

Quantified Recess: Design of an Activity For Elementary Students Involving Analyses of Their Own Movement Data

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ABSTRACT

Recess is often a time for children in school to engage recreationally in physically demanding and highly interactive activities with their peers. This paper describes a design effort to encourage fifth-grade students to examine sensitivities associated with different measures of center by having them analyze activities during recess using over the course of a week using Fitbit activity trackers and *TinkerPlots* data visualization software. We describe the activity structure some observed student behaviors during the activity. We also provide a descriptive account, based on video records and transcripts, of two students who engaged thoughtfully with their recess data and developed a more sophisticated understanding of when and how outliers affect means and medians.

Categories and Subject Descriptors

K.3.1 [Computers and Education]: Computer Uses in Education - Collaborative learning.

General Terms

Human Factors.

Keywords

Quantified self, collaboration, competition, Fitbit, TinkerPlots, physical activity, elementary students, activity trackers.

1. INTRODUCTION

For many children, recess is a favored part of the school day. It provides the opportunity to be physically active, mingle with friends, and play. While free activity recess has clear, documented benefits for students' academic performance [6], we are interested in considering the potential for recess to serve both as a time for students to play and as a time for children to easily obtain data about their activities for later review during the school day. In considering this, our goal is not to detract from the importance and enjoyability of recess as a recreational time for students. Rather, in following with the broader "quantified self" movement in which adults are leveraging mobile and sensor technology to gain insight into their activities, we wish to see what opportunities may exist for students to engage with data that may hold some

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inherent interest to them.

In pursuing this endeavor, we had two main motivations. First, we began with the assumption that children already have a wealth of prior knowledge about their physical activities. By virtue of being active, moving individuals, elementary school-aged children are naturally familiar with a number of movements and motions that comprise physical activities associated with recess. While they may not be experts on the underlying science of bodily activity, most children should know enough to be able to make predictions and interpretations of data about their physical activities. Given strong constructivist leanings with respect to how students learn and expertise is ultimately developed, this prior knowledge was thought to be very useful to leverage [7].

Second, current activity tracking devices are available now that can allow children to collect large amounts of data without requiring the traditional work (making a recording document, adding and checking records as they are added to the document, etc.) associated with doing the often-laborious task of data collection. It is now quite easy for anyone to find an off-the-shelf device that will passively collect dozens or hundreds of data points from just a few minutes of bodily activity [5].

Given those two motivations for this work, we describe below one of our more recent efforts to encourage elementary students to collect and analyze data about their own recess activities. Specifically, we used two existing technologies—Fitbit Ultra activity trackers and *TinkerPlots* dynamic data visualization software [2]—and an interaction design intended to encourage children to collaborate with a partner while also competing with other pairs of students. In contrast to some of our earlier efforts which were situated in the context of math or science class [5], we were interested in less formally structured times during the school day. Thus, the activity we designed was intended to motivate students' quantification of their lunchtime recess. We were specifically interested in seeing what kinds of strategies students would use to change a statistical measure of center given personal familiarity with the source of the data that were being measured. After describing the technologies and the activity we developed, we summarize some of the observed behaviors and then provide a descriptive account, accompanied with transcript excerpts, of an interaction between two students who discussed changes to measures of center by discussing observed and hypothetical outliers in a portion of their activity data.

2. TECHNOLOGIES AND ACTIVITIES

After review and trials with several different physical activity data recording devices with children of various ages [4], we opted to use a wearable activity tracking device designed by Fitbit and named "Ultra" for this activity. The Ultra uses a three-axis accelerometer to track the wearer's activity throughout the day. Information that may be tracked by the Ultra includes the number

of steps, calories, flights of stairs (equivalent) climbed, and distance traveled (in miles). The three-axis accelerometer also allows the Ultra to estimate an activity level for each action. Real-time results are available via an LED display. These data are logged to internal memory in 60-second increments. When within range of a wireless base station, the Ultra uploads the data to fitbit.com, where users of the Fitbit web service can view their data aggregated in five-minute increments across individual days or aggregated by day across several days (see Figure 1).

