Teacher Training College Student Performance in Statistics and Probability Exams in Rwanda

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Abstract

Teacher Training Colleges (TTCs) were established in order to produce qualified primary teachers in Rwanda. However, reviews on primary teacher training have consistently highlighted serious shortcomings in the quality and relevance of the courses offered. They argue for poor alignment of the teacher training curriculum with the school curriculum and lack of teaching experience of tutors. In this paper, we analyse TTC students' performance in statistics and probability and compare their performance in these specific areas with other mathematics topics areas. This is done through analysing their success rate in questions related to statistics and probability in national examinations over the period 2014-2016. Pearson coefficient reveals no relationship between students' performance in statistics and probability and other topic areas. Furthermore, some students performed better in other areas of mathematics but failed in statistics and probability questions and vice-versa. Although students are trained to teach mathematics in primary schools, they still poorly perform in national examinations, thus hypothetically leading to poorly teach this subject in primary education.

Key words: Probability, statistics, students' performance, Teacher Training Colleges

Introduction

The aim of Rwanda vision 2020 is to transform the country from agriculture based to knowledge-based economy with ultimate goal to shift into middle income country (MINICOFIN, 2013). Education is considered as key to the achievement of this vision and hence a lot of effort and strategies were put in place. It is therefore, in this regard that emphasis was put on Science, Technology, Engineering and Mathematics subjects which are considered as the driving force for the development of any nation (MINICOFIN, 2000). In order to achieve this mission, the major change in the education system was the shift from knowledge-based curriculum to competence-based curriculum and the re-activation of the mission assigned to pre-service teacher training institutions to produce qualified teachers. Currently, the Rwanda operates on a 6-3-3-4 system (Primary School, Junior Secondary School/Ordinary level, Senior Secondary School/Advanced level, and University Bachelor's degree).

Teacher Training Colleges (TTCs) are part of advanced level specialized in training pre-primary/primary teachers while secondary school teachers are trained at the University of Rwanda-College of Education. Erduran, Kaya, and Cetin (2014) suggest that professional development of teachers, particularly starting at the pre-service stage is significant in ensuring that future teachers can be equipped with sufficient skills to support active learning in science lessons to some extent any subject. However, reviews of primary teacher training have consistently highlighted serious shortcomings in the quality and relevance of the courses offered (World Bank, 2011; Livingstone, 2005). They further argue for poor alignment of the teacher training curriculum with the school curriculum and lack of teaching experience of TTC staff. The alignment of the implemented curriculum in mathematics and intended school

curriculum may reduce newly qualified mathematics teachers to teach using a traditional teacher-centred method, instead of using the promoted competence-based teaching approach at school.

While students in TTCs are future teachers, the present paper intends at examining to what extent they performed statistics and probability questions during national examinations of mathematics over the period of 2014 to 2016. The reason for considering the period 2014-2016 is that during this period the UR-CE was overseeing the academic quality of TTCs, thus in charge of preparing and administrating all TTCs national exams. However, since 2017, all responsibilities related to TTCs were handed to Rwanda Education Board. Therefore, it was possible for the researcher to access students' booklets by the period of 2016. In addition, we hypothetically assume that findings can still inform us on the question in study since there was no big change, if any, in terms of TTC tutors' status as well as criteria in admitting students in TTCs. The paper findings are drawn from a large study that plans a close collaboration between the authors and TTC mathematics tutors for improving the teaching and learning of mathematics in general and the mentioned topics in particular. In general, it was observed that there is a consistent poor performance in mathematics (Uworwabayeho, 2009) in Rwanda, but no study has focused on statistics and probability in particular. Of particular information, the concepts of statistics and probabilities which used to be taught in advanced level are currently introduced in primary education within the Competence-Based Curriculum (CBC) framework. Since teacher training colleges are mandated to train preservice teachers for the primary level, it is worthy to examine to what extent these future teachers are knowledgeable in the new topics. The findings of this paper are part of a longitudinal study whereby quantitative data are composed of TTC students' scores on past national exams and qualitative data are collected through classroom observations and teachers 'interviews. The present paper is restricted to findings from quantitative data only as the collection of qualitative data is ongoing thus limiting this study from detecting factors for observed students' performances. Despite this limitation, the study findings may be used to predict to what extent TTC mathematics curriculum enable preservice teachers to implement primary mathematics curriculum.

