Teachers' claims about their competence in teaching data-handling in grade 11

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Abstract

This study investigated problems experienced in teaching of data-handling in grade 11 mathematics classes. Data-handling is a relatively new topic in school mathematics. To some teachers incorporating the data handling into their instruction poses challenges because their knowledge in this content area is limited. The government arranged in-service training programmes to capacitate teachers to deal with data-handling in class. A descriptive survey design which entailed the use of a questionnaire was followed to determine the types of problems, if any, encountered by teachers when teaching data-handling. A stratified sample of 100 grade 11 teachers based in schools in the Gauteng[16] province participated in the study. The results showed that there were problems experienced by teachers in the area of representing data on graphs/plots, interpreting as well as determining the measures of dispersion.

Keywords: data-handling, teaching,and pre-service and in-service teacher training

INTRODUCTION

Data handling was only introduced in school mathematics after 1994 in South Africa. It is an aspect to be covered under the fourth learning outcome (LO4) of mathematics in the outgoing National Curriculum Statement (NCS) (Department of Education [DoE], 2003). Data handling was only taught as a component of statistics in universities and technikons (technikons are now known as universities of technology) and was never taught in colleges of education where a considerable number of teachers got their pre-service training. Thus, there is a significant number of teachers who saw data handling for the first time when it became part of school mathematics in recent years (Mokgaphame, 2001; Owusu-Mensah, 2008).The Ministry of Education organised numerous in-service training programmes to develop the statistics content-knowledge of teachers (DoE, 2008). Nevertheless, the intervention has had little effect on improving the situation because teachers still have problems that range from having to teach the material that they are not familiar with to experiencing problems in implementing necessary assessment procedures as stipulated by NCS policy guidelines (Carnoy & Chisholm, 2008;Mahlobo, 2009).The problem has been passed to most learners, who performed poorly in statistics-related questions in the grade 12 end-of-year mathematics examination of 2011 (Cassim, 2012).

On the other hand, there have been other in-service training initiatives aimed at providing teachers with the necessary content-knowledge and skills to teach statistics (data handling implied) mainly organized by non-governmental organisations such as South African

[16] Gauteng is one of the nine provinces in South Africa.

Statistical Association (SASA), Statistics South Africa (Stats SA) and Association for Mathematics Education of South Africa (AMESA). According to North and Zewotir (2006) the in-service workshops on probability give teachers the opportunity to upgrade their knowledge to achieve statistical literacy of the school leaver in South Africa. AMESA also organised in-service initiatives for subject facilitators or advisors, who were then expected to provide similar training to teachers; arranged an hour–long supportive talks to teachers at its annual conferences and other similar forums as well as demonstration lessons illustrating the significance of statistics as a problem solving tool and how to conduct a learner-centred and interactive statistics lessons.

Furthermore, the Institute for Science and Technology Education (ISTE), at the University of South Africa (UNISA), has also offered workshop lessons during school winter vacation to mathematics teachers intended to improve and upgrade their content-knowledge of data handling, among others, because teachers consider it as one of the topics in mathematics that is instructionally and conceptually problematic (Atagana, Mogari, Kriek, Ochonogor, Ogbonnaya, Dhlamini & Makwakwa, 2010; Atagana, Mogari, Kriek, Ochonogor, Ogbonnaya & Makwakwa, 2009). Even though, ISTE's in-service initiatives have been successfully taking place since 2009, there are teachers who still have difficulties with teaching data handling (Atagana et al., 2010; Atagana et al., 2009).

In-service training programmes are seen by teachers as the remedies to their teaching problems. It is through such programmes that teachers are able to strengthen their subject-matter knowledge; develop new teaching strategies and own work programmes; and are also assisted to plan their work accordingly (Owusu-mensah, 2008). Effective and meaningful in-service training programmes can also identify teachers' needs by collecting information about problems they encounter in teaching (Owusu-mensah, 2008). However, Owusu-Mensah have noted that most of the in-service training programs do not conduct surveys or interviews that are likely to expose topics and areas that teachers feel uncomfortable or difficult to teach. The study reported in this paper investigated problems teachers encounter when teaching data handling. This paper does not suggest solutions to the problems elicited from teachers as it is presented only in a reporting mode. However, by reporting on teachers' problems this paper may help the in-service training programs organisers to become aware of areas that need attention. Therefore, the study addresses the question: What problems do grade 11 mathematics teachers experience in the teaching of data handling?

