

FATHOMING STUDENT LEARNING: A SURVEY BASED APPROACH USING FATHOM SURVEYS TO FORMATIVE ASSESSMENT IN AN AP-STATISTICS CLASSROOM

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This paper describes a classroom experience using a data gathering and analysis tool to scaffold a learning process that involves classroom surveys as a means of gathering formative assessment data.. An AP-Statistics class uses data about their own sleep patterns to investigate measures of variability. The class applies various measures of variability to the sleep data set and comments on their efficacy using a survey created in Fathom. The students comment on the measures in groups, rate the measures, and provide justifications. Students in a statistics class should find themselves routinely engaged in data analysis. Asking students to comment on invented measures of variability provides valuable formative assessment data for the instructor.

INTRODUCTION

Statistics: a branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data. -- Merriam-Webster Online.

Surveys have been used in statistics classrooms to teach about sampling and survey design. In some cases, students use surveys to collect data as a part of term projects, which takes the data collection out of the classroom. The 45-50 minutes available in a typical class period often means that statistics classrooms concentrate on the “**analysis, interpretation, and presentation**” of the data. The **collection** of data either becomes an outside the classroom activity unconnected to the practice of statistics in the classrooms, or it never gets done, instead is replaced by ready made data sets that come with textbooks. In this paper, we describe the nature of learning that takes place when surveys play an *integral* role in a statistics classroom. The lesson on which we report relies on an online survey tool for gathering raw data from students and as well as for formative assessment of their understanding.

Students in statistics classrooms need to be deeply engaged in data analysis to get a feel for how data behave and what stories can be told with statistical measures. Students are likely to remember what they learn when they can engage in analysis of what matters to them - when not just the analysis in data analysis comes from them but also the data. In this paper for example, the outliers in the data set are represent students who report sleeping not at all or as much as 16 hours. The source of the data lends it an immediacy that is hard to create with textbook data sets. Research around teaching and learning, especially work around the participatory model of learning and situated cognition (Lave, 1991), provides strong support for using student experience as the basis of instruction. Jerome Bruner’s (Bruner, 1967) work on discovery learning provides a basis for curriculum design that uses the irregularities of real-world data to inform the mathematics in which the students engage

In this paper, we describe the use of Fathom Dynamic Data™ software (Finzer, 2007), along with Fathom Surveys (Key, 2006) - its online data gathering counterpart - to implement a survey based approach to formative assessment in a statistics classroom. The students in the classroom described in this paper gather data, analyze it, compute measures, and comment on the resulting graphs - all by using technology designed for statistics learning. They enter data about themselves - specifically, how many hours they slept each night. They look at that data, keeping in mind what they learned about center, spread, shape, and outliers. They see the variability in the

data and design a measure to capture this phenomenon. They apply multiple measures to their data and comment on their measures.

ASSESSMENT, DATA COLLECTION AND EXPLORATION

In statistics education, there is an advocacy movement to think creatively in new ways to assess performance in statistics courses (Garfield, 2000; Chance, 1997; Gal, 1997). Formative assessment helps teachers gain insight into student understanding with the purpose to inform instruction on a ongoing basis. Examples of tools for conducting formative assessment include journals, pop quizzes, minute papers and mid-year reviews.

The paper based nature of traditional assessment tools implies a minimum turn around time between the collection of the data and the impact of it on the instruction. Too often, in busy 45 minute periods, a teacher practicing formative assessment is forced to look at the resultant data later on her own thus losing an opportunity to involve the students in understanding their own learning as well as an opportunity to adjust the immediate instruction based on the data. The design of Fathom Surveys allows for very quick classroom data collection thereby making it possible for the teacher to look at formative assessment data in the moment and make quick adjustments to the instructional plan. Using Fathom Surveys to gather formative assessment data, provides an anonymous and asynchronous method for the teacher to get an insight into possible misconceptions. The fact that this tool is the same as that used in the classroom instruction, offers a meta-opportunity for the students to explore data - not just for learning statistics but also for looking at what they learned.

