IMPLEMENTING THE USE OF PERSONAL ACTIVITY DATA IN AN
INTRODUCTORY STATISTICS COURSE

by

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Statistics

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Abstract

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by

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Integrating real data into a classroom is one of the recommendations in the Guidelines for Assessment and Instruction in Statistics Education (GAISE) college report (Committee, GAISE College Report ASA Revision, 2016). In order to assess the effect of using real data in a classroom, the students received physical activity trackers to wear during an undergraduate introductory statistics course taught in the summer. This tracker, a Fitbit, enabled students to monitor and record their steps, calories, and active time throughout the class. Collecting personal activity data (PAD) creates a large database which students can then analyze and use to build statistical thinking. Since the students are intimately familiar with the data they gathered, they could focus on the patterns they saw in the data based on their own personal experiences. With this data, the students completed tasks that asked them to analyze their physical activity using methods including summary statistics and bivariate analysis. These projects encouraged students to think about problems that arise from data collection and analysis in real life situations. We saw that using PAD helped the tasks become more personal, increased interest and engagement, and reinforced the material taught in class.

(39 pages)
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CHAPTER I
INTRODUCTION

In the world today, statistics appear in a multitude of places including the newspaper, on Facebook posts, in science journals, in health magazines, and in business. The growing prevalence of large scale data collection has created pressure on statistics education to help create a population that can correctly analyze statistics to make decisions. The amount of available data grows every day and it is estimated that 90% of the total data in the whole world has been collected in the last two years (Horton, 2015). Many jobs remain available for individuals that know how to organize and analyze data. Still many students leave their first, and often only, statistics class with little experience applying statistical reasoning in real life situations. Teaching statistics with only trivial or made up examples can affect the students’ interest in statistics and their ability to make decisions based on sound reasoning. The classroom needs to bridge the gap between application and theory in order to help prepare students for the situations they might encounter later.

Teaching is a constant experiment to find ways to help students learn and understand the concepts that they will need. Building a class from research based methods can both enrich and improve student learning. The Guidelines for Assessment and Instruction in Statistics Education (GAISE) college report provided guidelines for teaching an introductory statistics course and it emphasized building an authentic experience by using real data in a classroom (Aliaga, et al., 2005). Data can come from a multitude of sources, but we focused on the implications of using personal activity data (PAD) in a classroom. Physical activity trackers like the pedometer, fitness wristbands, or
cell phone apps provide good sources for PAD and can then be incorporated into assignments. For this project we chose to use Fitbits, a widely used commercial fitness tracker that records fitness data every minute and then syncs its data to an online database. Our goal was to judge if utilizing this technology can enhance an introductory statistics class.

In this project we proposed two initial research questions: 1. Where can PAD be naturally and usefully integrated into the introductory statistics curriculum? 2. How do students think about PAD in a statistical context? These questions influenced the tasks we designed for the students and motivated the questions we asked on the surveys after each task. This qualitative study focused on the need to increase student engagement in learning statistics so they can become critical consumers of the data.

LITERATURE REVIEW

Integrating PAD offers a novel way to incorporate technology into a college statistics curriculum. The growing prevalence of wearable devices or apps can open many possibilities not only for statistics education but also provide tools for behavior analysis. There have not been many studies using these devices in education, mostly due to the cost (Lowe, 2016). Previously Lee, et al. (2015) implemented PAD driven activities in elementary schools. They argued that teachers can take advantage of regular daily activities to collect data in the background. The students then used the PAD to make visualizations and discuss conclusions about their own questions (Lee et al., 2015). Building off their work we incorporated the data collected by the Fitbits in the college curriculum.

To test the effectiveness of using PAD in a classroom would require conducting
an experimental study with two classes. One class would use PAD to complete assignments and the other data from an online repository or textbook. Still, a wealth of information can come from an observational study (Carver & Stephens, 2014). With the current push for schools to focus more on statistics from a younger age (Committee, GAISE College Report ASA Revision, 2016), there exists a growing need for more informational studies about statistics education. We conducted a small pilot study to determine if using PAD engages the students. In this study, using the same data throughout the course helped provide continuity to the assignments and connected concepts.

Since many devices now exist that gather activity data automatically, it was important to select a device that best fits the needs of the class. With the growing awareness of health, activity trackers that monitor an individual’s movement throughout the day have become increasingly popular. A Fitbit was one available device which can track an individual’s steps, calories burned, sleep schedule, and their active time. This one device created a database full of useful information that students could then use in a summarized or raw form. Fitbits use an opportunistic approach to incorporate the activities of a regular day into a learning experience (Lee et al., 2015).

Collecting data from Fitbits could both immerse students in a real life situation while using data that should be of greater interest to them. Not only do the students get to learn more about themselves, but they know the data they collected better than anyone else. They know why one day had lower steps since they spent that day on the couch, or they might look at an extremely active day and remember a hike. Drawing on this previous knowledge could make statistical analysis easier (Lee, et al., 2016) because they
collected the data themselves. Libman (2010) encouraged learning while “immersed in context-bound experience” where students are encouraged to ask questions, search for patterns in their own data, and think of strategies to analyze the data. Without a specific context, students focus only on mastering an algorithm or abstract concepts, whereas statistical problems in the real world revolve around a complex and challenging topic that relates to the job at hand (Libman, 2010). Making examples in the classroom relevant to students could help build a sense of ownership which then helps provide the motivation to learn. “For complexity often teases out curiosity and interest” (Libman, 2010, p. 4).

When there exists little confusion about the data itself, data analysis may then become the center of the activity. Newman, et al. (2013) indicated that focusing on data analysis will help the students become more actively engaged in the learning. Students will then have a chance to reflect on their own data which will lead to a unique answer, not just the “right” answer that is so often the crux of math problems. “Made up data reinforces the perception that statistics is artificial, dreary, and uninteresting” (Neumann, Hood, & Neumann, 2013, p. 60), whereas real data can be multifaceted, enlightening, and engaging. Teachers can obtain real life data that is automatically relevant to the students by gathering it from the students themselves.

