Practical Problems:

Using Literature to Teach Statistics

A meaningful *driving question* motivates kindergartners to engage in all five stages of the PPDAC data cycle.

Mairéad Hourigan and Aisling Leavy

"I have a friend who is a preschool teacher. Her name is Miss Rice," began Mrs. Holly in her kindergarten classroom. "Do you remember when you went to preschool?"

As the children respond with a resounding yes, Holly continues. "Miss Rice has sent us a letter explaining a problem, and she needs some help. We are going to have to work together to help her figure it out. I will read the letter to you.

3CLICKS/THINKSTOCK

Dear children,

I have a lovely story that I want to surprise some preschoolers with, but I am in a bit of a pickle. I am going to buy one puppet that appears in the story, but I can't decide which one. I was wondering if you could listen to the story and help me decide which puppet to buy.

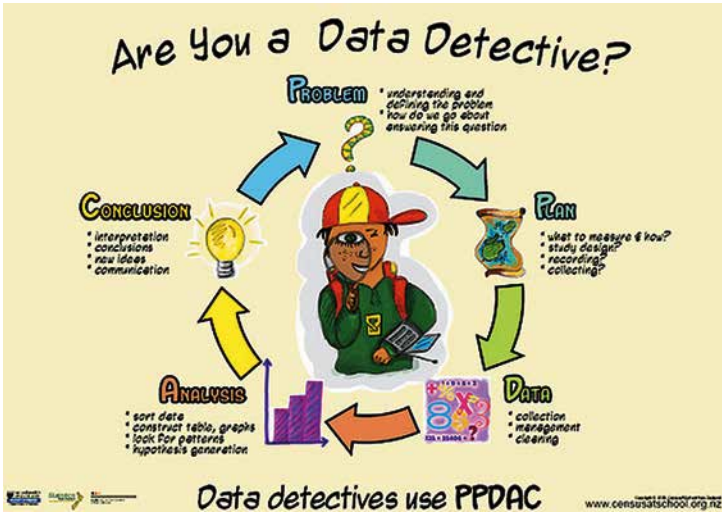
Thank you,
Miss Rice, preschool teacher

When Holly asked her students if they were ready to help Miss Rice solve her problem, the excitement in the room was high. The instructional unit that followed was designed and taught to two classes of kindergarten children. Our goals were to present a *driving question* to motivate the process of statistical investigation, to genuinely engage children in the stages of statistical investigation, and to facilitate them in experiencing an alternative data collection method. In an elementary school classroom, data are usually collected through surveys (asking people their favorite ice-cream flavor) or observing events (counting the colors of cars in the parking lot). A survey is a popular and effective data collection method (compare Cook 2008); neverthleless, we wanted the children to experience an alternative method of data collection, namely *observation*.

The use of children's literature has been found to support the development of mathematical concepts (Marston, Muir, and Levy 2013). Young children can collect and represent data regarding the occurrence of repeated words and phrases in rhymes (e.g., "Hickory Dickory Dock") and stories (e.g., *Goodnight Moon*) (Van de Walle 2013), but we wanted them to experience statistics also as a tool to investigate everyday problems. So, we presented the children with an ordinary problem: What puppet should a teacher buy for her class? To solve the problem, they would have to collect data to identify the character that appeared most frequently in a piece of children's literature. After struggling to find a suitable story, we decided to create our own (see the **online appendix**).

FIGURE 1

The authors used a five-stage framework for the unit because it would engage the two kindergarten classes in carrying out activities that real statisticians do as *data detectives* during their investigations.



Teaching the instructional unit

We used the five-stage PPDAC (problem, plan, data, analysis, conclusion) cycle (Wild and Pfannkuch 1999) as a guiding framework for the unit (see **fig. 1**). We selected the PPDAC structure because it engages children in carrying out the activities that real statisticians engage in during statistical investigations: asking questions, planning data collection, analyzing data, and drawing conclusions. This structure offers children ownership over the mathematics, and it supports analysis, reasoning, and mathematical discourse in the classroom. Furthermore, this structure analogizes the work of a statistical investigator as becoming a detective, that is, a *data detective*.

