TEACHER KNOWLEDGE AND CONFIDENCE IN GRADE 8 AND 9 DATA HANDLING AND PROBABILITY

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This research reports on the profiling of teachers with regard to statistical knowledge, beliefs and confidence to inform the development of a professional development course for Grade 8 and 9 teachers. Poor TIMMS results and continuing disappointing mathematics results over the whole spectrum in South Africa necessitate more efficient professional development of in-service teachers. Watson's profiling instrument (2001) was adapted and used to profile 90 mathematics teachers in Pretoria, South Africa. Although quite a number of these teachers attended professional development workshops and courses in statistics, they still teach traditionally, as opposed to a data driven approach using authentic data. Almost all teachers indicated high levels of confidence in teaching statistics but show low levels of statistical thinking when applying their knowledge in context.

BACKGROUND

Local context

Statistics plays a more prominent role in mathematics curricula all over the world than a few years ago. In South Africa, as in many other countries, quite a number of mathematics teachers do not have a sound background in statistics (North & Scheiber, 2008; North & Zewotir, 2006; Wessels, 2009), undermining their competence and confidence to teach topics in data handling and probability. Even teachers who have studied statistics as a major or as part of their mathematics training sometimes only have theoretical knowledge and lack pedagogical knowledge for teaching statistics (Batanero, Godino, & Roa, 2004). Ingvarson, Beavis, Bishop, Peck and Elsworth (2004) conclude from their research that classroom practices of teachers have a direct effect on student outcomes and that these practices "... are reciprocally related to the teachers' knowledge, beliefs and understandings. These in turn are shaped by the school and their educational and professional development experiences, as well as school system factors".

Teachers in South Africa are, because of bad mathematics results at exit level, increasingly under pressure to keep up with the demands of, amongst others, statistics content, forms and documentation of assessment, and large classes. Although a series teacher training initiatives in statistics started when ICOTS6 were held in South Africa in 2002 and were strengthened when the national statistics office (STATS SA) provided financial assistance for professional development in statistics by launching the Maths4Stats campaign in 2006 (North & Scheiber, 2008), many teachers did not have any exposure to professional development in statistics by 2008 (Wessels, 2009). Virtually no research about the statistical content knowledge as well as pedagogical content knowledge of South African teachers, their beliefs about statistics education, their confidence to teach different statistics concepts and their levels of statistical thinking have been documented (Wessels, 2009). Against the background of poor learner achievement in mathematics in South Africa and increasing demands for the assessment of mathematics teachers' knowledge and competencies worldwide, the research project focused on profiling Grade 8 to 12 mathematics teachers concerning their knowledge, practices, confidence and beliefs with regard to statistics. A series of professional development workshops were designed and presented to a group of volunteer teachers. This paper reports on the first part of the research, namely the profiling of teachers for gathering information about teacher knowledge, practice and beliefs in the field of statistics and to assess professional development needs.

Profiling teachers

Effective teaching and learning in mathematics and statistics pivot on a number of crucial factors, of which effective teachers are the most important (Ingvarson et al., 2004). In a literature review of research by these authors, a number of factors were found to impact on teacher

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effectiveness, especially in the teaching of mathematics. Teacher knowledge of the subject and pedagogical content knowledge is crucial, but the teacher's organisation and application of the knowledge are equally important. Qualifications were found to be important in some studies, but contradictory findings were also recorded. Teacher beliefs about teaching and mathematics were found to play an important role in the shaping of teaching practices. Learners showed higher performance when their teacher majored or minored in the subject they were teaching. Moreover, learners whose teachers had received professional development in higher order thinking skills outperformed learners whose teachers had not and learners also performed at a higher level if their teacher received professional development in working with different learner populations.

Teacher knowledge is multi-faceted. Schulman (1987) identified seven different kinds of teacher knowledge necessary for effective teaching, including content knowledge, pedagogical content knowledge, curriculum knowledge, knowledge of students and their characteristics, knowledge of educational contexts, and knowledge of education ends, purposes and values. Hill, Ball and Schilling (2008) refined the concept of mathematical knowledge for teaching (MKT) which they define as "… the mathematical knowledge needed to carry out the work of teaching of mathematics". They divided MKT in two main categories: subject matter knowledge and pedagogical content knowledge. Subject matter knowledge contains three strands, namely common content knowledge, specialised content knowledge and knowledge at the mathematical horizon, with pedagogical content knowledge consisting of knowledge of content and students, knowledge of content and teaching, and knowledge of curriculum.

In order to plan meaningful professional development for teachers, it is necessary to profile teachers according to their beliefs, confidence and background as well as their mathematical knowledge for teaching. Watson (2001) developed a teacher profiling instrument, based on Schulman's knowledge types, which was adapted for use in other studies (Watson, Beswick, & Brown, 2006; Fitzallen, 2004) and also for the research described in this paper.

