SPECIAL ISSUE

Journal of Problem Solving

Effects of Cover Stories on Problem Solving in a Statistics Course

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Keywords:
Problem solving, statistics, expertise, knowledge

Does having more knowledge or interest in the topics used in example problems facilitate or hinder learning in statistics? Undergraduates enrolled in Introductory Psychology received a lesson on central tendency. Following the lesson, half of the students completed a worksheet with a baseball cover story while the other half received a weather cover story. Learning was assessed using a quiz that contained two kinds of items: computation and explanation. Measures of baseball knowledge and interest in baseball were collected. The results indicated that overall the students performed better on computation items than explanation items. The weather example led to better performance on the explanation items than the baseball example. No differences were seen in performance on the quiz as a function of gender, prior knowledge, or interest. If anything, the results indicated that interest in baseball seemed to hinder learning in the baseball condition. Possible reasons for differences in performance due to the cover story are discussed.

There are some major challenges associated with teaching statistics. These challenges include capturing students' interest and maintaining it long enough for learning to occur (see Bergin, 1999, for review). Statistics is often a required course for many college majors, yet students may have little inherent interest in the topic (Garfield & Ben-Zvi, 2007; Gordon, 2004). This lack of interest can be exacerbated as many students are scared of statistics due to their lack of confidence in their mathematical ability (Ashcraft, 2002; Hembree, 1990). They also fail to understand that the goal of statistics instruction is not just to gain computational skills, but to understand concepts and to interpret results (Canham, Wiley, & Mayer, 2012; Mayer, 1974; Mayer & Greeno, 1972; Mayer, Stiehl, & Greeno, 1975). One method of capturing students' interest and helping them to gain conceptual understanding in statistics has been to embed problems within interesting cover stories and data sets (Macnaughton, 2002). Although it is widely believed that instruction using interesting or familiar cover stories is beneficial, no research that we know of has measured whether differing levels of interest and prior knowledge for the topics used in cover stories predict learning. The goal of this research is to test whether being interested in or familiar with the topic for a problem solving exercise affects learning in statistics.

PERCEIVED BENEFITS OF INTEREST

In a survey of secondary school mathematics instructors, 84% expressed a belief that using real-world examples facilitates learning (Howard, Perry, & Tracey, 1997). Interviews of college statistics instructors in varying departments confirmed this same belief that embedding examples and problems in real-life situations benefits learning (Gordon & Nicholas, 2009). Similarly, students prefer learning with problems posed as real-life situations (Smith, 1998). Research in mathematical education has indicated that problems that are embedded within a cover story can make learning seem more interesting (Parker & Lepper, 1992). Given student preference for real-life cover stories, the use of problems embedded within real-life situations may facilitate student learning by motivating them (Bassok, Lewis, Reinman, & Glaser, 1989; Gordon & Nicholas, 2009). Therefore, embedding problems within real-life contexts could increase students' willingness to expend more effort or attention toward the problems, which would improve learning.

POSSIBLE BENEFITS OF GROUNDING

Another possible benefit of embedding problem solving exercises within familiar, real-world contexts is that grounding problem solving may facilitate cognitive processing. Problem solving exercises embedded in story contexts can provide conceptual scaffolding that helps to connect mathematical principles to real-life situations (Goldstone & Son, 2005; Schwartz & Moore, 1998), aid the development of problem representations (Cummins, Kintsch, Reusser, & Weimer, 1988; McNeil, Uttal, Jarvin, & Sternberg, 2009), and provide access to effective problem solving strategies (Koedinger & Nathan, 2004).

For example, in one study where learning was measured by the ability of individuals to transfer principles between

http://dx.doi.org/10.7771/1932-6246.1162

isomorphic problems (Goldstone & Son, 2005), the best learning (transfer) was observed when students were presented with problems using concrete representations before problems using more abstract representations. This study suggests that presenting a word problem that provides a real-world context first may provide some sort of scaffolding which then enables individuals to more effectively learn abstract principles and transfer those principles to isomorphic problems.

Another line of research suggests that word problems can assist problem solving through the activation of effective strategies (Koedinger & Nathan, 2004). Koedinger and Nathan observed that introductory algebra students were more likely to solve algebraic problems presented in stories or verbal format than problems using algebraic notation. The students given story problems involving money were able to use informal strategies associated with their knowledge of the story and were less prone to mistakes than student presented problems with algebraic notation. Similarly, another study demonstrated that when Brazilian elementary school children who were also street vendors were administered math problems embedded within a real-world context of selling wares, they performed much better than when presented with formal math problems (Carraher, Carraher, & Schlieman, 1987). Analysis of the students' work demonstrated that when solving story problems posed in a vending context the Brazilian children utilized informal strategies that were easier to execute than the strategies taught in their school (Carraher et al., 1987). These efficient informal strategies were less likely to be utilized when problems were presented in algebraic notation.

