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The Use of Principles of Learning Statistics to Promote the Teaching and Learning of Statistics at High School in South Africa

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Abstract

Several studies on methods of improving learners' general mathematical competence have relevance for teaching statistics. Many of these studies help reinforce and extend the research on statistical learning. Based on these studies in the context of constructivist the general principles of learning statistics have been formulated. In South Africa, the high schoolMathematics Curriculum does not mention any theory or principleson how to teach and learn statistics but provides teachers with specific aims and skills to be developed. Despite this provision, many teachers may be unaware of the growing body of research related to teaching and learning of statistics. This is an exploratory study sought to explore the use of principles of learning statistics to promote the teaching and learning of Statistics at high school. The sample of 66Grade high school Mathematics teachers (58 females and 42 males) was randomly selected to respond to 26-item of Likert questionnaire on using the general principles of learning statistics. Teachers' responses were reported descriptively as frequencies and percentages. The results lead to the conclusion that teachers training need to strengthen and spread the teaching and learning of statistics by using different various aspects of reforms in statistics education and theories such principles of learning statistics.

Keywords: Statistics education reforms; Principles of learning Statistics; Statistical learning, Outcomes, Teaching Statistics

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Introduction

In South Africa, the Mathematics curricula in high school includes Statistics or Data handling (Department of Basic Education [DBE], 2005).The South African Mathematics Curriculum does not alludeabout any theory on how to learn and teach statistics. However, there are some basics of learning statistics outlined in the Curriculum and Assessment Policy Statement (CAPS). The Mathematics CAPS provides teachers with specific aims and specific skills (DBE, 2011, p. 8-9). Thus, these mathematical skills need to be also developed in Statistics.

Reforms in statistics education are aimed at changing the attitudes towards Statistics and improving the teaching and learning of Statistics (Tishkovskaya & Lancaster, 2012). Regardless of where you teach statistics, a major concern is how to ensure that the learners understand statistical ideas and can apply what they learn to real-world situations (Garfield, 1995). Based on the relevant research in the context of constructivist principles, Garfield formulated somegeneralprinciples of learning statistics.

Although statistics teachers often express frustration about learners' difficultiesin learning and applying course material, many may be unaware of the growing body of research related to teaching and learning statistics (Garfield, 1995). This might be the case in South Africa, with the inclusion of Statistics in the Mathematics curriculum(Wessels, 2008). There is a need for South African Mathematics teacher to know about how learners learn statistics to improve their teaching,thus the useof various aspects of reforms and principles of learning statistics during instructions is important.

The Purpose and Question of the study

The current paper sought to explore the use of principles of learning Statistics to promote the teaching and learning of Statistics at high school in South Africa. This paper was guided by the following research question.

- How do high school teachers promote the teaching and learning of statistics using the principles of learning Statistics?

The answers to this investigation will form part of the explanations that the learning of statistics requires learners to constantly engage in statistics class activities aimed at the attainment of the principles of learning Statistics.

Literature Review

In this study the literature review is subdivided into two sections.In the first section, the purpose is to understand and describe the major foci for contemporary statistics teaching.In second section, the purpose of the review is to elaborate on the principles of learning Statistics.

Major foci for teaching Statistics

Tishkovskaya and Lancaster (2010) established a variety of innovative instructional techniques employed in many Statistics classes using the three major foci for contemporary statistics teaching.

Develop Statistical Literacy and Critical Thinking Skills

Statistical Literacy

Ben-Zvi and Garfield (2004) explained that statistical literacy includes basic and important skills that may be used in understanding statistical information or research results. These skills include being able to organize data, construct and display tables, and work with different representations of data. Statistical literacy also includes an understanding of concepts, vocabulary, and symbols, and includes an understanding of probability as a measure of uncertainty. Gal (2002) described statistical literacy as the ability to interpret, critically evaluate, and communicate about statistical information and messages. delMas (2002) agreed that to demonstrate or develop an understanding in statistical literacy, teachers can ask learners to; identify examples or instances of terms or concepts; describe graphs, distributions, and relationships; rephrase or translate statistical findings, or interpret the results of a statistical procedure. Hence, teachers must perceive the nature of the task in order to identify whether instruction promotes literacy.

