

SUSTAINING TEACHERS' CAPACITY FOR TEACHING STATISTICAL INFERENCE THROUGH REFLECTIVE PRACTICE

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In this paper, we present reflective practice as an approach to sustain teachers' ability to teach statistical inference in more meaningful, relevant contexts using real data and technology integration for optimal student learning outcomes. From an initial workshop with college statistics teachers on statistical inference and reflective practice, we followed up selected teachers and built multiple case studies to examine how these teachers' understanding of statistical inference evolved and influenced their classroom practice. Using Taggart's (2005) Reflective Thinking Model, we classified teacher's reflective thinking level into technical, contextual and dialectical. Teachers reflect on their own teaching experiences to improve instructional decisions and classroom practice in these levels using techniques such as self-reports, peer assessment, journal writing and focus group discussion to support the integration of reflective practice into their teaching.

BACKGROUND

Over the past two or three decades, statistics education reform efforts have focused on the teaching of college introductory statistics courses. Garfield, Hogg, Schau and Whittinghill (2002) claim that a major aspect of the reform movement is the focus on concepts, reasoning, and thinking. Moore (1997) further describes the reform in terms of changes in content, pedagogy, and technology. In all these aspects of reform, the preparation and training of statistics teachers is a key component in its success of implementation. Given that it is largely the responsibility of the teacher to manage the teaching-learning environment in order to attain the desired outcomes of statistics education, schools, colleges and universities find it necessary to upgrade and sustain teacher capacities through continuous professional development.

In targeting professional development efforts for college introductory statistics teachers, the most popular approaches in practice are in the form of seminar-workshops which are usually "one-size-fits-all" form of training. In developing countries and emerging economies like the Philippines, sustaining teachers' professional development through seminar-workshops require much financial outlay yet their impact on teaching practice is not well established. Most often, teachers attend seminar-workshops without any follow-through program on how these have improved their teaching practice. Further, for faculty development strategies to be effective and sustainable, they must reflect a systematic understanding not only on the content and pedagogical knowledge base of the teacher, but also on their beliefs, perceptions and dispositions as well. In relation to this, there is a growing body of literature in education which explored reflective practice as a professional development model for improving and sustaining teacher capacities (Osterman & Kottkamp, 1993; Poblete, 1999). In statistics education, Porter (2001) proposed a model for improving statistical education that involved a reflective practitioner methodology. This involves teacher's reflection upon student lives, curriculum, the pedagogy, how students experienced learning, and the comparison and contrast of teacher experiences and understanding with those reported in the literature.

Reflective practice in education literature is viewed in different but related ways. Osterman and Kottkamp (1993) consider reflective practice as a broader conceptual framework for understanding individual and organizational stability and change and a means of facilitating significant change. Moreover, from a more focused perspective, reflective practice is viewed as a process of professional development. More precisely, it is viewed as "a means by which practitioners can develop a greater level of self-awareness about the nature and impact of their performance, an awareness that creates opportunities for professional growth and development" (Osterman & Kottkamp, 1993, p. 2). Poblete (1999) also discussed various conceptualizations of reflective practice, particularly reflective teaching, as an inquiry-oriented approach to teacher education and presented a model of reflective teaching which includes various dimensions; namely:

knowledge base, love of teaching, ethics of caring, constructivist approach to learning, artistic problem solving, and inquiring attitude toward education. In higher education, reflective practice may refer to teachers, as professionals, reflecting on the practice of teaching. Moreover, a more in-depth view of reflective practice may be also seen when teachers employ activities and assessments that require students to reflect on their learning (Porter, 2001).