LITERATURE REVIEW

Several studies have been conducted to investigate problems experienced by teachers when teaching data handling (see for example, Atagana et al., 2010; Atagana et. al., 2009;Garegae, 2008; Wessels & Niewoudt, 2011; Cardoso, 2007; Silva & Countinho, 2008). Garegae (2008) studied challenges mathematics teachers experience when teaching statistics. Her study used an open-ended questionnaire that was completed by 23 senior teachers and 30 ordinary teachers to solicit teachers' experiences about the teaching of statistics in schools in Botswana. The data collected were analyzed using Tesch's (1990) and Bogdan and Biklen's (1992) techniques for analyzing qualitative data. The results of study showed that mathematics teachers in high schools face problems in explaining statistics concepts to learners; solving statistics problems from past examinations papers; coming out with appropriate statistics activities for learners; figuring out syllabus objectives; and relating the teaching of statistics to learners' real-life experiences. Garegae (2008) indicated that those problems were faced particularly by teachers who initially were not trained to teach statististics.

Atagana et al. (2009) investigated perceived difficult topics by learners and teachers in the teaching and learning of mathematics. Atagana et al. (2009) adopted a descriptive survey design and used educator questionnaire to collect the data. One of the objectives of Atagana's study was "to identify the topics that teachers have difficulties in teaching in Mathematics, Science, and Technology at Further Education and Training phase (grades 10 - 12) and General Education and Training phase (grades 8 and 9)" (p.9).The educator questionnaire was used to collect data from teachers on the sections of the NCS that they find difficult to teach in mathematics at the Further Education and Training (FET) level. The results of the study showed that data handling is one of the topic that teachers experience problems with.

In Atagana et al. (2010) a highly improved and adjusted educator questionnaire was administered to a much more geographical diversified sample of teachers from various provinces. One of the improved objectives in the instrument was to take the teachers through a coordinated intervention programme in order to make the teaching of the identified difficult topics and subjects effective (Atagana et al., 2010). The results of the 2010 study also revealed data handling as one of the topic that teachers experience problems with. The validity of instrument in the two studies were confirmed when the same results were obtained in successive years and in different areas.

Wessels and Nieuwoudt (2011) studied the profile of mathematics teachers' statistical knowledge, beliefs and confidence in order to inform the development of in-service teacher education programmes in statistics for grade 8 and grade 9 teachers. The profiling questionnaire was completed by Grade 4–9 teachers after their completion of a series of three in-service training workshops of four and a half hours each on data handling and probability. They found that teachers show high levels of confidence in teaching most statistics topics and low levels of statistical thinking when they had to apply their knowledge of concepts, such as sample and average in social contexts including newspaper articles and research reports. Wessels and Nieuwoudt also reportedthat more teachers indicated lower levels of confidence in aspects that involve sampling and probability topics (probability language, basic probability data handling calculations). Perhaps, it is for reason that Iversen (1992) warn that statistics has its own subject matter which is reasoning from uncertain data and taking decision in the face of uncertainity and its origins differs from that of mathematics. It has also been found that teachers still use theoretical traditional approach for teaching data handling where they put emphasis on identifying the correct formula and performing calculations, as opposed to data-driven approach using real data to emphasize statistical principles, procedures and statistical reasoning (North, Scheiber, & Ottaviani, 2010; Wessels & Nieuwoudt, 2010). Our study intends to invetsiagte issues embedded in the teaching of data handling.

DATA HANDLING and TEACHER EDUCATION

Generally prospective secondary teachers are taught mathematics during their pre-service training with little or no focus at all in statistics unless they register for statistics (data handling implied) separately. Seemingly, the view is supported by Batanero and Diaz (2010) who state that during initial teacher training student teacher tend to focus largely on theoretical (mathematical) statistics. Wessels and Nieuwoudt (2010) even teachers who have studied statistics as a major or as part of their mathematics training shows that they only have theoretical knowledge and their statistical thinking level is not helpful enough when they deal with real context situations such as reading and interpreting statistical data

presented in newspaper, articles and short research reports. According to Nicholson and Darnton (2003), statistics may pose particular problems if a teacher has not studied statistics as part of his or her mathematics course, or indeed if the teacher is not a statistics subject specialist. Even though statistics in school is offered as part of mathematics, the style of teaching mathematics and statistics subject differs, mainly with regard to emphasis on concepts and ways of knowing (Garegae, 2008). Iversen (1992) concur that statistics has its own subject matter which is reasoning from uncertain data and taking decision in the face of uncertainity and its origins differs from that of mathematics. Thus we surmise that teachers with deficient content knowledge of statistics will also lack pedagogical knowledge for teaching statistics.