Critical Thinking Skills

Both critical thinkingand statistical literacy refer to areas of thinking skills and dispositions which are necessary for social participation of responsible citizens in democratic societies (Gal, 2002; Gal, 2003; Schield, 2004). Whereas critical thinking focuses on rather general thinking skills and strategies which are considered useful almost regardless of specific content domains, statistical literacy concentrates on learners' strategies of dealing with data and statistical representations or models (Aizikovitsh-Udi1 & Kuntze, 2014).

Integrate New Authentic Assessment Techniques

Authentic assessment is used to describe the means of measuring student performance on tasks that are relevant to the student outside of the school setting. Authentic assessment is a viable vehicle to assess a student's understanding of statistics (Colvin & Vos, 1997). The use of real-world situations in assessment settings is promoted by the National Council of Teachers of Mathematics (NCTM) Assessment Standards and other reform documents (NCTM, 1989; 1993; Mathematical Sciences Education Board, 1993).

Develop the Skill of Communicating Statistics

The ability to communicate statistics evidence is identified as an important theme in the connection between statistics and the outside world (Tishkovskaya & Lancaster, 2010; 2012). Greenfield (1993), in addressing the question of communicating statistics, says that a change of

culture is needed in how technical information is communicated to practitioners and the public in such a way that they can use and understand it. According to Des Nicholls (2001); Rumsey (2002); and Schield (2004) one aspect of communicating statistics is asking learners to explain terminology and to interpret the statistical results in everyday words.

The Principles of Learning Statistics

Several research studies formulated principles of learning statistics offering a general framework that can be applied to a variety of courses. This paperfocuses on the eight principles of learning statistics (Garfield and Ben-Zvi, 2007).

Learners Learn by Constructing Knowledge

Biehler, McCown and Snowman (2009, p. 325) maintain that each learner builds a personal view of the world by using existing knowledge, interests, attitudes, and goals to select and interpret currently available information. Lehrer and Schauble (2007) recognized that ignoring, dismissing, or merely "disproving" the learners' current ideas will leave them intact and they will outlast the thin veneer of course content.

Learners Learn by Active Involvement in Learning Activities

Jacques and Salomon (2007, p. 10-11) confirmed that learning is not a spectator sport. Furthermore, they established that learners do not learn a great deal by sitting in classes and listening to teachers, memorising pre-packaged assignments, and reproducing the expected answers. This is supported by the National Research Council (1989) who revealed that learners appear to learn better if they work in small cooperative groups to solve problems and learn to argue convincingly for their approach among conflicting ideas and methods.

Learners Learn to do well only what they practise doing

Garfield (1995), described that practice may mean hands-on activities, activities using cooperative small groups, or work on the computer. Learners also learn better if they have experience in applying ideas in new situations. Furthermore, De Corte and Masui (2008) asserted that classroom activities should firstly monitor learners' progress toward the acquisition of all components of competence. Secondly, activities should provide diagnostic feedback about learners' deep understanding of content and their mastery and productive use of learning and thinking skills.According to Watson and Shaughnessy (2004); and Pfannkuch (2005) merely repeating and reviewing tasks is unlikely to lead to improved skills or deeper understanding.

Teachers should not underestimate the Difficulty Learners have in Understanding Basic Concepts of Probability and Statistics

Many research studies have shown that ideas of probability and statistics are very difficult for learners to learn and often conflict with many of their own beliefs and intuitions about data and chance (Shaughnessy, 1992; 2007; Garfield & Ahlgren, 1988).

Teachers often Overestimate how well their Learners Understand Basic Concepts

According to Garfield and delMas (1991);Clark, Karuat, Mathews, and Wimbish (2003), studies have shown that although learners may be able to answer some test items correctly or perform calculations correctly, they may still misunderstand basic ideas and concepts.