Stage 1: The problem

We selected a *driving question*, closely related to a children's story, which generated curiosity and motivated the students to want to collect data. We presented the question in the form of a letter that their teacher read to the class. The letter from a preschool teacher requested help in selecting a puppet for her classroom. We discussed the problem to ensure that the children understood what was required of them; that is, they were to help the teacher choose a puppet to buy.

FIGURE 2

One goal of asking the children to silently count the number of times the puppet came out of his box was to demonstrate that sometimes when we count in our heads, we get different answers.

Stage 2: The plan (procedures used to collect the data)

Young children are inexperienced in collecting and recording data. Before introducing the story, we provided practice in *collecting* and *recording* data using informal tallying. Rather than teach formal tallying, we intended that the students would use tallying approaches that felt natural to them.

We told students that we were going to practice collecting information and asked them to count the number of times the puppet *Mike the Monster* appeared out of his box (see **fig. 2**). We encouraged the children to watch carefully and to silently count (in their heads). After they reported their count, it was apparent that sometimes when we count in our heads, we get different answers. The teacher and the class engaged in a conversation regarding the shortcomings of the count-in-your-head strategy:

Teacher: So, can anyone tell me: How many times did Mike pop out to say hello? Anybody?

Jack: Eight.

Teacher: Eight times. Did everyone get eight? [*Some children nod, and others shake their heads*]. Did anyone get a different number?

Anna: Ten.

Teacher: You got ten.

Charlie: I got eight.

Teacher: You got eight as well. What did you [*pointing to a child*] get?

Conor: Nine.

Teacher: Nine. So, it's kind of hard to keep track when you're counting in your heads. What would happen if he popped out 800 times—do you think it would be harder then?

Class: Yeah.

Subsequently, the children were encouraged to suggest alternative strategies.

Teacher: So, it's kind of hard to keep track when you're counting in your heads. Can you think of a better way to keep track of how many times Mike pops out of the box?

Ava: You could count out loud.

Teacher: But what if we wanted to keep it a secret?

Janet: You could whisper.

Lisa: Or count using our fingers.

Teacher: But what if the number is bigger than ten; what would we do then?

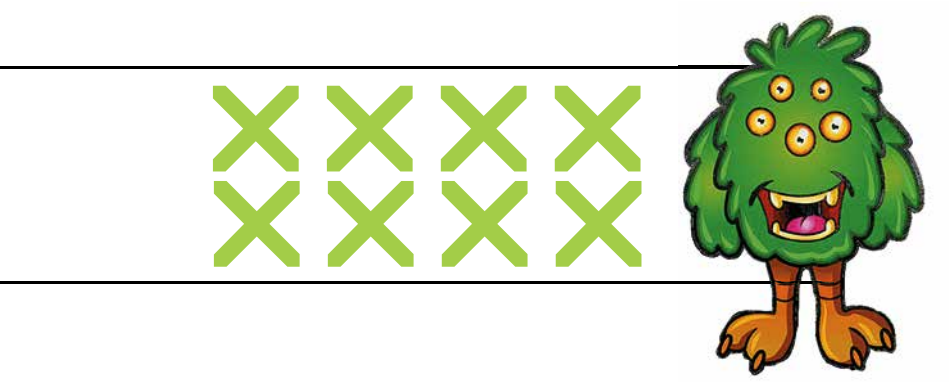
David: Or write it down.

Teacher: Writing it down. That's a great idea.

Then the focus moved to the idea of "writing it down" and how a pencil and paper might help children keep track of the numbers. Some students suggested writing the frequency of appearances, that is, one, two, …, but the teacher proposed and demonstrated that it would be easier and faster to tally the number of times the puppet popped up:

Teacher: What if I took a pencil and made a mark every time Mike pops out of the box? If Mike pops out once like this [*the puppet pops up*], I might make a tick [*demonstrating on the board*]. What other marks could I make?