The research that has found advantages for embedding problems within story contexts should be interpreted with caution as numerous studies have also found story problems may not help and can even hinder learning. For example, Koediger and Nathan's (2004) story problem advantage was only found with particular story problems that involved money and had an unknown at the beginning of the equation and not at the end. In addition when more complex algebraic problems with two unknowns were embedded within a story, they were more difficult to solve than if the problems were presented in algebraic notation (Koedinger, Alibali, & Nathan, 2008). Further, when Baranes, Perry, and Stigler (1989) attempted to replicate Carraher et al.'s findings using American students, they found that American children were more accurate at solving problems using abstract notation than a story. These findings indicate that embedding problems within a cover story is not always helpful.

POSSIBLE COGNITIVE DETRIMENTS OF GROUNDING

While several results suggest that problem solving can be facilitated by using real-life contexts as cover stories for problems, there is also evidence that cover stories can hinder participants' cognitive processing. Research has indicated that embedding problem solving in real-life contexts can hinder students' ability to transfer their learning to new contexts (Barnett & Ceci, 2002; Martin, 2009; McNeil et al., 2009; Peterson & McNeil, 2013). This detriment can be caused by the obstruction of the underlying principle by the cover story (Blessing & Ross, 1996; Sloutsky, Kaminski, & Heckler, 2005), the creation of a more complex problem representation than is needed (Bassok & Holyoak, 1993; Cummins et al., 1988) and the activation of inefficient strategies (Koedinger et al., 2008).

Even skilled math students can be misled by cover stories, as has been shown in several studies by Ross and colleagues. For example, in Blessing and Ross (1996) students were presented with one of three word problems that had the same underlying deep structure, but had three different cover stories. One cover story was appropriate to the problem type, meaning that the cover story was usually associated with the specific underlying problem structure in algebra textbooks. Another cover story was considered neutral to the problem type, meaning that the cover story had content that was not usually associated with any particular problem type. The last cover story was inappropriate to the problem type, meaning that the cover story was usually associated in algebra textbooks with another problem type not represented in the current problem (i.e., rate problems instead of work problems). When expectations about the cover story did not match the particular problem, students were less likely to solve the problem correctly and took longer to solve the problem. This study shows that providing a cover story can sometimes obstruct access to the underlying principles needed to solve the problem.

Embedding problems in real-life examples can also cause the creation of more complex problem representations than are necessary, which slows down the problem-solving process and makes participants more prone to error. A study that observed this effect looked at basic arithmetic word problems and the correspondence of the cover story to the real-world (Bassok, Chase, & Martin, 1998). Participants were presented with word problems and were asked to generate mathematical equations that would provide a solution to the problem. When the cover story was applicable to real-life expectations, participants generated the simplest equation possible. However, when the cover story was inconsistent with real-life expectations, participants came up with more complex equations to solve the problem. In the latter case, participants were distracted by the cover story, because they created a more complex problem representation than was necessary. These results indicate that using cover stories inconsistent with expectations can cause participants to neglect the possibility of simpler representations over more difficult, but pragmatic ones.

The third possible detriment due to the use of concrete cover stories involves the activation of inefficient strategies by participants. In a previous study mentioned above, participants benefited from a cover story when there was only one unknown (Koedinger et al., 2008). However, when an additional unknown was added to the problem, participants were less likely to activate an informal strategy and those who attempted to implement an informal strategy were more prone to error than participants who used numerical representations.

Finally, while embedding problems in interesting contexts is generally thought to be motivating for students, interest can be a two-edged sword. While interesting details can perhaps increase student motivation to engage in problem solving, they can also derail those efforts by priming irrelevant information or inappropriate goals. For example, Son and Goldstone found that problems that mentioned well-known celebrities made students less likely to discover key principles (2009). These detrimental effects of interest have been explored in research on "seductive details", where interesting features of the learning context distract learners from more central content, or cause them to over-estimate their understanding of the material (Harp & Mayer, 1998; Jaeger & Wiley, 2014; Sanchez & Wiley, 2006).

Thus, from previous research, it can be seen that there is a tension between whether embedding problem solving in specific, interesting contexts will support or obstruct learning. While previous research has investigated the effects of interest and familiarity by manipulating the content of the cover stories used in story problems (Baranes et al., 1989; Bates & Weist, 2004), the present research employs individual assessments of the learner's familiarity and interest in the cover story. The proposed research represents an initial foray into exploring how individual differences in knowledge and/or interest for problem cover stories may influence the effectiveness of embedding statistics instruction in real-world contexts.

This question was investigated using the performance of several professional Chicago baseball players as a target context for understanding central tendencies and variability. The weather at O'Hare airport was used as a comparison topic. These contexts were chosen for a number of reasons. First, there is variability between undergraduates in their knowledge of baseball (Ricks & Wiley, 2009; Spilich, Vesonder, Chiesi, & Voss, 1979). Second, students have shown interest in sports examples, like baseball (Kvam & Sokol, 2004) and there is even a textbook devoted to teaching statistics using only baseball examples (Albert & Schell, 2006). Third, the majority of students at a university located within Chicago should have some familiarity with professional baseball in Chicago and the O'Hare airport. At the same time, because there is concern that baseball or sports-related examples in general may be more engaging for men, differences due to gender were included in the analyses. The context of weather was chosen as a comparison because it represents another domain where variability and the value of prediction are salient features, so it is often used as the basis for examples in statistics courses.