Learning is enhanced by having learners become Aware of and confront their Misconceptions

Several research studies in statistics as well as in other disciplines show that learners' errors in reasoning (sometimes appearing to be misconceptions) are often strong and resilient. They are slow to change, even when learners are confronted with evidence that their beliefs are incorrect (Bransford,Brown, Cocking, Donovan, & Pellegrino, 2000). According to delMas and Bart (1989) and Shaughnessy (1977) learners learn better when activities are structured to help them evaluate the difference between their own beliefs about chance events and actual empirical results

Calculators and Computers should be used to help Learners Visualize and Explore Data, not just to Follow Algorithms to Predetermined Ends

According to Rubin, Rosebery and Bruce (1988) computer-based instruction appears to help learners learn basic statistics concepts by providing different ways to represent the same data set. or by allowing learners to manipulate different aspects of a particular representation in exploring a data set.

Learners Learn better if they Receive Consistent and Helpful Feedback on their Performance

Garfield (1995); Garfield and Chance (2000) stated that learning is enhanced if learners have opportunities to express ideas and get feedback on their ideas. Garfield and Chance (2000) added that feedback should be analytical and come at a time when learners are interested in it. There must be time for learners to reflect on the feedback they receive, adjust, and try again (AAAS, 1989).

The South African curriculum document does not allude on statistical literacy. But this document lists the aims of Mathematics, and the specifics skills to develop in Mathematics (DBE, 2011, p. 8-9). The curriculum stipulates that to develop essential mathematical skills, learner should: develop the correct use of the language of Mathematics, develop number vocabulary, number concept and calculation and application skills, learn to listen, communicate, think, reason logically and apply the mathematical knowledge gained, learn to investigate, analyse, represent and interpret information, learn to pose and solve problems, build an awareness of the important role that Mathematics plays in real life situations including the personal development of the learner (DBE, 2011, p. 8-9). Furthermore, the Curriculum Statement, uses words that develop learners' statistical literacy and thinking skills (DBE, 2011, p. 15, 27, 39, 48).

The South African Mathematics Curriculum does not specify how to learn and teach statisticsbut gives expression to the knowledge and skills worth learning in South African schools (DBE, 2011, p. 4-5). Thus, effort must be made to ensure that teachers understand how vital their statistics pedagogic content knowledge (SPCK) is in developing learners in Statistics

class.Wessels (2008), pointed out that, education in South Africa is still in its early stages: much needs to be done to prepare mathematics teachers to teach the widened Statistics curriculum in such a way that learners are statistically literateafter the completion of high school.Ijeh and Onwu (2012), recognised that, in South Africa, at high school level, statistics is taught by teachers who may or may not be specifically trained to teach statistics. Unfortunately to the knowledge of these two researchers, little research has been done on the extent to which teachers possess the statistical pedagogic content knowledge (SPCK).

In Kenya and Uganda, Statistics is offered at primary and secondary school level. Odhiambo (2002) revealed that, modern Kenyan society in general and industry in particular need people with an understanding of statistics and the ability to communicate its use. Gichohi (2014) pointed out that, given the current emphasis on statistical knowledge in Kenya, there is a need to review the scope of Statistics education in the primary and secondary school curricula. There is need to realign the Statistics education at tertiary institutions to trends and requirements of the industry. In Uganda, Opolot-Okurut (2011) established that teacher education programmes should address the deficiency of teachers' subject matter knowledge and pedagogical content knowledge related to statistics, because no pre-service training programme specifically offers statistics teaching methods.

Despite the widespread emphasis on reforms in statistics education, statistics is still viewed as a discipline with a need for significant improvement in how students are educated (Garfield and BenZvi, 2008). Consequently, it is clear that Statistics must be presented in a manner that seeks to acknowledge the changes resulting from the curriculum transformation in South Africa as well as from the reforms in statistics education abroad.This requirement challenges teachersto consider and continually assess their knowledge of reformsin teaching and learning statistics and principles of learning statistics.

Methodology

Sample and Sampling Technique

The target population of this study consists of all Mathematics teachers in public schools in the Motheo District, in Free State province, South Africa. A convenience sample of 66 senior Mathematics teachers (females = 40%) were selected out of 79 senior Mathematics teachers in the Motheo districtaccording to their availability and the rapidity with which data could be gathered.

