Student Difficulties Setting up Statistics Simulations in Tinkerplots™

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Introduction/Background

The past 20 years has produced a growing body of research on instructional technologies in mathematics classrooms, as well as a small, but growing, body of work on the impact of technology in introductory statistics classrooms (e.g., Chance, Ben-Zvi, Garfield, & Medina, 2007; Chance, delMas & Garfield, 2004). However, much of the work touting the benefits of using technology in the statistics classroom has not been empirically based (see Mills, 2002) and Shaughnessy (2007) has argued that there is a lack of research investigating the use of technology in statistics classrooms. Specifically, research is needed that explores how technology changes the way students think about statistics and the ways technology can be used to enable students to construct models to solve statistical problems. There are two fundamental reasons why such research is badly needed: (1) statistical literacy and computer literacy are vital skills in an information age; and (2) new dynamic educational technologies carry much promise for supporting student learning, but without knowledge of how these technologies impact student thinking they fall short of their potential. This proposal focuses on student challenges interpreting a single trial of a statistical experiment.

Methodology

Data was collected in an introductory statistics course at a large urban university in the the United States. The first author was the classroom assistant who helped with classroom activities and data collection during the quarter. The second author was the classroom instructor. This particular statistics course was designed for students prior to entering the traditional introductory statistics sequence (descriptive statistics, probability, inferential statistics). Students enrolled in this course as a prerequisite for the traditional sequence or to satisfy the required math elective needed to graduate. A total of 16 students enrolled in the course and all students consented to be participants in the study.

The second author implemented the CATALST curriculum materials (Garfield, delMas, & Zieffler, accepted) with some minor modifications. The CATALST curriculum consists of three units, and each unit begins with a model eliciting activity (MEA, see Lesh et al., 2000). Following each MEA, there are several activities in each unit that guide students through key ideas raised in the MEA (e.g., informal inference based on a single population, p-value). Data collection consisted of all student work on in-class activities, task-based semi-structured interviews, and student assessment items. This proposal focuses on one activity that will be used to illustrate the nature of student reasoning as they learned to construct a statistical model with the dynamical statistical software, TinkerPlots™.

The research team had students create simulation models to answer informal statistical questions with the modified CATALST curriculum. One such task involved the One Son Policy, a situation where families continue to have children until they have a son with the assumption that it is equally likely to have a boy or a girl. This task was the first time in the course where students needed to find a way to stop drawing from the sampler once the desired result was reached. Previous tasks only required students to choose the appropriate number of repeats for a particular trial. For example, students might be asked to model flipping a coin five times as a single trial and would flip (draw with replacement) one coin with a repeat of 5 for a single trial. We believe that the One Son activity created a cognitive hurdle because the students encountered a task with the necessity for the sampler to stop after a prescribed result was reached.

A correct way to model the One Son task using a spinner is shown in Figure 1. Notice the spinner shows two equal parts representing boys and girls, under the assumption each sex is equally likely, and the "Repeat" is set to "Repeat until pattern matched" is BOY. A single trial is completed after a boy is drawn and the variable of interest is the number of "spins" (births) until a boy is selected. Multiple trials can be run to investigate trends, such as the expected number of children under such a birth policy. The correct interpretation of a single trial would be the number of children a particular family has (i.e., the number of spins until a boy is produced).