METHOD

PARTICIPANTS

Participants were 85 undergraduates from the University of Illinois at Chicago who received course credit as part of an Introductory Psychology subject pool. Fourteen participants could not be included in analyses due to incomplete data. The final sample included 35 females and 36 males.

MATERIALS AND PROCEDURES

Upon arrival for the experimental session, participants completed an open-ended pretest on statistical concepts including central tendency, z-score, and correlation, as shown in Appendix A. All instruction and feedback occurred by students reading from a computer. Participants received a computer-administered lesson on central tendency via a PowerPoint presentation. Then, participants completed a central tendency worksheet with either a baseball or a weather cover story as shown in Appendix B. Students had access to calculators and the lesson while working on the worksheet. After the worksheet participants were presented with a "feedback" PowerPoint presentation that presented all of the correct answers to the worksheet and explained each answer in writing. The feedback presentation was generic and participants were not informed which questions they solved incorrectly. Participants were able to go through the feedback slides at their own pace. One week later participants returned and took a quiz on central tendency. Finally, all participants completed a final survey including measures of baseball knowledge and interest, and were asked to write a summary of the worksheet cover story from the previous week. A 12-item baseball knowledge questionnaire was adapted from Spilich et al. (1979). At the end of the questionnaire all students, regardless of cover story condition, were asked how interested they were in baseball on a scale between 1 and 10; 10 being "extremely interested" and 1 being "not having any interest." The summaries were scored for whether or not the student remembered the topic of the worksheet.

COMPUTATION AND EXPLANATION SCORES

The quiz contained four items that required basic computation practices (i.e., compute mean, draw a frequency table, describe skew), and five items that asked for explanations of concepts (i.e., Why did the mean and median differ? When would median be preferred?). The computation items required the participants to recall the procedures instructed in

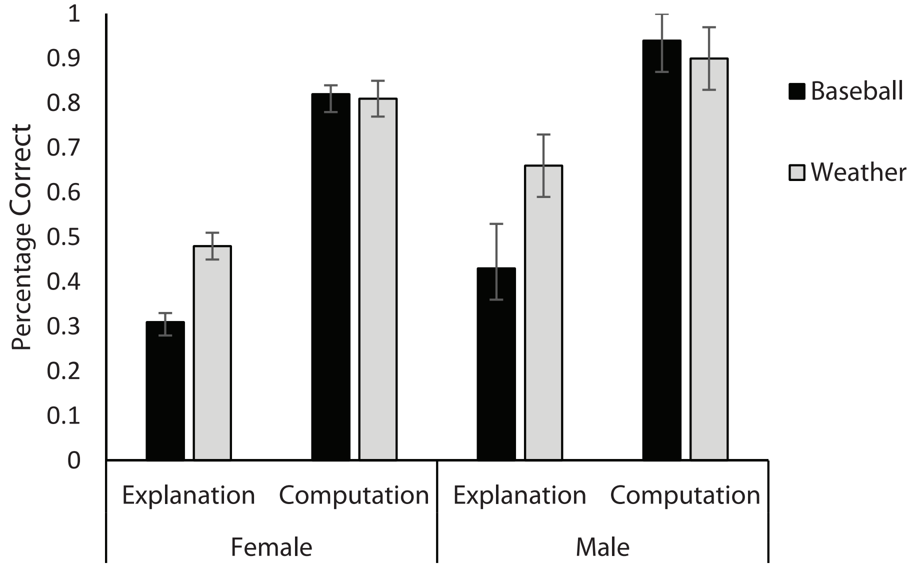

Figure 1.
The percentage correct on computation and explanation quiz items for baseball and weather worksheets by gender. Error bars represent standard errors.

the lesson. The explanation items assessed whether participants understood the concepts from the lesson. Performances on these two types of items were converted to percentages for analysis. All quiz items are included in Appendix C.

RESULTS

RELATION OF LEARNING TO COVER STORY AND GENDER

No significant differences were seen as a function of gender for Math ACT or Pretest Scores, *ts* < 1. However, pretest scores were higher in the weather story condition $t(69) = 2.43$, $p < .02$. Because the pretest scores varied with story condition, pretest scores were covaried in analyses of learning outcomes.

A 2 (story condition) x 2 (gender) repeated measures ANCOVA with computation and explanation item performance as the repeated measures and pretest scores as a covariate was performed. Pretest scores were mean-centered to improve interpretability. There was no significant main effect of either gender or story condition on learning. There was a significant main effect for outcome type with participants having higher computation, ($M = .89$, $SD = .12$) than explanation scores, ($M = .48$, $SD = .33$), $F(1, 66) = 71.23$, $p < .0001$, $\eta^2 = .52$. As shown in Figure 1, a significant interaction between learning outcomes and story condition revealed that explanation scores were higher when students completed the worksheet using the weather cover story than the baseball cover story, $F(1, 66) = 8.16$, $p < .01$, $\eta^2 = .11$. In addition, the data were examined by estimating a Bayes factor using Bayesian Information Criteria (Wagenmakers, 2007), comparing the fit of the data under the null hypothesis and the alternative hypothesis. An estimated Bayes factor (null/alternative) suggested that the data were .13:1 in favor of the alternative hypothesis, or rather, 7.47 times more likely to occur under a model including an interaction for story condition and outcome type, rather than a model without it. Follow-up analyses for the repeated measures ANCOVA showed that story condition had no effect on computation performance, but a significant effect on explanation performance. No other main effects or interactions reached significance.