Research Instrument

The data for this study were drawn from a questionnaire consisting of two sections, namely sections A–B.Section A involved the biographical information. Section B of the questionnaire with 13 items explored the use of principles of learning Statistics to promote the teaching and learning of Statistics at high school in South Africa (see Appendix A). Senior Mathematics teachers were required to choose an appropriate response from a five-point Likert-scale ranging from rarely to sometimes, uncertain, usually and almost always. Core issues related to statistical literacy and critical thinking, develop the skill of communicating Statistics, integrate new authentic assessment techniques were used to build question 1, 2, 3 and 4 respectively.

Furthermore, core issues involvingthe principles of learning statistics were used to build question 5, 6, 7, 8, 9, 10, 11, and 12, respectively.

Validity and Reliability

A pilot study was carried out with 3senior Mathematics teachers from districts that were not part of the sample (Fraenkel & Wallen, 2003). Content validity was strengthened by involving two Mathematics subject specialists and two academic mathematics educators in scrutinising the scope and depth of the questionnaire items (Fraenkel & Wallen, 2003). The data were analysed using the Statistical Package for Social Sciences (SPSS). The Cronbach's α coefficient of 0.942 was seen to be an excellent measure for determining the questionnaire's reliability (George & Mallery, 2003). In this study the findings cannot be generalised to senior Mathematics teachers of other districts in the Free State because of the small size of the sample (Cohen, Manion & Morrison, 2011).

Ethic

An authorisation to conduct this research in the Motheo district was obtained from the Free State Department of Education. Confidentiality of the data and freedom to withdraw at any time without penalty were guaranteed to participants.An information sheet, explaining the purpose of the study, was given to all participants. Informed consent was obtained from teachers involved in this research project in the Free State.

Data Analysis Methods

Descriptive statistics in the form of frequency percentages (%) were used to summarise the data collectedfrom the questionnaire.

Results

In Table 1 clusters of items representing the the three major foci for contemporary statistics teaching (Tishkovskaya & Lancaster, 2012) and the principles of learning statistics were interpreted together (Garfield & Ben-Zvi, 2007).

Table 1. *Summary of Questionnaire Responses: Frequencies and Percentages (N = 66)*

	Rarely	***Sometimes***	***Uncertain***	***Usually***	***Almost always***	***Missing***
Question	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
1.My learners are able to understand the use of statistical vocabulary in Statistics	3.0	13.6	19.7	51.5	10.6	1.5
2.My learners are able to work with different representations of data	1.5	13.6	12.1	60.6	10.6	1.5
3.My learners are able to interpret graphs that represent data in everyday words	4.5	10.6	16.7	53.0	13.6	1.5
4.My learners are able of critique statistical graphs that represent data or issues in the news	4.5	15.2	18.2	43.9	16.9	1.5
5.My learners are able to learn the concept of collecting and organising data even if it may not be totally correct	4.5	18.2	34.8	30.3	9.1	3.0
6.My learners are able to talk about what they are learning, write about it, relate it to past experiences, and apply it to their daily lives	4.5	15.2	48.5	18.2	12.1	1.5
7.My learners are able to learn better if they have experience in applying ideas in new situations	4.5	21.2	40.9	16.7	13.6	3.0
8.My learners find difficult to learn ideas of statistics and often conflict with their own beliefs	6.1	25.8	34.8	21.2	10.6	1.5
9.My learners may be able to answer some test items correctly they may still misunderstand basic ideas and concepts	4.5	21.2	45.5	19.7	7.6	1.5
10.My learners learn better when activities are structured to help them evaluate the difference between their own beliefs and actual results	1.5	21.2	53.0	12.1	9.1	3.0
11.My learners are able to use the computer to learn basic statistics concepts by providing different ways of representing the same data set	3.0	15.2	19.7	43.9	15.2	3.0
12.My learners receive feedback that they may apply to their projects after data-collection activities	3.0	19.7	45.5	24.2	6.1	1.5

In Table 2, the teachers' responses involving the three major foci for contemporary statistics teaching, and the eight principles of learning statistics, are summarised as frequency percentages (%).