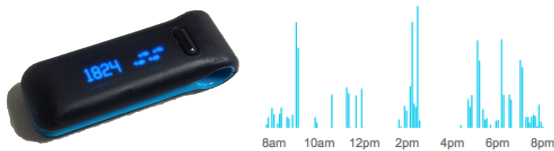


Figure 1. A Fitbit ultra tracking device displaying current number of steps recorded for the day (left) and the time-ordered data display prepared on the Fitbit website (right)

For this project, our primary interest was in using the step data, although we have used and are using other functions in other projects. Using the Fitbit Partner API, we developed a simple PHP interface for downloading and formatting the minute-by-minute step data for use in a student-centered data visualization tool, *TinkerPlots*. In *TinkerPlots*, children work with a database of “cases” that are each represented by a single, randomly placed point in a plot window. Children can select specific case parameters around which cases can be spatially organized, sorted, or ordered (e.g., Figure 2). This sorting is shown through dynamic animations in which all points reposition themselves on the screen to different cells.

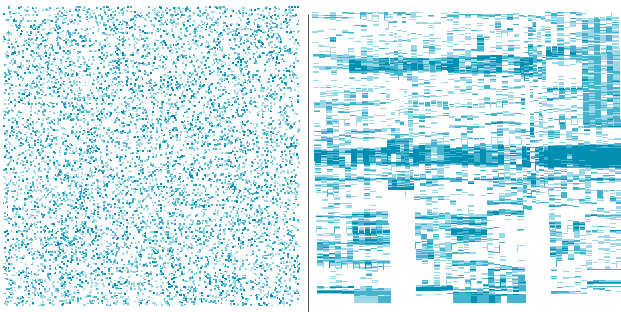


Figure 2. A set of randomly placed *TinkerPlots* data points (left) and a time-ordered display of student step data throughout the school day over a period of two weeks (right)

Beyond automatically sorting the data based on selected parameters, any data point in the visualization can be selected so that the user can see what information was associated with that record. For example, one could select any data point in the dark band in the middle of Fig. 2 and see how much activity was recorded and at what time. Also, given a set of data points, *TinkerPlots* also can display some basic descriptive statistics along with an auto-generated a line on the visualization that shows showing the exact numerical value for a given measure. Additionally, after points are plotted based on a set of parameters, it is possible for users to select and move individual points by dragging them. Doing this allows the students to explore counterfactual and hypothetical data scenarios, as the auto-generated line and listed value associated with that line will dynamically change.

We deliberately chose to organize the activity as a competition based on our observations of these students’ existing recess activities (in which students would create or enact competitive games or activities) and also based on some of our research on adult athletes who use fitness tracking technologies on a regular basis. In the latter study, we observed that for several adults, competitive group activities were motivators for using activity tracking device and competition helped to establish important meanings and reference points for the data that were collected [3]. While we centralized competition in the activity, we also felt it was important to foster some peer collaboration so that students would engage each other in sense-making conversations about the data that they had collected.

Therefore, to make the activity both competitive and collaborative, and in consultation with the students’ teachers, we grouped children into pairs. On the first day of the week, the entire group (six students total) obtained data about their activity during their lunchtime recess while the Fitbit Ultra displays were blocked. They then met with the research and design team in the afternoon. The students’ displays were immediately unblocked, and each child was each provided with the minute-by-minute data they had collected. We then discussed the structure of the activity with the students and worked with all the students to review the data obtained from that day’s lunchtime recess. The children then were led in a full-group collaborative process of creating some metrics to evaluate all of their respective recess activity levels (e.g., the combined average number of steps from both members of the pair divided by the number of minutes where the number of recorded steps was zero). This was followed by groups computing initial scores for each team, matching adult ‘coaches’ with each pair, and then devising strategies to produce the greatest increase in score by the end of the week.

The coaches were actually researchers from our team who were tasked with helping to ensure that the children talked with one another when reviewing their data and to follow up on any puzzling statements that one or both students might make. Each afternoon, the pairs met with their coaches, computed the current day’s score for their team, and then discussed whether they felt they needed to change strategies to further increase their score the next day. On the final day of the week, the pairs were all gathered in the same space, and the entire group examined the results for all students from all teams. Finally, a winner was declared and the entire group of students then discussed their strategies and readings in light of how their teams placed.

3. DATA SOURCES

The activity we designed lasted for one week. In following with a design-based research approach [1], we intentionally planned to do two consecutive iterations of the entire activity using different children. Each iteration involved six fifth-grade students from the same class, grouped into pairs. Our observations from the first week’s group informed and influenced our approach for the second week’s implementation. For example, we made some simplifications to the rules and encouraged students to pick different numerical contributions from each team member (e.g., one student is evaluated based on changes to their mean score and the other is evaluated based on changes to their median score).

