TRAINING STATISTICS TEACHERS FOR BOTSWANA SENIOR SCHOOLS: IS IT NECESSARY?

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The study sought teachers' views on the need to train statistics teachers in Botswana. A purposive sample comprising 23 senior teachers and 30 ordinary teachers responded to an open-ended questionnaire soliciting their experiences about the teaching of statistics in schools. It was found that all teachers offering statistics had limited qualifications to teach statistics as they have been trained for mathematics teaching. The biggest challenges in statistical instructional practices were difficulties in solving questions and explaining concepts to students. The study findings suggest the necessity to train teachers so as to empower them with statistical pedagogical content knowledge and knowledge for teaching statistics.

INTRODUCTION

> Do teacher education programmes make a difference? That is, is it possible to get the same result whether teachers are trained or not? (Garegae-Garekwe, 1999, p. 1).

These two questions could be summarized as: "Should training statistics teachers attract the same attention as training mathematics or science teachers?" To attempt to answer these questions, we draw from the literature on mathematics teachers' knowledge for teaching. Ernest (1989) proposed components of knowledge base for mathematics teachers, some of which are: (1) mathematics content; (2) knowledge of teaching mathematics; and (3) general pedagogical knowledge. Proficiency in mathematical content knowledge is said to have a greater impact on the teachers' teaching performance (Ferguson & Womack, 1993). Therefore, teachers who teach for understanding should understand mathematical concepts, structures, and their relationships as well as identify and interpret representations of such constructs (McDiarmid & Wilson, 1991). Nonetheless, the knowledge of the subject matter alone cannot determine the quality of teaching (Ferguson & Womack, 1993). In the opinion of the author this is why people who have learned mathematics only (without mathematics education) cannot be regarded as qualified teachers. The content knowledge only provides a basis for the teacher's pedagogical knowledge for teaching mathematics. One would assume, however, that even in statistics teaching, a teacher needs to be proficient in the subject matter as a pre-requisite to accumulating pedagogical knowledge.

Pedagogical content knowledge for mathematics, includes the knowledge of how to break concepts into smaller pieces and arrange them for easier understanding by students. It also consists of knowledge of children's thinking about mathematics, how the curriculum is arranged, as well as assessment issues. Similarly, a statistics teacher should have pedagogical content knowledge of the subject in order to be effective. This is in line with Rustagi's (1982, p. 300) sentiment that "the competent teacher should be able to provide the feeling of real world problems and application of statistics to the problems". Content pedagogical knowledge is therefore gained from teacher education programs but expands and is refined later in the teacher's career as she/he spends more years in the field and develops into an expert.

Statistics education is so important to the lives of people that its teaching should not be left to chance. It provides "...skills which enable an individual to cope with the practical mathematical demands of his everyday life" (Cockcroft, 1982, p.11) and "many of the major decisions affecting the lives of everything on this planet have some statistical justification or basis" (Gelman & Nolan, 2002, p. 3). Thus, Groth (2007, p. 428) warns: "If an explicit consideration of the differences between mathematics and statistics is not undertaken as research on mathematics teachers' knowledge is carried out, then the important differences needed to teach it are likely to be overlooked". This present study sought teachers' views based

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on their experiences, whether or not training statistics teachers is necessary in the context of Botswana.

BACKGROUND

For quite sometime, a shortage of mathematics teachers was a common phenomenon in this country. Consequently, more mathematics teachers were recruited from abroad including USA, India, UK, Jamaica, Zimbabwe, and Zambia, to mention just a few. The shortage was acute at senior secondary schools when compared to junior schools. For the past ten years or so, enough mathematics teachers were produced from the University of Botswana through the Department of Mathematics and Science (DMSE). Therefore, the Ministry of Education started being strict with the renewal of contracts for the recruited teachers in an endeavor to localize teaching posts in schools. Nevertheless, the HIV/AIDS pandemic is reversing this effort. Fewer teachers than needed are produced, and more are sick and dying from AIDS[(1)]. Recently, the department of Teaching Service put an advert in the media soliciting teachers who took mathematics as a minor subject from the Colleges of Education to apply for teaching positions at junior secondary schools. This gesture implies that the quality of education offered in schools is at stake because the epidemic is deceasing human resources in schools.

