High School Students’ Levels of Thinking in Regard to Statistical Study Design

Randall Groth
Salisbury University

The study describes levels of thinking in regard to the design of statistical studies. Clinical interviews were conducted with 15 students who were enrolled in high school or were recent high school graduates, and who represented a range of mathematical backgrounds. During the clinical interview sessions students were asked how they would go about designing studies to answer several different quantifiable questions. Several levels of sophistication were identified in their responses, and are discussed in terms of the Biggs and Collis (1982, 1991) cognitive model.

Study design is foundational to the practice of statistics. Cobb and Moore (1997) underscored this point with the following statement:

Statistical ideas for producing data to answer specific questions are the most influential contributions of statistics to human knowledge. Badly designed data production is the most common serious flaw in statistical studies. Well designed data production allows us to apply standard methods of analysis and reach clear conclusions. (p. 807)

Wild and Pfannkuch (1999) also emphasized the importance of study design, stating that it is an indispensable part of the overall process of statistical thinking. Recognizing the importance of study design, the National Council of Teachers of Mathematics (NCTM, 2000) recommended that students should begin to have experiences in designing simple studies during their preschool years and develop increasingly more sophisticated study design strategies throughout their years of formal schooling. Similar recommendations appear in other curriculum documents (e.g., Australian Education Council, 1991).

Purpose of the Study

Since the topic of study design forms an important part of statistics education, the need exists to understand students’ patterns of thinking in response to statistical study design tasks. Research that describes students’ cognition in regard to mathematical topics has the potential to help improve the teaching of the topics (Even & Tirosh, 2002; Fennema & Franke, 1992). The purpose of the present study was to contribute to the knowledge base concerning students’ understanding of study design by focusing on high school students (high school in the United States, where the present study was conducted, generally includes students 14-18 years old). The following two research questions were addressed.

1. What are the defining characteristics of high school students’ patterns of response to statistical study design tasks?
2. What cognitive level can be associated with each of the patterns of response identified?
Previous Research on Students’ Knowledge of Study Design

This section presents research that provides some insight about students’ abilities to design statistical studies. In carrying out the present study, special attention was paid to whether or not issues encountered in the literature arose among the students studied. Since the focus of the present study is upon the high school level, the research literature discussed includes descriptions of the thinking of students at or near the high school level.

Watson and Moritz (2000a) investigated Grade 3-11 Australian students’ abilities to detect bias when considering statistical samples. They found that students ranged in sophistication from those who offered no criticism of situations in which bias would naturally occur to those who recognised the need for samples to be representative and unbiased. The ability to detect bias seemed to be related to grade level. When Watson and Moritz studied some of the same students two to four years later, they found that students tended to improve by one or two levels of sophistication in thinking. The results of their study showed that students do not always recognise that unrepresentative and biased samples produce undesirable results, but that their ability to detect bias seems to improve as they progress through school.

Data supporting the finding that the ability to detect bias is related to grade level occur in United States students’ responses to an item on the 1996 National Assessment of Educational Progress (NAEP). Whereas approximately half of eighth grade students responded correctly to an item designed to assess their ability to recognise the potential for sample bias, approximately 75% of Grade 12 students responded correctly to the same item (Zawojewski & Shaughnessy, 2000). This finding suggests that the ability to detect bias in study design is present more frequently among older students.

In order to design an effective statistical study it is not sufficient simply to recognise that samples need to be representative and unbiased. One must also use methods with the potential to produce such samples. Watson and Moritz (2000b) conducted a study in which they interviewed Australian students in Grades 3, 6, and 9 about their ideas pertaining to sampling, finding that some of the students interviewed understood the roles of randomization and sample size in producing a representative sample. Zawojewski and Shaughnessy (2000) noted that about two-thirds of eighth-grade U.S. students taking the 1996 NAEP could correctly choose the sampling method that would provide the least biased results when given several choices of sampling methods in a multiple choice question. Given these findings, it seems reasonable to expect students to develop the ability to choose appropriate methods for sampling during their high school years.

Another essential part of effective statistical study design is deciding when and how to conduct experimental studies rather than non-experimental ones. This can be challenging even for college students. Heaton and Mickelson (2002) found that undergraduates had some difficulty matching appropriate data collection methods to the quantifiable questions they had posed for class projects. Derry, Levin, Osana, Jones, and Peterson (2000) described the development of undergraduates’ statistical thinking ability in regard to study design, finding that students showed significant gains in knowledge of the design of convincing experiments and the concept of random sampling during the course. Despite the overall gains, however, many students still tended to confuse the concepts of random sampling and random assignment after the course. Given the difficulties college students have exhibited with deciding when and how to conduct