Authentic Discovery Projects in Elementary Statistics

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Introduction

Development of pedagogically sound statistics instruction is essential. Statistics educators have repeatedly suggested improvements, especially ones that focus on implementing the scientific method utilizing authentic statistical experiences (Bryce, 2005). When best-practice pedagogies have been implemented in statistics courses, the results have been positive for achievement and for improved attitudes toward statistics. There is a strong indication that apprentice learning, wherein students complete real-world mathematics in authentic settings, develops better conceptual understanding as well as better transference of knowledge to non-mathematical and non-school settings (Boaler, 1998). Researchers found statistics courses based on more constructivist models improved student attitudes toward statistics and that personal relevance is important for successful learning in statistics (Mvududu, 2003). A researcher used case-study methodology to evaluate a real-world, project-based approach to learning statistics and found that students learned more from the project than from any other instructional component of the course. The researcher further reported improvements in student motivation (Yesilcay, 2000).

These findings in the literature prompted a curriculum development effort supported by a grant from the National Science Foundation. The grant, titled "*Authentic, Career-Specific Discovery Learning Projects in Introductory Statistics*," has funded development of instructional materials, creation of instruments to measure the

effectiveness of these materials, ongoing quantitative and qualitative research about the success of these teaching methods, and instructor training workshops to share materials and findings. The instructional materials were designed to facilitate student projects as a learning tool; we will describe these projects as a method of engaging students in the statistics classroom. Then we will share our preliminary findings regarding the impact of these teaching methods on student comprehension and attitudes.

Curriculum Development and Student Projects

The curriculum development effort was directed by three goals:

1) Increase students' knowledge and comprehension of statistics
2) Increase students' perceptions of the usefulness of statistics
3) Increase students' self-beliefs about their ability to use statistics

The instructional materials developed facilitate two collaborative discovery projects, designed to engage the students in their own authentic statistical research. Students work in teams of 3 or 4 to complete the projects, applying the major concepts covered in the statistics course.

The first project uses linear regression techniques, and the second uses comparison techniques with appropriate t-tests. Both projects simulate the real-world effort of scientists to hypothesize, collect and analyze data, and draw conclusions. Students select their own research topic, craft their own research questions, design surveys, collect their own data, apply the appropriate statistical methods to analyze the data, and report their findings in writing. Students also share their research with their peers in formal class presentations.

Interdisciplinary Research Constructs

As part of the curriculum development, an interdisciplinary team of instructors met to develop worthwhile research constructs for students. Team members wrote clear definitions of research constructs and provided instruments or instructions for measuring the construct quantitatively. Students were not required to use any of these research constructs; they were allowed to create their own. However, the research constructs developed by the interdisciplinary team gave students a springboard of ideas from which to start, as well as a good set of examples of how constructs may be defined operationally, measured, and quantified.

Among the disciplines that were represented on the team were psychology, sociology, criminal justice, ecology, physical therapy, nursing, and education. In the field of psychology, suggested research constructs included perceived stress, perfectionism, anxiety, attention deficit disorder (ADD), and obsessive compulsive disorder. Accompanying each of these constructs was a brief screening instrument that could be administered and scored easily for purposes of quantitative research. In the field of sociology, suggested constructs included attitudes toward various social issues (e.g., corporal punishment, homosexuality, racism), all of which could be quantified on a Likert type scale. In the field of criminal justice, suggested research constructs included attitudes toward various criminal justice issues (e.g., gun control, death penalty, legalization of marijuana, pornography), all of which, again could be measured on a Likert scale. These are just a few examples of the research constructs that were assembled by the interdisciplinary team. The constructs proved interesting and engaging to students as they worked to select research topics for their own projects.

Materials Developed

Online student and instructor guides were developed to facilitate these projects. These materials are currently available online at http://radar.ngcsu.edu/~rsinn/nsf.

The student guide includes three sections: 1) an overall project guide, which describes each project and the steps needed to complete it; 2) a technology guide, which directs students to use the features of Microsoft Excel to implement the project; and 3) a variables and constructs guide, which includes research ideas assembled by the interdisciplinary team, as well as guidelines on creating a viable research construct and a corresponding data collection instrument (e.g., a well crafted, unbiased survey).

The instructor guide includes four components: 1) project overviews with suggested timeline, project implementation details, and best practices; 2) links to appropriate student materials that correspond with different phases of the project; 3) student assignment sheets; and 4) a variety of evaluation rubrics that can be used to score the projects.

Strategies for Successful Implementation

As pilot instructors have implemented these materials and teaching methods, they have assembled a set of guidelines to help other instructors use such projects effectively. These guidelines touch on structuring and scaffolding the project, setting student expectations, and resolving potential issues with teams.