THE STUDY

Pilot study

The teacher questionnaire was piloted with 28 Grade 4-9 teachers at Sasol's Osizweni project in the Mpumalanga province of South Africa after a series of in-service training workshops. The aim of piloting the research was twofold: firstly to try out the questionnaire in the South African context and secondly to assess further professional development needs of the group of teachers after their statistics training workshops. Despite three workshops of four and a half hours each on Data Handling and Probability and three assignments on the content of the workshops, the teachers' answers to the content-related questions in the questionnaire were disappointing. Most of the teachers took more than two hours to complete the questionnaire; therefore two sections were subsequently dropped from the questionnaire to shorten it. In a group interview after completing the questionnaire all the teachers expressed the need for further training in data handling and probability as they felt that the lack of content knowledge and pedagogical content knowledge in this field seriously undermined their ability and confidence to teach the subject.

Participants in the main study

Twenty government and three private secondary schools (Grade 8 - 12) participated in the research, all having a mixed learner population regarding cultural groups. Out of 183 questionnaires that were handed out at the 23 schools 90 were returned: 39 from schools with Afrikaans and 51 from schools with English as language of instruction. In only 24 questionnaires all sections were completed. The gender distribution of all returned questionnaires was 22 male and 56 female, with 12 questionnaires not indicating gender.

Instrument

An instrument making judgments about teacher knowledge must be non-threatening and encourage authentic teacher reflection on beliefs, knowledge and practices to pass ethical requirements (Watson 2006; Gal, 2007). The Profiling Instrument developed by Watson was adapted to the South African context, e.g., by changing the currency in Task 1 from Dollar to Rand

and covered teacher preparation, practices, knowledge, beliefs, confidence, background and professional development experiences. Shaughnessy (2007) describes this profiling instrument as non-threatening, obtaining information about teachers' content knowledge and pedagogical content knowledge of statistics by asking them to suggest appropriate as well as an inappropriate answers that they think learners would give to a number of statistical tasks. The questionnaire was designed to be completed in a one to two hour group or individual interview and was adapted for the South African situation. However, except for a group of eight teachers at one school, the South African teachers completed the questionnaires individually as group interviews were not feasible because of teachers' busy schedules.

RESULTS

Due to the limited space available, the results of only six of the eight sections of the questionnaire are discussed. Relative values for all responses on questions are given, not only for the 24 fully completed questionnaires.

Section 1: Preparation for teaching a unit in Data Handling and Probability

The data on teacher preparation revealed that less confident teachers spent more time on preparation than confident teachers and that the teachers who spent little time on preparation, were less inclined to complete the questionnaire and indicate confidence levels (Figure 1).

Time spent on preparation	**% teachers**	**% of these teachers indicating high levels of confidence**	**% teachers not indicating confidence levels**
Less than 1 hour	12	72	9
1 to 6 hours	41	57	35
More than 6 hours (days/weeks)	26	0	83
No responses/ Anomalous responses	21		

Figure 1. Preparation and confidence levels

Section 3: The topics 'Sample' and 'Average' in Data Handling and Probability

Teachers' explanations of the word 'sample' were analysed according to an adapted SOLO framework to determine their levels of statistical thinking (Watson, 2006). Almost 60% of teacher responses were on the third and fourth SOLO level (multistructural and relational), indicating higher levels of statistical understanding. This result is in stark contrast to teachers' thinking levels when they had to transfer their understanding of the concept of sample to a social context in a newspaper article (see 'Handgun' article in Section 6). Teachers' confidence levels for teaching the topic of sampling however are on average 4.1 on a scale of 5 with 77% of them rating their own confidence levels a four or a five (see Section 4). These results point to high confidence levels concerning the theoretical knowledge of the concept of sampling despite an inability to apply this knowledge in context.

An adapted SOLO framework was likewise used for analysis of teachers' explanations of the meaning of "average" (Watson, 2006). Seventy seven percent of responses were on third or fourth SOLO level, which is consistent with teachers' high confidence levels on the teaching of the topic (see Section 4).

Section 4: Teacher confidence in the teaching of Data Handling and Probability

Confidence levels of 1 and 2 on a scale of 5 were regarded as low confidence levels while levels of 4 and 5 were grouped together as high confidence levels. Responses that are not reflected in the graph are responses indicating a 3 on the scale of 5 and 'no responses' (Figure 2). Teachers indicated very high levels of confidence in teaching Data Handling topics. These high confidence levels are not consistent with teachers' levels of statistical thinking on data handling problems in social contexts (see Section 3 and 6). Sampling and probability topics are areas where a number of teachers expressed somewhat lower levels of confidence (Figure 2). A trend that emerged was that teachers who attended professional development workshops or courses feel more confident than those who did not.

