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A Data Generating Review That Bops, Twists and Pulls at Misconceptions

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A data generating review that bops, twists and pulls at misconceptions

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Abstract Statistics is an integral part of the K–12 mathematics curriculum (age 5–18). Naturally, students construct misconceptions of what they learn. This article discusses The Bop It© Challenge, a review activity assesses student understanding and reveals their misundertandings of statistical concepts.

Keywords: Teaching; Formative assessment; Randomness; Data analysis.

Introduction

By the time students enter grade 9 (age 14), they have received much instruction on the investigative process and data analysis methods, as evident, for example, in *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics 2000) and *Guidelines for Assessment and Instruction in Statistics Education Report* (Franklin et al. 2007). Nonetheless, students' prior knowledge of statistical concepts must often be reactivated to teach or investigate new statistics topics. By traditional methods, a pre-test or review lesson is delivered to refresh students' memory. The review lesson is often teacher centred, and involves restating definitions and formulas, re-teaching graph and chart construction, or demonstrating numerous examples.

During my review lessons, I noticed low levels of engagement from my students, and they expressed boredom from encountering previous material they felt that they had mastered in earlier grades. I concluded that while contextual, relevant statistics tasks that use coloured candies, spinners, die, cards or marbles are exemplary for teaching statistics, their overuse or inappropriate use tremendously lower students' interest. Similar conclusions have been drawn, particularly on the matter of student motivation and disposition (see Devlin 2011; Middleton and Jansen 2011). In an attempt to assess my students' knowledge and to maintain high engagement, I created the Bop It Challenge. I have used the activity in grades 9 (age 14), 11 (age 16), and in tertiary probability and data analysis courses for pre-service teachers. The implementation of the activity for the pre-service teachers is described in this article. Regardless of age, the discourse fostered by the review always reveals some strong misconceptions students bring to the statistics course. What began as a review activity evolved into a course spanning, common experience for my students that I used to situate and introduce various statistics concepts.

Activity description

The Bop It Challenge was framed by the following objectives:

- Formulate questions that can be addressed with data.
- Collect, organize and display data to answer formulated questions.
- Select and use appropriate statistical methods to analyse data.
- Draw conclusions based on data.

Bop It is an audio game licensed by Hasbro that tests a player's speed and ability to react to various voice commands. The commands are *Bop It!* (a depressible button = drum sound), *Twist It!* (a twistable lever = ratchet sound) and *Pull It!* (a pullable handle = whistle sound). The player must execute the correct action when instructed, at an increasing pace. The game ends when an incorrect action is made, after which the score is announced. The object of the game is to get the highest score among all players.

I created the review activity as a means to formatively assess my students' understanding

Trial	Gender	Sequence of Commands	Tally of Commands			Score
			"Twist It"	"Bop It"	"Pull It"	
1	M	TTPTBPPBPBBTBB PTTBBBPTBT	8	10	6	24
2	F	PPBTBTPTTPBP TBBTPTBTTPT	10	6	7	23
3	F	PTPTPTBTBPBB TTPPBBTBB	7	8	6	21
4	F	TPPTTTBTBPPB TBPBTPBBTPTPBBB BPPTTTPBBPTBTTTP BP	16	15	14	45

Fig. 1. Student sample of the Bop It Challenge data collection sheet

of data analysis, probability and investigative process. The activity also informally introduced inference concepts that were covered later in the course. I knew the tasks needed to be authentic and meaningful to elicit interest and spark motivation in the students (Bobis et al. 2011). The data needed to be randomly generated, with little room for replication error from trial to trial. While there are numerous games for sale in the toy market that could be used to generate data, I decided to use Bop It because the manufacturer states in the instructions that the commands are random and because I was already a fan of the game.

Prior to the lesson, permission was granted to borrow Bop It games owned by students, or parents. On the first day of the review, I demonstrated the solo round of the game three times so that students unfamiliar with Bop It could observe how the game is played. I then asked students to write down questions that they would like to be answered about Bop It. A list of questions was compiled on the board, and ones that were similar were consolidated. I instructed the students to categorize the questions into two groups: (1) questions that could only be answered with data and (2) questions that could be answered without data. Focusing on the questions that required data collection, the class finalized three to investigate for the activity: (1) what is the average score, 2) how often is each command called, and (3) who scores higher, males or females?