Further, we argue that teachers need to develop reflective thinking skills in order to model and sustain reflective practice. Taggart (2005) defines reflective thinking as “the process of making informed and logical decisions on educational matters, then assessing the consequences of those decisions” (p. 1). Teachers manifest the characteristics of reflective teaching in their mode of delivery. Taggart (2005) further claims that scholars differ on the hierarchical nature of reflective thinking but generally agree on three modes or levels; namely: (1) technical, (2) contextual, and (3) dialectical as reflected in the Reflective Thinking Pyramid by Taggart (2005). This model provides a hierarchical framework for organizing teachers’ content knowledge, perceptions and teaching experiences in this study. In the *technical level*, the focus is on teacher competency towards meeting outcomes in relation to course content, behaviours and skills with reference to students’ past experiences. The *contextual level* focuses on relating content to context and student needs and the consideration of alternative practices while the *dialectical level* focuses on disciplined inquiry, individual autonomy and self-understanding, and consideration of moral, ethical and socio-political issues.

This paper recounts the journey of a select group of college statistics teachers as they explore their own levels of reflective thinking and capacity for reflective practice in teaching statistical inference. The choice of statistical inference as the subject matter content is based on previous findings that this topic is laden with misconceptions (Sotos, Vanhoof, Noortgate, & Onghena, 2007). Further, some case studies in the Philippines revealed that the teaching of introductory statistics has been primarily descriptive and whenever inferential statistics is covered, it is minimal and characterized by dominance of traditional formula-based and computational methods for teaching probability and hypothesis testing with little or no coverage in sampling distributions and estimation of parameters (Reston, Jala, & Edullantes, 2006; Jala & Reston, 2010).

Statistical inference is concerned with the problem of generalizing properties of an unknown population from data generated by a sample from that population. According to Sotos, et al (2007), a solid understanding of inferential statistics is of major importance for designing and interpreting empirical results in any scientific discipline. Many teachers emphasized the importance of sampling distribution as a core idea in understanding statistical inference yet many students were shown to have poor understanding of sampling distributions (Chance, delMas, & Garfield, 2004)

There are some studies abroad that explored teachers’ understanding of statistical inference and their implications for professional development. Liu (2005), for instance, explored teachers’ understanding of probability and statistical inference, and the analysis of data collected from videotape sessions and interviews, teachers’ written activities and researchers’ field notes revealed the following: (1) there was a complex mix of conceptions and understanding of probability and statistical inference among teachers; (2) teachers’ conception of probability and statistical inference are highly compartmentalized; and (3) many teachers have a conception of learning as “knowing how to solve problems”, and teaching as “displaying the expertise of problem solving”. These findings further support the need to investigate teachers’ conceptions on statistical inference.

In this paper, we argue that for a sustainable improvement in their content knowledge and pedagogical skills for teaching statistical inference, there is needed for statistics teachers to explore their own conceptions on statistical inference and their teaching practice on the topic as basis for more focused and improved instructional decisions and actions. Further, through the framework of reflective practice, statistics teachers will assess their own reflective thinking skills as foundation for reflective inquiry and improvement on their teaching practice.

PREVIOUS EFFORTS

In the Philippines, there have been some efforts directed toward improving teacher capacities for teaching statistics. At school level, basic concepts of probability and statistics are taught as part of the mathematics curriculum. At the tertiary level, introductory statistics courses are being offered in many academic programs. Many disciplines recognize the contribution of

statistics in enhancing their research and analytical skills. Moreover, several statistics educators and practitioners in the country have investigated the teaching of statistics in the various levels of the educational system and they found that it is plagued with problems: the lack of qualified teachers, lack of locally produced good quality statistics books and educational materials, inadequate facilities such as computer laboratories, software and other teaching aids, and mechanistic teaching methods that do not enhance the teaching of statistics (David & Maligalig, 2006; Tabunda, 2006; Reston & Bersales, 2011).

Many reform efforts have been done by different stakeholders in the country to improve the teaching and learning of statistics. The Philippine Statistical Association and the Philippine Statistical System have increasingly provided support for the academe in the teaching of statistics. Reston and Bersales (2011) reported these advocacy efforts such as the review of locally written textbooks, the grants for writing reference books, trainings for teachers teaching basic statistics in college, holding of fora to present research in statistics. Moreover, in spite of all these reform efforts, there are still many problems and challenges in teaching statistics and the focus of most reforms are in the tertiary level.