RELATIONS OF INTEREST AND PRIOR KNOWLEDGE WITH LEARNING OUTCOMES

There was a significant relation between interest in baseball and knowledge about baseball ($r = .79$, $p < .001$). However, neither of these measures predicted computation or explanation learning outcomes when participants were given the baseball example. If anything, there was a non-significant *negative* relationship between interest in baseball and learning (explanation, $r = -.20$, $p < .28$; computation, $r = -.19$, $p < .31$) in the baseball cover story condition. In the weather cover story condition there was no relation between baseball interest and learning (explanation, $r = -.02$, $p < .91$; computation, $r = .12$, $p < .48$) suggesting that the poor learning in the baseball story condition was not likely due to baseball-interested individuals having lower academic ability in general.

MEMORY FOR COVER STORY

There was no difference in the number of participants who recalled (Baseball n =10; Weather n = 12) vs. did not recall the topic of the worksheet (Baseball, n = 22; Weather, n = 25) across the weather and baseball story conditions, $\chi^2(1, 69) < 1$. It should be noted that recall for the cover story was poor with two-thirds of the participants failing to remember the cover story one week later. A binary logistic regression using baseball knowledge and story condition to predict the likelihood of remembering the story topic revealed no main effect for either story condition ($\theta = 3.16, p < .08$) or baseball knowledge ($\theta = 2.36, p < .13$), but there was a significant interaction, ($\theta = 5.02, p < .03$). Individuals with more baseball knowledge were more likely to remember the topic of the example used in the worksheet, but only in the baseball story condition. Baseball interest showed similar relations to memory for the cover story, but the interaction did not reach significance.

FOLLOW-UP SURVEY ON INTEREST IN BASEBALL AND WEATHER COVER STORIES

Because the original question for this study was how knowledge and interest in baseball might affect learning from a problem set using a baseball-related cover story, a weakness in the design of this experiment was the failure to assess the interest of participants in the weather topic or in the worksheets themselves. Although we had intended the weather worksheet to serve as a mundane comparison activity for the baseball worksheet, we did not assess whether this was actually the case for participants in this experiment. However, based on the findings of the study, it seems important to understand whether the weather story is actually seen as interesting to students. Thus, we conducted a follow-up survey using a new sample of 37 students at the University of Illinois at Chicago who were enrolled in a psychology statistics class. First we asked for general interest in baseball and the weather on a 1-to-10 scale (1 = not at all interested, 10 = extremely interested). Then students were presented with both the baseball and weather-related worksheets used for this experiment and were asked "On a scale of 1–10 (1 = not at all interested, 10 = extremely interested), how interested are you in this cover story?" The students were also administered the baseball questionnaire that was administered to participants in the experiment.

A paired sample *t*-test revealed no differences in interest for the weather ($M = 4.27$, $SD = 2.09$) or baseball ($M = 4.11$, $SD = 2.55$) cover stories, $t(37) < 1$. In addition, there were no significant differences observed between males and females' preference for the baseball or weather worksheets, $ts < 1$. However, there was a positive correlation between interest in the baseball cover story and baseball knowledge ($r = .41, p < .01$), and general baseball interest ($r = .63, p < .01$). There was no correlation between interest in the weather worksheet and baseball knowledge ($r = .09, p < .61$), nor with general baseball interest ($r = .04, p < .81$). This demonstrated that overall the baseball and weather worksheets were equally interesting, except for individuals who are more knowledgeable and interested in baseball.

DISCUSSION

The present results suggest that the worksheet using the weather-related example was more effective for promoting student understanding of central tendency than was the worksheet using the baseball-related example. Although no differences were seen due to gender, suggesting that using baseball-related examples may not specifically disadvantage female participants, the weather-related example produced better learning for both males and females. Benefits of prior knowledge were seen in memory for the cover story, consistent with much previous work on the benefits of prior knowledge on memory (e.g., Chase & Simon 1973; Hambrick & Engle, 2002; Ricks & Wiley, 2009; Spilich et al., 1979), but similar advantages were not seen for learning from the baseball-related example.