Literature Review

During the past decade much has been done globally to provide quality basic education for children, an obligation for the Convention on the Rights of the Child (UNICEF, 2000). However, defining quality in education has encountered debates in the existing literature. UNICEF (2000) takes a broader perspective and demonstrates that quality in education would entail programmes involving learners, content, processes, environments and outcomes. The desire from parents for their children to perform better in the examinations has increased the pressure on governments and other stakeholders which has led to fluent reforms in the education system in order to achieve a higher performance among learners (Anderton, Hine, & Joyce, 2017). Students' poor performance in mathematics continues to persist in many countries, and this is a major concern among educators (Samuel, Shammah, & Mary,

2013; Zalmon & Wonu, 2017). Scholars indicated that teacher's content knowledge is one of the factors that contribute to students' poor performance (Maniraho & Christiansen, 2016).

The Trend in International Mathematics and Science Study (TIMSS) that measures the degree to which extend students have learned mathematics and science and make cross national comparisons in order to get what students have achieved in school in each grade (Mullis, Martin, Foy & Hooper, 2015) found out that countries from eastern Asia outperform others. The driving force for this good performance was associated to the rigor of the curriculum, the focus, and the coherence of the curriculum. Unfortunately, Rwanda has not participated into the TIMSS competition and there is limited number of studies conducted in Rwanda about students' performance in mathematics. Few studies conducted in Rwanda found out that mathematics' performance is behind other subjects in Rwanda national examinations especially in primary level (Uworwabayeho, 2009). The reason might be diverse, but among those highlighted by few studies conducted indicated that primary students' performance depends mostly on the instructional method use by the teacher, the school environment (schools with better equipment), students whose parents are educated, and the socio-economic status of students 'family (DeStefano, Ralaingita, Costallo, Sax & Frank, 2012). The content and process that lead to the more affective outcomes of community participation and responsibility often happen in the classroom (UNICEF, 2000) and the teacher is a key to ensuring students' achieving learning outcomes.

Key educational outcomes would include academic achievement in general and achievement in literacy and numeracy in particular (UNICEF, 2000). Teaching students to read, write and calculate is often considered the primary purpose of formal education, but students' regular attendance and attention in school does not guarantee this outcome. Investigations into literacy levels in recent years have shown that children in developing countries had lower levels of literacy than children in high-income countries who had received similar amounts of schooling (Willms, 2000 cited by UNICEF, 2000). The need for citizen to know basic statistical concepts has gained considerable attention. The reason is reflected in the daily press, economic, medical reports which require that the readers have little understanding of statistics (Batanero & Diaz, 2010). In Rwanda like in many countries, statistics and probability is included in all educational level though for the former, these topics are introduced in primary education recently in 2015 within the competence-based curriculum framework. However, statistics is taught as one of the topics in the mathematics syllabus and there is a need for preparation of primary and secondary school mathematics teachers who are responsible for its delivery. Although professional development for mathematics teachers is organized in many countries, the literature shows that little effort has been given to statistics in particular (Batanero & Diaz, 2010).

Like for any other subject, the teaching of mathematics in general and statistics and probability in particular requires specific considerations not merely the content knowledge. The knowledge needed to teach statistics and

probability should go beyond the concept's knowledge and mathematical representation. Different research (e.g., Cook, 2010; Garfield & Everson, 2009; Moore, 1997; Garfield & Ben-Zvi, 2007) suggest the change in the way statistics is taught. Teachers must use real world data and learners should not be tasked to compute simple statistics such mean, median or produce specific graphs. They recommend that learners should be required to design their own investigation, formulate research questions, collect data themselves and make conclusions and prediction based on the data (Batanero & Diaz, 2010; Batanero & Diaz, 2012; Cobb, 1991; Gail, 2014).