THE PROBLEM

In line with the global reform efforts in teaching college introductory statistics courses, statistics teachers in the Philippines are faced with the greater challenge of retooling themselves in both content and pedagogy and improving their capacities for using technology in teaching statistics. Teachers, being implementers of the curriculum, play a vital role in attaining the desired outcomes of statistical literacy, reasoning and thinking among students in these courses. With all various forms of developing capacities for teaching statistics, the problem of sustaining improvement in teacher capacities is best carried out by individual teachers who need to reflect on their own teaching contexts as basis for guiding practice.

This study aims to explore how selected college statistics teachers self-assess and reflect on their content knowledge and pedagogical skills for teaching statistical inference in college introductory statistics as basis for sustaining improvement in teacher capacities in these areas through reflective practice. In particular, this study sought to answer the following:

1. What is the extent of these statistics teachers' content knowledge and pedagogical skills for teaching statistical inference concepts and methods?
2. What misconceptions, if any, do these statistics teachers have on statistical inference concepts and methods?
3. What is the level of these statistics teachers' reflective thinking skills based on Taggart's (2005) Reflective Thinking Pyramid?
4. How do these teachers' content knowledge, pedagogical and reflective thinking skills evolve as they engage in reflective practice in teaching statistical inference?
5. What needs, problems, and challenges do these teachers encounter as they apply reflective practice to their teaching?

METHODS

This paper is a qualitative case study of 28 selected college statistics teachers in Cebu City, Philippines who participated in a workshop for improving teacher capacities and reflective skills for teaching inferential statistics topics as part of the college introductory statistics courses for non-majors. As part of the workshop, teachers were given a pre-assessment of their knowledge of probability and inferential statistics concepts and methods. The pre-assessment consisted of a two-tiered 10-item multiple choice questions whereby participants chose one correct answer from four options and provide a reason for their answers. The reasons provided were analyzed for their accuracy and possible misconceptions on the topic were identified. This instrument was pretested among a sample of graduate statistics students.

Aside from this pre-assessment, the participants also answered a Profile Inventory of Reflective Thinking Attributes (Taggart, 2005) which consisted of 30 items that elicited their responses when confronted with a problem situation and when preparing, implementing, and assessing a lesson. Each item is rated in a scale of 1 (seldom) to 4 (almost always). The total score,

which ranges from 30 to 120, determined the teacher's level of reflective thinking using the following categorization as adapted from Taggart (2005): (1) Technical Level – below 75; (2) Contextual Level – 75 to 104 and (3) Dialectical Level – 104 to 120.

The results of these two pre-assessment instruments were used to provide baseline information on these teachers' content knowledge base and pedagogical and reflective skills for teaching statistical inference. Workshop activities followed to help teachers develop capacities for teaching statistical inference. The design of the activities were guided by the recommendations of Rossman and Chance (2000) on the teaching of the reasoning of statistical inference. The topics built around understanding the following concepts and methods related to statistical inference; namely: (1) probability and randomness, (2) sampling and sampling distributions including the Central Limit Theorem, (3) margin of error and confidence intervals in Parameter Estimation, and (4) statistical hypotheses, level of significance and p-values under Tests of Hypotheses. Another consideration in the design of the activities is the development of statistical literacy as the overarching goal of statistics education in introductory college statistics (Rumsey, 2002). The workshop activities were anchored on real data and provided the participants to reflect on their own prior knowledge and teaching practice.

After the workshop, selected teachers have been followed up for reflections on their classroom practice. Data were gathered using class observations, interviews and other reflective techniques such as self-reports, peer observation and assessment, and journal writing to support the integration of reflective practice into their teaching.

