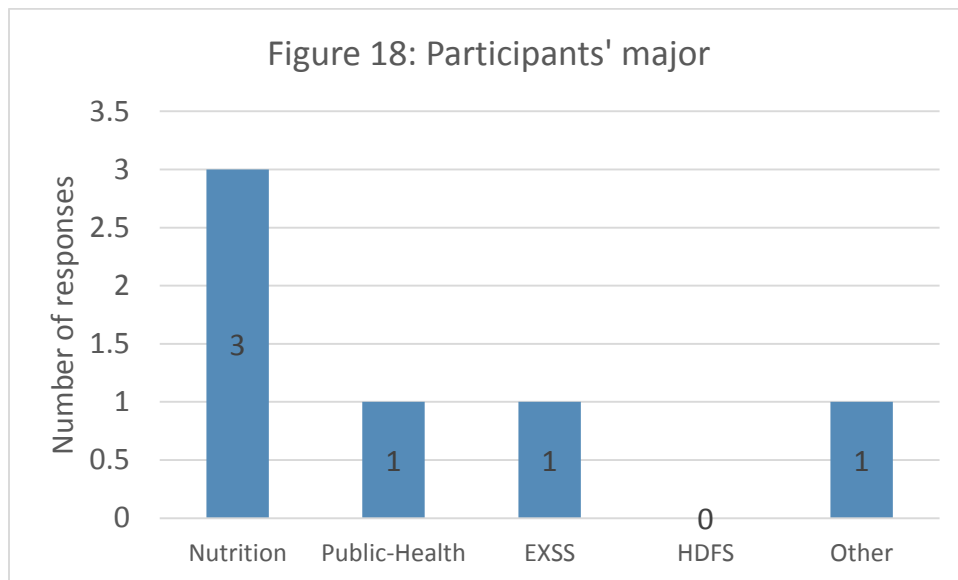
As seen in Figure 18, most of our participants were from the Nutrition department.

Q3. Do you currently use a smartphone?

Figure 19: Participants' smartphone usage
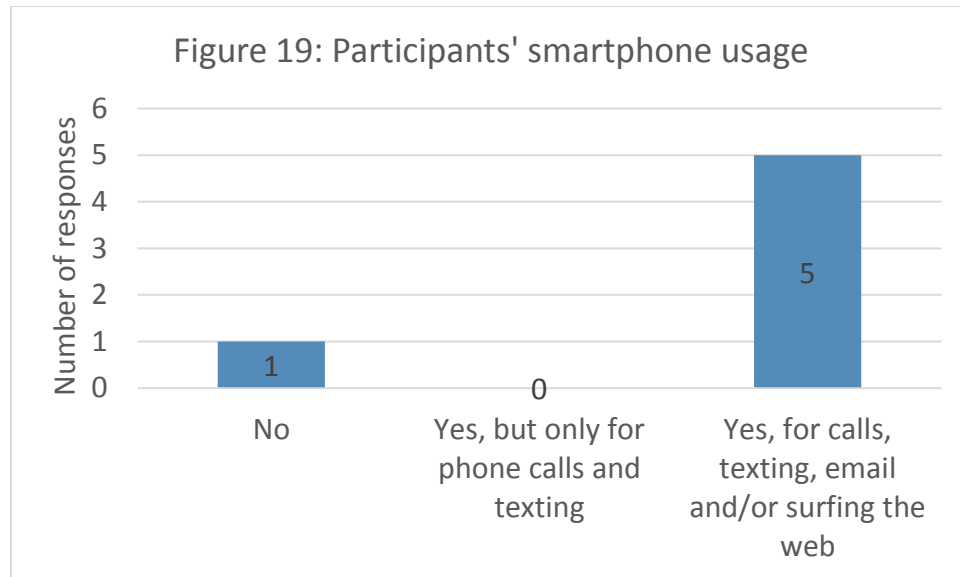
As seen in Figure 19, most of the participants used smartphones for more than just calling.