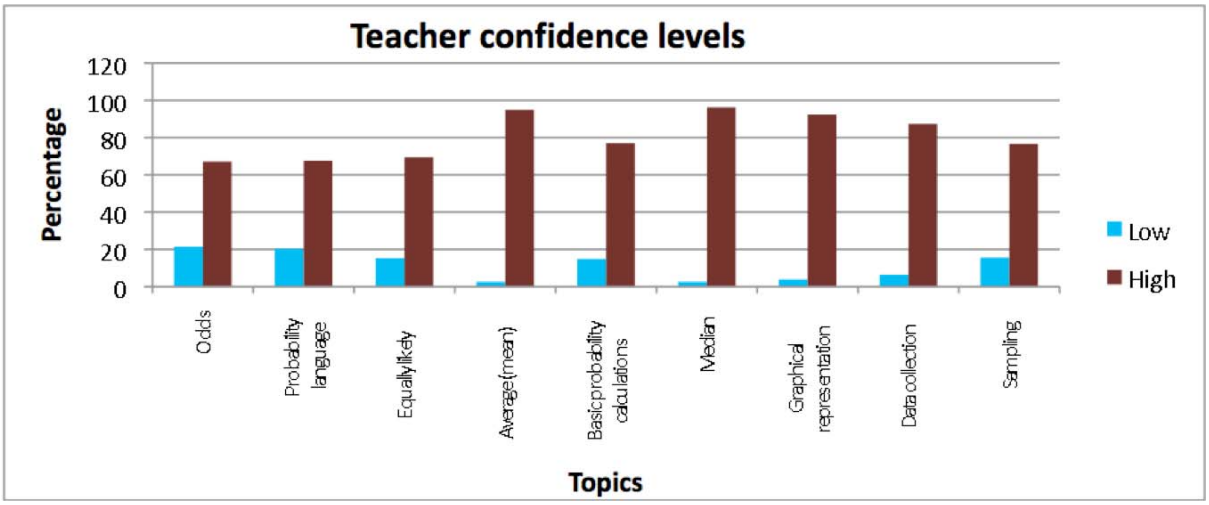

Figure 2. Teacher confidence levels

Section 6: Teacher comments on Learner Survey Items to determine content knowledge and pedagogical content knowledge

Five learner tasks were given and teachers were asked to give an example of an appropriate as well as an inappropriate response that learners would have given. The first and third tasks were about sampling, the second about graph interpretation, the fourth about graphing and informal inferential reasoning while the last task was on probability. Responses to this section were disappointing. Many teachers did not respond at all to the questions in this section, others only answered some of the questions. Virtually no inappropriate responses to any learner item were suggested. Generally, teacher responses showed statistically inappropriate answers, e.g., for Learner item #3 which cited a media report about a survey on handguns in schools in Chicago (sampling).

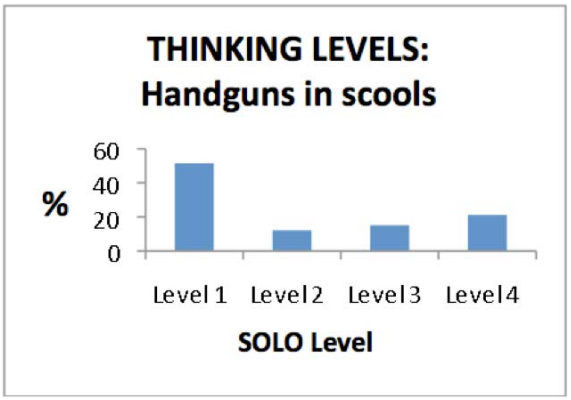

Figure 3. Statistical thinking levels: Article on Handguns in schools

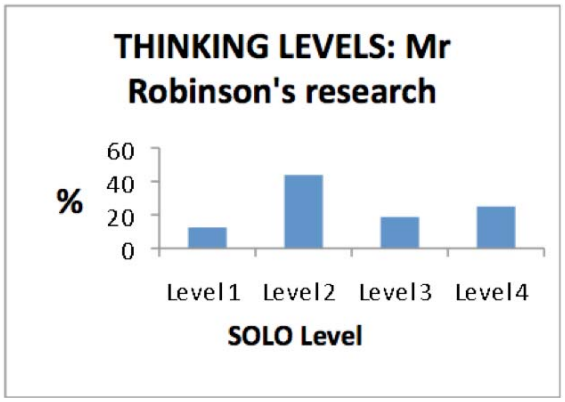

Figure 4. Statistical thinking levels: Article on Mr Robinson's research

More than 50% of the teachers responded on an emotional level to the Handgun task giving statistically inappropriate answers when asked to criticise claims about the issue (Figure 3). An example of a statistically inappropriate answer is "Weapons must be banned; schools will be extremely dangerous with this number of weapons available". Only 12% of responses were on a statistically appropriate level. An example of a statistically appropriate response is "Chicago is only one area in the US and does not represent the whole US". High crime levels in South Africa and the exposure of citizens to newspaper reports about violence in schools might have contributed to these emotional responses.