Tom: A line.



Teacher: We could do a line like this [*demonstrating on the board*]. Any other ideas?

Briana: A dot.

Teacher: A dot—so we might do a dot like this [*demonstrating on the board*].

The children were encouraged to watch carefully when Mike the Monster came out of the box and to make a mark of their choice each time the puppet appeared. Tallies included check marks, crosses, and circles (see **fig. 3a**) as well as writing the counting numbers (see **fig. 3b**).

Stage 3: The data (collection process)

We created the story *Green Monster Explores the Jungle* for the purpose of the lessons. We presented the pictures using a projector (see the **online appendix**). The teacher discussed the cover page and introduced the five story characters: Green Monster, Blue Bird, Black Bug, Red Rhino, and Brown Bear. Before reading the story, she asked students which puppet character they thought that the preschool teacher should buy and the reason for their decision.

Sophie: The brown bear because he's the nicest.

Jack: The green monster because he has four eyes.

Grace: The blue bird because it can fly.

Before proceeding to read the story, the teacher told the children that she had forgotten to tell them an important part of the letter!

> PS I would really like to buy the puppet for the character that appears the most.

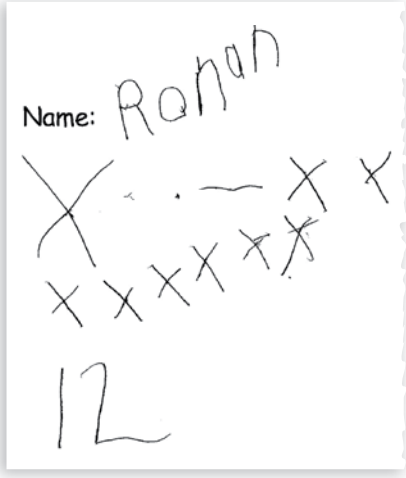
After a discussion regarding what *the most* means, the teacher read the story (see the **online appendix**). She asked students to look carefully at the pictures to see which character they thought appeared the most. She told the children that we were going to solve the problem by keeping track of each character. As there were five characters in the story, we arranged the class into groups of five. Each child received a different character assignment and a special tallying sheet with a picture of their allocated character. We gave clear instructions; for example, "Whatever creature is at the top of your sheet, you must watch out for him in the story. Every time you see him, you will make a mark." Before reading the story for the second time, we reminded the children of the character they had to keep track of, asking, "Hands up: Who is looking for Green Monster?"

The story was read slowly while children kept a tally of their respective creatures. Conceptually, the children had no difficulty with understanding the task—that they had to keep track of the appearance of creatures. Any problems encountered were procedural in nature, such as missing the appearance of a creature when not looking at the whiteboard. The first time the lesson was taught, many students' errors were because they did not take into account in their tally the fact that their creature was present on the cover page of the story.

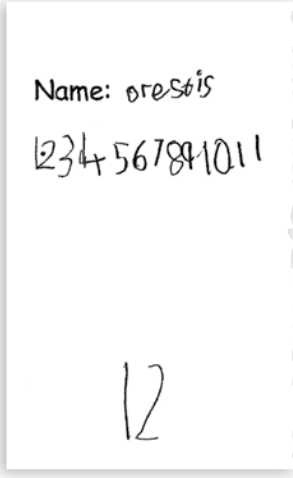
FIGURE 3

The kindergartners watched carefully for when their assigned story character appeared and made a mark of their choice each time.

(a) Marks included check marks, crosses, and circles.



(b) Some children wrote the counting numbers as they tallied.



Subsequently, the teacher addressed this issue by using the cover page as an exemplar to model the tallying activity; she instructed each child in the group to make a mark to represent the presence of their character on the cover page.

Also, we felt that many were struggling to keep up with the story and were missing the appearance of their designated creature when making a mark on their sheet. To counteract this in the subsequent lesson, we inserted a blank slide between each of the story slides to facilitate giving the children time to record their observations. **Figures 4a** and **b** illustrate two children's different, yet accurate, approaches to tallying.