For all the questions that follow, these were the rule that were considered for evaluating positive or negative responses:

- 'Yes' and 'Mostly' are positive responses

- 'Somewhat' and 'Not at all' are negative responses

Q4. The 'Your goals' section of the report states the goals that person filling out the report has set for each question at the start of the study. Does the column 'Your goals' state the personal goal clearly?

Figure 20: Participants' approval of 'Your goals' column
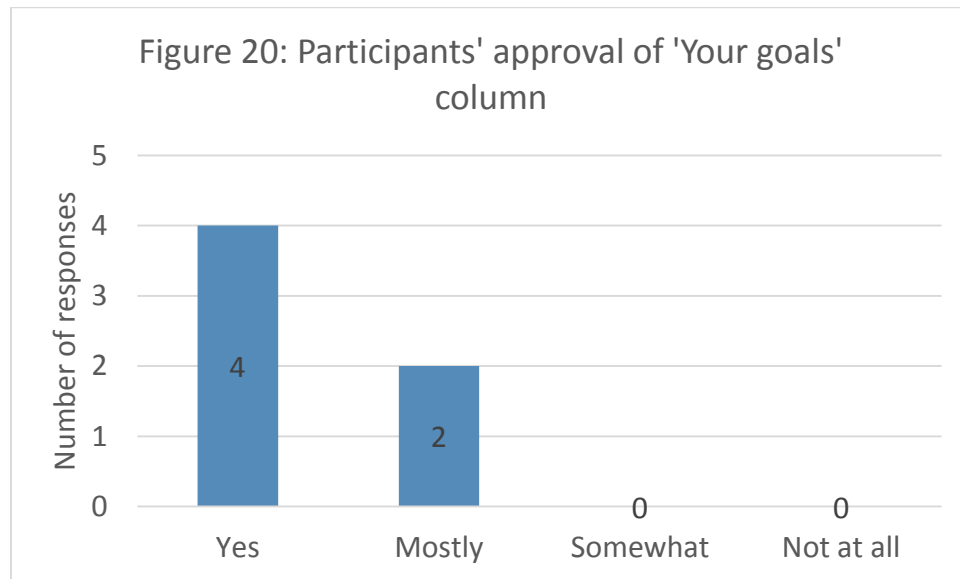
As seen in Figure 20, most of the participants understood the purpose of 'Your goals' column in the report. 4 out of 6 participants felt that the column conveyed the user's goals clearly and the remaining 2 felt that the column mostly conveyed the goal. Based on the rules that were pre-established, all participants had a positive opinion about the column. Two participants felt that subjects should not set goals because they could set a goal that is excessive.

Q5. 'Your average' summarizes the mean frequency of a targeted goal during the week. Does this feature make sense to you?

Figure 21: Participants' approval of 'Your average' column
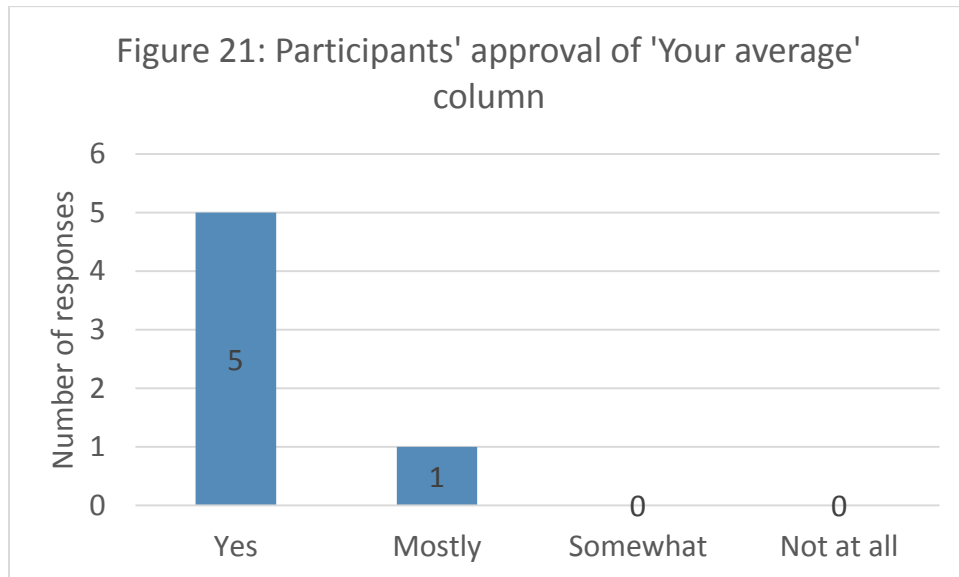
As seen in Figure 21, most of the participants understood the purpose of 'Your average' column in the report. 5 out of 6 participants felt that the column conveyed the user's average clearly and the remaining participant felt that the column mostly conveyed the goal. Based on the rules that were pre-established, all participants had a positive opinion about the column.

