Models of Student Learning in Graduate Statistics Education: Towards Statistical Literacy and Research Competence

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1. Introduction

Statistics education research literature has well documented the link between the teaching of statistics and research methods courses to meet the challenges and demands of statistical literacy in an information-driven society. While much of the research literature focused on reform efforts in teaching introductory college statistics courses (Rumsey, 2002; Del Mas, 2002; Chance, 1997; Cobb, 1993), there are very few studies that explore the challenges of graduate statistics education. In a discussion document in one of the IASE Round Table Conferences, statistics is considered as "an important component in the training of new researchers within masters and doctorate courses" (Schuyten, 2001).

Graduate education is one effective means of developing capacities related to doing research in specific fields and many graduate programs in non-statistical disciplines require statistics and research methodology courses as basic courses. In particular, doctoral level preparation is research oriented and aims to develop in students competence to undertake independent research in an area of specialization.

Moreover the teaching of statistics to non-statistics majors at the graduate level poses several challenges. Graduate students are adult learners with diverse backgrounds and professional interest, and their prior knowledge and possible misconceptions may have diverse impact on their attitude and performance in the course. This paper examines the impact of a more customized learning and assessment framework for a doctoral statistics course at the University of San Carlos, Philippines with the end view of characterizing models of student learning that promote statistical literacy and research competence.

2. Related Literature

The connections between the development of statistical literacy and research skills as primary goals of statistics education abound in the literature. Gal and Garfield (1997) believe that "the overarching goal of statistics education is that students, become *informed citizens* who are able to : (1) comprehend and deal with uncertainty and variability, and statistical information in the world around them, and participate actively in an information–laden society; and (2) contribute to or take part in the production, interpretation, and communication of data pertaining to problems they encounter in their professional life." An analysis of these goals reveals that the first aims for "good citizenship" in an information- driven society while the second goal focuses on the training of the "research scientist."

Modern educational theories further suggest the need to address students' diverse backgrounds and prior knowledge of the course to optimize student learning. Dansie (2005) discusses the challenges provided by graduate quality frameworks in the design and implementation of a curriculum for an introductory statistics course, foremost of these is "the challenge to statistics educators to be able to make connections between the models being developed to support statistical approaches with the experiences that students have in other courses within their degree and within other contexts." Chance, Garfield and del Mas

(1999) have also explored how prior knowledge affects students' experiences with the learning activities. The have designed an assessment framework which enabled them to better track student misconceptions and their sources and consequently, redesign the activity to address the most prevalent misconceptions.

The methodology of this study is drawn from current research literature in statistics education which suggests new approaches to gathering data on student learning beyond the traditional measurement techniques. Chance and Garfield (2001) contend that in order to assess more important learning goals on statistical literacy, conceptual understanding and communication skills, new approaches on gathering data on student learning such as classroom based research, teaching experiments and naturalistic observations must be done instead of relying solely on high-impact standardized examinations and traditional testing. These approaches allow teacher-researchers to continually relate what they observed in the classroom with existing theory while also generating new models of student learning.

3. Methodology and Course Implementation

This study is part of an on-going effort of the University of San Carlos College of Education to promote statistical literacy among adult learners, particularly among graduate students who are mostly teachers, and other professionals with related interest in education. This classroom based research uses naturalistic approaches to gather evidence of student learning in a doctoral course, EDUC 321 (Statistical Procedures and Research Methods in Education) and examines models by which adult learners transfer their learning in the conduct of research. The two-fold goals of the course are the development of two life-long skills; namely: *statistical literacy* and *research competence.*

The class comprise 10 doctoral students in Education with have diverse backgrounds and professional experiences: 7 of them are in social sciences and humanities while 3 are in the natural and technical sciences. Most were college teachers while the a few were practicing professionals in other fields. This diversity in previous educational backgrounds and learning opportunities poses concerns and challenges for the teacher on how to deal with these adult learners. To address this challenge, some baseline data for each graduate students' level of statistical literacy and prior knowledge were obtained through a pre-assessment of their statistical literacy at the beginning of the semester using the Statistical Literacy Assessment Scale (SLAS) I developed earlier (Reston, 2005). The SLAS is a 15-item scale for assessing statistical literacy in two levels; namely: (1) understanding of basic statistical concepts and terminology, and (2) ability to understand and follow claims and arguments based on data in tables or graphs presented in newspapers and research reports.

Further, the learning materials and activities of this course were designed to attain the overarching goal of statistical literacy and research competence. The course culminated with the submission and oral presentation of a research report within their area of professional interest which was assessed using a teacher-made 100 – point rubric that reflects 3 dimensions of desired learning outcomes; namely: (1) demonstration of statistical literacy in the presentation and justification of claims in the research report using data as evidence (40%); (2) demonstration of research competence in the formulation of research problems and the choice of appropriate methodology (40%) ; and (3) communication and mechanics (20%).

