EXPLORATION OF PROBLEM SOLVING PROCESSES OF STUDENTS WITH LEARNING DISABILITIES

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Students with learning disabilities (LD) comprise an increasing portion of the university population. These students often face a disproportionate host of educational and attitudinal challenges, including dysgraphia, ADHD, reading comprehension issues, problems with information retention, and learned helplessness. Current instructional practices may not address obstacles faced by these students. In this study, students with LD will verbalize their thought processes and strategies as they work through a confidence interval word problem. We first identify several primary obstacles to student success. We also explore students' response patterns and their attempts to use aids to overcome obstacles. By gaining an improved understanding of how learning disabilities affect students' efforts toward statistical problem solving, we hope to develop more effective methods to sustain statistical literacy for their long term success.

PURPOSE

The percentage of students with registered learning disabilities in college increased from only 0.5% in 1983 to 2.8% in 2004 (Pryor, 2007). It seems safe to assume that more students with learning disabilities on college campuses will lead to more students with learning disabilities enrolled in introductory statistics courses. These students may experience disproportionate challenges in problem solving. In order to further explore the issues faced by these students, an exploratory investigation was conducted through clinical interviews.

BACKGROUND

Statistical problem solving involves a complex interplay of statistical literacy, reasoning, and thinking—three ideas which have featured prominently in statistics education research over the last two decades (c.f. Ben-Zvi & Garfield, 2004). Additional work has been done to scale expectations regarding these overarching goals appropriately for students in introductory statistics courses; for example, Rumsey (2002) pared down the broader idea of statistical literacy to a core of "statistical competence."

It is reasonable to question whether the additional challenges faced by students with LD affect their progress toward these introductory goals. Does documented difficulty with processing and retaining information (Miller & Mercer, 1997) translate into difficulty with Rumsey's (2002) recommended "understanding of certain basic statistical concepts and terminology"? Likewise, students' efforts toward statistical literacy may be impeded by a host of other documented challenges affecting students with LD in mathematics and science courses, including difficulties with: word problems, distinguishing symbols, integrating knowledge, persevering after encountering obstacles, focusing, working under timed conditions, and communicating ideas clearly (Brigham et al., 2011; Miller & Mercer, 1997; Carnine, 1997; Mocko, 2012).

The last challenge listed above—communication—makes studying the experiences of students with LD in statistics courses particularly formidable because written answers may not accurately reflect the student's understanding or reasoning. Clinical interviews allow investigators to explore a student's thinking by asking them questions while they complete a task. "The value of the clinical interview as means to 'enter the learner's mind' has been discovered by researchers and the appreciation for this method is growing." (Zazkis & Hazzan, 1999, p. 430). Researchers in statistics education have already used clinical interviews to explore the thoughts and practices of statistics students (cf. Budget & Pfannkuch, 2010), but there is a need for further attention to address the experiences of the subpopulation of students with learning disabilities.

SETUP OF STUDY

The students were selected from a special section of introductory statistics course at a large research university in the southeastern region of the United States. This section was comprised of

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twenty students with registered learning disabilities such as dysgraphia, dyslexia, and ADHD. During the Fall 2013 semester, volunteers were given the opportunity to earn extra credit on an exam grade by participating in the interview (even if they chose not to have their results recorded in the study.) Eleven students participated in the study. The students met with one of the authors outside of class to work on a confidence interval problem for the population mean. This problem was adapted from the CAOS test (del Mas et al., 2007):

> The researcher measures the word lengths (numbers of letters in each work) for a sample of twenty-six words from a statistics text book published in 2004. The mean of these word lengths is 4.19, and the standard deviation is 2.45. A.) Read the given problem out loud. B.) Identify the important pieces of information given in the problem and label them with the appropriate notation. C.) Define the parameter that could be estimated using this information. D.) Make the graph of the data provided below and interpret the important characteristics. E.) Below is the output from a statistical software package. Explain the information that is given here. F.) Using the above information, describe how to get the margin of error. G.) Interpret the '95% CI' stated above in context. H.) Give an example of a statement that incorrectly interprets the confidence interval, and explain why it is wrong. I.) What does it mean to be 95% confident?

The students were asked to explain how they completed each part. If the students became stuck when they were working out the problem, they were given prompts to help them continue. For example, if they had trouble making a graph, they might be asked, "What kinds of graphs do you know?" Additional open-ended prompts were adapted from Hunting (1997) to encourage students to explain their reasoning and methodology. The results from these interviews were recorded. The authors then reviewed the videos together to analyze student responses.