Using PAD in the classroom helps explore the possible ways to connect the topics learned in class to something they can use in their lives. For a researcher, statistical analysis consists of more than just crunching numbers, but methodology used to search for answers to a specific question (Singer & Willett, 1990). Then it can develop into a project that requires the researcher to delve deeper than the surface and scour background material to make sense of results. Therefore, real data requires a higher level of thinking
than canned textbook problems that students only think about once and then move on. The rigid structure of most introductory courses can drive the enjoyment out of learning. For this reason, many schools have searched for new strategies to incorporate technology based activities (Neumann, et al. 2013). When using PAD, students formulated their own questions found trends in their activity data and simulated the research process. The usefulness of PAD stems from its ability to help students build statistical thinking in a situation relevant to the real world.

The struggle with real data stems from the fact that it arrives to the student in a messy form. This leads to unanticipated issues like missing data points, formatting issues, skewed distributions, and often too much data to sort through. An authentic learning experience helps student focus more on problem solving and interpreting their findings within the given constraints (Libman, 2010). Many teachers find running a real life experiment in their classroom more difficult because of the time and resources required to set up the project. Giving the students, the raw data will not always be feasible and so the teacher must spend time summarizing and cleaning before the students ever see it. In order to incorporate real data, teachers will need to adjust their perceptions about learning and invest in improving their curriculum.

Many students experience statistical anxiety and thus it becomes important to motivate students to learn (Bradstreet, 1996). Sproesser, et al. (2016) researched the relationship between interest and intrinsic motivation. Looking at multiple studies they found a positive correlation between interest and achievement in a classroom. “Interest is accompanied by a high readiness to acquire new knowledge and skills related to the object of interest as well as by the desire to apply such knowledge and skills” (Sproesser,
et al., 2016, p. 31). Finding tasks that interest students provides a strong motivation base for them to build knowledge. Working on PAD tasks will not only help students learn statistical concepts but facilitate the discovery of information about themselves through relevant research questions (Singer & Willett, 1990). Nevertheless, teachers should avoid just using real life examples to help motivate students. Instead the activity should reinforce specific statistical topics (Neumann, et al., 2013). Thus, in the PAD experiment we first chose the statistical topics and then chose the appropriate data to illustrate the particular topic.

As one of the goals of this project we focused on helping students create hypotheses, design studies, build graphics to summarize the data, and make informed conclusions about the data (Sproesser, et al., 2016). Often statistics courses have only focused on methods, because of the difficulty of providing authentic experiences for the students to develop statistical thinking. For non-statisticians minimizing the use of complex formulas can instead shift the focus onto how to seek answers (Bradstreet, 1996). Most of the students will not remember the methods that they used a few years in the future, but we hope to instill a pattern of statistical reasoning that students can use throughout their lives (Singer & Willett, 1990). PAD will help students make a connection from the classroom to real life while increasing their knowledge about the statistical process.

The traditional method of teaching requires the student to sit as a passive learner engaging only in teacher assigned homework or tests. In this approach the teacher’s goal is to transfer all their knowledge to the listening students. Bradstreet (1996) mentioned how this approach often does not work as well as the teacher anticipated. Whereas, when
a student engages in investigating PAD with open research questions the student becomes a joint participant in statistical investigations (Libman, 2010). New knowledge builds upon the students’ prior knowledge about their own physical activity and data collection from the Fitbits. Following the constructivism approach to education requires calling upon prior knowledge to assist current learning (Lee, Drake, & Thayne, 2016). Right before each task we extracted the data students gathered up to that point on their Fitbits and gave the data to the students to perform the specific task. This allowed the students to see real data analyzed by the available software (Teachout, 2016). Statistics lends itself to a technology driven class and this helped us to integrate PAD into the curriculum more naturally.

Our project built on the availability of new technologies to bring real data into the classroom and help increase interest, motivation, and statistical knowledge for the students. Using the same data set, with different subsets of variables, helped provide continuity a framework to build statistical reasoning. We believe that focusing on student comments from surveys can assist in gauging the effectiveness of using a Fitbit to answer our research questions. This project can help students gain a fluency with data in a firmly rooted context driven experiment (Lee & Thomas, 2011). When students engage in situated learning experiences it could help them gain a greater appreciation for the uses of statistics.
CHAPTER II
PERSONAL ACTIVITY DATA

An introductory statistics course introduces students to methods and techniques to evaluate data. This study occurred during the summer of 2017 with a statistics course for scientists and engineers. This introductory statistics course required students to have previously taken calculus. The students who registered for the class were asked if they would voluntarily participate in the study. At the beginning of the summer 30 students registered for the class, but only 27 finished the class and participated in the study. The majority of the students were male at 67% and the average age was 26. The integration of the PAD gathered from Fitbits came easily for a few of these activities, or tasks. In order to change tasks to assist the students in learning statistics we had to address the question ‘How can PAD activities be most effectively used in an introductory college course?’ PAD needed to fit both the topics of the scheduled tasks and the data that the Fitbits had available.

EXTRACTING FITBIT DATA

The process of getting the data from the Fitbits to the students was more involved than initially anticipated. First, we had to select an appropriate and inexpensive device

Figure 1. Fitbit Flex 1 wristband and tracker used in class (Press Kit, 2018)
from Fitbit’s many models and styles. We selected the Fitbit Flex 1, shown in Figure 1, because it had previously been used in other studies at Utah State University (Lee, Drake, & Thayne, 2016). Each student wore a Fitbit for the entire class or seven weeks. The students were asked to wear the Fitbit at night and try to charge it at times when they were least active. To extract students’ data collected from the Fitbits the university had to establish a connection to the main Fitbit database. From this database we could access the date and time, number of steps, calories, metabolic equivalents (METs), minutes awake during the night, minutes active, minutes sedentary, and distance traveled by each individual student. All these variables were utilized for different assignments. The data for all the students in the study within the specified range of dates was grabbed from the database using SQL queries. After saving this data into a csv file, we separated the data by student and added convenience variables for the date and day of the week using R. Depending on the data the students needed we summarized the data by hour or by day, instead of just by minute. Then we made the data available to each student on Canvas, the school’s online website for transferring course content and files, labeled by their individual Fitbit code.