As discussed in the introduction previous research has indicated that cover stories can have a detrimental effect on learning (Barnett & Ceci, 2002; Martin, 2009; McNeil et al., 2009; Son & Goldstone, 2009). One of the possible explanations for the poor learning associated with the baseball worksheet is that the baseball cover story may have made students more likely to attend to the problems at a superficial level, or attend to irrelevant aspects of the problem, which would have obstructed their ability to learn from the baseball example (c.f. Wieth & Burns, 2014). The baseball cover story about a Chicago Cubs baseball player (Derrek Lee) may have been more personally relevant to these students attending a university in Chicago. This is consistent with previous research that observed that cover stories can obscure the underlying principles of problems (Blessing & Ross, 1996; Sloutsky, Kaminski, & Heckler, 2005). During this experiment Derrek Lee, one of the protagonists in the baseball-related cover story, was traded to the Atlanta Braves, and this was a popular topic in Chicago at the time. Therefore, when presented with the statistics about the popular Chicago Cubs player this might have reminded these Chicago students that he was just traded to the Atlanta Braves and reminded them of the profound disappointment in the Cubs during this (and every) season. This knowledge activation is not related to the statistical concept that was being taught and could obstruct the understanding of the underlying principles of the problem and thus would not promote learning. Similar to the use of celebrities in Son and Goldstone (2009) problems, the use of real-world baseball figures introduced irrelevant but interesting features into the cover story in this case. As a result, this interesting information seems to have introduced seductive details that distracted the students who were particularly interested and familiar with baseball.

There are two main weaknesses with the present study that impede the ability to draw strong conclusions from these results. The first is that interest and familiarity ratings were not collected on both topics and cover stories as part of the study. This would have allowed for a more thorough analysis of how interest and familiarity with story problem contexts might affect learning and problem solving. The second major need is for yet another comparison condition where students are not given any cover story for the worksheet and only solve the problems using the numbers from three generic datasets. Such a condition is needed to understand whether providing cover stories or a context for problem solving is generally helpful or harmful for learning this statistical concept versus providing no context for the problem solving activity.

As discussed previously, research has suggested that cover stories can provide a useful conceptual framework on which to build understanding. But the results of this study suggest that not all cover stories will promote understanding equally, and interest in and personal relevance of cover stories can distract participants from grasping the underlying principles. Future research is needed to identify how to maximize the effectiveness of personally relevant and interesting cover stories for problem solving. One possibility suggested by prior research on transfer is to utilize multiple cover stories. The use of multiple cover stories while maintaining the same underlying abstract principle is likely to increase the salience of the repeated underlying abstract principle (Gick & Holyoak, 1980, 1983; Goldstone & Son, 2005). Individuals who are able to compare multiple examples or problems have shown better learning for abstract principles (Catrambone & Holyoak, 1989; Gentner, Loewenstein, & Thompson, 2003; Rittle-Johnson, Star & Durkin, 2009; VanderStoep & Seifert, 1993). Increasing the salience of an abstract principle might create a context in which personally relevant and interesting cover stories might be able to support and not distract students.

Another possible way to maximize the effectiveness of personally relevant and interesting cover stories is to have students engage in more active learning with problems. This experiment provided a lecture on central tendency followed by a worksheet with a cover story. In this format students can memorize or reference the calculation steps for the equation and ignore the cover story almost completely. This could have been the reason that the majority of participants failed to remember the cover story for the worksheet a week later. Thus, participants may not benefit from the conceptual framework and improved problem representation that cover stories can provide because the cover story is not an important part of the problem. Roth (1996) observed that when problem solving is contextualized within a hands-on field study students benefited from that context.

Another alternative is to have students engage in a more constructive approach to learning formulas. Instead of being taught a procedure first and then practicing it on a problem set, "learning by invention" or "preparation for future learning" activities reverse this sequence of events. Before instruction, students are given a problem set or problem solving worksheet and are asked to invent a method that solves the problems. This approach has been found to improve conceptual understanding of statistical and mathematical concepts (Loehr, Fyfe, & Rittle-Johnson, 2014; Schwartz & Martin, 2004; Wiedmann, Leach, Rummel, & Wiley, 2012; Wiley, Goldenberg, Jarosz, Wiedmann, & Rummel, 2013). In this paradigm, having knowledge and interest for the cover story could play a bigger role.

As discussed in the introduction there are many challenges associated with learning and teaching statistics. A common strategy utilized by teachers and textbooks is to try to make learning more interesting by embedding the problems and instruction in real-life contexts (Howard, Perry, & Tracey, 1997). The use of cover stories is widely believed to pique students' interest and facilitate learning, but this study provides a cautionary tale showing that familiar and interesting story contexts can have a detrimental effect on learning, and suggests that more work is needed to understand the best use of cover stories to support effective problem solving.

ACKNOWLEDGEMENTS

This research was part of Travis Ricks' dissertation at the University of Illinois at Chicago. We would like to thank Jim Pellegrino, Ben Storm, Gary Raney, and Thomas Griffin for valuable guidance and support of this research. Caicina Jones was integral in the collection and organization of the data and the authors thank her. We are also appreciative to Andy Jarosz for help with data analysis; to Rebecca Koppel for performing a follow-up survey; and to the Research Open Access Publishing (ROAAP) Fund of the University of Illinois at Chicago for providing financial support towards the open access publishing fee for this article.

REFERENCES

Albert, J. (2002). A baseball statistics course. *Journal of Statistics Education, 10*, 1–9.