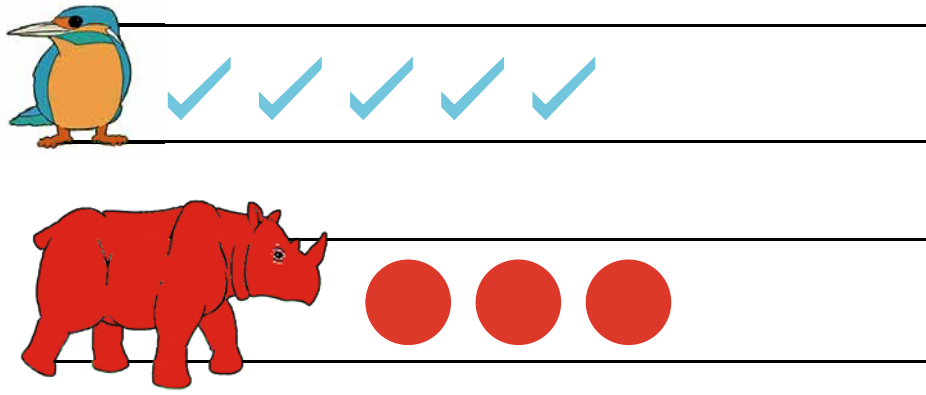


FIGURE 4

Much of the class initially struggled to simultaneously tally the number of times that a story character appeared and to keep abreast of the story.

(a) Subsequently, the authors inserted a blank slide between each story slide to give the children more time to record their observations.

(b) Although students' tallying approaches remained varied, their accuracy improved.

Stage 4: The analysis (summaries and analyses of the data)

Data were *summarized* by constructing concrete graphs (in small groups) and a bar graph (as a whole class). Although graph construction is important, the skills required are generally procedural and lower order in reasoning. Hence, we were careful to allocate sufficient time for the class to develop skills that are higher order in thinking, reasoning, and literacy through analyzing the data presented on the graph.

A. Making concrete graphs

Each child in a group was given a different character, and each group was encouraged to work together to represent (using cubes) the number of times each of the various characters appeared in the story. We gave guidance as necessary:

Teacher: Brian, how many times did the brown bear appear?

Brian: Two.

Teacher: How many cubes will we need in the brown bear space?

Brian: Two.

Each group received chart paper on which the categories (five creatures) were identified in advance. Groups used different methods to construct graphs. Some groups placed a loose collection of cubes above the corresponding category (see **fig. 5**). Others made towers, which they placed either flat on the chart (see **fig. 6a**)

FIGURE 5

Each group received chart paper on which the categories (five creatures) were identified in advance. Some groups placed a loose collection of cubes above the corresponding category.

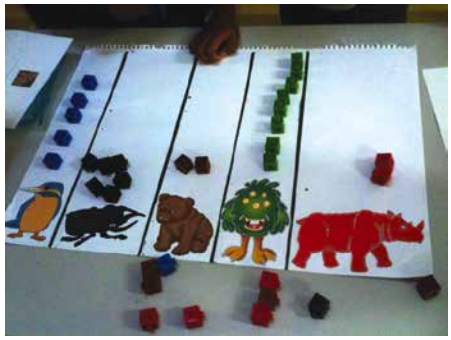


FIGURE 6

Groups used different methods to construct their graphs. The adults emphasized that all the graphs, although they looked different, gave an accurate picture of the collected data for their respective group.

(a) Some groups made towers, which they placed flat on the chart.

(b) Other groups stood their towers on end (i.e., standing upright).

or standing up (see **fig. 6b**). We briefly discussed the number of different graphs and emphasized that they all, although looking different, gave an accurate picture of the collected data for that group.

In the two classes we observed, we commonly found that each group had different counts for the story creatures. Our response varied depending on the children's awareness of the differences. If students were concerned about getting different answers or anxious to know what the "correct" count was, we reread the story and completed a whole-class tallying activity. Alternatively, if the children were content to rely on their groups' tally, we chose to let them work with the data they had collected. We subsequently addressed the variation by completing a class tally before creating the whole-class bar graph.