Structuring the project

Projects are more successful when intermediate goals are set and students are required to submit defined deliverables along the way. For instance, students completing the regression project must first submit a list of several potential research ideas with

specific variables, from which they will eventually select their final topic. After the topic is selected and approved, students must create a survey or other data collection instrument and submit this to the instructor. The instructor often needs to help the students refine the survey to set the stage for a more successful project. Once the survey is sufficiently refined and approved, students begin the data collection process, recording their data and beginning data analysis under some supervision. Sometimes an instructor will devote a day of class time for teams to engage in hands-on data analysis when the instructor is nearby for guidance. Finally, the team writes a report describing the research and the findings. This phase of the project is most successful if the students are given a template or outline of what should be included in the report. Some instructors also provide work samples from previous semesters for students to use as examples. By structuring the projects into these phases, instructors ensure that students stay on course and have a more successful experience overall.

Setting student expectations

Most instructors who have implemented these projects in the classroom will agree on the need to set student expectations early. Students often underestimate the effort and organization required to make their project a success. Many students also don't have a clear idea of exactly what they will do to analyze their data once they have collected it; this part of the project is often a bit fuzzy in their minds (which is, of course, precisely why they need to do it for themselves!)

As one team of students elaborated on a post-project reflection:

> *"The main thing that we have learned is that statistics take time. They cannot be conjured up by a few formulas in a few minutes. The time and effort that is put into a small research*

project such as this is significant. On a large scale, one can quickly understand the kind of commitment of money and time that is required just to obtain reasonable data."

Students will be much more successful if they know at the outset what to expect in terms of their own commitment of time and effort.

It is also a good idea to set student expectations regarding the findings of their data analyses. Students often expect to find strong correlations or highly significant statistical results, and upon obtaining some other outcome, they feel they must have done something wrong. In fact, researchers often obtain non-significant results; it is the appropriate interpretation of those results that is important. As another student noted:

"While our results did not meet our initial expectations, this is not an utter disappointment. Before this project, statistics looked simple enough for anyone to sit down and do, but now it is evident that it requires more creativity and critical thinking than initially expected. Overall, it was an edifying experience."

If students are prepared for the possibility of getting "disappointing" results, they seem more likely to believe the project was worthwhile.

Resolving team issues

Some students dislike team projects. Many instructors allow students the option to complete a modified version of at least one of the two projects by themselves. Even among students who don't outwardly object to team projects, poor team dynamics can lead to a great deal of frustration. Some of this frustration can be avoided by establishing explicit guidelines for communication and cooperation among team members. Some

instructors also define each team member's role and responsibilities to hold individual team members accountable for the final product.

Preliminary Findings

A pilot study using these materials was conducted with 10 sections of elementary statistics, of which 6 sections comprised a control group (with traditional instruction) and the other 4 sections comprised an experimental group (using the discovery projects as learning tools). At the end of the course, willing students in all sections completed 2 surveys and a content knowledge test. 164 students participated from the control group, and 116 students participated from the experimental group.

The content knowledge test was a 21-item multiple choice test. Control group participants obtained a mean score of 8.87; experimental participants obtained a mean score of 10.82. The difference between the groups was significant ($p < .0001$) with an effect size of 0.59, suggesting that students in classes using the discovery projects had a stronger grasp of the content at the end of the course.

One of the surveys measured perceived usefulness of statistics, using a 12-item Likert style survey in which all items were scored on a scale of 1 to 6. The Cronbach alpha reliability coefficient for the instrument was 0.93 in this study. Control group participants obtained a mean score of 4.24; experimental participants obtained a mean score of 4.51. The difference between the groups was significant ($p < .01$) with an effect size of 0.295, suggesting that students in classes using the discovery projects perceived statistics to have more utility than did students in the other classes.

The second survey measured students' beliefs in their ability to understand and use statistics correctly. The survey was a a 15-item Likert style survey in which all items

were scored on a scale of 1 to 6. The Cronbach alpha reliability coefficient for the instrument was 0.95 in this study. Control group participants obtained a mean score of 4.70; experimental participants obtained a mean score of 4.82. Although the experimental group obtained the higher score, the difference between the two groups was not significant. A possible confounding factor is that students who have experienced statistics for themselves gain a new respect for the complexities of statistics that may not exist in classes where the subject is treated purely academically.

Summary

The method of using discovery projects to foster deeper understanding of statistics has shown promise. Students taught with this method showed better content knowledge and greater respect for the usefulness of statistics than did their counterparts in traditional classrooms.

As with most teaching techniques, the method in which discovery projects are implemented will have a direct impact on the success of the projects. Instructors find it helpful to structure the project with intermediate goals, to set student expectations early and clearly, and to establish clear guidelines for working effectively as a team.

The instructional materials developed for this study are continually being revised and enhanced. Instructor training materials are also planned. These instructional materials and teaching methods should prove increasingly beneficial as instructors gain experience with them.

References

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