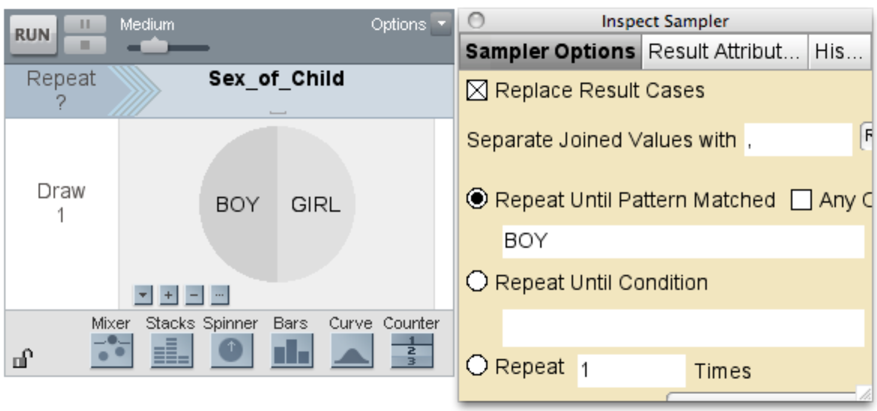

Figure 1. Tinkerplots™ One Son Policy Simulation Model

The instructors modified the CATALST curriculum by removing the instructions regarding how to setup the simulation in Tinkerplots™. Specifically, they removed instructions that detailed how to make the simulation stop after a boy was drawn from the sampler. The classroom instructor and assistant first had students brainstorm in groups how they might set up a model for the One Son Policy without the use of technology and then to try using the technology to build simulations from their mental models. After students investigated the technology they began to raise the question of how to "tell" the computer when to stop the simulation, at that point we gave them the Tinkerplots™ instructions. The next section details the results of student thinking during this investigation.

Initial Results

All 16 students created their simulation using a spinner[1], but had different ways of setting up their models, interpreting a trial and making an inference about the average number of children born under such a policy. Table 1 outlines the different student interpretations of a single trial in the One Son activity.

Characterizations of Student Interpretations of a Single Trial	Evidence	Students (Pseudonyms)
A trial is the number of children a family has *until* a boy is born	The verbal model was expresseed to be the number of children that were born in a single family up to and including the son, so the sampler would need to stop	Arnold Bill George Becky Danika Sally Kate Helen

[1] The spinner in TinkerPlots is automatically set at with replacement.

	drawing once the son was born	
A trial is the number of children a family has *before* a boy is born	The students collected counts on the number of girls born resulting in the average number of children to exactly one less than expected.	Ellen Starla Nils Andrea
A trial is each spin of a spinner (but only when the spin lands on a boy)	Knew when a trial would end, but did not account for the total number of children that would be born before a boy	Carolyn Kimberly
A trial is looking at the sex of the first born child in ten families	Used a "draw" value of one to represent the sex of the first child and a "repeat" of 10 to represent the ten families	Jennifer Jill

Jennifer and Jill reported the most idiosyncratic interpretation of a single trial in the One Son activity. These students worked together and reasoned that a single trial was identifying the sex of the firstborn child in ten families. Their samplers were set up with a "draw" value of one to represent the sex of the child with a "repeat" value of ten to represent the ten families in the trial. With the sampler set up in this manner, there was no way to answer the research question because they struggled with the definition of a single trial, making it impossible to simulate using technology or physical simulation.

After students spent time discussing possible models in small groups, the class discussed various ideas and converged on an appropriate model to carry out using Tinkerplots^{TM}. The strategy of choosing a draw value instead of having the sampler "repeat until pattern match" was not uncommon at this point in the activity. Helen, Carolyn, Andrea and Kimberly initially used the approach of choosing the number of "repeats", although for a different reason than Jennifer and Jill did. These students chose an arbitrary "repeat" value that they deemed sufficient enough to produce a boy. Andrea argued that a "draw" value of 5 was an adequate "draw" value to have a boy because the assumption was that it was equally likely to have a boy or girl. This approach could not be used successfully without more advanced mathematical logic statements necessary to count the number of children up to and including the point a boy is born and disregard any children after. While the students' intuition about the likelihood of the event of having a boy was correct, it was not sufficient as a method when incorporating Tinkerplots^{TM} as an effective tool to help them successfully answer the statistics research question.

While some students struggled with the correct interpretation of a trial, eight of sixteen students identified a single trial and were able to correctly set up their model in Tinkerplots^{TM}. These students accurately collected statistics on the total count of children born in a family as shown in Figure 2. Figure 2 describes a single trial of three females born before a son, where statistics will be collected on the total count of Boys and Girls that are born.