The importance of developing statistical literacy and statistical reasoning among teachers as well as students is also being emphasized in the literature (Timothy, 2007; Sabbag, 2016). In US Carver (2016) elaborated the Guidelines for Assessment and Instruction in Statistics Education which contains six recommendations that teachers should follow when teaching introductory statistics. A study conducted in Argentine found out that primary school teachers are not able to explain statistics in a way that can allow learners to understand it (Carrera, 2002). A similar study found that primary school teachers in Chile are not well prepared to teach statistics (Soledad, Raimundo & Arturo, 2015). Maniraho and Christiansen (2016) observed that the content knowledge of grade six Rwandan mathematics teachers is better in numbers and measurement with a low content knowledge in other areas of mathematics such as algebra/patterns, geometry, and statistics and probability with a score less than 50%. Participant teachers showed a relatively low confidence in doing statistics questions although they showed a higher level of pedagogical content knowledge in the area of statistics and probability.

Although a lot of effort is made to enhance the teaching and learning of statistics, it is argued by many researchers that a big portion of the students don't understand the basic concepts of statistics they have studied (Burrill, 2014; Le, 2017). The reasons vary from a context to another but include content itself, teaching approaches, students' readiness to learn the subject and school environment. As mentioned earlier, the present paper draws on a longitudinal study that is exploring how the mathematics is taught in TTCs is concerned with analysing TTC students' performance in mathematics national examinations over a period of three years (2014-2016).

General Description of TTCs Structure

Recently, they were reform in the teaching and learning approaches in Rwanda where the focus is to train learners who are skilled and competent for job market. In CBC, learners are required to be problem solvers and critical thinkers as teachers are now playing the role of facilitator. This is a big challenge for secondary school teachers as most of them were familiar with the teacher-centred approach whereby they used to give explanations and to provide notes to the learners. In the new CBC, statistics and probability is taught from primary level, so it is important that primary school teachers be equipped with basic concept of statistics and probability and have the pedagogical skills to deliver the content.

To improve the quality of education, the government of Rwanda established Teacher Training College (TTC) in order to train and prepare qualified pre-primary/primary school teachers. Since 2010 up to 2016, the University of Rwanda-College of Education was overseeing the academic quality, the delivery of the programs and the award of degrees (MINEDUC, 2007). At TTC level, students can choose one option to undergo in four existing pathways: Modern Languages Education (TML), Social Studies (TSS), Science and Mathematics (TSM) or Early Childhood Education. Learners who are doing TML are trained to teach languages, TSS learners are prepared to teach social science, and TSM learners are prepared to teach integrated science and mathematics while those follow early childhood education trained to teach in pre-school program. Integrated science is a subject developed from a combination of traditional physics, chemistry and biology subjects. Although all combinations must take mathematics course, graduates from TSM are the ones who are trained to teach mathematics and sciences at primary level, and they are allowed to pursue undergraduate studies in mathematics or science in higher education. But the emphasis of the curriculum for TSM consists in equipping students with competencies in both subject content and pedagogy so that they can facilitate the learning of mathematics and science at primary education level.

Concerning with statistics and probability topics, the first-year students are introduced to descriptive statistics where graphs, the variability and the measure of dispersion are covered, and the content ends with the comparison of two different set of data. The curriculum suggest that teaching should be based on data-oriented where teachers are encouraged to prepare project for learners so that they collect their own data using different techniques of data collection, do the analysis and interpretation, propose and justify conclusions and predictions that are based on the data. The probability part is learnt in year three where the content covers the combinatory analysis which allows students to acquire knowledge and skills that are useful in different areas such communication network, biology, database, operation research and others. Students are also introduced to some concepts of probability where random experiments are defined and designed, and the concepts of population and samples are discussed in the context of students' daily life.

An analysis conducted by Uworwabayeho and Muhire (2016) on TTC students' performance from national examination results revealed a consistent performance across all TTCs but also many variations in teaching and learning that are caused by availability of physical resources. In particular, although the curriculum suggests the use of technology such as Microsoft excel and other ICT tools to visualize and conceptualize the data, it is very hard to ascertain that mathematics teachers integrate these ICT tools while teaching given that most of the TTCs do not have enough computers and many of the mathematics teachers are not familiar with statistical software.

TSM Mathematics Examination Papers

In Rwandan education system, students completing advanced level sit for the Rwanda National Examinations (RNE) to get a secondary school certificate. Mathematics is one of the examined subjects for TSM students. The exam is made up of different questions of which are picked from different area of mathematics such as algebra, calculus, arithmetic as well as statistics and probability.