RESULTS AND DISCUSSION

This section presents the first phase of the study based on initial results from the workshop on reflective practice in teaching statistical inference. The results showed that majority of the teachers had undergraduate degrees in mathematics, education and social science areas and not in statistics; for most of them, their knowledge of statistical inference is limited to hypothesis testing. Teaching methods are limited to traditional formula-based and problem-solving approaches with no or minimal use of data-based and technology-driven simulations and research-based contextualization of data. Knowledge of probability and sampling distributions were limited and some misconceptions on random sampling procedures, sample representativeness, margin of error, level of significance and p-values were evident from their responses on the pre-assessment. The findings confirm with Sotos et al (2007) who identified the common misconceptions under sampling distributions such on sample representativeness and the confusion of population and sampling distributions would result to a failure to detect the difference between the distribution of a *sample* and the *sampling* distribution of a statistic (Chance et al, 2004, cited in Sotos et al, 2007). Another set of misconceptions concerns the Central Limit Theorem, which states that for sufficiently large sample sizes, the sampling distribution of the sample mean can be approximated by a Normal distribution, which facilitates inferential calculations. These misconceptions have a direct impact on teaching and learning inferential statistics because of the interconnection of the concepts and methods and the relevance of their understanding for an appropriate interpretation of inferential results and conclusions.

As to the level of these statistics teachers' reflective thinking skills based on Taggart's (2005) Reflective Thinking Pyramid, most of the teachers were at the technical level and contextual level, and one at the dialectical level. At the technical level, when confronted with a problem situation and when preparing, implementing, and assessing a lesson, most of these teachers' concern is on their competency towards meeting outcomes in relation to course content, behaviors and skills with reference to students' background and there is minimal consideration of alternative teaching practices in relating content, examples and exercises to context, other social issues and real life uses of statistical inference.

In addressing the common misconceptions and the need for reflective thinking, teachers' engagement in workshop-based activities and later in reflective journal writing showed evidence of their expressed need to improve their content and pedagogical knowledge base and translate this improvement to classroom practice. The realization to improve their teaching practice and reach inferential techniques in their classes was expressed by most of the participants. Some constraints were identified by the participants in their resolve to improve their own teaching practice, including

the lack of time for class preparation due to heavy teaching load, the lack of activity-based teaching materials and computer technology facilities for teaching statistics and the need for institutional and collegial support in their department.

Most teachers were at the technical and contextual levels in Taggart's Reflective Thinking Pyramid and this is confirmed in their reflection on their past experiences in teaching and learning statistics. Most teachers expressed their poor and limited background on teaching inferential concepts having been in past statistics classes characterized by mechanistic, formula-based calculations. Also, understanding probability, sampling distributions and parameter estimation were identified to have been missed out since focus was on hypothesis testing. Their concerns in teaching statistical inference methods were primarily focused on content and skills and their competency towards meeting desired learning outcomes. As they went through the workshop activities, exploring real data to understand the concepts, they realized the need to move up to the contextual and dialectical levels of a reflective practitioner as they expressed the need to look at alternative practices, choices on different strategies based on knowledge and commitment to the goals of statistics instruction, and the need to provide context in data-based activities and relate them to content and student needs.

RECOMMENDATIONS AND FUTURE DIRECTIONS

These preliminary results show the potential for reflective practice in improving teacher's own learning and teaching practices in statistics instruction. As teachers own their limitations in content knowledge and pedagogical skills for teaching inferential concepts and methods, they express more resolve to do concrete actions in their teaching practice in order to improve their own teaching and students' learning outcomes as well. Moreover, there is need to build up stronger evidence to support the impact of reflective practice among teachers through multiple in-depth case studies with individual statistics teachers. The second phase of the study is on-going which involves class observations and follow-up interviews with individual teachers who volunteered to be part of reflective practice in action. Getting students make sense of statistics particularly on inferential procedures such as parameter estimation and hypothesis tests can be a difficult and challenging task for statistics instructors who themselves realize that they too held misconceptions about inferential concepts and methods. Most of these misconceptions were attributed to the mechanistic, decontextualized and formula-based teaching of statistics with little or no emphasis on conceptual understanding which they also experienced as students. Indeed teaching mediocrity breeds itself and there is need to break this vicious cycle of routine and mechanistic teaching practices as teachers reflect on their instructional decisions and actions.

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