A CONSTRUCTIVIST APPROACH TO COURSE DESIGN IN A GRADUATE STATISTICS COURSE

Paul J. Fields, Aubrey Baxter and Larry Seawright
Brigham Young University, United States
pjfields@byu.edu

Too often students leave their first statistics course with at best a fuzzy understanding of basic statistical concepts and procedures. A disconcertingly high proportion cannot adequately describe or perform a t-test, for example, when taking subsequent courses. This suggests that a different approach to teaching and learning is necessary, particularly for graduate students who will need statistical tools in their research. Rote memorization of facts does not provide the preparation requisite for graduate research. A constructivist approach in course design could provide a learning environment in which students move beyond lower level cognitive skill development. Initial implementation of this approach has produced encouragingly positive results.

INTRODUCTION

Constructivism in instructional design originated from the work of Benjamin Bloom and others (Bloom, 1981) and identifies levels of cognitive development. Bloom's taxonomy lists six levels of cognitive skills:

- Knowledge
- Comprehension
- Application
- Analysis
- Synthesis
- Evaluation

In examining the hierarchy of cognitive skills, we see that the skills needed by graduate students are clearly the higher level skills. Therefore, a course appropriate for graduate students must facilitate achieving mastery at the higher levels.

The constructivist view of learning is based on the premise that learners construct their own personal meaning out of a given educational experience. This view seems particularly relevant in educating graduate students to promote the development of their own personal paradigm for creative work. A broad spectrum of learning opportunities is needed so that students from diverse backgrounds and heading in different academic directions can construct his or her personal meaning. Constructivist practice is characterized by complex learning environments, authentic tasks, multiple representations of content, shared responsibility of learning, constructed knowledge and student focused instruction (Woolfolk, 2001). Constructivists further contend that learning is social and embedded in a particular cultural setting (Cobb and Bowers, 1999).

Research from neuroscience in how the human brain processes information through experience and reflection supports the constructivist theory of educational design. For example, Sousa (2001) and Zull (2002) show how the brain learns by making connections from prior knowledge to new knowledge. Learning can be viewed as a physical process of "constructing" new connections within the neuronal network of the brain. Additional references on constructivist theory and the neuroscience of learning are provided in the references.

The constructivist approach is consistent with and incorporates the principles of statistical education recommended by Garfield (1995):

- Students learn by constructing knowledge
- Students learn by active involvement in learning activities
- Students learn to do well what they practice doing
- Students learn better if they receive consistent feedback
- Students learn to value what is assessed.

COURSE DESIGN

We have implemented the constructivist approach in designing an introductory statistics course for graduate students preparing for their thesis or dissertation research. The students are all non-statistics majors and come from academic disciplines spanning the social and physical sciences. We have structured the course around Bloom's taxonomy, rich in learning experiences, and set in the cultural context of scientific research.

For each topic area in the course, specific learning activities are provided to the students through which they can learn the course content and demonstrate mastery of the cognitive skills at each level of Bloom's taxonomy:

- Quizzes are used to assess the students' knowledge of the vocabulary and facts of statistical topics. The quizzes are taken in class and can be repeated in lab at the student's election.
- The student's write a concept paper in memo format for each course topic to show their comprehension. The students write their concept paper from the viewpoint of how a statistical topic could be used in his or her own academic area.
- The students do homework exercises to demonstrate their ability to apply the course material and they do mini-projects (hands-on experiments) in lab to show their analysis capabilities. A report on each experiment is prepared by the students using the research method as the outline for the write up. The homework and mini-projects are done in groups of two students each.
- To demonstrate they have synthesized the course material into a new and personal whole, they take an essay exam at the end of the course. The essay is a description of the personal research paradigm each student has developed during the course.
- Each student demonstrates his or her evaluation skills by submitting a written evaluation of a research paper from his or her own field of study.

The relationship between the learning activity and the cognitive skill level is identified for the students. The learning activities often combine skill mastery and skill assessment in the same activity. The students have the opportunity to repeat iteratively each learning activities until they are satisfied with their mastery of each topic and each cognitive skill level.

LEARNING ORIENTATION

Martinez (1999) shows that students' orientations toward learning can be parsed into four categories. Learners are either:

- Transforming – Assertive, highly self-motivated students who are innovative and seek to transform themselves to meet high personal standards;
- Performing – Self-motivated students who implement the course content to meet above-average group standards when they find the course appealing;
- Conforming – Extrinsically motivated students who use learning to conform to easily achieved group standards; or
- Resisting – Resistive students who avoid using learning to achieve academic goals assigned by others.