Over the academic years 2014- 2016, the TSM mathematics examination paper was made of ten questions where section A made of six questions was compulsory, and the remaining four questions of section B students had to choose three. The duration of the exam was three hours. The examination papers had questions from the four areas mentioned above. It was observed that for each school year, the examination paper has one compulsory question of statistics and probability which curried 10 marks out of 100 marks for the whole examination. For instance, for the school year 2016, the statistics and probability question has two sub-questions; one focusing on statistics (where students were asked to calculate the measures of variability and spread such as mean, mode, and standard deviation given a set of data) and another sub-question focusing on probability (where students were asked to find the probability of two unbiased dice).

In this paper, we analyse students' performance in statistics and probability and compare their performance statistics and probability and other areas of mathematics for TTCs students. The aim is to show that although TSM students are trained to teach mathematics in primary school level, they still have difficulties in understanding mathematics particularly in statistics and probability. We argue that teachers and their teaching practices contribute largely to students' mathematical achievement (Ingvarson, Meiers, & Beavis, 2005). We will therefore propose some recommendations which may help to improve the teaching and learning of statistics. The findings may also help policy makers, especially REB and UR-College of Education and other stakeholders to figure out what training mathematics teachers need. It also serves as reminder to the mathematics teachers that although statistics and probability play an important role in our daily life, students are finding it difficult even when it comes to computing mean of a simple set of data.

Methodology

The study adapted the ex-post facto research design to analyse the trend of students' performance for statistics and probability questions in national examination. This design is appropriate for this study because the researcher has not inferred with the occurrence of the fact. The target population comprises of all 2348 TSM students who sat for the RNE over the academic years 2014-2016. The data are the marks scored by students collected from students' booklets collected directly from the department of Early Childhood and Primary Education which were overseeing TTCs examination over the period of the study. The data were analysed using the Statistical Packages for Social Sciences (SPSS version 2016); they were analysed as they have collected and hence deemed valid and reliable. The purpose of the study is to analyse how students performed in statistics and probability question and to compare

their performance with other areas of mathematics. Since the total marks of the whole exam are 100 marks and statistics and probability question was out 10 marks for each academic year, the other areas of mathematics were considered out of 90 as we have to subtract the marks scored for statistics and probability.

Data Presentation

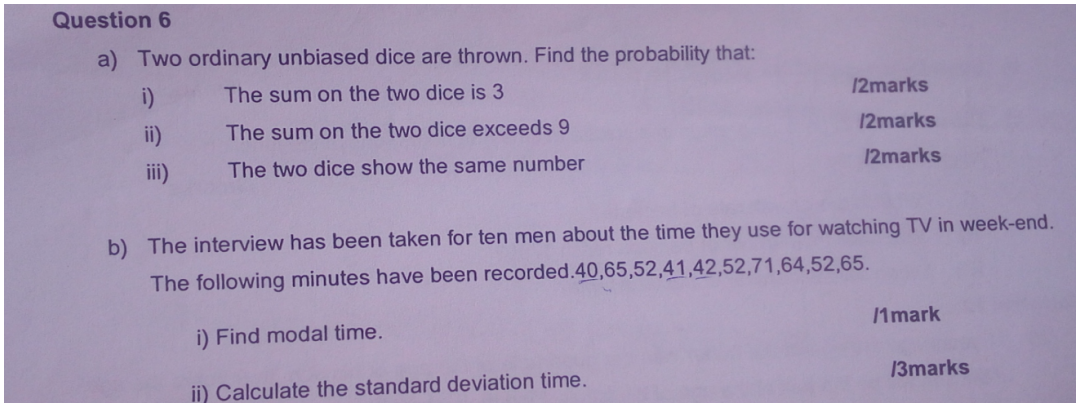
The table below shows the number of students who participated in the examination in each academic year, those who attempted statistics and probability questions and those who did not attempt it at all.

Table 1: Percentage of students who participated in national examination over the period 2014-2016.

