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Exploring Mathematics Students' Understanding of Language of Estimative Probability in Relation to the Probability Scale

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ABSTRACT This paper sought to investigate students' difficulties in understanding probability language and ideas as well as their meanings in relation to the probability scale. The study explores students'interpretation of some of the words that are commonly used when teachingand learning probability. The sample for the study consists of 67 randomly selected grade 12 secondary school students drawn from multi-lingual schools in Limpopo Province, South Africa. A self-constructed questionnaire was administered to assess students' understanding of probability language. Descriptive statistics were used to analyse the data. The results of the study show that students' informal meanings for probability language were distant from conventional meanings. In addition, there was a variety of meanings associated with each of the selected words. An analysis of the students' meanings and a possible explanation to their thinking seem to be embedded in their first languages. The paper highlights the importance of having an awareness of students' informal meanings, and also stresses the importance of language in learning probability.

INTRODUCTION

Mathematical language is often a challenge for students (Thompson and Rubenstein 2001). Teachersat times forget that the words and phrases that are familiar to them are not commonto students. Learners struggle to understand this language if they are to read, comprehend, and discuss mathematical ideas. Students often become confused when they listen to or read about new and unfamiliar topic. They are often tumbled up by unfamiliar terms, phrases, and concepts that are exclusive to the subject matter. When this happens, it frustrates and they develop a negative attitude towards the topic.

The medium of instruction in the selected schools is English language and is not the learners' first language. The participants in this study had a variety of first languages. Learners focus on the "language" of probability as they use their day to day experiences to recall events that are certain, impossible, likely, and unlikely to occur. Learners are introduced to a probability scale, ranging from 0-1. They are encouraged to evaluate the chance of occurrence of a given event and assign the event a position on the probability scale.

The study adopts a constructivist view of learning which according to Piaget (1977) which states learner's not passive recipients of knowledge are but they can actively construct their own meanings through interaction. Students' preconceived ideas interact with what they areexposed to in the classroom to develop meanings for the concepts that are being taught. The challenge in learning probability is that there are socially agreed conventional meanings, and therefore the construction of meaning by learners cannot be random but should be directed towards the agreed conventional meanings. The students tend to hold on to their own informal understandings and meanings for particular probability concepts and words. Investigating these is likely to be useful for mathematics teachers and educators searching for effective ways of teaching probability.

South Africa, among other countries, have recommended and included probability as fundamental part of the school curriculum. The general view of looking at statistics as an important branch of mathematics has changed; there has not always been a corresponding evolution in how probability is taught in schools. An analysis of students' use of common probability terms and vocabulary and developmental structure in understanding of probability is helpful in both developing appropriate curriculum and teaching strategies. Therefore, understanding students' use of probability language is both timely in terms of current educational reforms taking place in South Africa as well as adding value to existing knowledge of learners' probabilistic thinking.

Probability language is spoken consciously or unconsciously in many situations by students and adults in their everyday lives. This ranges from predictions of the likelihood weather patterns, gaming activities, the possibility of success in games and decisions about insurance and investments. Notions of probability are also encountered in disciplines such as the physical and biological sciences which are linked with the foundations, applications and interpretations of statistics (Seefeld and Linderi 2007). Students sometimes have misconceptions about probability concepts as a result of incorrect meanings attached to some probability terms. These ideas are rooted in personal life experiences and preferences (National Statement on Mathematics for Australian Schools 1991).

According to Meaney et al. (2012), language can be both a support and a barrier to students' learning of probability. When learners have sufficient fluency in the mathematics register, they turn out to beexperts who are capable of thinkingand reasoning mathematically. The same observation was made by Langa (2007) who noted that when learners use their home languages, they interact better with their peers, teachers and their tasks. Learners' understanding of probability is influenced by home language. However, learning the mathematics register of an indigenous language is not a simple exercise and involves many challenges not only for students, but also for their teachers and the wider community. Probability terms are accurate and powerful but can sometimes lead to misleading impressions among students. The concept of probability can be described using special words such as certain, never, impossible, unlikely, likely, probably, certain, and so on. However the way they are used may be different from their real-life usage since it is a complex concept with many dimensions (Lou 2005).