According to Martinez (2001), transforming students prefer a learning environment with occasional mentoring, while performing students prefer frequent coaching and interaction, and conforming students prefer continual guidance and reinforcement. The resistant students need compellingly attractive learning environment to counter previously conditioned apathy, frustration, discouragement and fear. The constructivist approach permits the instructor to accommodate all four of the learning orientations. Consequently, we used a questionnaire developed and scored by Martinez to determine each student's learning orientation and then assess if he or she had been able to perform at a higher level in the constructivist-designed course than might have been expected based on his or her learning orientation.

RESULTS

Based on the students' learning orientations, the initial results show that students do tend to perform at a higher level as measured their overall breadth of mastery of course content and by their grades in the course. We have observed that the students generally cover more material in the constructivist-designed course. Specific instances of students achieving higher grades than they might not have otherwise are identifiable, and the students report that they perceive a deeper understanding of the course content than they anticipated.

Overall student reaction has been positive, particularly from students who recognized the constructivist approach in the design of the course. In fact, students heading for a career in academia have often stated, "This is how I am going to teach."

At the end of the course, two important outcome measures we have noted are:

- Each student can identify his or her specific "take away" from of the course; and
- Students express greater satisfaction with the course and place greater value on their experience in the course.

When queried about their experience in the course and the personal meaning about the course content that they have constructed during the course, the majority of students describe that they:

- Can "now see the big picture" of statistics;
- Recognize they have a greater ability to think critically;
- Have improved their decision-making skills; and
- Can relate statistics directly to their academic work, their professional careers and their personal lives.

Interestingly, the students see the mastery of statistical tools as a "given" in the course and as a secondary outcome. They say, "Of course I learned how to do the statistical tests, but more importantly I learned why and when to use them." This is a highly positive outcome since in the previous course design students often showed limited mastery of the tools of statistics, frequently missed the "big picture" and expressed dissatisfaction that they could not "see the relevance of statistics" to their work.

LESSONS LEARNED

We have learned two important lessons from implementing the constructivist approach in an introductory statistics course for non-majors:

First, we have observed that students must demonstrate mastery at the lower level before moving on to higher levels. We also observed that mastery at one level cannot compensate for lack mastery at a lower level. Otherwise, students do not build a foundation of cognitive skills before attempting to develop higher levels skills. Consequently, a precedent relationship is necessary between cognitive levels when assessing student mastery (mastery at one level must be demonstrated before mastery at the next higher level) otherwise students attempt to "short cut" the process to the detriment of their cognitive skill development.

Second, the most critical factor for success with this approach was observed to be the feedback system. In a more traditional course design, feedback to the students is typically delayed by days or even weeks. With this approach, it was quickly revealed that feedback must be a rapid as possible. Immediate feedback is, of course, optimum. Without immediate feedback, students are unable to determine their current level of mastery and to make adjustments in their learning strategies and techniques. The students' need for feedback is accentuated by the fact that delaying learning to the end of the semester is not practical. Even if a student can "make the grade" with a push at the end in another educational setting, in the constructivist setting, such an approach becomes logically as well as pedagogically

CONCLUSION

At the end of the course, students generally display greater understanding of statistical concepts and their application in research than had been observed previously. Students display cognitive skills beyond rote memorization. This is highly encouraging. However, the results are still preliminary and largely anecdotal. Longitudinal studies are needed to measure student retention over time.

Students from each semester are being surveyed at six-month intervals over the following two years. An individual student is only surveyed once during the follow-up period, so that the survey itself is not producing a conditioned response in the students. One-fourth of the students are surveyed at the end of each six-month period.

The “acid test” of mastery and retention of statistical thinking concepts we use is a student’s ability to explain the concept behind the *t*-test and to describe the mechanics of conducting a *t*-test. We chose the t-test since it is a foundational statistical tool for research.

In addition, a control comparison is needed to provide stronger evidence of improved learning. Therefore, the same follow-up survey is being conducted with similar students who have taken a similar course. Although the results of comparing and contrasting the two groups will be qualitative in nature, it is hoped that they will provide meaningful support for or against the null hypothesis of “no difference” between the groups.

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