RESULTS

During the problem-solving process, students experienced three main types of stumbling blocks: the structure of the assignment, the use of statistical symbols and language, and the synthesis of statistical concepts into cohesive ideas. As the students worked through these stumbling blocks, we witnessed different response patterns in their explanations and different aids that they attempted to employ.

The first stumbling block we observed was the physical structure of the written assignment. Since the assignment involved multiple parts, we split the activity up across four pages and gave students one page at a time. Thus, the data was given on a different page from the story stem. Although the parts of the problem were sequentially lettered (part a, b, etc.), six out of the eleven students did not make the connection between the story stem and the data. Some students viewed each lettered part as a distinct task, unrelated to previous parts; this confusion made it more difficult for them to develop and communicate a cohesive strategy.

Apart from the physical structure of the assignment, students encountered obstacles related to retention and use of fundamental statistics concepts and notation. Over half of the students interviewed struggled to write down the information given in the problem stem using the correct symbols. Many used mu and sigma to represent sample mean and standard deviation; others failed to record the sample size correctly, either by not writing it down at all or by using an incorrect symbol (such as s or p). In addition to misuse of symbols, nearly all of the students were unable to recall at least one of the statistical terms used in the interview. Nine of the eleven students had difficulty correctly identifying or explaining the appropriate parameter to be estimated. Some students decided that the parameter was a proportion, even after identifying the (sample) mean in an earlier part. Others, having specified the parameter was a mean, could not correctly differentiate between sample and population (students M and J). Additional, similar issues with understanding basic concepts became evident when students were asked about margin of error and statistical confidence.

In addition to revealing student difficulties with fundamental statistical concepts, the interviews also suggested that student knowledge is compartmentalized and inconsistent in nature—often without the students themselves being aware of any inconsistency. Students recalled formulas or terms in earlier parts of the interview, but not in later (students E,R), or vice versa (students M,N). Student J gave both correct and incorrect explanations of how to find the mean within a single section of the interview, without acknowledging the contradiction. The most common manifestation of this inconsistency, however, was in the notation: student use of symbols changed frequently depending on the part of the problem. For example, sample size changed from p to N (student B), and the sample mean changed from x-bar to sigma (student R). It is perhaps unsurprising that students provided conflicting answers during the half-hour interview, particularly in light of the above findings regarding their use of statistical terms; however, the lack of recognition of that inconsistency stands out as noteworthy.

When confronting the non-statistical and statistical obstacles identified above, the students' responses fell into five general patterns:

(1) Non-explanation. Some students attempted but were unable to give explanations; others responded with short non-answers (e.g., "don't know why").
(2) Non-statistical explanation. Students attempted to explain concepts or reasoning using subjective, non-statistical approaches.
(3) Incongruous explanation. Students attempted to parrot statistical ideas and phrases used in class, but gave incorrect explanations or created idiosyncratic connections between concepts. For example, when explaining why he might make a graph of the data, student C said, "We're proving in this step, if it were homework, that we can use the data and show that it's not a bad sampling, or not an incorrect… average, it's not average. So by doing this, we prove that it's average from the number of letters in each word from the textbook."
(4) Tangential explanation. Students use examples or explanations of a different statistical topic or task. For example, when asked about the margin of error for a confidence interval about a mean (covered in chapter 8), student T quickly turned to chapter 4 and looked up an old formula approximating the margin of error to use with a proportion.
(5) Correct progression. Students eventually reached a (mostly) correct written or verbal explanation of the concepts or reasoning involved.

When students reached a stumbling block, some students reached out to aids that might help them. These aids included (1) using mnemonics, (2) using the textbook or notes, (3) recalling an experience from an activity, (4) drawing an image, and (5) writing out all the options. Sometimes the use of the aids led to successful completion of the problem, but other times it did not. The first aid students employed was the use of mnemonics (memory aids). For example, student M recalled that since "margin of error" had one more word than "standard error", the formula for margin of error must have one extra part to it. Second, students attempted to use references such as the textbook or course notes. Out of eight students who utilized these resources, however, over half were unable to independently retrieve the definitions or formulas they needed. A third tool that students used was writing out all the possible options when a choice was necessary. For example, student L wrote down two possible formulas for the margin of error, "$1/\sqrt{n}$") and"$ts/\sqrt{n}$", before deciding to use the second one. A fourth aid was the use of images. For example, when student E was asked to explain 95% confidence, he drew a picture of the empirical rule. Although, he didn't accurately explain the statistical connection between the term "95% confidence" and the empirical rule, he knew that they were connected. Finally, a fifth aid that the students used was to refer back to statistical applets or activities that they had done. Student A recalled an applet on simulating repeated confidence intervals to correctly explain the concept of confidence. Overall, students attempted to use a variety of aids when dealing with stumbling blocks; however, their attempts were not always successful.