South Africa continues facing some challenges in meeting academic targets in mathematics (Modisaotsile 2012). This might be attributed to the fact that mathematics is more than just numbers; math education involves terms and its associated concepts as well as oral or written instructions on how to complete problems. The language of instruction plays an important role in understanding probability although the importance of teaching probability is still underestimated in South African schools. However the South African Department of Education has already put plans in place to introduce probability at secondary school level. Since this research studied students' understanding of probability vocabulary, the research findings will provide implications for the mathematics curriculum improvement in South Africa. In addition to this, research on probability has predominantly been undertaken in the Western countries as well as in China. However there is a dearth in knowledge regarding students' understanding of the language of estimative probability in relation to the probability scale in South Africa. South African students come from diverse cultural backgrounds and have diverse experiences with probability, both in school setting and everyday life. Given this background, this study seeks to investigate whether there are significant differences between students' background and probability misconceptions.

The main purpose of this study was to investigate learners' interpretations of probability related terminology and match them to a probability scale. There is a need for learners to acquire skills which will give them autonomy as users and analysers of probability language (Svalberg 2007). Given this, most of the research on students' probabilistic thinking appeared around the 1970s and very few attempts were made to investigate students' experiences with probability language. A better understanding of students thinking is crucial for effective teaching.

Problem Statement

Students in South African secondary schools have very limited knowledge and skills about probability. This is due to both internal andexternal school influences. Probability was recently introduced in the syllabus to become an integral part of the mathematics curriculum. Given this background, it is not surprising that students' knowledge about the topic is still very limited. The use of probabilistic arguments and language in everyday life and academic activities is verylimited. Teachers had very little exposure to probability since it was not part of the syllabus during training. In addition to this, there are very limited teaching resources, such as textbooks, activities and materials (dice, marbles…) provided by schools. Students' limited experience with probability language compounds the problem as they experience difficulties in verbalising their thinking in probabilistic terms. Students are often tumbled up by unfamiliar terms, phrases, and concepts that are exclusive to the subject matter. When this happens, it frustrates then and consequently develops negative attitudes towards the topic.

Therefore this study soughtto explore mathematics students' understanding language of estimative probability and the probability scale in secondary schools.

Purpose of the Study

The main purpose of this study was to investigate learners' interpretations of probability related terminology and match them to a probability scale. The study sought to report on grade 12 students' understanding probability concepts via its complex vocabulary. It is hoped that the findings of this study will inform teachers about the students' informal meanings of probability language. It will also inform students about their informal ways of thinking and ideas are inconsistent with the accepted definitions of probability.

Research Objectives

The objectives of this study were to:

a) Investigate students' understanding of probability keywords and how their meanings differ from conventional probability definitions;
b) Assess students' ability to describe events that are certain, impossible, likely, and unlikely to occur and,
c) Assess students' ability to determine the likelihood of an event occurring using a probability scale.

Research Questions

a) What kind of conceptions do secondary school students have regarding probability language?
b) How do students' informal meanings differ from the conventional meanings of probability terms?
c) Are grade 12 students capable of using common probability words to describe the chance of something happening?

Mathematical Meaning of Probability

Probability has become a topical issue in mathematics that has grown out of societal needs. Probability is helpful indetermining the likelihood of something happening. It is a branch of statistics that helps to determine the occurrence of real life events with greater accuracy. In simple terms, probability is the study of chance. The language of probability starts as early as preschool level and stretches up to tertiary level and beyond (New Zealand Council for Educational Research 2011). A typical mathematics curriculum will require students to be able to conduct experiments, understand fairness, interpret and analyse the data, and try to relate the occurrences according to probability scale (The Ontario Curriculum 2005).