Table 2. *Aspects of Reform in Teaching Statistics and Principles of Learning Statistics Average Frequency Percentage (N=66)*

	Rarely	***Sometime***	***Uncertain***	***Usually***	***Almost always***	***Missing***
Question	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
The three major foci for contemporary statistics teaching	3.4	13.0	16.7	52.3	12.9	1.5
The eight principles of learning statistics	4.0	19.6	40.8	22.7	10.6	2.4

Teachers' use of the Three Aspects of Reforms in Teaching Statistics

In this category, the *aspects of reforms*teachers' responses involving the three major foci for contemporary statistics teaching, included question 1, 2, 3 and 4. These responses indicated respectively that 62.1%, 71.2%, 66.6% and 60.8% of the teachers agreed that their learners usually/almost always are able to use of statistical vocabulary in Statistics, work with different representations of data, interpret graphs that represent data in everyday words, critique statistical graphs that represent data or issues in the news. The perceptions are reasonably consistent across these various aspects reform in teaching statistics. It is notable and striking that the percentage of teachers suggesting that they are rarely/sometime/uncertain about their learners'abilities to use these aspects of reforms in teaching statistics varyfrom 28.8% to 39.2%.

From Table 2, it might be noticeable that 65.2% of the teachers indicated that usually/almost always their learners are able to use the three aspects of reforms in teaching statistics. It is a matter of disconcert that 33.1% of the teachers specified with rarely/sometime/uncertain about their learners' being able to use the principles of learning statistics.

Teachers' use of the Principles of Learning Statistics

*The use of the principles of learning statistics*involved question 5, 6, 7, 8, 9, 10,11, and 12.From Table 1, the teachers' responses to these questions are not entirely consistent across the use of principles of learning statistics.

The responses to question 5, indicated that 39.4% of teachersagreed with usually/almost always that their learners are able to learn the concept of collecting and organising data even if it may not be totally correct.It is matter of concern that 57.5% of the teachersindicated with rarely/sometime/ uncertainabout this question.

Teachers' responses to question 6 and 12 indicated that 68.2% of teachers specified thatthey are rarely/sometime/uncertain about: their learners being able to talk about what they are learning, write about it, relate it to past experiences, and apply it to their daily lives;and receive feedback that they may apply to their projects. It is a matter of disconcert that, only 30.3% of teachers responded with usually/almost always to these two questions.

The responses to question 7, showed that 66.6% of the teachers indicated with rarely/ sometime/uncertain that: their learners learn better if they have experience in applying ideas in new situations. From table 1, one might see that 30.3% of the teachers responded to question 7 and 8 with usually/almost always.

Teachers' responses to question 8, indicated that 66.7% of the teachers agreedthat rarely/ sometime/uncertain that ideas of statistics are very difficult for their learners to learn and often conflict with many of their own beliefs. One might see in Table that 31.8% of the teachers answered back to question 8 with usually/almost always.

The responses to question 9, showed that 71.2% of teachers indicated with rarely/sometime/ uncertainthat their learners may be able to answer some test items correctly, but they may still misunderstand basic ideas and concepts. It is striking to see that 27.3% of teachers repliedwith usually/almost always to question 9.

Teachers' responses to question 10 revealed that 75.7% of teachers specified with rarely/sometime/ uncertain that their learners learn better when activities are structured to help them evaluate the difference between their own beliefs and actual results. It is remarkable to seethat on 21.2% of teachers pointed out with usually/almost always to this question.

The responses to question 11sowed that 37.9% of teachers indicated with rarely/sometime/ uncertain that their learners are able to use the computer to learn basic statistics concepts by providing different ways of representing the same data set. From Table 1, one might notice that54.1% of teachers indicatedwith usually/almost always to question 11.

It might be noticeable in Table 2 that on average, only 33.3% of the teachers considered that their learners usually/almost always are able to use the principles learning statistics. It is striking to see that 64.4% of teachers are rarely/sometime/uncertain about their learners' ability across the principles of learning statistics.

Discussion

The focus in this study was to explore the use of principles of learning statistics to promote the teaching and learning of Statistics at high school.