The data we collected included video footage of each pair using a standing high definition camera, screen recordings from a shared laptop during coaching sessions that also included video and audio captured by the computer’s internal webcam and microphone, step data records for each student, and all student

TinkerPlots files. For the full group sessions on the first and final days of the week, an additional camera was setup and pointed at whoever was speaking during full group conversations. In total, we collected 26 hours of video over the two weeks. Transcripts from selected groups were prepared for subsequent analysis.

4. RESULTS

4.1 Overall Engagement and Behaviors

From the two iterations, we observed students taking the competition aspect of the activity quite seriously. The simplest and perhaps obvious strategy to boost one's score given the rule structure we described was to just move around more. However, this took a number of different forms. For some students, they felt they should just run nonstop. Others felt they should take as many small shuffle steps as possible to increase their step count (although they quickly discovered that shuffle steps do not register as counted steps on the Fitbit tracking device). Still others thought they should go about recess normally but make sure to select an activity that involved a lot of continuous movement, such as soccer (rather than a more stationary game like "four-square"). One group decided to try giving other kids "piggyback" rides during recess under the assumption that the steps taken while doing that would be more difficult to complete and perhaps "count more" toward their score. (They quickly realized that afternoon when they saw their results that that strategy did not help, and thus they changed their approach the next day.)

The competition aspect figured prominently in other ways as well. Students were keeping track of what they saw other groups were doing during recess. Some groups even tried to create some deception by having one student hide while running in place or changing behaviors when they discovered they were being watched.

Given the focus on finding ways to increase their activity, it was not too surprising to see that all pairs showed significant increases in the number of steps taken during the week ($p < 0.001$). On the first day, the average number of steps per minute taken by all participating students during recess was 33.95 (SD = 34.06). On the final day, their per-minute average was 107.79 steps (SD = 26.17).

4.2 Productive Talk About Outliers

One of our goals was to better understand how students thought about sensitivities of measures of center when they were intimately familiar with the data. To illustrate what this looked like, we present a brief descriptive example taken from one session with a pair during the second iteration. This pair included Chris, a tall boy who prided himself on his athletic abilities, and Emma, a much less athletic student who had said previously to us that she would rather read than run around at recess. In school, they had learned the algorithmic procedures to compute means and medians, but they did not know how they were used nor what sensitivities each measure had.

During the kickoff meeting, Chris chose to have his score represented by his mean steps during recess, and he assigned Emma to be represented with the median. These were each their lower values. Emma, who struggled with the computations associated with the activity, objected to this because she thought that she should measure herself with the value that seemed to produce better results (which for her, was the mean). Chris convinced her that this would be a more strategic move since they could show greater relative gains by the end of the week. Chris was very confident about his performance and ability to help their

team win, but time and again expressed frustration with Emma's performance. This frustration is demonstrated in the following excerpt, taken from the third day, in which they discussed with their coach (V) how they were performing.

C: (to V) I saw her taking a lot of breaks for about 2 minutes. She took about 10 for 2 minutes.

E: I was starting to get tired.

C: (to E) You've got to still go strong. (to V) I saw her run for like 30 seconds and then take a 2-minute break.

Chris was able to easily run throughout the recess and expected Emma to be able to do the same. However, Emma was simply not accustomed to this level of activity. When we had observed her during recess, she became winded and sweaty and often needed to rest. She stated several times that she did not feel that maintaining the level Chris expected was possible for her. At the same time, she did not want to cost her team the competition. Chris stated on numerous occasions that Emma should just work harder, even making appeals to the coach. When asked about Chris's urgings, Emma responded:

E: I think we should actually be able to take more breaks because eventually you'll get dehydrated, too tired to hardly even walk, so that's why I would take breaks.

Following Emma's comment, Chris and Emma shifted their attention to the current day's data in *TinkerPlots* and proceeded to review their score, computed by adding their respective mean and median values for that day. In discussing Emma's data, he persisted in talking the importance of consistency in their data.

C: Well you started and you were up and down up and down [on your plot] and that's why your number [line] was so much lower because your numbers were up and down. But if you were more consistent-

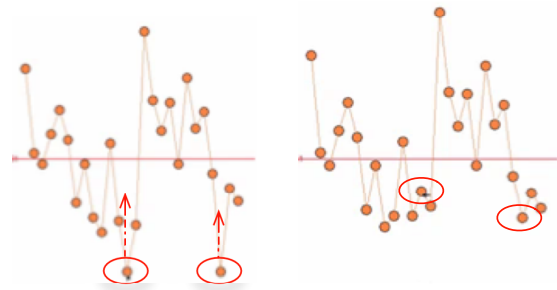


Figure 3. Emma's recess data before (left) and after (right) Chris moved her lowest points higher. The red line representing her median does not change.