Q6. Notice the feedback message at the top of the report. We want to give meaningful feedback to all who complete the survey that is used to create this report. Is this feedback message clear?

Figure 22: Participants' approval of the feedback message
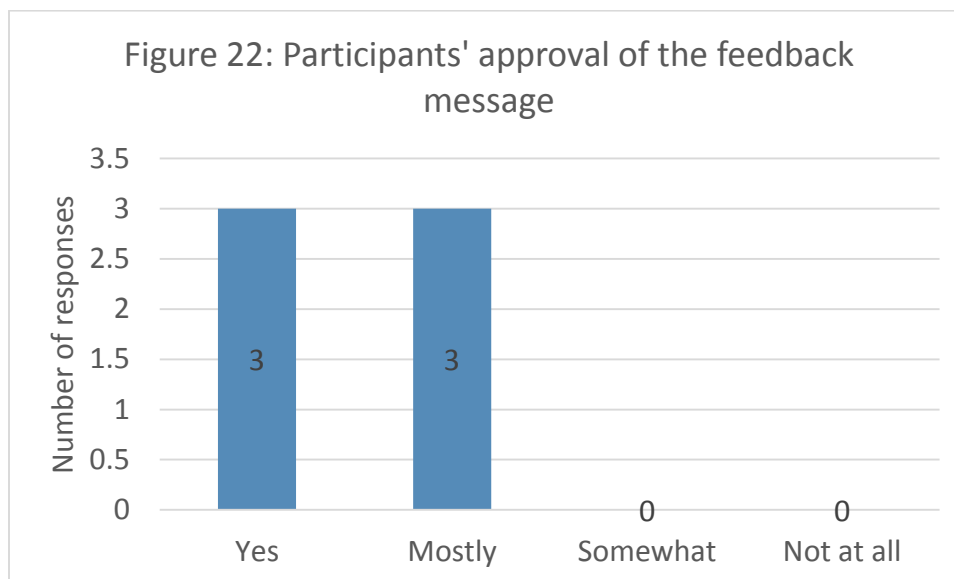
As seen in Figure 22, most of the participants felt that the feedback message was clear in the report. Half the participants found the feedback completely clear while the other half found it mostly clear. Based on the rules that were pre-established, all participants had a positive opinion about the column. One participant felt that the term 'activity' in the feedback message indicated 'exercise'. It was suggested to be changed to 'eating habits'.

Q7. Here is our final question. It's about the color code we use to indicate the level of achievement in meeting the set goals. Looking at these ranges, are red, orange and green acceptable to you?