One of the major concerns brought up from previous studies (Lee, Drake, & Thayne, 2016) was that students sometimes have a difficult time charging and syncing their Fitbits. In an elementary school setting they set up a charging and syncing station in the classroom, but we decided to leave that responsibility mostly up to students. In order to track students’ usage of the Fitbit, a website periodically updated listing both the last sync time and indicated the charge status of each Fitbit. From this website we could view who had not synced their Fitbits in a while. Also, it made it possible to check the battery
life of each Fitbit. When a student neglected charging or syncing their Fitbit we could send them a reminder email. During class a syncing station could remotely sync Fitbits that certain students had neglected. This worked with varying levels of success, but ultimately the responsibility fell on the student to make sure they collected the data properly. If their Fitbit did not sync, they had to use the less personalized sample data instead to complete the assignments or tasks. During the second task, nine students did not have sufficient data to complete the task. For these students we provided data collected by the student researcher to use so they could still complete the assignments. After this PAD task, students became more motivated to check their Fitbits and less students needed to use the sample data in subsequent tasks. The importance of syncing and charging the Fitbits was reinforced by the natural consequence that some students did not have their own data to analyze.

PAD TASKS

In the seven-week course, six tasks or homework assignments were given and three of them utilized the data from the Fitbits in different ways. The three PAD tasks replaced similar tasks used in other semesters. The previous tasks had been used and edited multiple times to ensure that they met the needs of the students in learning the course material. We modified the old existing tasks to utilize the data collected from the students’ Fitbits. Our goal in using the Fitbits was to leverage the students’ familiarity with the data they collected in order to encourage them to think through statistical problems. The data naturally lent itself to tasks involving descriptive statistics and regression analysis. We also used PAD to solidify the concept of random variables because many students often struggle understanding them and their distributions. All
these tasks utilized different aspects of the data collected by the Fitbits. Also, we began each task in class to allow time for the students to ask questions and collaborate with their peers. Outside of class most tasks required a write-up which we later analyzed to find patterns in student thought. The write-up asked the students to discuss the problem statement, methods used to complete the assignment, state the student’s conclusions, and discuss what they had learned.

The first task required students to design an experiment and brainstorm ways to design a statistical study comparing Fitbits and treadmills. This both helped introduce the capabilities of the Fitbits and provided a good introduction to experimental design. We gave students the research question “Is there a difference between the calories or distance reported by a Fitbit Flex versus a treadmill?” From there we asked them to identify the population and parameter, consider factors that could affect the experiment, and decide specific ways to implement the study. One question asked, “How would you analyze the data?” Because this task was assigned the first week it allowed the students to come up with their own solutions instead of just what they had learned in class. At the end of the semester some students conducted their own experiment for extra credit. This allowed the students to think creatively about the ways to answer the research question while considering the statistical issues investigators should address before performing any experiment.

The second task introduced students to creating numerical and graphical summaries with their personal data and programming in R. They used the data from the Fitbits to explore the patterns in different days or times for one week. At this point the students had only gathered data for one week, and therefore could not see long term
trends in the data as preferred. We gave the students their step count summarized by the hour each day as shown in Table 1. We designed this task to help students discover ‘which days are you the least active?’ and ‘During which waking times are you the least active?’ Before looking at their data, each person predicted the answers to the questions, and then updated their response while analyzing their data. The definition of ‘active’ was left up to the students to defend and support with evidence from their data. Using R, the students visualized the data with boxplots and found the relevant summary statistics. Ideally, this task would be more beneficial if the students had data collected over a whole month to really find patterns. Unfortunately, the short seven-week session restricted the amount of time we had to collect data to one week. Nevertheless, the students could still make meaningful conclusions and practice using statistical language to justify their claims.

The fourth task used PAD to explore the concept of random variables. As previously mentioned, students often struggle grasping this critical concept in an introductory statistics course. We also decided to use PAD to explain random variables because the students had collected the data themselves and had an innate familiarity. We

<table>
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<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Hour</th>
<th>Day of Week</th>
<th>Steps</th>
<th>METs</th>
<th>Distance</th>
<th>Calories</th>
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<td>5</td>
<td>9</td>
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<td>5</td>
<td>9</td>
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<td>1190</td>
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<tr>
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<td>12</td>
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<td>74.3559</td>
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<tr>
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<td>9</td>
<td>13</td>
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<td>656</td>
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<tr>
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<td>0.09210</td>
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Table 2

Sample Data Used for Task 4

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<tr>
<th>Month</th>
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<th>Steps</th>
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</tr>
<tr>
<td>5</td>
<td>23</td>
<td>17</td>
<td>1062</td>
</tr>
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</table>

gave the students hourly step data from the Fitbit as shown in Table 2. In the task the students first guessed what the distribution of a randomly chosen hour of their week would look like and then used R, along with the data from their Fitbit, to generate an actual distribution. Through this task the students discovered the distribution of a random variable using what they already knew about the distribution of steps over the course of the day. Then they built off this knowledge to go one step farther to find the distribution of the average of two random variables. At the end of the assignment they simulated the Central Limit Theorem by finding the mean of multiple samples. This helped students discover the concepts for themselves with PAD.

The last PAD task employed regression methods to find which variables can predict calories burned each day. This task utilized almost all the available data from the Fitbits. We could now summarize the data by day, unlike the previous tasks, because by now the students had collected data for over a month, if they diligently synced and charged their Fitbit. This task asked students to find ‘Which of the variables being tracked is most strongly associated with daily calories burned?’ The variables provided to predict the calories burned included the day of the week, steps each day, distance, minutes active in a day, minutes sedentary, and minutes awake during the night as shown
Table 3

Sample Data Used for Task 6

<table>
<thead>
<tr>
<th>Date</th>
<th>Calories</th>
<th>Steps</th>
<th>Distance</th>
<th>Minutes Sedentary</th>
<th>Minutes Active</th>
<th>Sleep Minutes Awake</th>
<th>Time in Bed</th>
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<td>2,385</td>
<td>10,531</td>
<td>4.72</td>
<td>671</td>
<td>30</td>
<td>18</td>
<td>440</td>
</tr>
<tr>
<td>5/9/2017</td>
<td>2,150</td>
<td>7,378</td>
<td>3.27</td>
<td>82</td>
<td>20</td>
<td>21</td>
<td>473</td>
</tr>
<tr>
<td>5/10/2017</td>
<td>2,397</td>
<td>10,760</td>
<td>5.08</td>
<td>683</td>
<td>67</td>
<td>9</td>
<td>429</td>
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<td>2,622</td>
<td>14,657</td>
<td>6.64</td>
<td>686</td>
<td>74</td>
<td>14</td>
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<tr>
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<td>7.71</td>
<td>646</td>
<td>125</td>
<td>15</td>
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<tr>
<td>5/13/2017</td>
<td>2,244</td>
<td>9,963</td>
<td>4.56</td>
<td>715</td>
<td>58</td>
<td>20</td>
<td>507</td>
</tr>
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</table>

in Table 3. The sleep data ended up being very inaccurate and some nights the Fitbit just did not record the data. Students used these variables to explore the correlation between two variables and make predictions with the regression line. This task used all the data they had collected throughout the semester together with all that they had previously learned about two variable analysis.