Furthermore, Cardoso (2007) showed that teachers wrongly analyzed concepts like mean and median. The results were diagnosed through the observation that some teachers attributed symmetry to all data distributions; leading to the confusion between median and mean. There is evidence that teachers have difficulties in interpreting measures of variation (Coutinho & miguel, 2007; Silva, 2007). Reading (2004: p85) asserts that the teaching of measures of variariation in schools, such as standard deviation is notorious among teachers as being particularly cumbersome resulting in many teachers having difficulty in teaching the concept to learners or avoiding it altogether. In some cases, teachers encounter problems with reasoning about variation (Silva & Countinho, 2008).

Silva and Coutinho (2008) conducted a research to explore reasoning about variability by teachers, and found that none of the teachers could do that. Silva and Coutinho attributed this deficiency to lack of understanding of mean, deviations from the mean, the interval of *k* standard deviations from the mean and estimation of frequency in this interval. Instead it found that the teachers' predominant reasoning about variation was verbal, with the understanding that standard deviation is a measure of sample homogeneity. On the basis of all these Silva and Coutinho concluded that by being limited to the verbal reasoning about variation does not allow mathematics teachers to teach the meaning of measures such as standard deviation, and this restricts them to the teaching of algorithmically. In other words, their teaching is more procedurally than conceptually focused.

The use of theoretical traditional approach for teaching data handling where emphasis is on identifying the correct formula and performing a calculation, as opposed to data-driven approach using real data to emphasize statistical principles, procedures and statistical reasoning is significantly prevalent (North, Scheiber, & Ottaviani, 2010; Wessels & Nieuwoudt, 2010).Groth (2007) observed that at times mathematics teachers show some of the same cognitive difficulties as learners in understanding statistical concepts, as a result these teachers "tend to focus on machenics of constructing plots rather than interpretation, and on calculation rather than on data" (Watson, Burrill, Landwehr, & Scheaffer, 1992: p.51).

There is therefore a need to establish a close link between the intended mathematics curriculum reforms and teacher development initiatives.In essence, the intended pre-service and in-service teacher programmes have to be informed by classroom experiences or reflect on what happens in class. This means, during pre-service teacher education, aspirant teachers have to be taught aspects of the curriculum such as data handling in addition to professional training that deals with teaching methodologies. Further content knowledge of data handling must be consolidated to enrich aspirant teachers' subject matter knowledge.

On the other hand, in-service teacher education has to keep abreast of developments taking place within the mathematics education. It is through the latter that teachers are kept up-to-date with changes made in the curriculum as well as ensuring that teachers are always ready and well prepared to deliver the newly presented curriculum that may even include aspects such as data handling.

Indeed, it will be suicidal for teacher education not to work in line with the development in school mathematics curriculum. Put differently, for teacher education programmes to ignore what is happening in school mathematics curriculum would be counter-productive. Teachers may find themselves not being able to teach new aspects of the curriculum which they were never taught before largely because of their deficient content knowledge or insufficient pedagogical knowledge or both.

Another factor to consider is that teachers tend to be enthusiastic with what is being taught during in-service teacher programme if it has any relevance to what they do in class. In this case teachers can display positive attitude and probably participate with interest in the programme if they see its relevance to their everyday instruction. Then, there is a strong likelihood that teachers will effectively grasp what is being taught to them, and further transmit it to their learners. On the other hand, when the content of the in-service teacher programme is not related to any aspects of the school mathematics curriculum, teachers may switch-off and just flow unwillingly with the activities of the programme. Upon return to their respective schools it will be business as usual.

On the other hand, before changes are made in school mathematics curriculum,changes must be communicated to teachers and be empowered on how to manage the change. Teachers have to be informed in advance about intended reforms as well as how to deal with reviewed aspects of the curriculum. Otherwise, teachers are most likely to encounter difficulties in teaching the newly introduced aspects of the curriculum. It is this conception that forms the backdrop of this study.

METHODOLOGY

Study design

The study followed a descriptive survey research design. Teachers completed a questionnaire to elicit problems they experienced when teaching data handling.