INVENTING MEASURES OF VARIABILITY

Working from a talk by Gould, in which he describes a classroom activity that uses data gathered from the students to motivate teaching of statistics (Gould, 2005), we decided to choose sleep data as the topic for the initial survey. A high school Advanced Placement (AP) Statistics class taught by one of us (Beals) used Fathom Surveys to collect data about their sleep patterns over a period of two weeks. Figure 1 shows the online data gathering form.

The screenshot shows a web form titled "Sleep Data" with the instruction "Please fill this one for each day you have sleep information". It contains five numbered questions: 1. A text input field for a consistent identifier. 2. A dropdown menu for "Select the day of the week". 3. A dropdown menu for "Was it a school night?" with "Unknown" selected. 4. A text input field for "Type in the hours of sleep you got in the 24 hour period". 5. A dropdown menu for "What month was this data collected?" with "December" selected and a list of months (December, November, January) visible. At the bottom are "Submit" and "View Results" buttons.

Figure 1: Online Survey to collect sleep data.

This form was created by the teacher in Fathom and uploaded to the Fathom Surveys website on which the teacher has an account. In Fathom, the data lives in an object called the collection. You can turn any collection into a survey, annotate the attributes with questions, and, if desired, specify a set of choices for answers.

The lesson utilizing the survey data focussed on measures of variability and was spread over three class sessions. In the first session, the teacher led a whole-class brainstorm for about 30 minutes with the aim of finding different measures of variability. A student suggestion that they look at “average distance away from the center” seeded the discussion. With some discussion around how to get at the average and what is a distance, the students came up with the idea of calculating the absolute value of the difference between the median and or the mean and data value and dividing the sum of these values by the total number. The teacher then said that they needed more formulas to really get a sense of what would work. This then led to the idea of square root of squares from the distance. The students related to this formula as similar to the distance formula from Algebra. The students entered these measures of variability into a survey.

Attribute	Format	Description
ID	None	Type in a constant, identifier so that you know which data goes together but not necessary
Day	Day, Sat	Pick a day of the week
School	School, Set	What is a school night?
Sleep	None	Type in the hours of sleep you got in the 24 hour period
Month	Month, Set	What month were the data collected?

Instructions:

Measure 1: This one for each day you have sleep information:

☐ Replace Data On Site

Figure 2 : Survey Panel in Fathom

Table 1

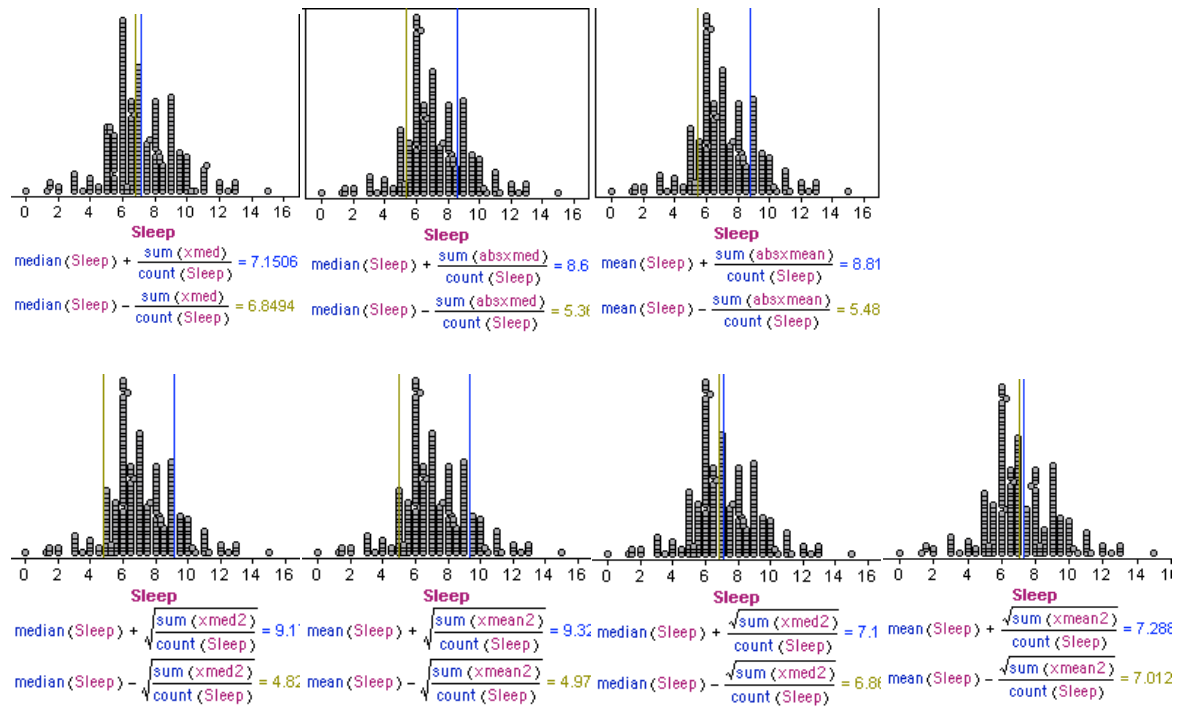
Table of Fathom formulas for the measures of variability