Two tasks, the third and fifth, did not involve PAD because it did not naturally fit in with each task. These assigned tasks had inherent differences from the PAD tasks but we may use them for a loose comparison. The third task asked the students to analyze the court case People v. Collins. In this court case, the prosecution used probability to argue how unlikely all the circumstances in their case and characteristics of the people occurred due to chance alone. The students then investigated the validity of their claim. The fifth task allowed the students to design a paper airplane and test its performance against a traditional design. The whole class collected the data together and then the students analyzed the results individually. This experiment allowed the students to work through the whole process of a hypothesis test with data they collected. These two tasks had the same style as the PAD tasks to provide consistency.
DISTRIBUTION AND ASSESSMENT OF FITBITS

Students’ sentiment about using Fitbits in the class can be summarized by the comment, “It was exciting at first.” Some already had similar devices, but to extract the data all students needed a Fitbit issued by the university. When distributing the Fitbits, we gave each student a wristband and the charger for the device. Each student received instructions on how to sync a Fitbit to a phone or computer, and was provided with printed step-by-step instructions. These instructions also explained to the student their responsibility to charge and sync their device. For many students, syncing became a problem because they forgot to charge their Fitbits or even wear them. One of the benefits of using a Fitbit is the user apps that the students can interact with at any time during their day. They did not have to wait until class to familiarize themselves with the data and the information available. Figure 2 shows an example of the Fitbit app which made it easy for the students to see their current data and check the battery life of their

![Fitbit App](image)

*Figure 2. Common default display on Fitbit mobile app. On the app students were free to set goals or personalize the features (Press Kit, 2018)*
In order to collect the students’ feedback during the class, we required each student to turn in a survey collecting their opinions about a particular task. The questions asked students to reflect on what they liked, disliked, or what they might improve about each task. Other questions prompted students to rate each task by how much they learned from the task, how interested they were in the task, and if they understood the instructions. We used the information from these surveys to make adjustments for the next task during the summer. Furthermore, they helped us gauge how well the tasks were received by the students and concerns they had about using the Fitbits. During the duration of the course, most of the students’ actions and comments about the Fitbits had a positive thread.
CHAPTER III

SURVEY RESULTS

To answer the research questions, the main method we used to gauge the students’ reactions to the study involved the students completing surveys after each task. Soliciting for feedback from students can help them feel like an active participant of their education (Bradstreet, 1996) and help improve the courses in the future. In total, we administered seven surveys to the students, and we received a varying number of responses. Table 4 shows all the tasks, the number of students that responded, and if PAD was used. Many students did not submit the surveys with the tasks or left them blank. Using these results, we then assessed the effectiveness of using PAD in a classroom.

Table 4

Information on the Seven Surveys Given to the Students

<table>
<thead>
<tr>
<th>Assignment Number</th>
<th>Title</th>
<th>Number of Responses</th>
<th>Used PAD</th>
<th>Written Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>Designing an Experiment</td>
<td>25</td>
<td>Yes*</td>
<td>No</td>
</tr>
<tr>
<td>Task 2</td>
<td>Data Summary: Take it Easy</td>
<td>20</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Task 3</td>
<td>The Collins Case</td>
<td>21</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Task 4</td>
<td>Random Variables</td>
<td>22</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Task 5</td>
<td>How Far Does it Fly</td>
<td>21</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Task 6</td>
<td>Regression: Estimating Calories Burned</td>
<td>19</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Final Survey</td>
<td>--</td>
<td>19</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

*Task 1 did not use the data from the Fitbits, but did involve designing an experiment with PAD.
Many factors could affect the ratings students gave each task. In Figure 3, it shows the range of time students reported it took to complete the task outside of class. These numbers represent estimations supplied by the students on the survey. The outlier on Task 2 shows that one student took 8 hours to complete the task and their survey attributes the extra time to problems the student experienced with R. The two tasks that took the longest median time to complete were Tasks 2 and 6 which tasks involved PAD along with a written report. This shows that on average the two of the PAD tasks with reports required the most time because of the heavy use of R and the analysis involved.

![Figure 3](image)

*Figure 3. Time students reported it took to complete the assigned task outside of class time*

Students expressed their feelings about integrating PAD by rating each task. To compare the students’ reactions to the six tasks, Figure 4 shows the ratings students gave each task. The rating was from 1 – 5 with 1 being the student strongly disagreed with the statement and 5 being the student strongly agreed with the statement. The three statements were: “I was interested in this task,” “The task helped me to understand statistical methods,” and “I understood the instructions.” These questions tie back to the
research questions by judging whether or not integrating PAD increased interest and helped reinforce statistical concepts. The level of interest of the students in each task was similar except Task 5 with paper airplanes that had the highest level of interest. Most students reported that the tasks helped them to understand the statistical methods, except Task 2 (Data Summary) which received a lower score. This might be due to the high level of R programming involved and the fact that no sample code was given to the students. The reaction to the last statement varied more across the tasks, especially Tasks
which involved PAD. These tasks had more open-ended questions that required the students to make unique conclusions dependent on their own personal data.

On the surveys we asked six questions that students could respond to with their own thoughts. These questions allowed the students to express individual opinions. The first question “What did you learn from this task?” prompted the students to express what concepts this task helped to solidify. The next two questions provided students an opportunity to give positive or negative feedback with what they liked or disliked about the tasks. In order to improve the tasks for future use we asked, “This task would be better if?” One of the questions only applied to PAD and asked students to “describe how the PAD affected your learning and interest in the task.” The final question just asked for additional comments that student might not have expressed previously. Not many students used this section, because as one student eloquently stated, “I feel like I have response fatigue.” After receiving the comments, each comment was entered into the computer to make them accessible for searching and coding. Reviewing the comments, we can find trends and determine the effect of using PAD for the students involved in the survey.