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185. http://dx.doi.org/10.1111/1467-8721.00196

Baranes, R., Perry, M., & Stigler, J. W. (1989). Activation of real-world knowledge in the solution of word problems. *Cognition and Instruction*, *6*(4), 287–318. http://dx.doi.org/10.1207/s1532690xci0604_1

Barnett, S., & Ceci, S. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin, 128*(4), 612–637. http://dx.doi.org/10.1037/0033-2909.128.4.612

Bassok, M., Chase, V., & Martin, S. (1998). Adding apples and oranges: Alignment of semantic and formal knowledge. *Cognitive Psychology, 35*(2), 99–134. http://dx.doi.org/10.1006/cogp.1998.0675

Bassok, M., & Holyoak, K. (1993). Pragmatic knowledge and conceptual structure: Determinants of transfer between quantitative domains. In D. K. Detterman & R. J. Sternberg (Eds.), *Transfer on trial: Intelligence, cognition, and instruction* (pp. 68–98). Westport, CT: Greenwood.

Bassok, M., Lewis, M., Reinman, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*(2), 145–182. http://dx.doi.org/10.1207/s15516709cog1302_1

Bergin, D. A. (1999). Influences on classroom interest. *Educational Psychologist*, *34*(2), 87–98. http://dx.doi.org/10.1207/s15326985ep3402_2

Blessing, S. B., & Ross, B. H. (1996). Content effects in problem categorization and problem solving. *Journal of Experimental Psychology: Learning Memory and Cognition, 22*(3), 792–810. http://dx.doi.org/10.1037/0278-7393.22.3.792

Canham, M. S., Wiley, J., & Mayer, R. E. (2012). When diversity in training improves dyadic problem solving. *Applied Cognitive Psychology*, *26*(3), 421–430. http://dx.doi.org/10.1002/acp.1844

Carraher, T. N., Carraher, D. W., & Schliemann, A. D. (1987). Written and oral mathematics. *Journal for Research in Mathematics Education*, *18*(2), 83–97. http://dx.doi.org/10.2307/749244

Catrambone, R., & Holyoak, K. J. (1989). Overcoming contextual limitations on problem-solving transfer. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(6), 1147–1156. http://dx.doi.org/10.1037/0278-7393.15.6.1147

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, *4*(1), 55–81. http://dx.doi.org/10.1016/0010-0285(73)90004-2

Cummins, D. D., Kintsch, W., Reusser, K., & Weimer, R. (1988). The role of understanding in solving word problems. *Cognitive Psychology, 20*(4), 405–438. http://dx.doi.org/10.1016/0010-0285(88)90011-4

Garfield, J., & Ben-Zvi, D. (2007). How students learn statistics revisited: A current review of research on teaching and learning statistics. *International Statistical Review, 75*(3), 372–396. http://dx.doi.org/10.1111/j.1751-5823.2007.00029.x

Gentner, D., Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. *Journal of Educational Philosophy*, *95*(2), 393–408. http://dx.doi.org/10.1037/0022-0663.95.2.393

Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology*, *12*(3), 306–355. http://dx.doi.org/10.1016/0010-0285(80)90013-4

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 15*(1), 1–39. http://dx.doi.org/10.1016/0010-0285(83)90002-6

Goldstone, R. L., & Son, J. Y. (2005). The transfer of scientific principles using concrete and idealized simulations. *Journal of the Learning Sciences, 14*(1), 69–110. http://dx.doi.org/10.1207/s15327809jls1401_4

Gordon, S. (2004). Understanding students' experiences of statistics in a service course. *Statistics Education Research Journal, 3*(1), 40–59.

Gordon, S., & Nicholas, J. (2009). Using examples to promote statistical literacy. *Proceedings of the Australian Conference on Science and Mathematics Education* (pp. 58–64), Canberra, Australia.

Hambrick, D., & Engle, R. (2002). Effects of domain knowledge, working memory capacity, and age on cognitive performance: An investigation of the knowledge-is-power hypothesis. *Cognitive Psychology, 44*(4), 339–387. http://dx.doi.org/10.1006/cogp.2001.0769

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90*(3), 414–434. http://dx.doi.org/10.1037/0022-0663.90.3.414

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*(1), 33–46. http://dx.doi.org/10.2307/749455

Howard, P., Perry, B., & Tracey, D. (1997). *Mathematics and manipulatives: Comparing primary and secondary teachers' views*. Paper presented at the annual conference of the Australian Association for Research in Education, Brisbane.