Probability deals with patterns and trends that occur in random events. Probability language infiltrates many areas of our lives such as predicting the state of weather, effectiveness of new medicines and passing judgements in courts. Students experience probability in real life situations such as the Lotto draw, poker machines proliferate, and many games that are governed bystochastic rules (Berg and Briggs 2002). They are aware of probability in the context of games where they often informally evaluate the probability of winning and even determine if a game istruly "fair." However it can be debated whether probability and chance actually exists in the real world. Some researchers claim that given sufficient information, everything can be exactly predicted or specified (Garfield and Dani 2007). Contrary to this, some studies revealed that the laws of probability do govern at least some physical events (Muhammad and Mumtaz 2013). Given this background, one can argue that probability can be viewed as a way of modelling many real life situations.

A number of words and terms are used to describe the occurrence of events such uncertainty, chance, risk, odds, likely, likelihood, possibility, luck, gamble, fair game, random or randomness, haphazard, chaotic, hit and miss. These are qualitative words that are used to describe probability. However their meanings and numerical values associated with them often confuse students. Probabilities are often expressed as percentages, such as a "50% chance." In other instances, probabilities are often represented by qualitative terms such as "sure," "unlikely," or "almost certain" (Baer 2008). However these words often confuse students since they are represented in differing ways all of which mean the same thing. These representations include ratios, percentages, fractionsas well as decimals. Therefore students need to be aware-of the multiple ways in which probability is represented.

The current changes in the South African mathematics curriculum brought along with a notable increase on the content coverage in probability (CAPS 2012). Students' understanding of probability related terminology has a strong bearing on their retention of the concepts. Probability has come to gain importance as a topic that students need to have familiarity with in order to be well-informed citizens since its study can raise the level of sophistication at which a person interprets what he sees in ordinary life (Jones 2004). The Principles and Standards for School Mathematics (2000) recommended that "middle-grades students should learn and use appropriate terminology and should be able to compute probabilities for simple compound events … In high school, students should compute probabilities of compound events and understand conditional and independent events" (NCTM 2000: 51). Understanding the wording is the first very important step in solving probability problems (Susan and Illowsky 2012).

RESEARCH METHODOLOGY

Research Design

A quantitative research design was used to explore students' language difficulties related to probability and was explorative and descriptive in nature. An explorative design is one in which the major emphasis is on gaining ideas and insights and not designed to come up with final answers or decisions but to produce hypotheses and explanations about what is going on in a situation (Mutodi and Ngirande 2014). The study is also descriptive in nature since the emphasis is on determining the frequency occurrences. It also provides a picture of the specific details of a situation, a social setting, a relationship (Neuman 2011) or a picture of a phenomenon as it naturally occurs (Bickman and Rog 2009).

Participants

Participants were both male and female grade 12 students (n = 67) randomly selected from five (5) secondary schools around Polokwane Province in South Africa. Efforts were made to include students from a wide range background to ensure the inclusion of students with varied level of exposure and experience with probability terminology and terms.

The Research Instrument

A questionnaire consisting of 40 questions was used to gather information from respondents. The construction of the questionnaire was guided by Green's (1996) principles. The responses for section A which dealt with probability terminology were coded using a 5-point Likert scale (1: Impossible, 2: Unlikely 3: Even chance, 4: Likely and 5: Certainly). The responses for section B which dealt with chance implied by words were coded using a 5-point Likert scale (1: 0%, 2: 30% , 3: 50%, 4: 70% and 5: 100%). The responses for section C which dealt with words implied by chance were coded using a 5-point Likert scale (1: Certain, 2: Most Likely 3: Even chance, 4: Unlikely and 5: Impossible. The questionnaire was self- administered to the sampled respondents in order to examine their understanding of probability terminology. Participants' responses were rated on 5-point scale which measures students' level of understanding of probability language.