After all the surveys were collected, a coding system was used to find patterns in the responses. First, reading through all the surveys helped locate the broad themes in the responses. Then looking at single words showed repetition confirming and narrowing the broader ideas. The three most common words included data, learned, and task. Many of the other words related to the specific concepts taught using PAD like regression, sample, variables, hypothesis, and distribution. These words were then grouped in similar categories to assist in extracting similar sentences using R. Further refining was done by
reading through the sentences associated with each theme to calculate the percent of students who mentioned each theme. Similar sentences were then grouped among each theme to find the most common supporting comments. Utilizing this process, four main themes emerged. 1) Gathering PAD affected the students personally through the process of gathering data. 2) PAD increased student interest and engagement in the classwork. 3) Using PAD provided real-world relatable problems for students to work through. 4) PAD helped reinforce the statistical methods taught in class. Each theme can be supported by comments from the students themselves in their responses to the survey questions.

THEME I: INFLUENCE STUDENTS

People have often used Fitbits to help increase exercise and as a tool to assist individuals in becoming more health conscious. Studies have found that being aware of your physical activity by wearing a pedometer or similar device will cause an increase of physical activity the first few weeks after wearing it (Schaefer, Ching, Breen, & German, 2016). A few students exhibited this same linear trend in their number of steps, even for the short amount of time they collected data. Some students mentioned that wearing the Fitbit caused them to notice the amount of physical activity they participated in each day. The comments in Table 5 illustrate how students felt about watching their activity levels and using a Fitbit. Even though the purpose of the study was not to influence students’ physical wellbeing, it is a consequence of using PAD. Subsequently, because each person collected their own data, and tracked their activity periodically using an app, they could connect to the experiment in a personal way. Each sentence listed in the table as an example, was selected because 4 or more students made very similar comments.
Table 5

Theme 1 Student Comments About How Wearing a Fitbit Affected Them Outside of Class

<table>
<thead>
<tr>
<th>Task</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>“I was more interested in the task because it was my own data. I am able to see how active I am and possibly make changes if necessary.”</td>
</tr>
<tr>
<td>4</td>
<td>“I enjoyed being able to look at my own data to see how my steps varied per hour of a day.”</td>
</tr>
<tr>
<td>6</td>
<td>“It’s really fun and interesting to look at data that is representative of what I do during a day physically.”</td>
</tr>
<tr>
<td>Final</td>
<td>“It allowed me to see what my activity levels were like throughout the day and it helped motivate me to get up and move around.”</td>
</tr>
<tr>
<td>Final</td>
<td>“I felt lazy if I didn't get enough steps. It also showed me how little sleep I actually get.”</td>
</tr>
</tbody>
</table>

The real-time feedback of the Fitbit app allowed students to become familiar with the available data and observe the trends in the data as they went about their day. These observations allowed students to use their data to make conclusions about their movements or exercise even before we analyzed it in class. They could see their step count over time and estimate their daily average steps before they conducted any formal tests. The students often found they wanted to change or see if they could affect the data collection. When we analyzed the data in class they could then look at the data to see if they achieved their goals. Also, this lessened the time students spent in class understanding the data so they could spend more time digging deeper into the statistical
methods and making conclusions.

THEME II: CONNECT TO REAL LIFE

Collecting data from the Fitbits allowed students to know exactly where the data they analyzed came from because they collected it themselves. Often students tire of textbook problems that do not relate to real life or just provide practice but no context of when a certain method might be useful. In Table 6 students expressed why they liked using PAD instead of more traditional methods. The data students use later in life will not always involve PAD, but using it as an example allows students to see a situation in which statistics can provide a valuable tool for analysis. Students can then apply concepts learned in class to the real world. In every task, students commented on how using real life data helped statistical concepts become more relatable.

Table 6:
Theme 2 Student Comments on How Using PAD Helped Relate Statistics to Real Life

<table>
<thead>
<tr>
<th>Task</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>“It was helpful to see that the data was from real life instead of just random numbers from a textbook.”</td>
</tr>
<tr>
<td>2</td>
<td>“I liked learning about the Fitbit data and using it for the analysis because it applies to real life.”</td>
</tr>
<tr>
<td>4</td>
<td>“It’s always a lot more interesting to do problems that involve the real world instead of coins and balls in urns.”</td>
</tr>
<tr>
<td>Final</td>
<td>“I liked analyzing data deeper than just homework problems”</td>
</tr>
</tbody>
</table>
These comments and others illustrate how much students enjoyed using the Fitbit data more than what they typically encounter in a traditional class style. In the surveys for Task 2, 61% of students mentioned that using PAD felt more real and more personal. This percentage was a lot higher than any of the other tasks. There is slight evidence that knowing the data personally increased students’ willingness to face the added difficulty of using raw data. Many issues arise when dealing with real life data that would never come up otherwise. These issues introduced students to a different side of statistics than they would have otherwise observed in an introductory statistics class.

THEME III: INCREASE STUDENT ENGAGEMENT

One of the goals of utilizing PAD in a classroom was to observe if it increased student interest or engagement. This way we could judge how naturally PAD integrated into a statistics course. When determining whether to integrate PAD into a class, teachers need to think about the balance between increasing engagement and the effort it takes to gather the data. Table 7 includes just a small sample of the wide variety of comments that talked about how using PAD increased personal interest. Some students did not get to use their own personal data and so the effect of using PAD did not apply to those students as stated in one student’s comment.

To further quantify the effect of PAD, Figure 5 shows the percentage of students that reported increased interest because of the task. In Task 2, eleven students explicitly reported an increased interest, for Task 4 sixteen students stated an increased interest and one student said it “neither decreased or increased my interest”, and for Task 6 thirteen
students reported an increased interest. Through the students’ comments we can see an increase in engagement when using PAD. The effect of engagement should not be overlooked in a classroom. Jim Cangelosi focuses on the importance of the affective domain which includes both students appreciating the content the teacher presents and being willing to try the problem (Cangelosi, 2003). Without a willingness to try the students are unlikely to learn as much or even attempt the assignments. We can help students become intrinsically motivated by connecting to the students’ interests.