$\frac{\text{sum}(\text{Sleep} - \text{median}(\text{Sleep}))}{\text{count}(\text{Sleep})}$	$\frac{\text{sum}(\text{abs}(\text{Sleep} - \text{median}(\text{Sleep})))}{\text{count}(\text{Sleep})}$
$\frac{\text{sum}(\text{abs}(\text{Sleep} - \text{mean}(\text{Sleep})))}{\text{count}(\text{Sleep})}$	$\sqrt{\frac{\text{sum}((\text{Sleep} - \text{mean}(\text{Sleep}))^2)}{\text{count}(\text{Sleep})}}$
$\sqrt{\frac{\text{sum}((\text{Sleep} - \text{median}(\text{Sleep}))^2)}{\text{count}(\text{Sleep})}}$	$\sqrt{\frac{\text{sum}((\text{Sleep} - \text{median}(\text{Sleep}))^2)}{\text{count}(\text{Sleep})}}$
$\sqrt{\frac{\text{sum}((\text{Sleep} - \text{mean}(\text{Sleep}))^2)}{\text{count}(\text{Sleep})}}$	

The teacher helped them convert the description to the formulas shown in Table 1. In a subsequent class session, the students had time to apply the measures of variability to the sleep data and discuss as small groups the seven results – by looking at plots of center plus/minus variability and comparing them. Most students could decide what to plot to capture the interval.

Table 2

Graphs of the data. The graphs have plotted values on them to indicate where the measures of variability capture the spread of the data.



In groups, they discussed which is the “best measure of average spread” or “captures the ‘typical’ values.” The teacher found these small group discussions to be quite lively and engaged. The formulas that appear under the graphs have been expanded in Table 1 to make it clear what *absmed* and *xmed* and *xmean* stand for. (The graphs in this table were made by Beals, based on similar graphs made by the students)

COMMENTS AND JUSTIFICATIONS IN GROUPS

Comments on Measures of Variab

Comment on the formulae assigned to your group. Take this survey once for each formula.

1. Name of the formula
2. Formula
3. On a scale of 1-5, rate the formula as an effective measure of variability
4. Justify the above answer(at least 50 words).

Figure 3: Survey to collect student reactions to the measures.

In the last session, the students discussed the formulas in groups. There were four groups of four students each. They rated the seven measures and provided a justification for their ratings. They used numbers from 1-7 to name the formulas. The teacher had them write out the formula in text. The students were asked to complete the survey form shown in figure 3 individually - once for each of the seven formulas. However, given the time that they had, most of them only had time for two formulas. The teacher found that these comments allowed her to better understand both her students’ understanding and their misconceptions of variability. This method of gathering comments requires that even the quieter students provide justifications, thus allowing the teacher and other students to hear from all of the students. Table 2 captures a smattering of their justification for the ratings as collected from the survey.