In line with the country's endeavor to move from agro-based to industrialized economy, mathematics is given compulsory status from primary (seven years of school) through junior secondary (three years of school) to senior secondary (two years of school) level. This explains the high demand for mathematics teachers. It is also used as a gatekeeper for any advancement including further education. For instance, at the University of Botswana, the only public university so far, a Grade C in mathematics is required for all students even those in Humanities. Since students usually perform poorly in mathematics, this requirement is a huge barrier to pursuance of higher education for the majority.

Unlike the mathematics syllabus, which was localized in 1997, the statistics syllabus (Statistics 4040) is not localized but is housed at the University of Cambridge. Statistics examinations are therefore, set and administered in the United Kingdom. Statistics is offered as an optional subject and is usually paired with additional mathematics, which is also based in the University of Cambridge. Among the 27 government and government-aided senior secondary schools, only 10 have offered statistics at some point in time. Since DMSE does not train statistics teachers, and yet the subject is offered in schools, one wonders (1) "Who teaches it? (2) What challenges do they meet? (3) Is there a need to train statistics teachers? This exploratory mini project was undertaken to investigate these questions.

TRENDS IN STATISTICS TEACHING

In layman's language, the terms statistics and mathematics are used interchangeably and are regarded as one and the same thing. In fact, statistics seems to be considered as a branch of mathematics by both the public and mathematics teachers. As a result of this general view, there is a tendency to believe that mathematics teachers can teach statistics. It seems this belief is wide spread. Consequently, the global trend is that the teaching of statistics is carried out by teachers who were not initially trained for its teaching (Iversen, 1992). Studies on in-servicing mathematics teachers to help them teach statistics are common in the literature (Peck & Gould, 2005). Thus, more often than not, the focus of the interventions is either pedagogy or content depending on the needs of teachers. The observed hurdle in these short workshops is the lack of sustainability in terms of its impact on participants, and continued learning and enthusiasm are reported to be minimal.

One way to alleviate the impact problem is to conduct a workshop that takes more than a week or day. Peck and her colleague (Peck & Gould, 2005), for example, embarked on a year-long intensive project that involved both classroom face-to-face teaching and a distance mode with the purpose of teaching both the content and knowledge for teaching statistics. One wonders if the 'training' of teachers through workshops or projects is practical in terms of cost effectiveness, efficiency, and teacher productivity. Calling teachers from classrooms to concurrently learn and apply what they learn can result in time constraints, and emotional and physical exhaustion. Moreover, spending extra money on making uncoordinated 'fixes' on

teachers' knowledge may be the most expensive alternative form of training statistics teachers. Besides, Watson and her colleagues (1992) argued that the "in-service workshop does not entirely eliminate secondary school teachers' concerns" (Watson et al., 1992, p. 50). Workshops for in-servicing mathematics teachers on statistical content and its pedagogy may therefore not be a viable method for training statistics teachers.

RATIONALE FOR TRAINING STATISTICS FROM INITIAL STAGE

Statistics and mathematics are founded on different premises, and thus their knowledge structures are different (Moore, 1992; Peck & Gould, 2005). The styles of teaching for these two subjects therefore differ, particularly with regard to emphasis on concepts and ways of knowing. Moore (1992, p. 15) states clearly that statistics is not mathematics. Statistics has its own subject matter which is primarily "reasoning from uncertain empirical data", and its origins differ from that of mathematics (Iversen, 1992). Whereas it borrows tools from mathematics, statistics does not export its tools and ideas into mathematics (Iversen, 1992). As an illustration, a student without a good background in mathematics may have difficulties in understanding the meaning of formulas used in statistics. Although general mathematical knowledge may enable one to manipulate numbers, statistical methods of investigation such as question formulation, data collection, data analysis and interpretation of results—need specialized statistical knowledge (Groth, 2007). Groth further underscores both Moore's and Iversen's sentiments by saying that:

> Statistics is no more a branch of mathematics than is economics … It is a separate discipline that makes heavy and essential use of mathematical tools, *but has its own origins, subject matter, foundational questions and standards that are distinct from those of mathematics"* (Groth, 2007, p. 427) [emphasis added].

It is therefore safe to make a claim that knowledge required for teaching mathematics is not necessarily the same as that for teaching statistics. Gupta's (1982, p. 283) assertion is in accordance here: "The teaching of statistics calls for expertise and hence in-depth understanding of the subject is the best preparation". No wonder Iversen (1992, p. 38) has this to say concerning mathematicians when faced with challenges: "mathematicians who are called upon to teach statistics are neither qualified nor comfortable with it. … As a consequence, it is natural for such individuals to react to teaching a statistics course by falling back on their mathematical experience". If mathematics teachers who have been trained on new methods often fall back to their traditional old style of teaching if they are called upon to teach statistics, a subject to which they are alien. For that reason, we conclude that "the increased demand of statistical knowledge can be met adequately if universities will produce qualified teachers" Gupta (1982, p. 283), not through in-servicing mathematics teacher.