LIMITATIONS OF THE STUDY

One limitation of this exploration is that the same interviews were not conducted with students who did not have registered learning disabilities; however, during 2014, clinical interviews will be conducted with students who do not have a registered learning disability. These experiences will also be presented at ICOTS 9. Additional limitations of this study are the small sample size and the lack of a random and representative sample. Finally, this activity only focused on elements related to the confidence interval, so this study only gives us a small window into the thoughts of students with learning disabilities when faced with a statistical problem.

CONCLUSION

Over the course of the interview process, the students evinced difficulty with fundamental statistical language and integration of knowledge. This was manifested in the repeated use of incorrect symbols and even in the inconsistent symbol use across various parts of the problem. The students themselves cited memorization and formulas as primary obstacles in statistics; ironically, however, the students reached primarily for formulas to solve parts of the activity, even though no formulas were needed. Most importantly, students often failed to see the big picture of statistics. They frequently showed awareness of pieces of statistical ideas and of strategies for individual parts of the task but were unable to connect those pieces into cohesive thoughts and thus into an understanding of larger goals in the task. This may have been what led to the incongruous responses, as students either attempted to fill in the missing connections on their own, and tangential responses, as they altered the focus of their response to suit their fractured knowledge.

Although many students struggle with retention and integration of statistical knowledge, the extent to which these problems affect students with LD may necessitate additional intervention from instructors in order to help students succeed. Unfortunately, our interviews do not suggest a simple solution. It is clear that students' attempts to use an indexed textbook and carefully organized course notes were frequently unsuccessful, so students might benefit from additional help with study/organizational skills. Also, students tended to recall and rely on simple, concrete aids (images, etc.). However, the frequent misuse of these aids by the students underlines the need for the instructor to emphasize integration of the aid with the bigger picture. Part of the issues with knowledge integration may stem from information processing difficulties; students with LD may require more time to acclimate to the statistical landscape and may be more easily overwhelmed with an influx of new information. Instructors should be aware that students with LD may try to rely solely on earlier material that is inappropriate for newer applications.

Overall, our findings suggest the need for further research into (1) how learning disabilities influence memory and integration of basic statistical knowledge and (2) how instructors may mediate these challenges to better develop statistical literacy in students with learning disabilities.

REFERENCES

Ben-Zvi, D., & Garfield, J. (Eds.) (2004). The challenge of developing statistical literacy, reasoning, and thinking. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Brigham, F. J., Scruggs, T. E., & Mastropieri, M. A. (2011). Science education and students with learning disabilities. *Learning Disabilities Research & Practice, 26*(4), 223-232.

Budget, S., & Pfannkuch, M. (2010) Using media reports to promote statistical literacy for non-quantitative majors. *ICOTS 8 Conference Proceedings*. http://icots.net/8/cd/home.html

Carnine, D. (1997). Instructional design in mathematics for students with learning disabilities. *Journal of Learning Disabilities*, *30*(2), 130-141.

delMas, R., Garfield, J., Ooms, A., & Chance, B. (2007). Assessing students' conceptual understanding after a first course in statistics. *Statistics Education Research Journal, 6*(2), 28-58. http://www.stat.auckland.ac.nz/~iase/serj/SERJ6(2)_delMas.pdf

Hunting, R. (1997). Clinical interview methods in mathematics education research and practice. *Journal of Mathematical Behavior*, *16*(2), 145-165.

Miller, S., & Mercer, C. B. (1997). Educational aspects of mathematical disabilities. *Journal of Learning Disabilities*, *30*(1), 47-56.

Mocko, M. (2012, April 10). Lessons learned from teaching introduction to statistics to learning disability classes [Webinar]. In *CAUSE teaching and learning webinar* series. http://www.causeweb.org/webinar/teaching/2012-04/

Pryor, J. H., Hurtado, B., Saenz, V. B., Santos, J. L., & Korn, W. S. (2007). *The American Freshman: Forty-Year Trends, 1966–2006*. Los Angeles: Higher Education Research Institute.

Rumsey, D. (2002). Statistical literacy as a goal for introductory statistics courses. *Journal of Statistics Education, 10*(3). http://www.amstat.org/publications/jse/v10n3/rumsey2.html

Zazkis, R., & Hazzan, O. (1999). Interviewing in mathematics education research: Choosing the questions. *Journal of Mathematical Behavior*, *17*(4), 429-439.