B. Making a bar graph

When we constructed a whole-class bar graph of the data (see **fig. 7**), we displayed the bar graph on the whiteboard and used it to facilitate analysis of the data through whole-class questioning. Data were *analyzed* on the basis of observations of the bar graph. We emphasized developing the children's graphical literacy and reasoning skills by posing a series of questions designed to address skills in each of the following categories (compare Friel, Curcio, and Bright 2011).

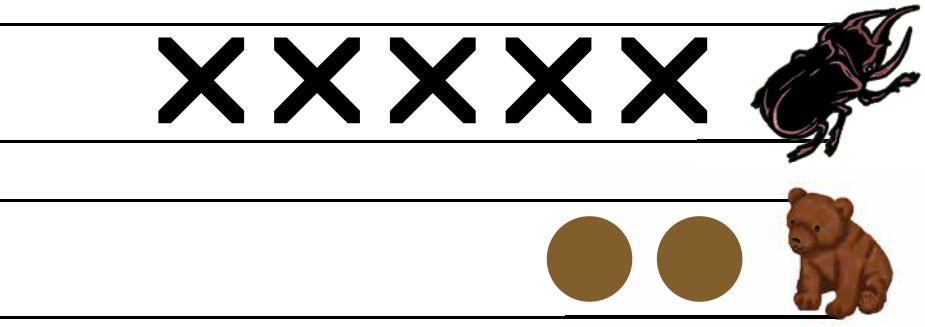
Category 1 questions: Reading the data

These are the simplest type of question, which required the children to read information directly off the graph. The teacher asked questions like the following:

- Which character appeared the most? How do you know?
- Which character appeared the least? How do you know?
- How many times did Blue Bird/Black Bug/Brown Bear/Green Monster/Red Rhino appear?
- Did any characters appear the same number of times? How do you know?

Category 2 questions: Reading between the data

These questions are more complex and required that the children interpret the graph. The answer



takes one step to solve and usually involves the addition, subtraction, or comparison of data.

- How many characters are there altogether?
- How many more times did Black Bug appear than Brown Bear?
- How many more times did Blue Bird appear than Red Rhino?
- If the teacher had enough money to buy two puppets, which two should she buy?

Category 3 questions: Reading beyond the data

These questions require the children to extend, predict, or infer from the data. Such reasoning is quite complex, but because students were motivated by the investigation, they were quite good at making accurate predictions based on their sample.

- How many more times would Red Rhino have to come up to be the same as Green Monster?
- If we had lost one page of the story and then found it, which creatures do you think would appear on the page? Why?

The children were capable of answering the category 1 and 2 questions:

Teacher: If the teacher had enough money to buy two puppets, which two should he or she buy?

Moira: Green Monster.

Teacher: And then, after that, which one should she choose?

David: Black Bug.

Teacher: Black Bug. Why?

David: It was the next. It came up five times in the story.

Teacher: Green Monster appeared in the story the most. Black bug was next. But who else could it be then?

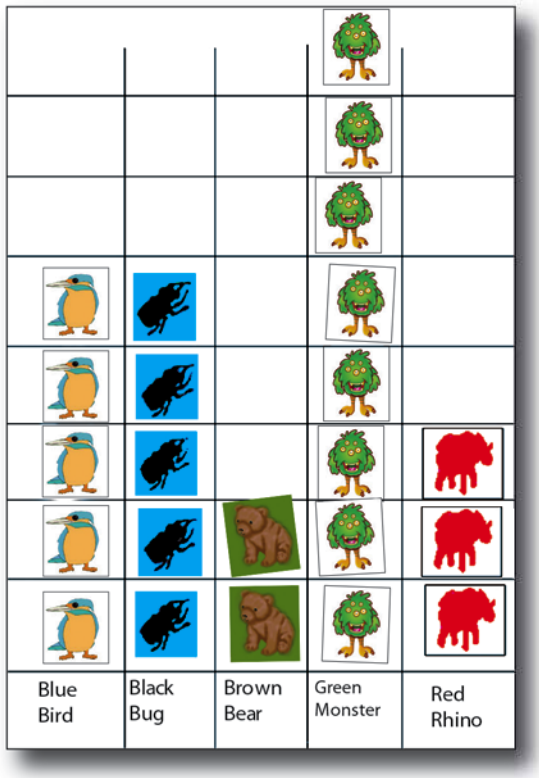
Class: Blue Bird.