To obtain a large data set on the same variables, the whole class created the data collection sheet, incorporating variables needed to answer the investigation questions. The solo mode of the Bop It game was played again by a volunteer so that students practiced recording the sequence of commands, tallying the commands and recording the score. To ensure precise replication of trials, each group was instructed to discard the last command given because it constituted a miss, which terminated the round and was not included in the score. The only exception was if a student made a perfect score of 100, on level one. Groups of 4–5 students were dispersed throughout two empty classrooms. Each student played one solo round each and completed the data collection sheet. Figure 1 is a student sample of the data collection sheet.

Afterwards, students engaged in small group discussions about how their data could be used to answer the investigation questions. After the class, I compiled each group's data into one table so that it could be disseminated during the next session lesson. The class data set can be found at the end of this article in table 1, along with photos of students generating the data in figure 2.

During the next session, I asked each student to revisit the investigation questions, now using the class data set. Additional questions were projected on the board for the students to answer and submit individually. The questions were as follows:

1. The manufacturer stated that the commands are randomly generated. Why do you think this assumption is important for our investigation?

2. Is there evidence the game favours a particular command? Explain.

3. Do you think your conclusions about our three investigation questions would hold for data collected by a different class?

A sample of student responses is included at the end of this article in figure 3. Once each student submitted answers to the investigation questions and the three additional questions, I facilitated the whole class discussion. Throughout each lesson spanning the activity, I formatively assessed students' understanding by analysing and responding to their comments and answers.

Table 1. The Bop It Challenge class data set

Trial	Gender	Twist It	Bop It	Pull It	Score
1	F	35	39	26	100
2	F	16	15	14	45
3	F	0	1	0	1
4	M	6	7	6	19
5	F	0	1	1	2
6	M	39	31	30	100
7	M	8	10	6	24
8	F	10	6	7	23
9	F	7	8	6	21
10	F	16	15	14	45
11	F	12	16	8	36
12	F	1	3	1	5
13	M	1	1	1	3
14	M	6	7	8	21
15	F	6	5	3	14
16	M	0	1	0	1
17	M	11	10	13	34
18	F	7	6	5	18
19	M	1	1	0	2
20	M	18	19	24	61
21	F	26	31	28	85
22	M	22	20	23	65
23	F	17	12	12	41
24	M	28	31	28	87
25	M	20	21	21	62
26	M	11	14	9	34
27	F	10	7	7	24
28	F	14	11	14	39
29	F	8	5	10	23
30	M	7	3	4	14
31	F	0	0	0	0

Discussion

The investigative process for statistical problem solving involves formulating questions, collecting and analysing data, and interpreting results (Franklin et al. 2007). With relative ease, the students were able to formulate questions and to categorize them as those requiring data versus those that did not. When I asked the students to identify a possible methodology for the study, the class' silence prompted my discussion of observations, surveys, experiments and simulations. After reviewing the types of investigative studies, the students decided that the investigation was observational in nature.

Small group discussions

While working in small groups, students were proficient at creating charts and graphs, and at computing numerical summaries. However, some groups in which an extreme score of either 0 or 100 was recorded were questioned about their use of only the mean as the measure of centre. When other groups reported using the median or excluding the outlier to compute the mean, groups committing the measure of centre error realized their mistake. This indicated to me that most of the students were knowledgeable of the effects of extreme values on non-resistant measures, although some did not make this connection during the activity.

In another group I was observing, a student insisted that the manufacture's claim was incorrect. The bar chart they had constructed showed the total count of each command. The command *Bop It* occurred 62 times, *Pull it* occurred 46 times and *Twist It* occurred 57 times. The student concluded that the commands were not random because *Bop It* had 16 more occurrences than *Pull It*. In fact, several students fixated on the misconception that random implied equally likely. Similar counterintuitive conclusions that students tend to draw about randomness and probability are well documented (see Borovcnik

Fig. 2. Students generating data for the Bop It review activity

and Peard 1996; Konold 1995; Wild and Pfannkuch 1999). I later addressed the misconception in a class discussion.

I was surprised that none of the groups addressed the variability of their data, other than recognizing outliers. The size of the data set may account for them neglecting variation, but box plots, which are commonly used to investigate variability, had not been constructed by any of the groups either. Later in the semester, I lectured and assigned tasks from the course textbook that exploited the need to address the variability of the data in a statistical investigation.