Academic Year	No of students	Attempted	Percentage	Did not attempt	Percentage
2014	751	722	96.10%	29	3.90%
2015	772	711	92.10%	61	7.90%
2016	825	799	96.80%	26	3.20%
Total	2348	2232	95.10%	116	4.90%

We can see from Table 1 that about 4% of the students did not attempt the questions in 2014, 8% in 2015, and 3.2% in 2016. Note that we did not count those who attempted question and scored zero. We can also observe that the number of students enrolled in TSM has been slightly increasing throughout the years; with little variations in percentage of those who did or not attempt statistics and probability questions

The way students performed in statistics and probability question was not dependent on the way they have performed in general. Some students performed better in other areas of mathematics considered in the examination but failed in statistics and probability questions and vice-versa. Further research would explore why students score zero or do not attempt at all the questions; one would look at whether its misunderstanding of the question, difficulties in English, misconception in subject areas, or it is the exam paper itself being ambiguous. For illustration, we include a sample of questions and students 'answers to questions.


Question 6

a) Two ordinary unbiased dice are thrown. Find the probability that:

i) The sum on the two dice is 3 /2marks

ii) The sum on the two dice exceeds 9 /2marks

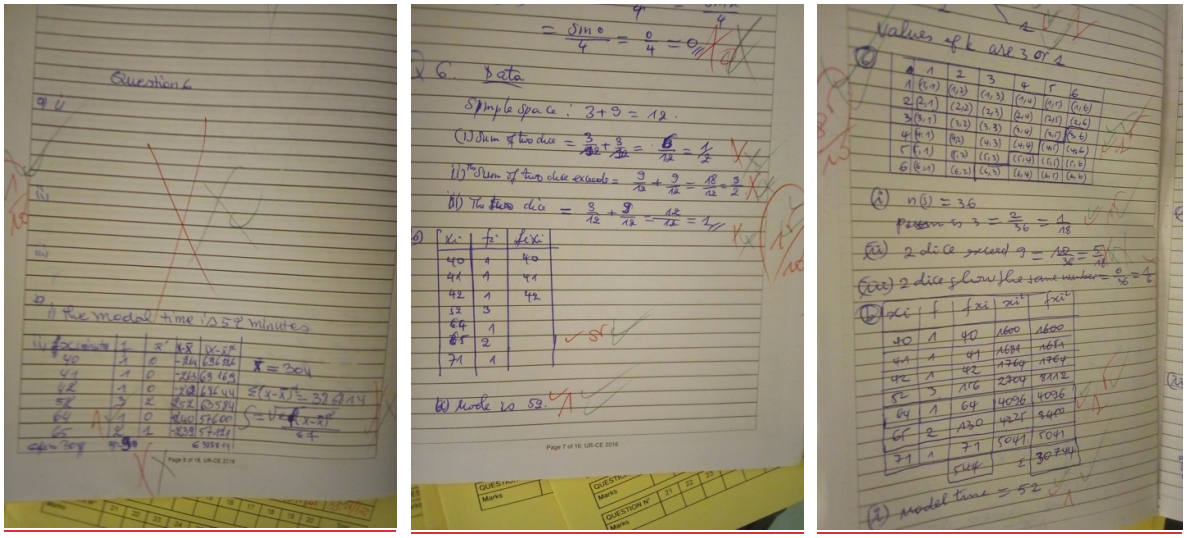
iii) The two dice show the same number /2marks

b) The interview has been taken for ten men about the time they use for watching TV in week-end. The following minutes have been recorded.40,65,52,41,42,52,71,64,52,65.

i) Find modal time. /1mark

ii) Calculate the standard deviation time. /3marks

Figure 1: Statistics and probability question (source: TTC national exam paper, 2016)



Student A Student B Student C

Figure 2: Sample of students' answers (source: students' exam booklets)

As it appears in Figure 2, the 3 students attempted the sub-question (b) related to statistics. The student A did not attempt the question 6(a) at all, while the student B attempted but was challenged by determining the random space. The student C showed an understanding of the question and what to do but most likely did wrong counting of the pairs that lead to the sum exceeding 9. Let get closer look at how the question 6 (a) was formulated: (i) the sum on the two dice is 3. The examiner assumes students being familiar with the dice otherwise failure to answer the question would be not directed to low knowledge of students on probability rather to the unclear situation. However, since the three copies are drawn from a same class, answers of students B and C reveal that the context was familiar, thus the unattempt of A is individual challenge in probability. It can also be observed the non-importance given to or non-mastery of principles of naming events as well as mathematical signs by both students B and C. This bring us to further question related to the importance given by teachers to naming and symbolizing random events; to some extent to mathematical signs and symbols in general.