Sample

The target population of this study consisted of 100 grade 11 mathematics teachers from public schools in the Gauteng province. Public schools are government-aided to some extent where government provides the minimum, and parents contribute to basics and extras in the form of school fees (Education, 2010). Government also assists teachers from public schools with funds to attend the educational development programmes to improve the teachers' knowledge.A stratified sampling technique was used to select a sample of teachers consisting of 58 males and 42 females. The sample was classified into two subgroups based on schools' geographical location, namely township and urban.

Instrument

The study used a teacher questionnaire to collect data on aspects of data handling. The questionnaire consisted of 17 items focusing on aspects of data handling taught in mathematics grade 11. For an example, one item relating to the measure of central tendency with grouped data was: *how competent do you feel when teaching learners to do calculations of measures of central tendency (mean, mode median) with grouped data?*

Respondents had to demonstrate their competence on a Likert type scale. The Likert type scale was anchored by 1= Not all competent; 2= Not competent, 3= Competent, and 4= Very competent.

VALIDITY AND RELIABILITY OF INSTRUMENT

The teacher questionnaire was validated using content and construct validity. Content validity was carried out by involving experts in statistics and statistics education field. Each expert was given a validity form to judge whether the questionnaire measured the intended content area of the study (cf. Gay & Airasian, 2003). For construct validity, a factor analysis was performed to ascertain if the individual questions contributed to the dimensions as in the questionnaire.The analysis was computed by using Statistical Package for the Social Sciences (SPSS). Reliability was determined by computing Cronbach's (1951) alpha as a measure of the internal consistency of scores from the questionnaire. The value of alpha was 0.950. The values for reliability coefficients range from 0 to 1.0. A coefficient of 0 means no reliability and 1.0 means perfect reliability. Generally, if the reliability of a test is above 0.80, it is said to have very good reliability; if it is below .50, it would not be considered a very reliable test (George & Mallery, 2003). The value of 0.950 was seen to be excellent based on the rule of thumb.

DATA ANALYSIS

Descriptive statistics (frequencies) were used to analyze the data collected. The percentages of the teachers' actual problems in the teaching of data handling are reported in table 1.

Table 1: Teachers' problems in teaching data handling (n=100)

	Scales items	%
1	Explaining the meaning of measures of central tendency (mean, mode, median) to learners.	5.0
2	Teaching learners to do the calculations of measures of central tendency (mean, mode, median) with an ungrouped data.	8.0
3	Teaching learners to do the calculations of measures of central tendency (mean, mode, median) with the grouped data.	9.0
4	Interpreting the measures of central tendency (mean, mode, median) for learners.	14.0
5	Explaining the meaning of measures of dispersion (standard deviation, range, and variance) to learners.	31.0
6	Teaching learners to do the calculations of measures of dispersion (standard deviation, variance, range).	25.0
7	Interpreting the measures of dispersion (standard deviation, variance, range) for learners.	33.0
8	Teaching learners the calculations of contents of five number summary (lower quartile, middle quartile, upper quartile) to learners.	12.0

9	Teaching learners to make drawings of box-and-whisker diagrams on a number line.	14.0
10	Teaching learners to construct stem-and-leaf plot.	13.0
11	Teaching learners to use stem-and-leaf plot to determine the quartiles (lower quartile, median and upper quartile).	21.0
12	Constructing cumulative frequency tables for learners.	14.0
13	Making a drawing of an Ogive (cumulative frequency curves) for learners.	20.0
14	Interpreting an Ogive (cumulative frequency curves) to learners.	29.0
15	Teaching learners to represent bivariate numerical data as a scatter plot.	37.0
16	Determining the line of best fit on a scatter plot for learners.	39.0
17	Teaching learners to select a function that best fit the data.	41.0

In order to probe the problems encountered in the teaching of data handling: the study measured if the teachers had problems with (i) interpretation and determination of measures of dispersion (item 5 to 8), (ii) representation of data using graphs/plots (item 9 to 17), and (iii) interpretation and determination of measures of central tendency (item 1 to 4).

The table 1 shows that few teachers have problems with interpretation and determination of measures of central tendency. This means that teachers have problems with explaining and showing calculations of measures of central tendency (i.e. mean, median and mode) to learners. In this category, it can be seen that only 5% of teachers have problems with explaining the meaning of measures of central tendency (mean, mode, median) to learners. Of all the teachers 8% have problems with teaching learners to do the calculations of measures of central tendency (mean, mode, median) with an ungrouped. Also, 9% of the teachers have problems with teaching learners to do the calculations of measures of central tendency (mean, mode, median) with the grouped data, and 14% of the teachers have problems with interpreting the measures of central tendency (mean, mode, median) for learners).