At various points in the discussions, each group recognized that their sample was too small to gain any useful information that would help answer the investigation questions. I deduced that the students had accurate intuitions about the central limit theorem and the law of large numbers, even if these statistical laws had not been formally introduced to them.

Class discussion

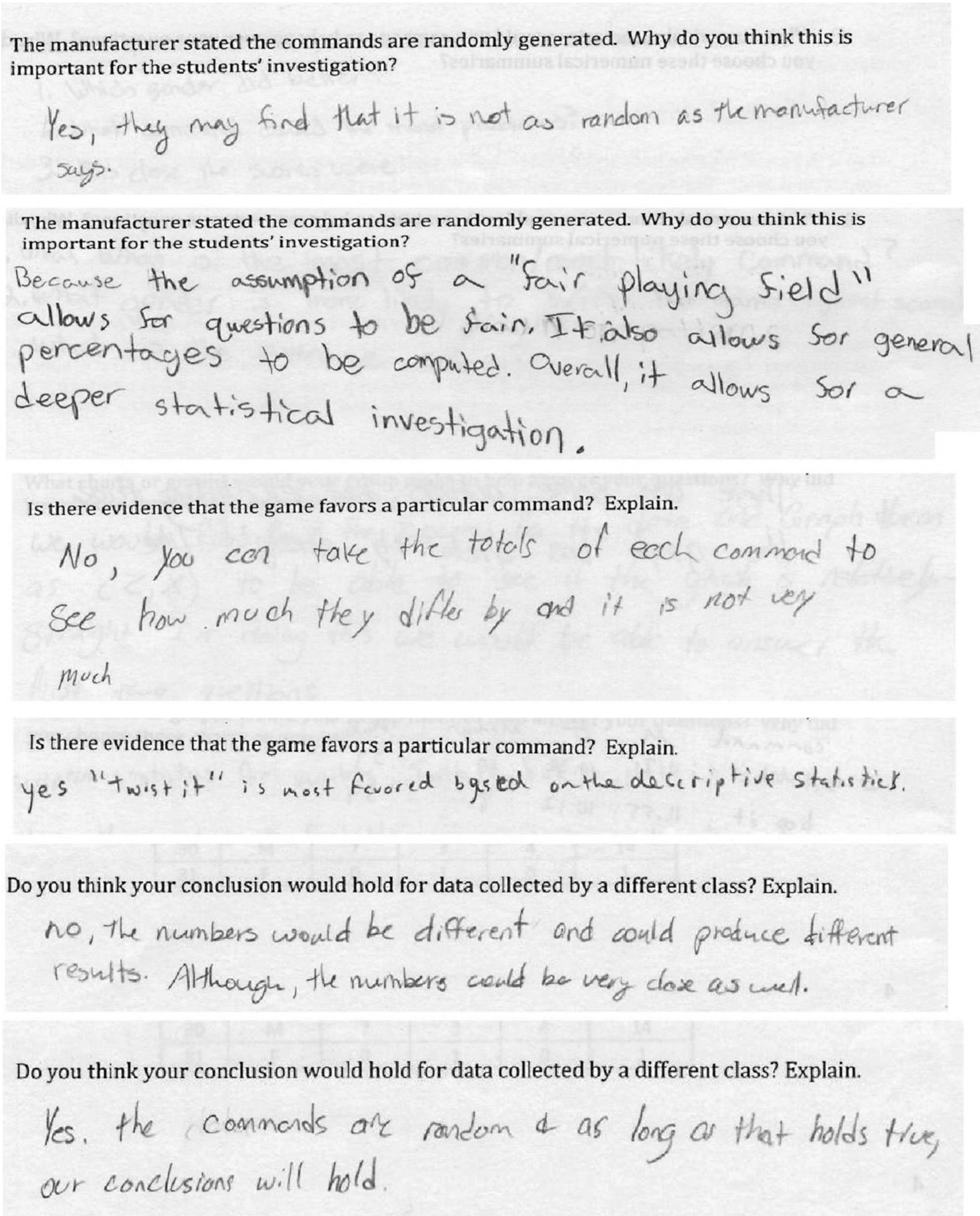
After students had time to revisit the investigation questions and to answer the additional questions using the class data set, their responses were collected. I then asked the class to define the word random. Students responded using terms such as unpredictable, chaotic and unexpected, mostly in the context of real world scenarios such as flipping a coin or drawing cards from a deck. I asked if there was a distinction between statistical randomness and real-life randomness. One student stated that there was no difference, offering the example that the unpredictability of a random act of kindness was just like the unpredictability of tossing a coin.