METHODOLOGY

Participants

Twenty three (23) Heads of Mathematics Department (HoDs) in their respective schools who attended the 2007 annual In-service (INSET) workshop (for managing departments) organized by DMSE-INSET unit participated in this study. An additional 30 teachers from five (18.5%) senior schools within Gaborone, the capital city, and surrounding areas also participated. The study excluded teachers who were not locals. Participants' years of teaching experience ranged from 2 to 20, and their statistics teaching experience ranged from 1 to 8 years. Out of the 53 who completed the questionnaire, only 31 (10 HoDs and 21 ordinary teachers) were teaching statistics or had ever taught the subject.

Data collection procedures

Eligible participants were given an open-ended questionnaire soliciting their experiences about statistics education in senior secondary schools. HoDs completed the questionnaires within two days while still attending the workshop, and questionnaires for other

teachers were hand-delivered by part-time graduate students to their respective schools and then collected after 3-5 days. This cohort gave a poor response (60%), and most teachers thought the questionnaire was for those who had taught or were teaching statistics.

Data analysis procedures

Data collected were analyzed using Tesch (1990) and Bogdan and Biklen's (1992) techniques for analyzing qualitative data. Tesch identified eight steps for organising data. In the third step, the researcher divides data into three columns: (1) very important, (2) relevant and (3) leftovers, and uses data from the first and second columns. Anything in the third column is considered as irrelevant to the issue under investigation. Bogdan and Biklen's (1992) cut-up-and-put-in-folder approach allows the researcher to prepare data for synthesis. Codes or topics were grouped into categories represented by different envelopes. The researcher read codes from each envelope and labeled the category according to emerging themes.

PRESENTATION OF FINDINGS AND DISCUSSIONS

Below are discussions of the themes and categories, which emerged from the data.

Decision to Teach Statistics

Forty-eight (~91%) participants said that teachers teach statistics voluntarily. A teacher's choice to teach it is influenced by (1) passion for the subject, (2) being adventurous, and (3) having taken some courses during training. About 23% of the teachers claim that being passionate about the subject propels one to teach. Such individuals introduce statistics in every school to which they are transferred. In most cases however, when they leave on transfer, statistics education ceases to exist in that school. According to Rustagi (1982), statistics teachers should be filled with enthusiasm and have a plethora of experience with applications to share with students. It seems therefore, that teachers who are said to have taught statistics out of passion for the subject may show potentially promising results.

Other teachers venture into statistics teaching because they are "experienced … they already know the mathematics syllabus and are not afraid of a new challenge". This quote implies that new teachers may not teach statistics because of lack of interest, but because they need time to get established in teaching mathematics. About 31% of participants shared the same sentiment. The last category of teachers who volunteer to teach statistics are "experienced teachers who did statistics at school". Another participant has stated that even new teachers who have taken statistics course(s) during their pre-service training do participate in statistics teaching, although rarely. About 38% shared this belief.

Decision not to Teach Statistics

Reasons for not teaching statistics either as an individual or as a school fall under three themes: (1) teachers' negative attitude, (2) statistics as an enrichment subject, and (3) teachers' incompetence in subject matter content and pedagogical content knowledge. About 15% of participants reported that some teachers regard statistics teaching as an extra load for which they are not employed. "I am posted in this school to teach mathematics and nothing else". "It is not a must that schools should teach statistics; it is left to individual schools to decide". Others do not teach it because of heavy loads; thus when they have many mathematics classes to teach, they opt to eliminate statistics to lessen their burden. This is another reason why schools are not consistent in their offering of this subject. About 30% of participants claim that statistics education is not offered in all schools because it is regarded as an enrichment subject. Therefore, no teacher would want to waste time with a subject that does not directly contribute to students' entry requirement into the University of Botswana. This attitude is said to be contagious.