Table 3

Selected student comments on observing how the measures captured the variability

Measure	Rating	Justifications
$\text{sum}(x-\text{med})/n$	Least Effective	Number one is bad because it is very very very small. Since it is very small the data the spread is quite small.
$\text{sum}(\text{abs}(x-\text{med}))/n$	Most Effective	It was good because it included most of the high peaks. Also, it used the median which should not be too effected by outliers when compared to the ones using mean However, it didn't include one of the peaks on the right, so it could have been better.
$\text{sum}(x-\text{med})/n$	Least Effective	The spread does not include majority values
$\text{sum}(\text{abs}(x-\text{med}))/n$	Effective	pretty close to 3, a little smaller range, covers most of the values, but leave out 9 and 5, which are both biggies
$\text{sum}(\text{abs}(x-\text{med}))/n$	Effective	This formula gives a spread which leaves an equal amount of values outside of the spread. Whereas 4,5,6, and 7 all include values which give uneven amount of values on either the left or the right of the spread.
$\text{sqrt}((x-\text{med})^2)/n$ [sic]	Moderately Effective	This formula is a little too high in its variability

They were also asked to rate the formulas on a scale of 1-5 with 5 being the most effective and 1 being the least effective. This rating was to illustrate how well the measure captured the variability of the data.

Comments on Measures of Variab

		Rating					Row Summary
		Least Effective	Not very effective	Moderately Effective	Effective	Most Effective	
Formula	$\text{sqrt}((\text{sum}(x-\text{mean})^2)/n)$	1	1	0	1	0	3
	$\text{sqrt}((\text{sum}(x-\text{median})^2)/n)$	0	0	3	1	1	5
	$\text{sqrt}(\text{sum}(x-\text{mean})^2)/n$	3	0	1	0	0	4
	$\text{sqrt}(\text{sum}(x-\text{median})^2)/n$	1	0	1	0	0	2
	$\text{sum}(\text{abs}(x-\text{mean}))/n$	0	0	2	1	1	4
	$\text{sum}(\text{abs}(x-\text{median}))/n$	0	0	1	4	1	6
	$\text{sum}(x-\text{med})/n$	8	0	0	0	0	8
Column Summary		13	1	8	7	3	32

S1 = count ()

Figure 4: Summary Table of ratings by students

This summary table from Fathom is a two-way comparison of the ratings that the students accorded the formulas. Thirteen of the thirty-two entries were for the Least Effective rating. Of these 8 were for the same formula. Here are a few student comments on this formula -

- *Formula one yields a value that is so low it cannot possibly ever give the spread of the data. Since the data spreads from 0-14 and the formula yielded a value that is less than 1. This cannot be as the mean of the data is well over 5.*
- *It's too small, doesn't have a good range, tallest column of values is not included in the range, doesn't cover enough variables*
- *Simply from eyeballing the graph you can tell that 1 has far too small a spread to accurately represent the data. It includes only the middle column and neglects almost all of the rest of the data. Also, it uses the mean which is susceptible [sic] to outliers.*