At the end of the semester, a retrospective pretest-posttest instrument was administered to the students to determine the impact of the student learning approaches used in the course. The retrospective pretest (RPT) method was first described by Campbell and Stanley (cited in Lamb and Tschillard, 2002) as an alternative to traditional pretests to counter possible "response shift effect" where participants may under-

or overestimate their knowledge, skills, abilities or understanding prior to course implementation or any program intervention.

In this retrospective pretest-posttest instrument, students were asked to rate in a scale of 1 (poor) to 5 (excellent) their understanding or competence in 12 areas identified in the course; namely: Statistical Literacy, Descriptive Statistics, Exploratory Data Analysis (EDA) , Electronic Data Processing (EDP), Sampling, Probability Distributions, Parameter Estimation, Hypothesis Testing, Effect Size, Research Problem Formulation, Drawing Statistical Inferences and Data Interpretation in Research.

4. Bringing Statistical Knowledge and Discipline-Specific Knowledge Together through Research

Results of the statistical literacy pre-assessment scale shows that although most of these doctoral students had taken previous statistics courses in their undergraduate and masters' program, their performance in the SLAS indicate the need to review basic statistical literacy skills, such as reading and interpreting percentages, tables and graphs. The explanations they provided on their answers also uncovered several misconceptions, including: judging sample representativeness based on sample sizes, treating sample statistics and population parameters in the same way, comparing data with different reference bases using raw figures instead of percentages, and making conclusions on experimental data based on numerical deductions instead of looking into statistical inference results. These pre-assessment results provided the directions for curricular restructuring of the course to include additional learning and assessment activities to promote statistical literacy.

Despite the limitations of a small sample, results of paired t-tests for significance of differences in the pre-test-posttest ratings showed statistically significant gain scores in all 12 areas of competence ($p < 0.001$). The areas which yielded the 3 highest mean gain scores were EDA, Statistical Literacy and the use of Effect Size measures in research. As to students' prior knowledge, it was found relatively substantial in descriptive statistics and very minimal in hypothesis testing while several students admitted it was their first time to learn EDA and parameter estimation and most had no prior knowledge of effect size measures. Ratings on the research output based on the 100-point rubric revealed positive correlations with the course gains obtained by the students in the retrospective pretest-posttest instrument.

The findings suggest that for adult learners like doctoral students, learning is optimal when students actively engage in (1) goal-setting for the course goals based on pre-assessment data, (2) the design of learning and assessment activities and (3) self-assessing and evaluating their own learning progress. Further, models for learning and assessment activities must: (1) reflect real world needs in their professional settings; (2) reveal how students solve problems and reason with data; (3) reflect interests of their professional community from which the tasks are derived, thus providing a context for learning and enhancing retention, meaning, and appreciation; (4) provide opportunities for collaboration since much of life requires an ability to work in cooperation with others; and (5) promote transference by presenting tasks that require students to intelligently apply statistical tools in research.

From analysis of students' responses and performance in the activities, a characterization of models of student learning in graduate statistics education were derived to provide guidelines for adult education programs. For the teaching and learning of graduate statistics to be more meaningful and relevant, these models must account for three classes of factors affecting students' learning and motivation in a graduate statistics course; namely: (1) students' personal characteristics, which include professional background,

experience, prior knowledge and needs/interest towards learning statistics; (2) situational characteristics concerning the administration of learning, such as materials, activities and assessment contexts; and (3) the and the interaction between statistical knowledge and student's discipline-specific knowledge through research.

5. Conclusions and Future Directions

Statistics serves as the link between theory and the empirical world in the research process as it provides the principles and methods in the appropriate handling of research data. This paper has shown that new models of student learning, assessment frameworks, and creative methods of applying statistics in research may be derived to guide teachers in adult education programs. For these models of student learning to be meaningful and relevant, statistics educators need to frame their learning and assessment activities within broader statistical literacy framework and be able to integrate their discipline-specific applications in education and other fields with statistical knowledge and research.

Abstract

This paper examines the impact of a more customized learning and assessment framework for a doctoral statistics course with the end view of characterizing models of student learning that promote statistical literacy and research competence. Analyses of students' inputs from various classroom-based sources, including a pre-assessment statistical literacy scale, papers and research report, and a retroactive pretest-posttest suggest that for teaching and learning of graduate statistics to be more meaningful and relevant to adult learners, these models must account for three classes of factors; namely: (1) students' personal characteristics, (2) situational characteristics concerning the administration of learning, and (3) the interaction between student's statistical knowledge and discipline-specific knowledge through research.

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