In order to get in depth students' performance, we calculated the mean and standard deviation for statistics and probability and that of other areas of mathematics for each academic year.

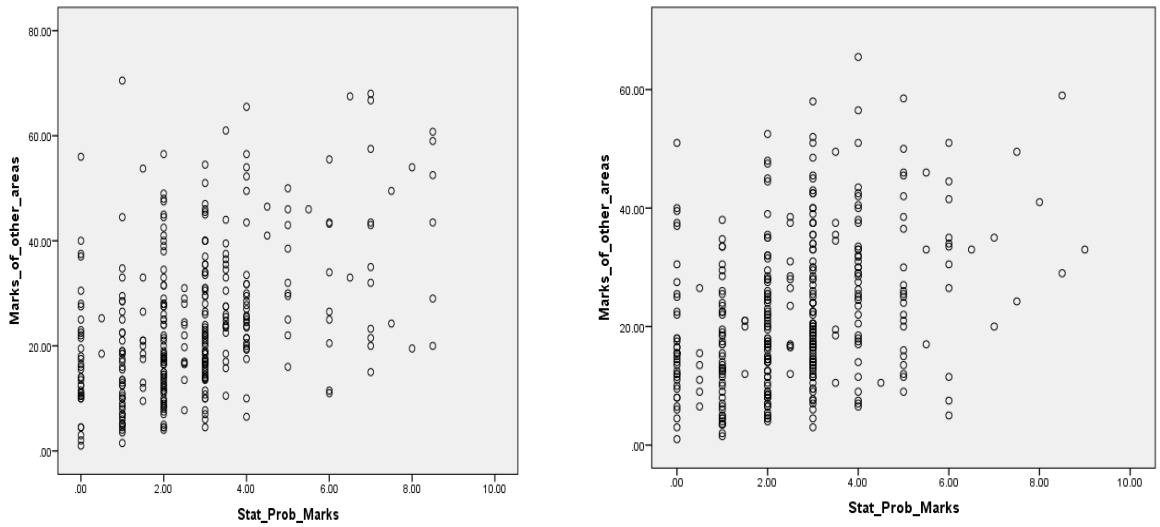
Table 2: Mean and standard deviation.

Academic Year	M (Prob & Stat)	SD	M (other areas of maths)	SD
2014	2.59	1.70	22.10	14.10
2015	3.97	2.46	22.05	14.48
2016	2.70	1.91	24.12	14.10

From this table, we can see that although the average means are low in both statistics and probability and the other areas of mathematics considered in the examination, the standard deviation for statistics and probability show the overall performance of students is relatively the same in the academic year 2014 and 2016. Over the academic year 2015, the overall performance of students was higher compared to the other academic year but the gap between student's performance is also high (higher standard deviation in both statistics and probability question and other areas of mathematics considered in the examination). Of course, many factors such as those yearly exams having been undertaken by different students interplay in explaining the observed differences but at least a deep analysis of question papers for those three school years would be of great contribution.

Figures below compare the performance of students in other areas of mathematics considered in the examinations and that of statistics and probability over the academic year 2014 to 2016. We can observe that the performance of students in statistics and probability questions was not good as the majority of students got less than half marks. We can also observe that there is no linear relationship between the score in statistics and probability and other areas of mathematics considered in the examination. Moreover, over each academic year, we have a big number of students who scored zero in statistics and probability question. We also observe cases where students score higher marks in other areas of mathematics but scored lower marks in statistics and probability (e.g. a student who score 70 in other areas but scored 1 in statistics and probability question in 2016). Again there are students who scored higher marks in statistics and probability but score lower marks in other areas of mathematics (e.g. a student who scored 9 in statistics and probability but scored only 20 marks in other areas of mathematics in 2016).