Many students mentioned repeatedly in the surveys how using PAD had increased interest and helped them remain more engaged in the assigned tasks. Students could draw on their personal interest in health or fitness to help them better connect with statistics. The actual process of gathering the data may require time from the student but in the end,
they better understood and appreciated the tasks. Students even asked questions beyond the prompts in the homework. One student stated, “I’d be curious to see what my sleeping habits were like over the course of the semester” and a few students wanted to delve into their minute by minute data. The questions they posed often had a more personal note on how they could improve their physical activity. Curiosity may often lead to further investigations and engage the students in statistical thinking even after the assignment finishes.

**THEME IV: REINFORCE STATISTICAL CONCEPTS**

Teachers design assignments outside of class to help reemphasize the material...
learned in class and this was also the purpose of the PAD tasks. We hoped to help students understand concepts learned in class in a hands-on way. The intent behind integrating PAD into the classroom included helping students think about process of gathering and analyzing data in an accurate statistical context. In Table 8, student

Table 8:

*Theme 4 Student Comments About How Using PAD Helped to Reinforce Concepts*

<table>
<thead>
<tr>
<th>Task</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>“It forced me to apply the knowledge I had gained from lecture. I really liked using R as in a future career I may be handling a lot of data and could manage it easier with R”</td>
</tr>
<tr>
<td>6</td>
<td>“They helped me understand concepts we learned in class by having a more hands on approach.”</td>
</tr>
<tr>
<td>6</td>
<td>“Using my own data allowed me to connect to the task and be more interested in doing the analysis correctly.”</td>
</tr>
<tr>
<td>Final</td>
<td>“The characteristics of tasks I found interesting was a simple relevancy but made the task applicable while maintaining the relevance to help my understanding.”</td>
</tr>
<tr>
<td>Final</td>
<td>“I liked using PAD because it made me more interested in the outcome of the data. It was also easy to see if something wasn't right because I knew what the data should look like.”</td>
</tr>
<tr>
<td>Final</td>
<td>“In task 4 when everything clicked together from the previous lectures I was so excited. This doesn't happen very often in engineering classes where you can clearly see the connections to the lecture”</td>
</tr>
</tbody>
</table>
comments reflect how they could use the PAD tasks to solidify concepts learned during lecture.

For PAD to integrate effectively into a classroom it needed to improve statistical reasoning. Students mentioned that they could connect to the material taught in class and then deepen their understanding. This agrees with the rating the students gave to the statement, “The task helped me to understand statistical methods” in Figure 4. Though the two tasks not involving PAD got a higher rating, a majority of the students felt that PAD helped them develop better understanding. Passive learning often leaves holes in a student’s understanding, instead the PAD tasks promoted students to think through real problems in their own personal data. The tasks’ simple open-ended prompts required the students to search through notes or resources to determine how to proceed. Often, they had to also seek help to remember a concept they had learned or fill in gaps of understanding. The work the students put into these assignments helped the student achieve a deeper level of statistical thinking.

ANALYZING COMPLETED TASKS

Examining the students’ completed tasks that utilized PAD can reveal if the tasks helped to build statistical thinking or new themes in the responses. The students answered the prompts that were assigned on the tasks with their own unique data, and so each person could discover individual trends. Themes that appeared in their responses complemented the themes in the surveys. Some students found surprises in their findings, while others concluded what they expected. Students used their data to discover statistical relationships taught in class or think deeper about a concept mentioned in class. The tasks provided an opportunity for students to ask questions and suggest other areas of possible
research to broaden their understanding and increase interest. Also, students could compare their results to other students and have a glimpse of the complexity that exists in answers to actual life situations.

Since students collected their own data they could compare their findings to actual experiences which made their conclusions more personal. Still, some students still found surprises in their data. In task 2, on summary statistics, 44% of the students found that their data followed their predictions, whereas 32% found that the results surprised them (not all students reported their conclusions). In their conclusions students addressed their specific routines as evidence for the behavior of the data. “Another data point that skews the data is that I went on a 5 mile hike in the morning… which would adjust the mean of the calories and steps per hour because my hike started around 8:00 and ended around 11:00 which were times on the graph as being just barely above the inactive mark.” In contrast, for the same task, another student commented that “I had to use a sample which makes it harder for me to interpret because when it comes to things such as outliers I wouldn’t know why they may be there. However, if it was my data I would know that I ran a marathon, or took a long hike.” In task 4 students compared their hypothesized distribution of a random variable to the one found on R. One student stated, “It is similar to what I had sketched however I expected a decrease near the 2000 step mark but I saw the contrary.” Looking at the actual data helped either confirm or modify students’ perceptions about their own physical activity.

An achievable learning level for students is to discover a relationship (Cangelosi, 2003). PAD tasks often lead students to make statistical conclusions on their own before being taught the general rule. In task 1, on designing experiments, the task asked students
to think about “How would you analyze the data?” Some students had previously been exposed to statistics and so talked about significance testing. Still, a majority of the comments were similar to this student, “After all 5 trials have taken place we will find the average calories and distance measured by the Fitbit and treadmill. The means will be compared to see the difference between Fitbit and treadmills.” In task 4, on random variables, the task asked students to run a simulation in which they took a random sample of an increasingly larger number of samples. They found that the simulation “looks like a normal distribution when the sample size increases.” The students could see the central limit theorem in action in their own data. Students then discovered the relationship between sample size and ability to use the normal curve for approximation.

Often students have questions beyond what the assignment asks them to report. To bring out these questions, we provided sections in assignments for students to voice any additional inquiries that they would like to answer about the data. In task 6, on regression, many students mentioned additional possible studies. For example, “It may be interesting to repeat the experiment and have the test subject wear two separated personal tracking devices to see if or how much deviation can be seen between the data collected.” Students also expressed options about how to overcome assumptions by additional experimentation. “The biggest assumption I had to make for this analysis was that the Fitbit’s data collection method was flawless… It would be interesting to see if Fitbits are as accurate when compared to more expensive and less expensive PAD tracker.” Asking questions helps to increase interest and shows the students’ desire to learn more.