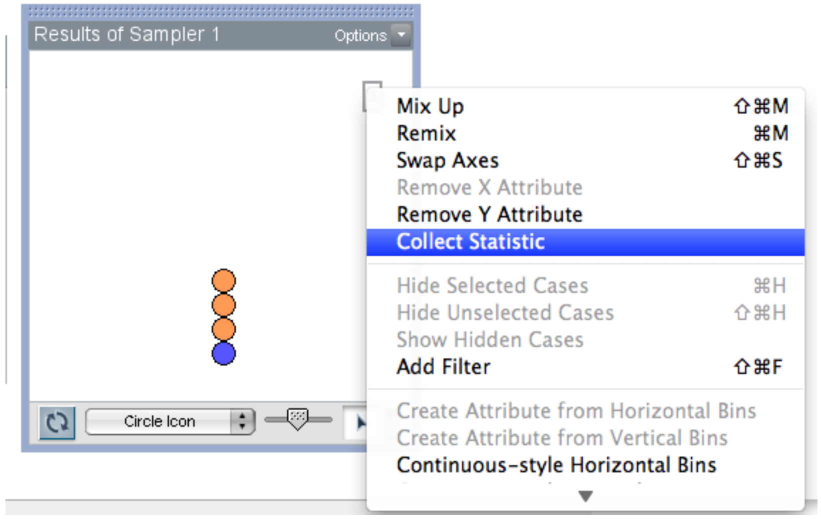

Figure 2: Students collecting statistics on the total count of children born in a single family.

Four of sixteen students also set up their model correctly in Tinkerplots^{TM}, but incorrectly considered the result of a single trial to be the number of females born. Their interpretation of a single trial was the number of children *before* a boy is born. This interpretation led these four students to have an average number of children per family to be exactly one less than expected because the count of the son was never included over many trials. These students found a solution to this issue without instructor assistance by simply adding 1 to their average children per family after many trials. However, this group never resolved the issue of how they collected statistics and were not able to prove that adding 1 to their average over many trials was the same as collecting statistics on the total number of children born.

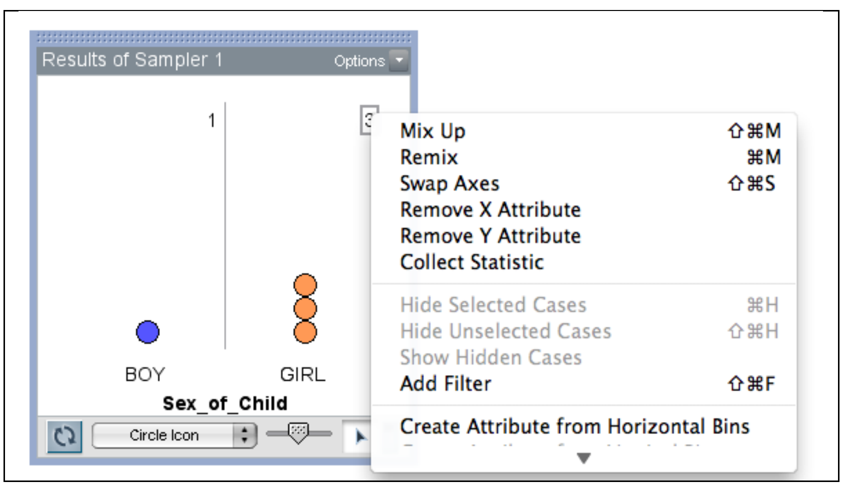

Figure 3: Students collecting statistics on the total count of females born in a single family.

Conclusions and Directions for Future Research

Students' interpretations of a single trial in the One Son activity fell into four different categories, three of which were incorrect or not useful in addressing the central question of the task. This suggests that the process of setting up a computer simulation to answer a statistical question is quite complex. Further, although the majority of students were able to correctly conceptualize the relationship between a single trial and the task situation, they still had difficulty using the technology to set up and interpret a simulation to address the question.

Future research should focus on identifying the source of the students' difficulties. In particular, it is unclear whether the students struggled primarily with understanding the statistics task, using the technology to conduct a simulation, or with the challenges of coordinating these. For example, future research could be designed to understand why students struggle to correctly use logical structures (e.g., If – Then) in order to set up a statistics simulation. Understanding more precisely the source of students' difficulties will support the design of more effective instructional approaches.

Questions for the Audience

- What kind of research design could help us tease out precisely where students' difficulties lie?
- Are there existing frameworks regarding use of technology in problem solving that could help us make sense of students' difficulties as they set up statistical simulations?

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