Teacher: Yes. Blue Bird because Blue Bird also came up five times in the story. She would have to buy three [puppets] then to be fair because Blue Bird and Black came up [*pausing*]—

Class: The same.

FIGURE 7

The authors addressed graph variations by completing a class tally before the children created a whole-class bar graph.



Teacher: Yes. The same number of times. How many?

Class: Five.

As expected, category 3 questions presented more challenge for children. The following excerpt demonstrates that some children had particular difficulty understanding the phrase *how many more*. We had expected this difficulty and had decided to use the term *extra* in conjunction with *how many more*.

Teacher: How many more times would Red Rhino have to come up in the story to be the same as Green Monster? How many extra times would he have to appear in the story to be the same as Green Monster?

Girl's voice: Eight.

Teacher: Red Rhino needs to come up eight times to be the same as Green Monster. So far, Red Rhino was in the story only three times.

How many more times does he need to be in the story to be the same as Green Monster?

Grace: Nine.

Teacher: Nine more times. So, if he came up nine more times, he'd have all these spaces filled and he'd be up to the roof nearly [*pointing to the graph*]. Wouldn't he? But he doesn't have to come up nine times to be the same as Green Monster.

Dara: He has to come up five.

Teacher: So if he had five more, he'd be right up here. So he'd be the same.

The children were misinterpreting the question. The term *extra* presented considerably less difficulty for students when it was included in a question.

Stage 5: Conclusion (what we learned)

The children's conclusions related back to their original question. The teacher asked which puppet the preschool teacher should buy and why. During the conclusion, we reminded the children why we were collecting the data—that is, to identify the puppet for the teacher to buy. We then asked them what their recommendation would be and how they arrived at their decision (i.e., by tallying and representing the data). To complete the PPDAC cycle, we had the preschool teacher visit the classroom and ask the children to explain what they did to come to their conclusion to buy the Green Monster puppet. The children were quite excited and very enthusiastic to describe their data investigation.

Teachers can use any piece of literature to support student understanding of statistical concepts.

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Reflections

The investigation detailed in this article focused on a number of specific goals. The first of these was to present a *driving question* that motivated the process of statistical investigation (Hourigan and Leavy 2015). The selection of an interesting and relevant context generated high levels of enthusiasm and engagement throughout the investigation. The authors made a conscious decision to use children's literature to support and direct young children's learning of statistical concepts. Although these teachers created their own story, teachers can select any piece of children's literature for this purpose, as long as it contains a limited number of distinct, recognizable characters that appear a manageable number of times during the story.

The second goal was to genuinely engage children in the stages of statistical investigation. The request to help Miss Rice choose a puppet to accompany the book provided a springboard for engagement in the statistical investigation. Students engaged readily with the problem that was posed and, as a result, they embraced each of the data-handling stages—that is, collecting, representing, and analyzing data. The investigation was designed to incorporate multiple opportunities to share ideas, make decisions, report on findings, and justify thinking.

The final goal was to facilitate having the children experience an alternative data-collection method. This was realized through the introduction of "observation" as a data-collection method.

Common Core Connections

K.CC.B.5
K.CC.C.6
K.MD.B.3

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ALL FIGURE PHOTOGRAPHS BY AISLING LEAVY

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Go to **http://www.nctm.org** to access the images and story line for the Mike the Monster activity. The online materials are a members-only benefit.

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