Learner item #4 deals with a newspaper report stating claims by a Mr Robinson about the detrimental effect of family cars on health of citizens. Although 61% of the teachers represented

Mr Robinson's ideas with appropriate graphs, more than half of the teachers asked statistically inappropriate questions about Mr Robinson's claims, e.g. "What must be done to reduce that high risks? What material can be used to avoid the accidents on the road?" (Figure 4).

Only a few teachers responded to Learner item #5 (coin tossing before a cricket match) and many of the responses given were incorrect. This result may point to a lack of knowledge and experience with probability concepts and is also consistent with lower confidence levels for the teaching of probability topics.

Sections 7 and 8: Teacher background and professional development

Teaching experience of participants ranged from a few months to 30 years with 55% teaching less than 14 years and 25% of teachers falling in the 5-9 years experience interval. As in the case of teaching experience, professional development experiences of teachers ranged widely from no professional development experience to a post-graduate diploma in Statistics Education. Fifty-seven precent of respondents did not participate in any professional development experiences. No trend regarding teaching experience and completion of the questionnaire could be found.

DISCUSSION

Several teachers were not positive about completing the questionnaire. They felt that it took too long and that they had to put in too much effort to answer some of the questions (e.g., Learner items in Section 6). Another general comment of teachers was that they did not have enough content knowledge to answer the questions. Except for one school where teachers completed the questionnaire in a group, teachers completed the questionnaire in their own time and may not have felt obliged to complete all sections as may have happened when completing it in a group interview. Quantitative analysis could not be included in the results given above because of the fact that only 24 teachers completed all sections of the questionnaire, and the small numbers of completed questionnaires rendered any quantitative analysis speculative.

Despite the fact that 60% of teachers indicated that they studied Data Handling and Probability topics during their teacher education for at least a semester, statistical thinking levels of their responses show that they are unable to apply their knowledge to contexts such as newspaper articles and short research reports. Many teachers still use traditional methods of teaching data and probability topics (Section 2) instead of a data driven approach focusing on the development of statistical reasoning and quite a number of them also employ traditional methods when learners experience problems with specific topics. Worth emphasising is the discrepancy between teachers' confidence levels and their statistical thinking levels. It would seem that many teachers feel quite confident in teaching statistics, but might be doing it in a completely traditional way and are ignorant of the essence and nature of statistics, also in comparison to mathematics.

It is however useful to consider the picture not in the context of the large group, but looking at individual or small group profiles. When reflecting for example on the 24 questionnaires which in which all sections were completed, interesting facts and trends come to light. Twenty one teachers in this group indicated that they enjoy teaching Data Handling and Probability; two said that they sometimes enjoy it while another one said that she enjoys it but sometimes finds it boring to teach. Only 3 of the 24 teachers who completed all sections did not undergo statistics training during their teacher education, with 10 of them having undergone training in statistics for a year or more and 7 more spent a semester studying statistics. The implication might be that these teachers felt confident enough to complete all questions and might be more positive about teaching statistics, therefore putting more effort into the completion of the questionnaire. Teaching experience (2 to 29 yrs) and gender (10 males and 12 females) did not play any significant role in this group, and teaching experience did not play a role.

Limitations of the instrument included the length, which contributed to the fact that only 27% of the teachers completed all sections of the questionnaire. Interpretation of the data was limited by the fact that many teachers did not complete the last few sections which included questions on teacher background such as experience, initial teacher training and participation in professional development initiatives.

CONCLUSION

The profiling instrument provides a broad but incomplete picture of mathematics teachers' statistical knowledge, practice and beliefs. Measuring and interpreting teacher knowledge is not a clear-cut venture. Hill, Ball and Schilling (2008) describe the domain of teachers' knowledge of content and of students as "underconceptualized and understudied" and emphasise the necessity to use explicit criteria to guide measure development. It will be necessary to utilise teacher interviews and classroom observations to add to the picture compiled by the profiling instrument, as the reasons for specific answers or the lack of answers to questions are not always clear from the responses in the questionnaire. Developers of in-service teacher education programs in statistics, whether part of mathematics education or on its own, should take cognisance of the usefulness of a profiling instrument supplemented by data from interviews and classroom observations for informing the design of such programs.

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