Journal of Mathematical Behavior xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Mathematical Behavior

journal homepage: www.elsevier.com/locate/jmathb

Eye color and the practice of statistics in Grade 6: Comparing two groups

Jane Watson[a,*], Lyn English[b]

[a] University of Tasmania, Australia
[b] Queensland University of Technology, Australia

A R T I C L E I N F O

Keywords:
Comparing groups
Grade 6 students
Informal inference
Statistical reasoning in middle school

A B S T R A C T

This study followed the progress of 85 Grade 6 students as they expanded their understanding and application of the practice of statistics to include comparing two groups of people: those with brown eyes and those with eyes of other colors. Based on a claim in the media that brown-eyed people had faster reaction times than others, the students collected data from their class to explore and evaluate the claim for their class and make an inference for all Grade 6 students. They then collected and analyzed four random samples of the same size as their class from a national "population" of Grade 6 students. Finally the data from the "population" of 1786 Grade 6 students were used to evaluate the claim. Data for analysis of student capacity to engage in the practice of statistics were collected from student workbooks completed while carrying out the activity, corroborated by transcripts of all class discussion, and from an assessment administered following the activity. Although the correlation of outcomes from the workbook and assessment was significant ($p < 0.01$) and many students completed the activity in a highly competent manner, the analysis also found conceptual understanding was not retained as well as procedural understanding.

1. Introduction

As more research is carried out in relation to the implementation of school curricula including statistics, the question arises as to how far students can progress before they reach the need for formal statistics. Can they understand the concepts involved if they do not have formal techniques such as means, standard deviations, confidence intervals, and *t*-tests? Near the end of a 3-year longitudinal project introducing beginning inference, Grade 6 students participated in an activity that gave them the opportunity to answer a question based on comparing two groups, the type of question that would be introduced in a beginning tertiary level statistics course after the introduction of the normal distribution, *t*-distribution, and one-sample inference procedures (Moore & McCabe, 1989). Working within an informal inference context (Makar & Rubin, 2009), there was interest in what evidence students would use to make a decision and what degree of confidence they would have in that decision. Having previously experienced decision-making about typicality in a single set of data, students were introduced to a second variable, creating two groups for comparison. This paper surveys the three perspectives on statistics education that suggest such a study is feasible and relevant; presents the background of the students in readiness for the activity, including understanding measures of center; reports on the students' capacities to deal with the demands of the activity; and assesses their recall two weeks following the activity.

* Corresponding author.
E-mail address: Jane.Watson@utas.edu.au (J. Watson).

http://dx.doi.org/10.1016/j.jmathb.2017.06.006
Received 4 November 2016; Received in revised form 2 June 2017; Accepted 29 June 2017
0732-3123/

2. Perspectives and literature review

Three perspectives on statistics education provide the foundation and motivation for the study reported here. First is the growing interest in introducing students to authentic statistical investigations during the primary school years, going beyond a focus on the tools to be used in later more theoretical statistics. Second is the mystic associated with comparing two independent samples with *t*-tests, which is very common in tertiary statistics courses and much science and social science research. Third is the recognition that as well as learning and applying statistical techniques, students need to be able to understand and judge the results and claims of others. This is embodied in statistical literacy and includes the critical thinking ability to challenge, when necessary, claims that are made in wider society. These perspectives are considered in turn.

2.1. The practice of statistics

The phrase "practice of statistics" was coined by Moore and McCabe (1989) for an introductory tertiary statistics textbook the same year as the National Council of Teachers of Mathematics (NCTM, 1989) published the *Curriculum and Evaluation Standards for School Mathematics*. Moore and McCabe's intent was to "introduce readers to statistics as it is practiced … focused on problem solving" (p. xi). The NCTM laid the groundwork for accepting the importance of the practice of statistics early in students' mathematics education, with students in Grades K to 4 having the following experiences:

- collect, organize, and describe data;
- construct, read, and interpret displays of data;
- formulate and solve problems that involve collecting and analyzing data. (p. 54)

These are the ingredients that were later put together in the *Guidelines for Assessment and Instruction in Statistics Education (GAISE)* (Franklin et al., 2007) by a joint committee of the American Statistical Association (ASA) and the NCTM for statistics education at school. The *GAISE* framework for "statistical problem solving" is based on a foundation acknowledging variability:

- Formulate questions, anticipating variability;
- Collect data, acknowledging variability;
- Analyze data, taking account of variability;
- Interpret results, allowing for variability. (p. 11)

This framework places the experiences of the NCTM *Standards* in the required order for carrying out a statistical investigation. The emphasis on variability reflects the foundation laid by Moore (1990), whereas the label "problem solving" recognizes the earlier view of Rao (1975) that "statistics ceases to have meaning if it is not related to any practical problem" (p. 152).

In the years between 1989 and 2007, Wild and Pfannkuch (1999) analyzed the work of their statistical consultant colleagues and produced a 4-dimensional model of a statistician's work. The investigative cycle dimension closely resembles the *GAISE* framework, suggesting steps of Problem, Plan, Data, Analysis, and Conclusion (PPDAC), with Plan and Data combined in the *GAISE* description of Collect data. PPDAC has influenced the New Zealand *Mathematics and Statistics Curriculum* (Ministry of Education, 2009), which includes a subheading for Statistical Investigation at every level of the school curriculum.

The decision-making at this level of students' education is now generally termed "informal statistical inference" (Makar & Rubin, 2009), acknowledging that "formal inference" is the phrase used at the tertiary level where a theoretical foundation is laid first. Informal inference refers to decision-making in relation to a statistical question for a population based on evidence from a sample and acknowledging a degree of uncertainty in that decision. The degree of certainty depends on the quality of the evidence, which at the school level has a descriptive rather than a theoretical basis. In recent years, classroom interventions to document and evaluate primary school students' capabilities to undertake the practice of statistics have had a variety of foci, including having students pose survey questions for an investigation (e.g., English, 2014; Lavigne & Lajoie, 2007), having students collect data themselves (e.g., English & Watson, 2015a, 2015b Watson & English, 2015) and having students represent and analyze data to draw conclusions (e.g., Ben-Zvi, Aridor, Makar, & Bakker, 2012; Makar, 2014). The specific acknowledgement of uncertainty in the decisions reached has also received attention (e.g., Zieffler & Fry, 2015). Few studies, however, combine all aspects of the practice in one study.

Completing a statistical investigation involves both procedural and conceptual understanding (Baroody, Feil, & Johnson, 2007; Hiebert & Carpenter, 1992). Procedural aspects of calculating measures of center or drawing specific types of graphs are required as contributions to the conceptual understanding needed to connect all of the components of the *GAISE* framework for a complete investigation (Franklin et al., 2007). There is much literature on the relationship of these two types of understanding in mathematics more generally than statistics; for example, Hiebert and Grouws (2007) speak of skill efficiency and conceptual understanding, with the former related to procedures and contributing to the latter (p. 380). The question of procedural knowledge being deeper than skill efficiency is addressed by Baroody et al. (2007) in suggesting the interrelationship of procedural and conceptual understanding with the possibility of deep procedural knowledge arising from links to related conceptual knowledge. The aim of educational interventions should be to foster both types of knowledge and their continuing support of each other. In the context of statistical investigations, Groth and Bergner (2006) considered the existence and relationship of procedural and conceptual knowledge in understanding of measures of center by preservice elementary teachers. Groth (2014) extended this work to the concept of variation by considering preservice teachers' procedural and conceptual knowledge of the mean absolute deviation. Again the relationship was