It also appeared that most teachers have problems with interpretation and determination of measures of dispersion. This means that most of the teachers have problems with explaining and showing calculations of measures of dispersion (i.e. standard deviation, variance, quartiles) to learners. In this category 33% of the teachers have problems with interpreting the measures of dispersion (standard deviation, variance, range) for learners. It was observed that 31% of the teachers have problems with explaining the meaning of measures of dispersion (standard deviation, range, and variance) to learners. Few teachers, 25% of the teachers have problems with teaching learners to do the calculations of measures of dispersion (standard deviation, variance, range), and at least 12% of the teachers have problems with teaching learners the calculations of contents of five number summary (lower quartile, middle quartile, upper quartile).

Furthermore, most teachers have problems with teaching learners to representing data on graphs/plots (i.e. 14% of the teachers have problems with teaching learners to make drawings of box-and-whisker diagrams on a number line. Of all teachers 13% have problems with teaching learners to construct stem-and-leaf plot; 21% of the teachers have problems with teaching learners to use stem-and-leaf plot to determine the quartiles (lower quartile, median and upper quartile). Furthermore, 14% of the teachers have problems with constructing cumulative frequency tables for learners, and 20% of the teachers have problems with making a drawing of an Ogive (cumulative frequency curves) for learners; 29% of the teachers are not with interpreting an Ogive (cumulative frequency curves) to learners; 37% of the teachers have problems with teaching learners to represent bivariate numerical data as a scatter plot; 39% of the teachers have problems with determining the line of best fit on a scatter plot for learners; 41% of the teachers have problems with teaching learners to select a function that best fit the data).

DISCUSSION

In grade 11 the chapters on data handling is based on a number of activities. These activities relate to calculations and representations of measures of central tendency, measures of dispersion in univariate numerical data, A five number summary, box and whisker diagrams, Ogives, and variance and standard deviation of sets of data; Effectively communicate conclusions and predictions that can be made from the analysis of data; and differentiate between symmetric and skewed data and make relevant deductions (De Jager, Dewet & Raubenheimer, 2006). On the contrary, Table 1 above shows that most of the teachers have problems with representation of data using graphs/plots**,** interpretation and determination of measures of dispersion, and interpretation and determination of measures of central tendency respectively.

In the category of representation of data using graphs/plots, for example 37% of the teachers have problems with teaching learners to represent bivariate numerical data as a scatter plot; also, 39% of the teachers have problems with determining the line of best fit on a scatter plot for learners and 41% of the teachers have problems with teaching learners to select a function that best fit the data. These findings corroborate finding by Watson, Burrill, Landwehr and Scheaffer (1992) that teachers tend to focus on machenics of constructing plots rather than interpretation, and on calculation rather than on data.

In the category of interpretation and determination of measures of dispersion, Table 1 showed that 33% of the teachers have problems with interpreting the measures of dispersion (standard deviation, variance, range) to learners; and 31% of the teachers have problems with explaining the meaning of measures of dispersion (standard deviation, range, and variance) to learners. These findings corroborate finding by Silva and Coutinho (2008) that by being limited to the verbal reasoning about variation does not allow mathematics teachers to teach the meaning of measures such as standard deviation, and this restricts them to the teaching of algorithms. Also, the findings corroborate those by Reading (2004) that the teaching of measures of variariation in schools, such as standard deviation, is not producing intended results among teachers and are perceived as being particularly cumbersome resulting in many teachers having difficulty in teaching the concept to learners or avoiding it altogether.

According to Nicholson and Darnton (2003), statistics may pose particular problems if the teacher has not studied statistics, which in South African school mathematics curriculum is taught by mathematics teachers who lack statistics subject matter knowledge. Also, if the teacher is not a statistics subject specialist problems may be experienced because teaching mathematics and statistics is different compared with other subjects. The difference is mainly with regard to emphasis on concepts and ways of knowing (Garegae, 2008). Obviously the statistics content problems teachers experience suggest that changes were incorporated in the mathematics curriculum without first mounting an appropriate in-service teacher programme to orientate teachers with the desired changes and ensuring that teachers can handle these changes. In other words, it seems data handling was introduced without first ascertaining teachers knowledge that is needed to teach it. Ideally, in-service teacher programme should precede implementing changes in the class, otherwise teachers will encounter difficulties managing effected changes. This study recommends that the topics identified here as posing problems to teachers should be given preference in in-service training programmes.

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