Each student obtained an individual result and this allowed the results to remain very personal. In task 6, a student expressed their interest in others’ results by stating, “I
would like to compare my data to other students and see if they got similar results. Not only in a similar regression line, but if the same variable along with calories was used.”

To answer this question, we found that 12 students used the distance traveled as the best predictor, four used the number of steps, and the remaining three used the number of minutes active. This showed that while consistencies occur in the data collection by the Fitbits, the answer to the questions changed based on the individual’s activity. In task 4, when asked to compare their results to their neighbor a student realized, “Well mine is quite different. Normally others sleep during the night where I work and study... however variances compared would be similar.” Even though each student found different results they could stand confident in their conclusion, because they are the experts of their own data. Students also realized “One limitation of this study is that the results are only generalizable to myself and even then it would depend on the frequency of my running activities.” The individual nature of PAD makes it so the conclusions made by each student only applies to them. Still, each task allowed students to explore their physical activity and these comments showed that using PAD reinforced statistical concepts taught in class.

FINAL SURVEY

After the students completed all the tasks at the end of the course, they filled out a two-page survey. This survey collected their final thoughts on how they felt about what they had learned, enjoyed, or disliked about using Fitbits in the classroom. One of the first questions asked the students to rank the tasks from 1 - most interesting to 6 - least interesting and the results are shown in Figure 6. Some students might have ranked the tasks on which ones they liked the most. These responses show that students on average
found Task 5 with the paper airplanes most interesting. This task has often been a student favorite. Task 1 and 2 were tied for the least interesting. At least one student rated each task as either the most or the least interesting. The PAD task that students ranked as the most interesting was Task 6, which required them to use regression analysis. This task brought together all the data and information that the students had collected thus far in the class. This graph shows a general trend against student interest in PAD compared to other tasks.

The final survey also asked to student to rank statements like those found on the individual task surveys. Figure 7 shows that on average students felt that the PAD tasks helped them to learn the statistical method as well as the tasks in general, but with more variation in opinion. On average the students were interested in both the tasks and the
using PAD for the assignments. Many students enjoyed using PAD in the classroom, more than just completing the tasks in general, with a few ambivalent responses. This could have just been due to the novelty of using PAD. None of the questions received a strongly disagree response, and a higher percentage agreed with the statements than disagreed. Statements about PAD have a higher percent of students in favor with them. In the final survey, the students also provided demographic information and the number of hours they worked and studied. Most students had a job during the class, but still spent over an average of 11 hours of studying each week for this class. No trend was discovered between the demographic information and their responses. The class included students from diverse backgrounds and opinions which they expressed in their comments.

Figure 7: Student ratings on whether they agree - 5 or disagree - 1 with the given statements on the final survey
On the survey, free response questions asked students to write their thoughts about their experiences in the class. Some of these comments were included in the themes that were found in the other surveys. The questions on the final survey asked students to describe characteristics of the tasks that made it least or most interesting. In answer to this question some students responded that they did not like the essay format of some of the tasks. One student’s comment could either be good or bad, they stated that “The tasks were sometimes vague in the directions.” From an educator’s point of view this could actually be beneficial because it allows students to think through the problems and come up with their own solutions. Nevertheless, it is detrimental if the students did not understand what they needed to accomplish. When asked what task students would design a few students brought up looking more into sleep data. Another student said “I would design it so they built off of each other to culminate into a final task they have elements of the previous tasks. Also, all the tasks would be centered around the Fitbit.” Using PAD does not work with every type of task, but more connection could have existed between each task.

Following each individual students’ comments trends emerge. Usually if a student expressed positive opinions about PAD they only had one or two improvements that they would make to the tasks. In fact, many of these students responded that they disliked or would change nothing. Whereas if a student disliked using PAD they consistently remained very vocal about their opinions throughout each survey. Some students would have a positive comment about PAD and then an identifiable chorus of voices would refute it. One student in the final survey even contradicted themselves saying “Tasks were all bad, they were typically unrelated to learning as they did not improve
understanding.” Whereas later in answer to a different question the same student stated, “Most of them increased my understanding.” These trends illustrate the ambiguity and bias that can often exist in surveys. Strong voices tend to express themselves more adamantly.

Some of the other questions asked for what students liked, did not like, or what could have been better with the tasks or PAD. One student stated that “I liked learning about the world through statistics,” while another student expressed that they disliked “Doing them, getting confused in R [and] not understanding why we had to use data that was hard to work with.” In the final survey many students expressed their concerns. After the second task one of the biggest concerns students expressed was related to their struggles when programming with R. Most students had little to no background in programming and so the students had to overcome a steep learning curve to write their own code. Acting on this feedback we decided to give students sample code for the following assignment that they could copy and modify for their use. One of most the common negative comments mentioned how difficult students found it to charge and sync the Fitbit often. Another string of concerns brought up the issue that often the tasks seemed rushed. With a seven week course this comment is not surprising and would naturally be resolved in a longer course. When asked how the PAD tasks compared to the others 70% of students mentioned that they felt it was more personal, applicable to real life, and interesting. A student summed up their feelings about using a Fitbit in class by the equation “PAD = interesting tasks.”

The surveys both showed the benefits and illuminated future areas for improvement for using PAD in a classroom. While not all the students responded to the
surveys the results agreed with conversations observed in class. Students still found
statistics challenging, as you would expect. Nevertheless, they also made new
connections between statistics and their personal lives. We can now use the comments in
the surveys to either improve or modify these tasks for future class experiments.
CHAPTER IV

FURTHER CONSIDERATIONS

The use of personal activity data can have many benefits, the impact of using PAD requires further investigations. This study showed that using Fitbits in a classroom can have benefits, but also drawbacks. In order to judge the impact of using PAD an experiment would need to be implemented. This could involve acquiring Fitbits for one section of the class and no Fitbits for another section taught by the same teacher. Each class would be assigned the same number of tasks to complete, but the tasks for students without a Fitbit would use other data from another source that met the needs of the assignment. For example, in previous semesters instead of using Fitbit data to introduce summary statistics and visualization the students used data from cereals. Both classes would then need to complete surveys and take the same exams. This would make it so we could see in a greater depth the impact of PAD on student learning.