Academic year 2014 Academic year 2015



Academic year 2016

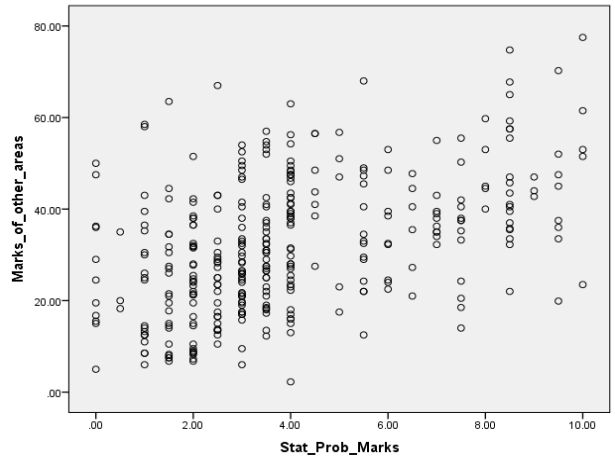


Figure 3: Comparison of students' performance in statistics and probability and other areas of mathematics.

The Pearson correlation coefficient was also used to measure the association between the performances of students in the two areas considered. The Pearson correlation coefficient measures the statistical relationship, or association, between two quantitative variables under study (Rebekić, Lunčaric, Petrović, & Marić, 2015). The correlation coefficient ranges from -1 to +1; where -1 indicates that the two variables are perfectly related in negative manner, a +1 coefficient shows a positive perfect relationship while zero coefficient indicates that there is no relationship between the two variables under study.

The Pearson correlation coefficient for each academic was computed to assess relationship between students' performance in statistics and probability and other areas of mathematics considered in the examination. There was a medium positive correlation between the two variables, $r = .37$, $p < .01$ (2-tailed) for the academic year 2014; $r = .46$, $p < .01$ (2-tailed) for the academic year 2015; and $r = .45$, $p < .01$(2-tailed) for the academic year 2016. This mean that the way students performed in statistics and probability does not depend on the way they performed in other areas of mathematics considered in the examinations.

Discussions

The data above show that TTC's students performed poorly in statistics and probability question and in mathematics in general. Some students performed better in other areas of mathematics considered in the examination but failed in statistics and probability questions and vice-versa. Although other studies have not focused on statistics and probability in particular, the same findings were obtained by other researchers who found out that grade six mathematics teachers lack content knowledge (Maniraho & Christiansen, 2016). It was also found out that mathematics' performance is behind other subjects in Rwanda national examinations especially in primary level (Uworwabayeho, 2009).

In order to understand the failure of students, further study would look at how the mathematics is taught in TTCs as well as how national exams are set up. Burrill (2014) highlighted that statistics teachers must recognize that working with data should go beyond manipulating and operating with numbers to content-related reading between and beyond the data. He emphasized that the teaching of statistics should differ from the teaching of mathematics. In mathematics, graphs are often used in order to show the same relationship while in statistics they are used to identify different aspects of the same data. It is the responsibility for mathematics teachers to understand the different approaches of teaching statistics by making clear to the learners that reasoning needed to interpret data should be different from that of mathematics. For example, to believe in a certain data requires understanding of the entire process of collection of data. To believe in a conclusion that was drawn from statistical data requires understanding of the entire investigating process while in mathematics we only need to make a proof in order to be certain. Although these differences might be hard for mathematics teachers who teach statistics as part of mathematics, it is important that in-service teachers receive adequate training in the teaching of statistics. TTCs as a solution to the need of qualified teachers seem to not respond to this question.

As implication for research, there is a need to conduct qualitative study (which is actually being conducted) to understand factors hindering TTC students' performance in statistics and probability areas in particular and in mathematics in general.

Conclusion and Recommendations

From the findings, it is clear that different trainings on how to teach statistics are required by TTCs mathematics teachers. The highest quality teachers, those most capable of helping their students learn, have deep mastery of both their subject matter and pedagogy (UNICEF, 2000). Students from the early age must be helped to understand that data are not simply numbers, categorical, or pictures but have context, vary and are used to answer real life questions.

The guidelines for assessment and instruction in Statistics Education (Carver et al, 2016) include six recommendations that can guide the teaching and learning of statistics. These recommendations stress that students learn statistics in activity-based environment where students explore, collect, and interpret data in order to respond to statistical questions. Accompanied with the use of technology to represent the data in a graphical way, students should use these results to analyse and communicate the findings by responding to the formulated questions. The TTCs mathematics teachers must help students to begin appreciating the importance of understanding the use of data to clarify situation and the role these data play in science and other areas of human activities. They must also develop an innovative pedagogy for effective teaching and learning of statistics and link the statistical concepts with the real life problems as recommended by CBC.

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