Lastly, teachers do not teach statistics because they are uncomfortable with the subject matter and lack the knowledge for teaching the subject. Over seventy percent (70%) of participants share the sentiment that "some content of the statistics subject is not easy for local teachers to teach and as such, many of them fear to teach statistics as they doubt their competence to handle topics like time series, scaled scores, linear interpolation". Codes that

were common in this theme include: teachers were not trained for the subject and therefore considered it challenging to teach; teachers were not competent in the subject; most teachers felt inadequately prepared by the university to handle most topics in the statistics syllabus, hence it is not popular in schools. One participant who has been offering statistics in schools to which he was transferred insinuated that "most schools however, respond to the problem of incompetence in subject matter by organizing internal workshops, which are also usually attended by very few teachers as many have little interest in statistics".

Participants who teach statistics have indicated that some topics are difficult for them to teach. In some cases they are unable to explain the content well, to solve problems from past examination papers and come up with appropriate activities for students. For instance, one of them said her challenge is "not being able to answer difficult questions from the past examination papers". "In some topics, I was not well grounded in knowledge so I had to keep on consulting other teachers". This finding corroborates Groth's (2007, p. 434) observation that oftentimes mathematics "teachers exhibit some of the same cognitive difficulties as young students in understanding [statistics] concepts". Only a competent teacher (in the subject matter and its teaching) can be able to demonstrate and dramatize "concepts that students find difficult" (Gelman & Nolan, 2002, p. 1). Thus, "unless they have substantial training [in statistics], teachers tend to focus on mechanics of constructing plots rather than interpretation, and on calculation rather than on data" (Watson, et al., 1992, p. 51).

Challenges in Teaching Statistics

Other challenges raised by participants besides those already mentioned above include the shortage of relevant teaching materials. Participants stated that prescribed textbooks are not only few but are also irrelevant. This seems to exacerbate teachers' inability to teach the subject effectively. As a result of not knowing the subject well , they cannot make activities that will facilitate objectives of the lessons. One participant said: "teaching statistics requires one to fully research and is forced to relate it to real life situations. Concepts are not always related in statistics; unlike in mathematics. In mathematics, one uses his knowledge from teacher training, but in teaching statistics, one relies on reading books before the lesson". Participants identified topics on which they would like to be in-serviced, but because of lack of space they are not described in this paper.

Reasons for Training Statistics Teachers

Not all participants (~38%) saw their limitations as directly related to being untrained in statistics education. The irony is that those who said there is no need for training are the same teachers who reported that they are unable to solve questions, interpret the syllabus or even construct appropriate activities. One of them said, "Trained? How? I believe we are trained teachers; we have done statistics as part of the mathematics degree programme. There is very little in the syllabus that we haven't done; just to research a little in textbooks." Nonetheless, the majority (77%) of participants recognize the differences between the mathematics and statistics teaching. Differences in the instructional demand in terms of preparation and actual teaching are cited by almost all (91%), and their concern is that it is a practical subject. The impression I got from their responses is that statistics teaching demands more than mathematics teaching for: "there is a lot of reasoning and explaining done. Most questions and answers in statistics require a lot of words unlike in mathematics"; and "The teaching of statistics is very different. However, some topics need to be made practical." These responses show that statistics strains teachers to a certain extent. Hence their reasons for training statistics teachers include "[it] makes the teaching of statistics easier"; and "so as to help teachers interpret the syllabus". Those teachers who said there is no need for training teachers seem to fall under Watson's and colleagues description, that "Teachers do not know what statistics is and what statisticians do" (Watson, et al., 1992, p. 51), and are unaware of their limitations.

CONCLUSION

This study has revealed that mathematics teachers are the ones offering statistics education in senior secondary schools. These teachers face problems in explaining concepts to

students and figuring out the syllabus objectives. Thus, statistics education in Botswana senior schools, just like in other countries where mathematics teachers and mathematicians are tasked with statistics teaching in schools, is impoverished. The literature has categorically stated that in-servicing mathematics teachers does not make them experts in the field apart from making them comfortable in teaching statistics. But, when difficulties arise, a teacher's tendency is to fall "back on their mathematical experience" (Iversen, 1992, p. 38). This is likely to happen if teachers are not trained at institutes of higher learning but in-serviced once they are in the field, and "in turn the gap between school statistics and the actual discipline of statistics is likely to widen because of an implicit errant assumption that statistics is a branch of mathematics" (Groth, 2007, p. 428). Hence we conclude that it is necessary to train statistics teachers.

Note:

(1) Secondary school teachers fall in the age bracket (25-49) where over 75% of people are living with HIV and dying from AIDS (Botswana AIDS Impact Survey (BAISS) II Report, 2005).

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