Green = 6-7 out of 7 days

Orange = 3-5 out of 7 days

Red = 0-2 out of 7 days

Figure 23: Participants' approval of the color ranges
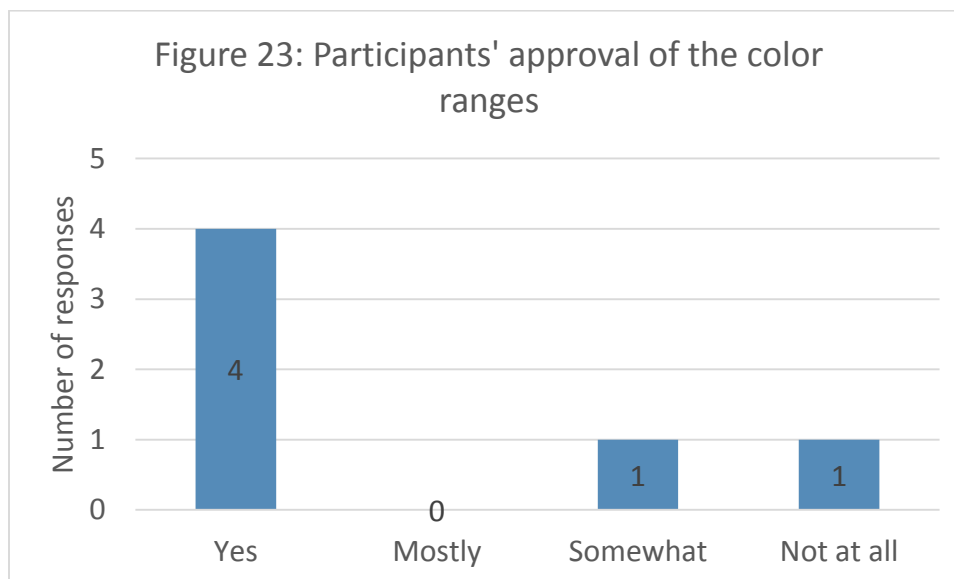
As seen in Figure 23, most of the participants found the three color ranges acceptable in the report. There was 1 participant who only somewhat accepted it and 1 other participant who did not accept it at all. The participant who somewhat found the ranges acceptable found them confusing. The participant who did not like the color ranges said he was color-blind. The participant suggested using 'light blue' color instead of 'orange'. The participant appreciated that the shades of 'red' and 'green' used in the report were not close making it easier to distinguish between the colors. Also, the 'orange' color made the participant not feel good about the report because orange is closer to red than it is to green.

7   Conclusion and Future Work

This master's project has presented a sub-system that lets scientists provide feedback to study subjects in response to their survey answers, thereby potentially helping to influence those subjects' behavior. Scientists can import surveys into studies, select goal-settable questions from the surveys and allow subjects to set goals on those questions. The new sub-system automatically generates custom reports for each subject by aggregating survey responses with the subject's and the scientist's specified goals. An evaluation of the subsystem showed that it is both usable and understandable.

The subsections below discuss opportunities for enhancing this sub-system in the future.

7.1   Potential future work related to customizability of reports

Currently, our sub-system generates reports by consolidating numerical data only. It would be interesting to extend the concept to generate reports containing non-numeric data. For example, in the future, we could look into how we can allow subjects to set goals on non-numeric options and consolidate reports that have options selected as the response. For example: Consider a goal question: 'Did you eat ice-cream today?' Let the responses be 'Yes' or 'No'. The scientist could then set color ranges for this question as the frequency of 'Yes' or 'No'. The corresponding report would also contain the frequency of the responses and the appropriate color.

In addition, although our sub-system currently only calculates the average of the responses for the report, in the future, we could extend the system to support other statistical operations as well. Reporting the mode of the response set to subjects could be a useful addition to the tool. That way, subjects can find out their maximum occurring response to the goal questions. For example, considering a goal question: "How many times did you have fried-food today?" the report could inform that a subject had reported 'X' as the response for the goal question on most occasions. Another useful statistical operation could be including the p-value of the response set in the report. For the above example question, the report could inform that the subject has had more fried-food than X% of the subjects. Lastly, the tool could also use z-score in the report by informing subjects how near/far they are from the average of the group. These operations could help generate more personalized reports for subjects. From a user-interface point-of-view, a scientist could be shown a web page after setting goal questions asking the statistical operations to be included in the report. The above discussed operations could be displayed with check-boxes next to each, indicating that the scientist can include some/all of the operations while generating the report.