To implement this study in the future, some considerations need to be addressed that surfaced during the study. Many students disliked using R with little background knowledge and so greater support with R and R Studio would help students succeed. This support could include sample code, or more extensive in class tutorials on R before students work on the task alone. Many students found the Fitbits annoying to wear after a few weeks, especially when some had their own Fitbits. Also after a while students got lazy and kept forgetting to sync. Devices exist that will sync all the Fitbits in the room and so it would have helped to sync the Fitbits every day during class. Other studies in elementary schools synced and charged Fitbits for the students, and even at a college level this might help reduce data problems (Lee, Drake, & Thayne, 2016). Students had
other complaints about using Fitbits, but overall, they had positive reactions to using them in class.

One of the bigger changes that could improve this study would require students to wear the Fitbits longer before assigning the first tasks. The students did not have enough data to answer the question ‘Which day are you least active?’ when they had only one week’s worth of data. In order to really see a trend, it would be beneficial to collect data for an increased number of days. This was partly due to the short seven week time allotted for the study. A follow up study would probably happen over the course of a semester and students would have more time at the beginning of the class to gather data.

CONCLUSION:

Integrating PAD in an introductory class can help promote student interest and can help students develop statistical thinking if done responsibly. We have presented some issues and possible solutions for future implementation of PAD. Even with the few issues, we found through this project that students can learn statistics with PAD. The students knew where their data came from and could understand the trends because they gathered the data from the Fitbits. As a teacher, using PAD will require more work to process the data, but allowing the students to do more data cleaning could engage them fully in the entire process. Involving the students in PAD allows student engagement to follow naturally into increasing student interest.

One important aspect of statistics focuses on helping students become consumers of data they will encounter every day. Society becomes more data driven each year and classes need to integrate data. This project helped investigate one possible way of using data collected from the students themselves to engage students in a more realistic way of
reasoning through problems. PAD comes with real world complications and helps connect a student’s interest in health to concepts taught in statistics. Collecting the data requires little effort on the part of the student and it is inherently relevant to their lives. Using this data can help students with tasks related to experimental design, summary statistics, random variables, and regression analysis with bivariate data. Many students reported increased motivation and understanding through this project that will then help them in future careers.
REFERENCES


APPENDIX: PAD TASKS AND SURVEY TEMPLATES
Task 1: Designing an Experiment

As an individual design and then later implement for extra credit a test to answer the research questions: Is there a difference between the calories or distance reported by a Fitbit Flex versus a treadmill? Consider the following elements of designing an experiment while keeping in mind the research question.

- Parameter and population of interest
- Most accurate device, treadmill or Fitbit
- Required time to complete each trial
- Include randomization in the trial
- How to analyze the data

Task 2: Data Summary – Take it Easy

Using your personal data create visual and numeric summaries of just two variables collected from the Fitbits. The data will include the number of steps, METs, distance, and calories. Your analysis should answer the following questions: On which days are you least active? During which waking times are you least active? Include in a 3-5 page paper:

- Predictions of the answers before completing the analysis
- Multiple numerical and graphical methods to summarize the data
- An explanation of why you chose the methods
• Report your findings from the summaries
• State your conclusions
• Discuss the reasons behind your conclusions

Task 4: Random Variables

Find the distribution of the number of steps from a randomly chosen hour from your day by:

• Predicting the possible values for the number of steps
• Predicting which values are most likely
• Sketch the distribution of the random variable
• Create a histogram of the data in R
• Create a histogram of the distribution of two random variables added together
• Simulate what happens to the distribution of the mean as the sample size increases

Task 6: Regression – Estimate Calories Burned

Explore the data that has been collected during the whole semester by answering the following question: Which of the variables being tracked is most strongly associated with daily calories burned? Look at data from each day and identify trends that could help you identify the variable that is most closely related to the calories burned each day.
• Identify outliers and decide if they can be removed
• Calculate the correlations between each variable and the calories burned
• Justify which one might be most useful
• Mention if it is a clear choice or if there are multiple contenders
• Find different lines to fit the chosen variable
• Discuss the meaning of the slope and intercept of the best line
• Estimate the calories burned on a very atypical day
• Discuss how or if your results can be generalized
Survey Task: 1-6  

How long did you spend working on this task outside of class? ______

Rate your agreement with each of the following statements using the following scale
1: Strongly disagree  2: Disagree  3: Neither Agree nor Disagree  4: Agree
5: Strongly Agree

I was interested in the task.
1  2  3  4  5

The task helped me to understand the statistical methods.
1  2  3  4  5

I understood the instructions.
1  2  3  4  5

What did you learn from this task?

What did you like about this task?

What did you dislike about this task?

The task would have been better if

If this task used Personal Activity Data (PAD) from the Fitbits, describe how the PAD affected your learning and interest in the task:

Additional comments:
Final Survey (This has two sides)  Date: __________________________

Age ______  Sex ______  Major ______  First language ______

Average Hours worked per week ______

Average Hours per week spent studying ______

Rank the tasks in order of interest to you from 1 – most interesting to 6 – least interesting.

Task 1: Designing an Experiment  ______
Task 2: PAD data distributions  ______
Task 3: The Collins Case  ______
Task 4: PAD random variables  ______
Task 5: Inference with Airplanes  ______
Task 6: PAD Regression  ______

Briefly describe characteristics of the tasks that made them the most interesting or useful.

Briefly describe characteristics of the tasks that made them the least interesting or useful.

Rate your agreement with each of the following statements using the following scale
1: Strongly disagree  2: Disagree  3: Neither Agree nor Disagree  4: Agree  5: Strongly Agree

The tasks helped me to learn how to apply statistical methods.
1  2  3  4  5

I was interested in the tasks
1  2  3  4  5

I enjoyed completing the tasks.
1  2  3  4  5

Using Personal Activity data (PAD, from the Fitbit) helped me to learn how to apply statistical methods
1  2  3  4  5

I was interested in the Personal Activity Data (PAD)
1  2  3  4  5

I enjoyed using Personal Activity Data in the tasks.
1  2  3  4  5
If you were to design your own task with using the personal activity data, what would it look like?

What advice would you give to future students completing tasks with PAD?

What I liked about the tasks:

What I did not like about the tasks:

The tasks would have been better if

What did you like/dislike about the PAD tasks compared to the others?

What did you enjoy about using the Fitbit?

What concerns did you have about using the Fitbit?

Additional Comments: