IMPORTANT IDEAS IN STATISTICS FOR CHILDREN AGED 4-8 YEARS

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This paper highlights important statistical ideas for children aged 4-8 years and the implications for teacher education and research. Drawing on both the Guidelines for Assessment and Instruction in Statistics produced by the American Statistical Association as well as standards/curriculum documents from other countries, I identify topics in statistics and probability that are appropriate for young children and to which they should be exposed in order to prepare them for later instruction. I also examine the knowledge that teachers of young children need to have in order to teach this content effectively. In addition, I suggest areas that are ripe for further research in this arena.

The curricular territory for children ages 4-8 is tricky to navigate as the age at which students begin compulsory schooling varies internationally. Very few countries require education for children aged 4, and few countries have a formal curriculum for children that age. In some countries, such as the United States, for example, education is available for children age 4, but the nature of that schooling varies widely from publicly funded to privately funded and from academically oriented to day care. Likewise, at the other end of the spectrum, children aged 8 have been enrolled in formal schooling for different numbers of years in different countries. For purposes of this paper I reviewed the publicly available curriculum documents from Australia, New Zealand, South Africa, Scotland, and the United States to gain a sense of the nature of curriculum standards related to statistics for children ages 4-8. For purposes of consistency, I confined my review to the grades of compulsory education in each country, thus eliminating the variability that comes with pre-school programs.

STATISTICAL IDEAS FOR AGES 4-8

Across countries curriculum standards include pre-numerical activities such as identifying attributes, sorting and classifying and early numerical activities such as counting and determining which has more or less for young children. Although not specifically tied to data analysis, these activities are clearly precursors for collecting and analyzing data.

Not all standards were explicit about the statistical problem solving process: formulate questions, collect data, analyze data, interpret results (American Statistical Association, 2007), but most standards seem to be built on this framework to some extent. The New Zealand standards were very explicit about the process, suggesting that young children conduct statistical investigations that utilize the entire process at least once a year. Countries that were not explicit about the process most often eliminated the formulate questions or interpret results phase of the process. For instance, the South African standards suggest that students gather data to answer a question posed by the teacher. This is in contrast to the Australian standards, which state that children should pose questions about themselves and familiar objects and events in the foundation year. With respect to the interpretation phase, the Australian standards stopped at answering questions about the data collected, such as “How many students have brown hair?” The Scottish standards mention drawing conclusions and interpreting information but do not elaborate. Research suggests that children have more ownership of a statistical problem when they are involved in all stages of the statistical problem solving process (Leavy, 2008).

The standards I examined mirror much of what I have observed in US classrooms: Teachers focus their attention on having students collect and represent data but spend little time on having students pose questions or interpret the data. This represents a significant disconnect between what happens in the “real world” when people collect and analyze data and what happens in the classroom. Generally when one is collecting data in the real world, one is motivated by a genuine question, and one would not neglect the interpret phase of the process because one needs to consider whether the results found would be stable across other situations or, if not, what

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variables would induce changes in the data. The collect and represent data phases that are emphasized in classrooms can take an enormous amount of time and materials, so it is desirable to get as much as possible out of each instance of data collection and analysis by attending to the first and fourth stages of the statistical problem solving process.

At first glance, it may seem that asking young children to pose questions is unrealistic as they are unlikely to come up with questions for which they can actually collect and analyze data. However, the only way for children to learn to pose reasonable questions is to practice posing and discussing questions. Leavy (2008) argued for the importance of children posing statistical questions about problems that have personal relevance. Konold and Higgins (2002) illustrated the difficulty that young children have in posing answerable questions, but they also advocated that teachers should assist children in shaping answerable questions so that they will have more motivation to follow through with the entire statistical problems solving process.

While it is ideal for children to engage in the entire statistical problem solving process, it is not always necessary to complete the entire process; pieces can be dealt with separately to great effect. For instance, children are naturally curious and inquisitive, so teachers can build off of this tendency to work on the formulate questions part of the process in isolation. If a class is going on a field trip later in the week, the teacher can ask the students what they are wondering about related to the field trip. Suppose the field trip is to the zoo. Children might wonder what animals they will see, which animals they can feed, or how old the animals are. The teacher can record the children's questions and then ask them to consider which questions they might be able to answer while they are at the zoo by collecting data. Once they eliminate some questions, they can discuss characteristics of questions they can answer with data, and this will likely generate more questions that they can answer with data. This process can also be followed by discussing how one would collect data to answer the questions posed, even if the data are not actually collected.