Reliability and Validity

The degree of consistency of the research instrument used was measured using Cronbach's alpha coefficient (á). The internal consistency (validity) of the research instrument was also ensured through a pilot study (Table 1). This was done to ensure that all the items in a given category measure the same attribute (Masitsa 2011). The Cronbach alpha coefficient for this study was calculated for the 40-item questionnaire and found to be 0.787 which is viable since an acceptable value must lie between 0.70 and 0.90 (Hof 2012).

Table 1: Cronbach's alpha reliability coefficient

Variable(s)	*Number of items*	*Alpha*
Probability vocabulary and terminology	18	0.741
Chance implied by words	10	0.697
Words implied by chance	12	0.743
Overall questionnaire	40	0.712

Data Analysis

The responses for section A which dealt with probability terminology were coded using a 5-point Likert scale (1: Impossible, 2: Unlikely 3: Even chance, 4: Likely and 5: Certainly). The responses for section B which dealt with chance implied by words were coded using a 5-point Likert scale (1: 0%, 2: 30%, 3: 50%, 4: 70% and 5: 100%). The responses for section C which dealt with words implied by chance were coded using a 5-point Likert scale (1: Certain, 2: Most Likely 3: Even chance, 4: Unlikely and 5: Impossible. The techniques used in data analysis included descriptive statistics of demographic variables and frequencies for each test item. T-tests were also conducted to test if the null hypothesis that the difference between two related means is 0. The test was conducted to see if the difference in performance between male and females was significantly different from 0. Analysis of Variance (ANOVA) was also conducted to test if there significant differences in success due to other demographic variables such as home language, residential area and age.

RESULTS

Demographic data about the respondents shows that 29 (43.3 %) were males and 38 (56.7%) were females. The dominated home language-was Sepedi 46 (67.7%) while Tshivenda 10 (14.9%) was also notable. The other languages were insignificantly represented. The majority of the participants 41 (61.2%) were in the 14-15 years age category (Table 2).

The frequencies for each item were analysed and the results showed that the overall mean (*M*) cognitive level was (*M*) =32.8%, with a standard deviation (*SD*) of 0.3308 which indicates that some evidence of use of probability language and principles and appropriate quantitative information is present (Table 3).The failure rate per each test item exceeds the pass rate.

Table 2: Demographic variables

Variable		*Frequency*	*Percentages (%)*
Gender	Male	29	43.3
	Female	38	56.7
	14-15	41	61.2
	≥	26	38.8
Home language	Sepedi	46	68.7
	Shangane	1	1.5
	Tshivenda	10	14.9
	Other	10	14.9
Residential area	Urban	11	16.4
	Semi-urban	16	23.9
	Rural	37	55.2
	Deep rural	3	4.5

Students indicated evidence of difficulty with language of uncertainty in trying to order phrases used to describe uncertainty. The results also indicated that students struggle to use the language of probability to discuss events, including those with equally likely outcomes. The most notable difficulty items were Q15 and Q20 where the success rates were 14.9% and 19.9 % respectively (Table 4). Students' performance on chance implied by words was better as compared to probability terminology, though most (79.1%) of them struggled to match 'improbable' with the approximate probability. The lowest success rate (M=28.44%) was recorded on words implied by chance. Students struggled to match 1.000 (success rate =19.4%); 1.2 x10^{-4} (success rate =19.4%) and 0.5% success rate =11.4%).