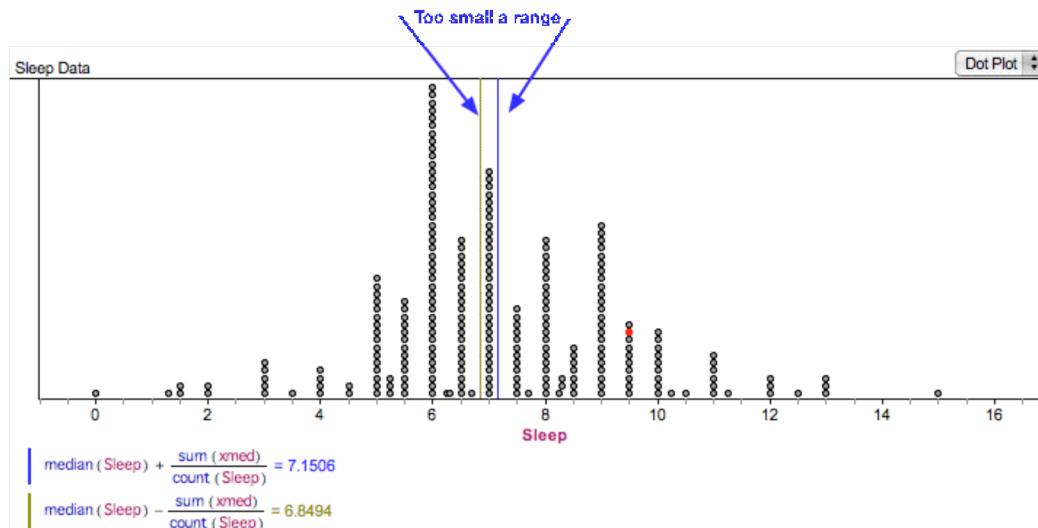


Figure 5: Graph of the measure rated “Least Effective” by the students

In a graph with this measure plotted on the data, we can see the small range it covers. The measure “ $\text{sum}(\text{abs}(x - \text{median}))/n$ ”, received favorable comments from students:

- It was good because it included most of the high peaks. Also, it used the median which should not be too effected by outliers when compared to the ones using mean However, it didn't include one of the peaks on the right, so it could have been better.
- This formula gives a spread which leaves an equal amount of values outside of the spread. Whereas 4,5,6, and 7 all include values which give uneven amount of values on either the left or the right of the spread. (4,5,6,7 refer to the formulas in the last two rows of Table 1).

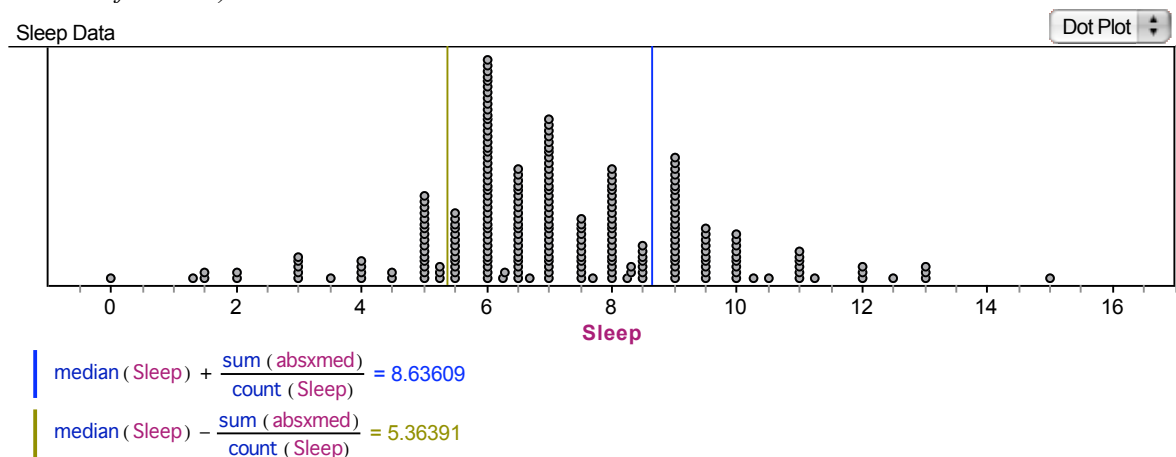


Figure 6: Graph of the measure that got the most number of “Effective” votes. Contrast with Figure 7 to note the larger interval captured here.

The student comments are very cogent. The teacher commented on how effective the anonymous survey was in getting the sometimes shy students to contribute in class. The fact that it was asynchronous meant that the students had the option of commenting without being influenced by their classmates. At the same time, it also allowed for them to compare their comments to their classmates if they desired.

In Fathom, the students can see their data, their measures and their comments all in one document - example in Figure 7. This allows them to move between their individual work and the communal space at will thus allowing them to compare their justifications with the graphs that

show the measures. The facility of moving seamlessly between the raw data, the summary statistics that can be computed, was a new way of working through a statistics lesson.