When asked to explain why the assumption of randomness was important for the investigation, several students stated that assuming the commands were random guaranteed that each command would be equally likely. Viewing this overarching misconception as one that would impede student learning of probability and inference later on, instructional time was dedicated to challenging the misconception and to explaining randomness. The definition of randomness I presented to the students stated that random in statistics meant, to be unpredictable or uncertain for a short run but to have an emergent pattern or order in the long run (DeVeaux et al. 2012; Moore et al. 2012). Terms such as unlikely, likely, equally likely, most likely, fair and bias were also discussed.

The misconception about randomness was challenged using an example of a basketball player who makes 60% of his free throws. When at the line, whether he makes nor misses the free throw is uncertain. Although not equally likely, the phenomenon is random, and from what is known about the shooter's free throw percentage, it is likely that he will make the shot. I explained that assuming independence if I reviewed the team scoring records after the season, I would most likely observe that the shooter's overall free throw percentage was about 60%. After this discussion, some students assimilated their conceptions by opting to use the term statistical randomness over randomness. I discerned that a clear departure from the misconception was established.

Later during the semester, graphs and charts for the class data set were used in various lessons. When the pie chart for the variable, *type of command*', was illustrated, care was taken to avoid reconstructing the misconception about randomness implying equally likely. I used the information in an introduction to the binomial distribution. Initially, students were asked to determine the probability of observing exactly one *Twist It!* in four commands given. The class agreed that it was plausible to assume that the game was fair. Thus, the theoretical probability of success (*Twist It!*) approached one third, and the probability remained fixed throughout the experiment. When asked if the commands and event could be assumed random, the class' quick affirmation led me to respond, 'How can you say it's random, if "*Twist It!*" occurs one-third of the time and not "*Twist It!*" two thirds? It's not fifty-fifty'. A student loudly proclaimed, 'Randomness does not imply equally likely!' I was confident that the misconception was dispelled because the students were able to articulate the behavioural short-term uncertainty, long-term predictability randomness imposed on the experiment.

Collectively, the students had retained a good amount of knowledge about data analysis from their previous courses, as evident in the depth of their discussion and answers to questions they provided during the review investigation. Albeit, without the review, the misconceptions they brought with them would not have been notice and corrected before encountering new material.



The manufacturer stated the commands are randomly generated. Why do you think this is important for the students' investigation?

Yes, they may find that it is not as random as the manufacturer says.

The manufacturer stated the commands are randomly generated. Why do you think this is important for the students' investigation?

Because the assumption of a "fair playing field" allows for questions to be fair. It also allows for general percentages to be computed. Overall, it allows for a deeper statistical investigation.

Is there evidence that the game favors a particular command? Explain.

No, you can take the totals of each command to see how much they differ by and it is not very much

Is there evidence that the game favors a particular command? Explain.

yes "twist it" is most favored based on the descriptive statistics.

Do you think your conclusion would hold for data collected by a different class? Explain.

no, the numbers would be different and could produce different results. Although, the numbers could be very close as well.

Do you think your conclusion would hold for data collected by a different class? Explain.

Yes. the commands are random & as long as that holds true, our conclusions will hold.

Fig. 3. Student responses to the additional discussion questions

Conclusion

Even though students are exposed to data analysis early in their schooling, it is important to assess their understanding of prerequisite statistics concepts when they enter higher grades. As evident in the discussion above, students will formulate misconceptions, even when they express confidence in their skills or perform proficiently on tests. Determining how my students conceptualized randomness provided a focus throughout the semester on dispelling their misconceptions, and not reconstructing them.

The extent to which misconceptions hamper the learning of new topics is perhaps immeasurable, which is why a review activity that gauges the depth and breadth of student knowledge is important. The Bop It Challenge provided a rich and flexible context for reviewing data analysis and the investigative process. Certainly, the students' misconception of randomness would have surfaced at some point during the course; however, a review of data analysis by means of this activity allowed for these misconceptions to surface and be corrected before they presented challenges in learning later topics. The experience the activity provided kept students highly engaged, and it meaningfully anchored future lessons on probability and inference.

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