Jaeger, A. J., & Wiley, J. (2014). Do illustrations help or harm metacomprehension accuracy? *Learning and Instruction*, *34*, 58-73. http://dx.doi.org/10.1016/j.learninstruc.2014.08.002

Koedinger, K. R., Alibali, M. W., & Nathan, M. J. (2008). Trade-offs between grounded and abstract representations: Evidence from algebra problem solving. *Cognitive Science, 32*, 366–397. http://dx.doi.org/10.1080/03640210701863933

Koedinger, K., & Nathan, M. (2004). The real story behind story problems: Effects of representations on quantitative reasoning. *Journal of the Learning Sciences, 13*(2), 129–164. http://dx.doi.org/10.1207/s15327809jls1302_1

Kvam, P., & Sokol, J. (2004). Teaching statistics with sports examples. *INFORMS Transactions on Education, 5*(1), 75–87. http://dx.doi.org/10.1287/ited.5.1.75

Loehr, A. M., Fyfe, E. R., & Rittle-Johnson, B. (2014). Wait for it . . . Delaying instruction improves mathematics problem solving: A classroom study. *The Journal of Problem Solving, 7*(1), Article 5. Retrieved from http://docs.lib.purdue.edu/jps/vol7/iss1/5

Macnaughton, D. (2002). *The introductory statistics course: The entity-property-relationship approach*. Retreived from www.matstat.com/teach/

Martin, T. (2009). A theory of physically distributed learning: How external environments and internal states interact in mathematics learning. *Child Development Perspectives, 3*(3), 140–144. http://dx.doi.org/10.1111/j.1750-8606.2009.00094.x

Mayer, R. E. (1974). Acquisition processes and resilience under varying testing conditions for structurally different problem-solving procedures. *Journal of Educational Psychology, 66*(5), 644–656. http://dx.doi.org/10.1037/h0037482

Mayer, R. E., & Greeno, J. G. (1972). Structural differences between outcomes produced by different instructional methods. *Journal of Educational Psychology, 63*(2), 165–173. http://dx.doi.org/10.1037/h0032654

Mayer, R. E., Stiehl, C. C., & Greeno, J. G. (1975). Acquisition of understanding and skill in relation to subjects' preparation and meaningfulness of instruction. *Journal of Educational Psychology, 67*(3), 331–350. http://dx.doi.org/10.1037/h0076619

McNeil, N. M., Uttal, D. H., Jarvin, L., & Sternberg, R. J. (2009). Should you show me the money? Concrete objects both hurt and help performance on mathematics problems. *Learning and Instruction, 19*(2), 171–184. http://dx.doi.org/10.1016/j.learninstruc.2008.03.005

Parker, L., & Lepper, M. (1992). Effects of fantasy contexts on children's learning and motivation: Making learning more fun. *Journal of Personality and Social Psychology, 62*(4), 625–633. http://dx.doi.org/10.1037/0022-3514.62.4.625

Petersen, L. A., & McNeil, N. M. (2013). Effects of perceptually rich manipulatives on preschoolers' counting performance: Established knowledge counts. *Child Development*, *84*(3), 1020–1033. http://dx.doi.org/10.1111/cdev.12028

Ricks, T. R., & Wiley, J. (2009). The influence of domain knowledge on the functional capacity of working memory. *Journal of Memory and Language, 61*(4), 519–537. http://dx.doi.org/10.1016/j.jml.2009.07.007

Rittle-Johnson, B., Star, J. R., & Durkin, K. (2009). The importance of prior knowledge when comparing examples: Influences on conceptual and procedural knowledge of equation solving. *Journal of Educational Psychology*, *101*(4), 836–852. http://dx.doi.org/10.1037/a0016026

Sanchez, C. A., & Wiley, J. (2006). An examination of the seductive details effect in terms of working memory capacity. *Memory & Cognition, 34*(2), 344–355. http://dx.doi.org/10.3758/BF03193412

Schwartz, D. L., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction*, *22*(2), 129–184. http://dx.doi.org/10.1207/s1532690xci2202_1

Schwartz, D., & Moore, J. (1998). On the role of mathematics in explaining the material world: Mental models for proportional reasoning. *Cognitive Science, 22*(4), 471–516. http://dx.doi.org/10.1207/s15516709cog2204_3

Sloutsky, V. M., Kaminski, J. A., & Heckler, A. F. (2005). The advantage of simple symbols for learning and transfer. *Psychonomic Bulletin and Review, 12*(3), 508–513. http://dx.doi.org/10.3758/BF03193796

Smith, G. (1998). Learning statistics by doing statistics. *Journal of Statistics Education, 6*, 1–10.

Son, J. Y., & Goldstone, R. L. (2009). Contextualization in perspective. *Cognition and Instruction, 27*(1), 1–39. http://dx.doi.org/10.1080/07370000802584539

Spilich, G. J., Vesonder, G. T., Chiesi, H. L, & Voss, J. F. (1979). Text processing of domain-related information for individuals with high and low domain knowledge. *Journal of Verbal Learning and Verbal Behavior, 18*(3), 275–290. http://dx.doi.org/10.1016/S0022-5371(79)90155-5

VanderStoep, S. W., & Seifert, C. M. (1994). Problem solving, transfer, and thinking. In P. R. Pintrich, D. R. Brown, & C. E. Weinstein (Eds.), *Student motivation, cognition, and learning: Essays in honor of Wilbert J. McKeachie* (pp. 27–49). Hillsdale, NJ: Lawrence Erlbaum.