DISCUSSION

It can be recalled that the purpose of this study was to explore the students' understanding of probability terminology and vocabulary and relate it to probability scale. The study sought to assess students' ability to evaluate the chance of given events occurring and assigning the event a position on the probability scale. The effects of demographic variables such

Table 4: Mean responses

Variable(s)	*Number of items*	*Mean success (%)*	*Standard deviation (SD)*
Probability vocabulary and terminology	18	33.03	15.06
Chance implied by words	10	37.15	8.82
Words implied by chance	12	28.44	8.00
Overall questionnaire	40	32.76	11.98

Table 3: Descriptive statistics of respondents' levels of understanding probability

Item	*Description*	*Responses (Frequencies)*					*Correct*	*False*	*Failure rate (%)*	*Success rate (%)*
		1	*2*	*3*	*4*	*5*				
Probability Terminology and Vocabulary										
Q4	The sun will rise tomorrow	20	23	5	4	15	20	47	70.1	29.9
Q5	I will go to a movie soon	4	22	14	11	16	22	45	67.2	32.8
Q6	If a die is rolled, a seven appears	1	11	9	34	12	34	33	49.3	50.7
Q7	Monday will follow Sunday next week	28	6	3	23	7	28	39	58.2	41.8
Q8	All students in a class are boys	2	9	26	22	8	26	41	61.2	38.8
Q9	John will live to the age of 142 years	3	10	16	22	16	16	51	76.1	23.9
Q10	1 Scoring an even number when a die is thrown	4	30	8	8	17	17	50	74.6	25.4
Q11	A year having 460 days	3	9	2	48	5	48	19	28.4	71.6
Q12	500 tickets are sold in a raffle. One ticket is drawn at random to win first prize. Jason bought five tickets in the raffle. His chance of winning first prize is:	14	16	15	3	19	15	52	77.6	22.4
Q13	Christmas day will be on 25th December this year	41	24	1	1	0	41	26	38.8	61.2
Q14	You toss a coin and get a head	9	25	12	1	20	20	47	70.1	29.9
Q15	You buy a lottery ticket and win a jackpot	3	24	13	10	17	13	54	80.1	19.9
Q16	The probability of at least one person in a group of 50 having a birthday next month is	12	21	14	5	15	21	46	68.7	31.3
Q17	Once in a blue moon'	6	14	15	23	9	15	52	77.6	22.4
Q18	Some slight chance	8	20	15	16	8	15	52	77.6	22.4
Q19	Remote	11	28	14	4	10	14	53	79.1	20.9
Q20	A little bit	14	27	10	10	6	10	57	85.1	14.9
Q21	Beyond reasonable doubt	14	23	21	4	5	23	44	65.7	34.3
	Mean								55.97	33.03
Chance Implied by Words										
Q22	Very rare	16	23	19	7	2	23	44	65.7	34.3
Q23	Maybe	3	12	38	8	6	38	29	56.7	43.3
Q24	Definitely	3	6	15	15	28	28	39	58.2	41.8
Q25	Perhaps	3	16	22	19	7	22	45	67.2	32.8
Q26	Sure	2	9	9	18	29	29	38	56.7	43.3
Q27	An outside chance	18	19	14	10	6	19	48	71.6	28.4
Q28	Improbable	22	14	13	11	7	14	53	79.1	20.9
Q29	Must	2	9	10	19	27	27	40	59.7	40.3
Q30	A good chance	2	7	21	27	10	27	40	59.7	40.3
Q31	Slim/ Slight chance	5	33	15	11	3	33	34	50.7	49.3
	Mean								37.15	62.85
Words Implied by Chance										
Q32	1.000	13	25	9	16	4	13	54	80.6	19.4
Q33	0	10	12	11	11	23	23	44	65.7	34.3
Q34	100%	18	17	16	10	6	18	49	73.1	26.9
Q35	7/8	6	23	21	12	5	23	44	65.7	34.3
Q36	0.005	12	13	14	20	8	20	47	70.1	29.9
Q37	1/2	8	26	21	5	7	21	46	68.7	31.3
Q38	75%	8	27	19	12	1	27	40	59.7	40.3
Q39	1/64	6	20	12	22	7	22	45	67.2	32.8
Q40	2/99	12	15	10	21	9	21	46	68.7	31.3
Q41	95%	9	20	17	13	8	20	47	70.1	29.9
Q42	1.2×10^{-4}	6	18	15	13	15	13	54	80.6	19.4
Q43	0.5%	19	25	10	8	5	8	59	88.6	11.4
	Mean									
Overall average									71.56	28.44
							Overall failure rate		67.24	*******
							Overall success rate		********	32.76

as gender, age and home language, were envisaged.