Similarly, focusing on the interpret results portion of the process can be done with data that have already been collected and displayed or using published graphs from new sources. For instance, many teachers keep a classroom display of children's birthdays or lost teeth on the wall all year. Such displays are ripe for interpreting results. The purpose of the interpret results portion of the process is to help children begin to think about variability and its sources. For instance, with the birthday graph a teacher can ask children to consider whether a birthday chart in a Year 5 classroom or a retirement home would be likely to look the same or different and why. In contrast, a chart of tooth loss would look very different in classrooms with older children. Pushing children to interpret the data they have collected and displayed allows them to gain an understanding of variability and its sources. For instance, if children have collected and graphed the shoes they are wearing, questions about whether they would expect the graph to look the same if the data were collected again in 6 months, in a secondary school, or at a local business force them to think about what sorts of things influence shoe choice (i.e., sources of variability). Weather, age, location, and vocation of those wearing the shoes all have an influence on the shoes we wear, thus inducing variability. It is important for children, even very young children, to being to recognize variability and to identify sources of variability. A study by Ainley et al. (2000) showed that 8-year old children were capable of predicting or "reading beyond the data." A study by Pratt (1995) showed that 8- and 9- year old children were capable of discerning patterns and making predictions based on bivariate data derived from an experiment. These studies are among the few that provide insight into the capabilities of young children, and while they do not speak to the youngest learners, they do provide evidence that, under appropriate circumstances, young children are quite capable of engaging in the full range of activities of the statistical problem solving process.

A second significant difference I found in examining standards from different countries was the representations or types of graphs that children were expected to use at young ages. In some countries (New Zealand, Scotland) the types of displays to be used were not specified. In South African the only type of display mentioned was a pictograph with each picture representing one data point. The Australian and Scottish standards specified lists, tables, and picture graphs (again with each picture representing one data point), and the US standards specified line plots and bar graphs. The Scottish standards suggested that students as young as 4-5 years of age be able to use technology and other means to display data simply, clearly, and accurately by using tables, charts, or diagrams with appropriate labels and scale. Leavy (2008) reviewed a number of studies of young children representing data and concluded that when the children were involved in the full statistical problem solving process, they were able to construct more “appropriate and sophisticated graphical representations” (p. 225). These results suggest that we should err on the side of expecting more from children rather than less. Teacher support and appropriate technologies likely can enhance what young children can do with data.

IMPLICATIONS FOR TEACHER PREPARATION

Teachers cannot teach what they do not know, and most teachers completed their own schooling when data analysis was attended to sparsely or not at all, and most of their experiences revolved around collecting and displaying data, mostly using bar graphs and categorical data. Thus, teachers of young children need support in understanding the full statistical problem solving process and examples of how children can be meaningfully engaged in the entire process. In my work with teachers, both preservice and inservice, I have found that once we begin to discuss the first and fourth stages of the process in a variety of contexts, they quickly see how children can be engaged in higher order thinking throughout the process. When coupled with concrete examples of children’s work throughout the process, teachers are further convinced that it is both possible and desirable to place more emphasis on the questions and interpret phases.

One of the challenges for mathematics teacher education with respect to statistics education is that many of the mathematics educators and many of the mathematicians who do the bulk of the work with teachers have little to experience with statistics education. While they may have received some formal training in statistics, they likely have not been privy to the contemporary conversations about statistics education. Thus, it is important that statistics educators continue the outreach to mathematics educators, mathematicians, and classroom teachers to broaden the number of individuals who understand the importance of the full spectrum of the statistical problem solving process.

Toward this end, the American Statistical Association (ASA) has undertaken the writing of a set of standards for teacher preparation in statistics education to elaborate on both what teachers need to know and how they need to learn it if they are to reach statistics in meaningful ways to students. The document, titled *Statistical Education of Teachers*, should be available in 2015 via the ASA web site.

In the United States, primary school teachers generally take between 1 and 3 mathematics content courses designed specifically for teachers. Such courses are generally taught in mathematics departments by individuals with no specialized preparation in statistics education. Much of content that is included in textbooks for such courses is a surface level treatment of a few topics from a typical collegiate level introductory statistics course. Thus, it is crucial for the statistics education community to make connections with mathematics departments and those who teach content courses for future teachers to broaden their perspectives on statistics and statistics education.

AREAS OF NEEDED RESEARCH

There is minimal research on the statistical thinking of children ages 4-8. Much of the literature that exists goes down only as far as age 8. Thus, it would be useful for researchers to investigate the ways that very young children think about important statistical ideas. Jones et al. (2000) developed a framework of children’s statistical thinking for all four stages of the statistical problem solving process, and it would be useful for researchers to replicate some of their work in order to refine, modify, or extend the framework for younger children.

It would also be useful to have research that documents teachers’ knowledge of important statistical ideas for young children and how teachers go about teaching these ideas in classroom settings. The field could benefit from having a better understanding of how children’s statistical thinking plays out in the classroom using the abundance of excellent curriculum materials that exist.

CONCLUSION

The paucity of standards for children age 4 and the fact that this is generally not compulsory mean that children will likely start formal schooling in very different places with respect to statistical thinking. It would be useful for professional organizations to issue some type of standards or suggested activities for very young children to guide both parents/caregivers and teachers of children this age.

Both standards and instruction for young children need to reflect the level of thinking of which they are capable by consistently engaging them in all four phases of the statistical problem solving process, with particular attention to formulating questions and making inferences as these phases tend to be neglected. Research that provides examples of children's thinking as well as papers that provide examples of successful classroom lessons would add to the field's understanding of robust instruction for young children.

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