A first major finding is that the data showed that around two out of three teachers considered that their learners are usually/almost always proficient in the various aspects of reform in the teaching and learning statistics. Still, only around one out of three teachers reported that their learners are rarely/sometime/uncertain proficient in the various aspects of reform in teaching and learning statistics. For the first aspect, "*statistical literacy",*around a third of teachers do not know if their learners understand the use of statistical vocabulary in Statistics. Contrary to what Ben-Zvi and Garfield (2004) and Gal (2002) highlighted about statistical literacy. Concerning the "*critical thinking skills",* one out of three teachers are not sure about their learners being able to work with different representations of data. This is conflicting with what Gal (2002; 2003); Schield (2004); Aizikovitsh-Udi1 and Kuntze (2014) painted. For second aspect, "*integrate new authentic assessment techniques"***,** a third of teachers are rarely/sometime/uncertain that their learners are able to interpret graphs that represent data in everyday words. This moves away from incorporate non-traditional assessment techniques and innovative models as stressed by (Colvin & Vos, 1997). The last aspect, "*develop the skill of communicating Statistics"*, shows that one out three teachers are not sure that their learners are able of critique statistical graphs that represent data or issues in the news. This is not in line with the ability to communicate statistics evidence as espouse by Tishkovskaya and Lancaster (2010; 2012); Des Nicholls (2001); Rumsey (2002); and Schield (2004).

A second major finding is the fact that between 37.9% and 75.7% of the teachers in question 5, 6, 7, 8, 9, 10 and 12are rarely/sometime/uncertain about their learners'proficiency in the principles of learning statistics. This finding may be interpretedin two ways. Firstly, it may indicate that teachers were unclear about what they were asked on the nature of their learners'abilities. Since the pilot phase showed that terms in the questionnaire were ambiguous,it is more likely that teachers were unclear about the relevance of their learners' abilities in Statistics. In other words, how can they apply the principles of learning statistics in their statistics classroom(Garfield & Ben-Zvi, 2007).

Although these abilities in statistics are not clearly stated in the CAPS document, this document containsthe definitions of Mathematics, the general and specific aims, specific skills and the action words in the curriculum statement (DBE, 2011; p. 8-9). The findings of this study show that about more Mathematics teachers do not see the connectionbetween the definition of Mathematics, the general and specific aims of Mathematics, specific skills of Mathematics and the Statistics subject matter content in the Curriculum. This finding points to a need for

strengthening the Statistics Subject Matter Knowledge (SMK)with a focus on specialised content knowledge for teachers. According to Ball, Thames and Phelps (2008; p. 399), theSMK is "the mathematical knowledge entailed by teaching, in other words mathematical knowledge needed to perform the recurrent tasks of teaching mathematics to students".

Even if teachers see the need for strengthening Subject Matter Knowledge, asecond interpretation of the large percentage of teachers uncertain about their learners' proficiency may highlight the fact that teachers do not know various aspects of reform in teaching and learning Statistics, and the use of principles of learning statistics. This would indicate a need for supporting teachers'statistical pedagogic content knowledge (SPCK), as suggested by Opolot-Okurut (2011), Wessels and Nieuwoudt(2011) in Uganda and South Africa, respectively.

Despite the widespread emphasis on reform in the teaching of Statistics and the increase in papers on Statistics education in the research literature, Statistics is still viewed as a discipline with a need for significant improvement in how students are educated (Garfield and BenZvi, 2008).Consequently, it is clear that Statistics must be presented in a manner that seeks to acknowledge the changes resulting from the curriculum transformation in South Africa as well as from the developments in Statistics research abroad.This requirement challenges teachers to consider and continually assess their knowledge on developing various reform aspects and principles of learning statistics.

Conclusion and Recommendations

Prospects for the enhancement of teaching and learning of Statistics at high school must consider the need for the Mathematics teachers to be aware of reform in the teaching and learning of statistics and to understand the use of principles of learning statistics,to enable learners understand statistical ideas and apply what they learn to real-world situations.

Based on the findings obtained from the questionnaires the following recommendations are made.Mathematics teachers need to be provided with appropriate training on how to teach statistics (their Subject Matter Knowledge of statistics) during pre-service and in-service programmes.

Finally, Mathematics teachers need to be exposed to various aspects of reform in teaching and learning Statistics and the eight principles of learning statistics to improve their statistical pedagogical content knowledge (SPCK).

Disclosure Statement

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