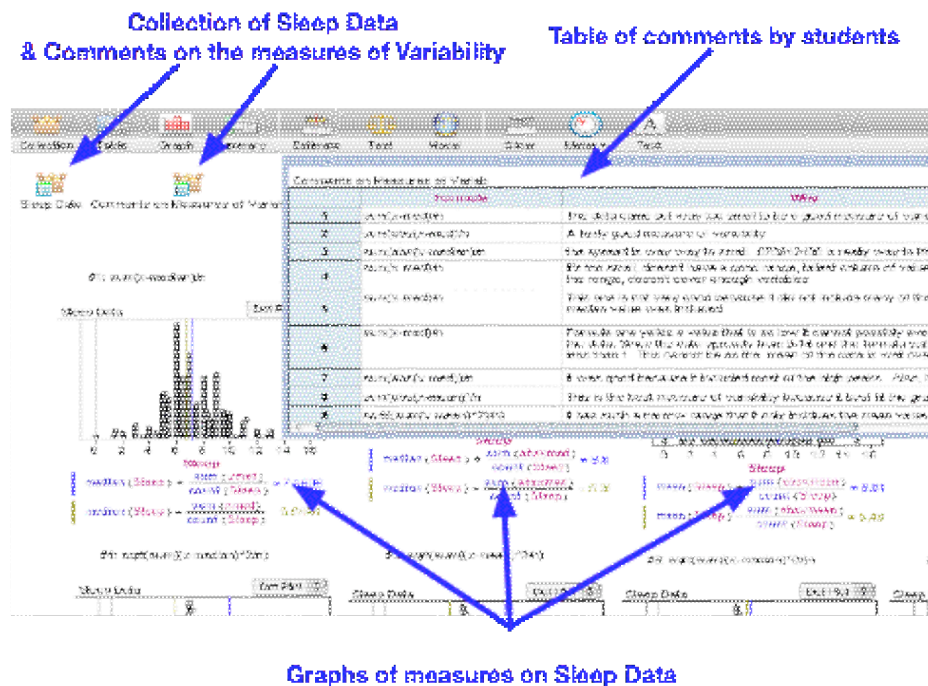


Figure 7: Sleep Data and Measures Ratings in the same Fathom document

For the teacher, the availability of immediate data, allows her to get instant insight into the misconceptions existing in the class without interrupting the flow of classroom learning with a test. As a tool for formative assessment, use of Fathom Surveys satisfies the criteria that it is in the moment, informs the ongoing instruction and provides an asynchronous and continuous way to peek into student understanding.

The section that follows captures the teachers (lightly edited) reactions to a series of questions asked of her after the lesson.

TEACHERS COMMENTS

Question: How much did the fact that the data was theirs help in motivation? *The kids LOVED being about to look at and analyze their own data. It helped bring the conversation much more alive in class. In addition, since they were so interested in finding out how they compared to their peers and how their peers responded, they remained engaged in the data even past the bell for two class days - I've never seen a set of data hold their interest so long!*

Question What did the students think of the last part of the lesson in which they rated the formulas? *They seemed to not fully understand why I wanted them to do it on the computer rather than just telling me their ideas. When I explained that this was a way that I could get feedback from/on everyone - they understood and thought it wasn't a bad idea. They really remained motivated so that certainly helped their involvement and thus understanding. Part of this was the fact that it was their own data that they had entered and were analyzing as much as anything. I think I gained more from the formulae piece than they did; however, it did help organize some of their thoughts on the different formulae.*

Question Do you think using surveys helped you to gain any additional insight into their thoughts? *Absolutely. Since they were commenting confidentially, I got feedback from some kids who usually don't speak up in class - some of which was quite helpful to the discussion and some helped illuminate some misconceptions I didn't realize were still out there from some of the other kids.*

CONCLUSION

Our students engage more and more with data in their daily lives. This kind of data collection and analysis activity, which is grounded in their own lives is one way to motivate the learning and application of statistics. We are in this exercise using "real-world" data and "bring(ing) together the values and practices of teaching with those of research" (Bostock 2001).

In addition to giving the students a taste for data collection, this activity allows them to look at the statistics they learned, as well as, their reactions to their work (in this case the justifications they provide for the ratings and the graphs of raw data) . The teacher can harness the on-line survey technology to gain insight into the student's understanding. The asynchronous nature of the response collections allows the students to enter their response without being influenced by others' responses. The anonymity allows for the student responses to be candid and expansive. In addition to giving the teacher data about student understanding, this method makes available the data to students to chart their own progress using the same tools that they use in their class.

It leaves us hopeful to investigate more classroom innovations using surveys in statistics classrooms.

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