To demonstrate this, Chris moved two of Emma's lowest points on her data plot to show how consistency would have improved Emma's score. In essence, he was moving the outliers so they would be closer to the center. However, when he did this, moving them did not change the placement of the median line on the plot. He moved them so that they were higher, but none were changed to a value greater than the median, and thus the median did not change (see Figure 3).

C: So if this was up here they were not at zero at all, so if they were raised up...

V: And you moved all those right? Has the [red] line changed?

C: No.

E: You need to change the ones that were *around the middle*.

During this transaction, Emma made a sudden, new realization about her median score. Having those low points in her plot did not negatively affect her score since she was contributing a median value to her team. This is because the median exhibits little to no sensitivity in the presence of a single outlier. Unless data points that were closer to the median changed, she did not feel there was a reason for her to switch to Chris's strategy. In fact, she felt that breaks were potentially beneficial as they may allow her to get more steps in at other times.

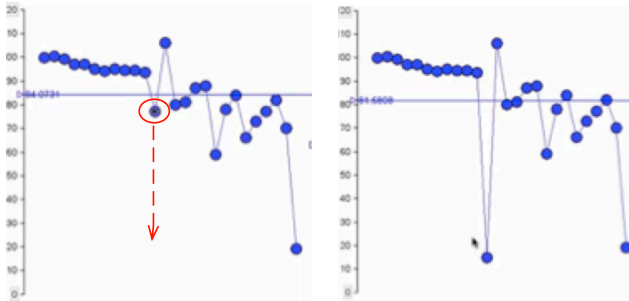


Figure 4. Chris's recess data before (left) and after (right) he moved a single data point to show what would happen if he had an exceptionally low value. The blue line representing the mean drops about 3 units after this change.

Following this transaction and some additional discussion and after seeing the lack of change in her median value, Chris seemed to be more willing to accept Emma's point and that is worked for her given that she was associated with the median. However, he maintained that it was not an appropriate strategy for him to adopt. To clarify this, the coach initiated the following exchange:

V: If I'm getting this right, its ok for one of you to take a break in this game, but it's not ok for the other?

C: Yeah, I can't—I don't really need it. She can take, like, breaks because it won't really affect her [measure] as much but for me...if its like this [in the plot] and I go and bring it down [so it looks like Figure 4] so its 71 [for the mean] instead of 74 [sic], so it took away 3...

E: Yeah it'll go down a couple points [for him]. Except for me, if I just take a couple breaks, see I only took about 2 with zero steps [referring to Figure 3] then I'll be just fine. What matters is around the middle for me. What matters for him is the whole thing.

As a result of this conversation, they were able to agree that breaks were acceptable for Emma but would lower Chris's score because of the different sensitivities of their two measures of center. They accepted these strategies would be fine to each pursue separately, and they would not hurt their overall score which they knew they were trying to maximize.

And it turned out, Emma mastered the sensitivities of the median ended up with the highest individual score of all the students in her group of six students. Additionally, Chris and Emma were both so enthusiastic about what they had discovered about outlier values that after the competition had formally ended, they shared their discovery with the other groups on the final day after the competition was formally over.

5. CONCLUSION AND NEXT STEPS

As a first effort, our "quantified recess" activity was able to be help students leverage their lived experiences as they explored sensitivities of measures of center about data with a visualization

tool. Sensitivities of different measures of center is a topic rarely broached prior to high school or even college level statistics. The observation that fifth-grade students could engage with this topic and be excited about sharing what they learned is encouraging.

However, as a design endeavor, we recognize there could certainly be further room for improvement. It remains an open question how essential the competition was for motivating students to examine and engage with their own activity data. What we have seen informally in some of our other efforts to incorporate physical activity data recording technologies into children's activities is that some larger task or activity context is often needed to encourage analysis of the data. For example, we worked recently with a different class of fifth-graders and were able to provide Fitbit Ultras for each student and teacher to use. That class was very interested in taking the Fitbit Ultras with them on a multi-day outdoor field trip that involved several hours of hiking. When they returned, they were provided their activity data, but when we visited that class to see what they discovered, the students were surprisingly uninterested in the data visualizations from that trip that they ultimately produced. The moments when they appeared the most engaged were those when they identified in their data visualizations which individual had moved the most on a given day or during the entire trip. It seems, at least initially, that quantification lends itself to activities that involve comparison, which resonates with children more than simply using quantification just for purposes of description. These are issues we intend to explore more in the future.

6. ACKNOWLEDGEMENTS

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