Wiedmann, M., Leach, R. C., Rummel, N., & Wiley, J. (2012). Does group composition affect learning by invention? *Instructional Science, 40*(4), 711–730. http:/dx.doi.org/10.1007/s11251-012-9204-y

Wieth, M. B., & Burns, B. D. (2014). Rewarding multitasking: Negative effects of an incentive on problem solving under divided attention. *The Journal of Problem Solving*, *7*(1), Article 7. Retrieved from http://docs.lib.purdue.edu/jps/vol7/iss1/7

Wiley, J., Goldenberg, O., Jarosz, A. F., Wiedmann, M., & Rummel, N. (2013). Diversity, collaboration, and learning by invention. *Proceedings of the 35th Annual Meeting of the Cognitive Science Society* (pp. 3765–3770). Austin, TX: Cognitive Science Society.

APPENDIX A

PRETEST

For each of the following questions please write as neatly as possible. Be sure to show your work for any calculations that are necessary.

1. For the following scores find the mean, median, and mode.

   1 2 3 3 5 6 8

   Mean:

   Median:

   Mode:

2. Without computing variance or standard deviation, which sample (A or B) has more Variance and what does that mean about the sample?

A	B
100, 101, 100, 102, 101	1, 7, 5, 9, 3

3. Which correlation coefficient represents the strongest relationship between two variables?

   -.67, .80, -.95, .45

4. What is the difference between +/- correlations?
5. What does a correlation coefficient represent?

APPENDIX B: WORKSHEETS

CENTRAL TENDENCY

The goal for using central tendency is to find the single score that represents the group of scores most accurately. This is valuable when you are presented with a large amount of scores and need to understand and explain them to others. For example, below are the number of hits Derrek Lee of the Chicago Cubs hit for 10 games in April, July, and September of 2009. Answer the questions below to better understand central tendency and how to use it appropriately.

April	July	September
0	0	1
1	2	1
1	2	0
0	0	0
0	2	2
0	0	2
2	0	1
3	2	1
0	0	1
2	2	1

1. Compute the Mean, Median, and Mode for the number of hits Derrek Lee hit in the first 10 games of April, July, and September.

April	July	September
Mean =	Mean =	Mean =
Median =	Median =	Median =
Mode =	Mode =	Mode =

2. Create a frequency distribution for each month. Label the mean, median and mode on each distribution.
3. Describe the distribution for each month: say whether it is normal, skewed (indicate positive or negative), or bimodal.
4. What is the relationship between the mean, median, and mode for each distribution?
5. For which month was the biggest difference between the mean and median observed, and why?

CENTRAL TENDENCY

The goal for using central tendency is to find the single score that represents a group of scores most accurately. This is valuable when you are presented with a large set of numbers and need to describe them to others. For example, below is the amount of rain received for the O'Hare airport of Chicago, JFK airport of New York, and LAX airport of Los Angeles for 10 days in April of 2009. Answer the questions below to better understand central tendency and how to use it appropriately. You can refer to the lesson to help you.

O'Hare	JFK	LAX
0	0	1
1	2	1
1	2	0
0	0	0
0	2	2
0	0	2
2	0	1
3	2	1
0	0	1
2	2	1

1. Compute the Mean, Median, and Mode for the amount of rainfall at each airport for 10 days in April.

O'Hare	JFK	LAX
Mean =	Mean =	Mean =
Median =	Median =	Median =
Mode =	Mode =	Mode =

2. Create a frequency distribution for each airport. Label the mean, median and mode on each distribution.
3. Describe the distribution for each airport: say whether it is normal, skewed (indicate positive or negative), or bimodal.
4. What is the relationship between the mean, median, and mode for each distribution?
5. For which airport was the biggest difference between the mean and median observed, and why?

APPENDIX C: QUIZ

CENTRAL TENDENCY KNOWLEDGE ASSESSMENT

1. Compute the Mean, Median, and Mode for this set of numbers:
   1, 6, 7, 7, 7
2. Create a frequency table for this sample.
3. Describe the distribution. Is it normal, skewed (indicate positive negative), or bimodal?
4. What is the relationship (<, >, =) between the mean, median, and mode?
5. Are the mean and median different from each other, and if so, why?
6. If you removed one number from this set, which one would have the largest effect on the mean?
7. Explain the difference between the mean, median, and the mode. In your answer, be sure to define each.
8. Under what circumstances might the median be a preferred measure of central tendency over the mean? Why?
9. (Students received EITHER Death Valley or Sandy Koufax depending on condition)

Death Valley is one of the driest places in the United States.

a. Compute the mean and median for Death Valley's inches of rain for 1961 to 1966.
b. Suppose that Death Valley had an extremely wet year and had 6.50 inches of rain for this year. Would the mean or the median change more if this yearly rainfall was also included into the calculating the mean and median in question 9? Why?

Sandy Koufax is one of the greatest baseball pitchers of all time.

a. Compute the mean and median for Sandy Koufax's ERA for the 1961 to 1966 seasons.
b. Suppose that Sandy Koufax played an additional season and had an ERA of 6.50 for this season. Would the mean or the median change more if this ERA was also included into the calculating the average in question 3? Why?

Year	Rain/ERA
1961	3.52
1962	2.54
1963	1.88
1964	1.74
1965	2.04
1966	1.73