A third area for future enhancement is in the configurability of the report's appearance. For example, while developing the feature, we have assumed that 'red' always denotes a bad value and 'green' always denotes a good value, but other color schemes might be needed in certain situations. For example, there are cases where these colors would not be meaningful, especially when the food is not good for people. Consider the question: 'How many times did you eat fried food yesterday?' For this question, the recommended average value should be as

low as possible. If a subject is conscious about nutrition and puts in low values for this question, according to our algorithm, 'red' color would be highlighted over this average. This is because our sub-system assumes that low value is always 'red'. Also, our color ranges start from red and finish at green in an ascending order of values. In the future, we could make the color order and the increasing/decreasing order of ranges interchangeable to incorporate accurate results for all types of questions.

Currently, the report only shows the data as it is. Excluding the color highlighting feature, the algorithm does not derive any other conclusions looking at the data. In the future, we could look into making the algorithm suggest subjects more things based on the report. For example: If the report shows that a subject is consuming less proteins, the observation could be explicitly mentioned in the report along with suggestions for good sources of proteins. This would require the algorithm to interact with a database of foods and their nutrition facts.

Subjects could be giving more control of what they see in their report. Currently, a subject has to see the report containing all the goal questions that a scientist sets. They could be given the flexibility to instruct the system to hide/show some of the questions. The idea could later be extended to the allow subjects to set the frequency of the reports as well. Consider a scenario where a subject is serious about reducing the intake of fats. In this case, a subject could opt for getting more frequent reports about question(s) that indicate fat intake as opposed to getting reports only at the time defined by the scientist.

Currently, the system supports only one algorithm for the data highlighting feature in the

report. A color gets chosen according to the range in which the average falls. The idea could be extended to a 'pool' of algorithms that determine the condition to highlight color. For example: In addition to the above mentioned criteria, another criteria could be to determine the color based on count of the number of times a subject's average for a question reaches the subject's goals. Then the algorithm could choose a color by checking where the count falls in the color ranges. For giving scientists control over adding new algorithms to compute colors, a domain-specific language could be introduced that is easy for scientists to learn and implement.

As discussed in the result section, the reporting feature is not suitable for color-blind subjects. To deal with this issue, next to the average, the color name could be displayed highlighted with that color. For example: If the average of a goal question is 4.5 and it falls under orange color range, the report could contain '4.5 (Orange)' or '4.5 (O)' with 'Orange' or 'O' highlighted with orange color.

7. 2   Potential future work related to other aspects of the sub-system

Configurability of the goal-setting email might be desirable in the future. When a scientist wants to send email with the sub-system to subjects for them to set goals on questions, emails can be sent to individual subjects or everyone at once. But we could extend this feature to send emails based on the study group the subject falls under (e.g., treatment versus control). This feature was suggested by a participant during the evaluation of our sub-system.

As explained in the 'Implementation' section, the time to generate and send email reports

is controlled through a cron job scheduler that is a part of the server. To change the frequency of sending reports, the cron has to be altered (creating dependency on developers). In the future, we could look into ways of allowing scientists be able to schedule the report whenever they want. This might require the system to stop using cron and look for other available options or develop a tool that takes in the time frequency from a scientist as input and alters the cron automatically.

There are a few more minor enhancements that could be implemented to improve the convenience of the sub-system for the scientist. For example, one limitation of the current sub-system is that once a Qualtrics survey is imported and registered, a scientist can only change the text of the goal questions, change their color ranges or reduce the number of questions. There is no way to go back to the original survey questions. To do that, a scientist has to create a duplicate copy of that survey in Qualtrics and import/register that survey for use in WavePipe. It would be interesting to look into how to solve this problem.

Finally, to be able to re-use the reporting feature in other systems or professional tools, we could develop an API that takes the data in a pre-defined format as input and outputs a report. This would require us to change the code to be more generic compared to the current code that is designed only for health studies.

In addition, an API could be developed for an app that collects user data offline, then posts it to our server to generate a report; however, it is not clear that it would be worth developing

such an app, since Qualtrics already provides an offline app that probably works just fine with

their system and, therefore, with ours.

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