Gender and Probability Language

The results for this study show that there was a significant difference in understanding probability language according to gender. Descriptive statistics indicated that males performed better than their female counterparts. The findingsare consistent with studies conducted by Assistance) (2012) who noted significant differences in probability language proficiency according to gender, with male students exhibiting higher probability understanding than their female counterparts. However, these findings contradict the findings of Marsh (2004) and Stevens (2013) which concluded that there was no relationship between performance and gender. Long research history in this area has shown thatmale advantage in mathematics achievement is a universal phenomenon (Mullis et al. 2000). Kaufman (2006) recognized that math interests of males are better than the females from secondary school onwards.

Age and Probability Language

The study found that there was no significant difference in the performance of students according to age. Descriptive statistics indicated that students in the 14-15 yearage category performed better than older students.This is consistent with findings by Lun (2000) which revealed that age was not statistically significant in explaining students' understanding of probability vocabulary. Literature also revealed that some of the misunderstandings decrease with age, while others are very stable and even grow stronger with age (Stohl 2005).

Home Language and Probability Language

The results for this study show that there was no significant difference in students' understanding of probability language across different language cohorts. Since South Africa is a multi-cultural and multi-lingual state, the expectation was that students from different language backgrounds tent to understand probability language differently. However, this is not the case; other factors other than language background such as educational background may give a better explanation to such findings.

Residential Area and Probability Language

This study found that there was no significant difference in students'understanding of probability language among students from different residential places. Most rural secondary schools are dominated by one common home language and students' understanding of subject- related vocabulary is often influenced by the local language. This view is supported by Liddicoat et al. (2003) who observed that learning to communicate in an subject specific language involve developing an awareness of the ways in which culture interrelates with language whenever it is used. The learner's culture and the context in meaning is created or communicated have an influence on the ways in which possible meanings is understood. Thus students for effectively engage with the concepts of chance, they need to acquire the language of probability, much of which is used in everyday situations.

CONCLUSION

The study revealed that the interpretation of probability terms is a complicated process. Students' interpretation of the meaning of probability terms does not depend on variables such as age, home language and residential background of the student. However gender differences were shown to be significant. Although many students are able to match probabilities with words such as certain, likely, even chance, unlikely and impossible in describing the chance, a significant number of students exhibit misconceptions.

RECOMMENDATIONS

The research recommends that teachers must link the informal interpretation of probability words with their corresponding formal meanings. Once these pre-existing conceptions are understood, the teacher can facilitate learning by making explicit the connections between them and the new ideas introduced in class. The study also recommends that familiarity with the probability language is necessary to understand concepts related to probability. A closer examination of the recommendations by researchers indicates that with respect to pedagogical content knowledge specific to probability, teachers need to acquire an awareness and ability to confront common probabilistic misconceptions and student difficulties relative to probability concepts. Teachers should also engage students in discussing probabilistic concepts in contexts allow them to consider multiple embodiments of concepts as well as confront their misconceptions. Students should be exposed to and experience as well as discussing a variety of situations that illustrate the concept of randomness. Such an approach makes teaching more effective and meaningful to students. In order to participate and engage with the concepts of probability, students need to be well-versed with the language of probability. Students should be introduced to and encouraged to use some of this language at an early age. Teachers should engage students in games and experiments that support the development and understanding of the everyday language of probability. Some of this language describes a range of values of likelihood, spanning from impossible to certain and relate them to the probability scale. Finally the study recommends that the introduction of probability must always be preceded by a one-on-one, comprehensive individualized assessment to investigate the intuitions that students have about specific probability concepts.

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