



Professional Development Needs to Improve Teaching Science in Secondary Schools: Case Study of Mbeya, Tanzania

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Author s' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Case Study

Abstract

Aim: This study examined pedagogy and subject content needs for Professional Development (PD) to improve teachers' skills in teaching science in secondary schools in Mbeya, Tanzania.

Study Design: The study employed a quantitative research approach and cross-sectional survey design.

Methodology: The main instrument used for the study was questionnaire. In this study, schools were randomly selected, and 256 respondents, science teachers were selected through stratified sampling technique. The data collected were analyzed quantitatively.

Results: Science teachers need Professional Development (PD) in Pedagogical Knowledge (PK), mastery of science subject contents and technological skills of modern teaching. There was no significant difference in the mean scores for components of pedagogy knowledge between teachers who teach math subject and those who teach physics, chemistry and biology at $\alpha = 0.005$ using independent samples t-test. Teachers need of PD in subject content in topics were as follows: accounts (61.7%), genetics (46.2%), electromagnetism (44.2%), electronics (40.4%), circles and the Earth as a sphere (29.6%), statistics and probability (28.4%), inorganic chemistry (25%), and ionic theory and electrolysis (24.1%).

Conclusion: Science and mathematics teachers in Secondary schools need PD intervention in the subject content of science subjects.

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1 Introduction

Competent teachers are the main actors in learning. Nevertheless, several factors are associated with teachers' performance. Such factors include teachers' qualifications, experience and participation in Continuous Professional Development (PD) program. Particularly, PD is a mechanism to boost learning in schools [1]. Success of education for all in primary schools raised the number of learners and triggered the teaching in secondary schools of Sub-Saharan Africa [2]. Since teaching of science integrates theory and practical skills, large number of students squeezes school owners to recruit under-qualified teachers; lead to scarce facilities, laboratory service and poor motivation, all that negatively affect the learning process [3, 4]. Examination results are one of indicators of poor learning.

According to United Republic of Tanzania (URT), there has been a remarkable increase in secondary schools by 474 schools which is 11.6% amounting to 4576 schools observed in 2013 compared to 4102 schools observed in 2009 [5, 6]. This was caused by implementation of Primary Education Development Plan I-III and Secondary Education Development Plan (SEDP) I-II [5]. On average 493547 form one and 40559 form five students were registered every year. However, a fluctuation existing in registration led to declining enrollment by 2% which is the difference of 524784 schools in 2009 and 514592 schools in 2013, and 10% which is the difference of 43052 schools in 2009 and 39173 schools in 2013 in respective forms of one and five both for the year 2013 and 2009 respectively. Enrollment of girls in advanced level secondary schools ('A' level) is lower than in ordinary level secondary schools ('O' level) as evidenced by gender parity index (GPI) of 0.9 and 0.5 for enrolled 'O' level and 'A' level students respectively in 2013. This signifies unequal access and equity relative to how it was supposed to be addressed by SEDP II [5, 7, and 6]. Given a non-promising enrollment and few girls compared to boys in schools, students must be retained and supported to perform better in examinations. However, studied data does not support existence of good student performance. For instance, by average of the studied school years from 2009 to 2013, less than 13.5% of candidates scored division I-III of which division I indicate excellent, division II indicates very good and division III indicates good. Basic mathematics and Biology are compulsory science subjects to imply that performing higher in these subjects is a significant contribution for scoring division I-III but on average of the studied school years from 2009 to 2013, 15.5% and 36.9% of candidates-the worst being for Basic mathematics passed the subject examination. Subject grade scored by physics/chemistry takers as optional subjects were ought to be A, B and C of which A indicates excellent, B indicates very well and C indicates well. However, on average of the studied school years from 2009 to 2013 less than 48.2%) scored A-D of which D is a weak grade.

Only few candidates manage to score grade A-C as evidenced by Mbeya Rural and Urban district secondary schools in CSEE results for 2013, 2014 and 2015 (National Examination Council of Tanzania [8]. By attaining 36.7% in 2013, 46.5% in 2014 and 32.6% in 2015, Mbeya rural district secondary schools have been leading as first in Mbeya region for large percentage of candidates who scored division I-III in CSEE results. Mbeya urban district secondary schools have been leading as second in the region by attaining 31.6% in 2013, 34.8% in 2014 and 31.4% in 2015, the percentages of candidates scoring division I-III in CSEE results. Yet the percentages of candidates scoring grade A-C are superior in private schools than in public schools. For example in 2015 CSEE results, private schools' record for candidates with grade A-C were 22.7% in Physics, 57.6% in Chemistry, 53.7% in Biology and 19.2% in Basic mathematics. Counterpart public schools' records for candidates with grade A-C were 10.3% in Physics, 29.3% in Chemistry, 18.2% in Biology and 4.9% in Basic mathematics.

Many factors account for these poor results. Reduced quality of learners join secondary schools as in 2012 Primary School Leaving Exams, 8000 pupils in Mbeya region left without attaining arithmetic, writing and reading skills, 319 pupils passed the exams while not able to read and write; and so joined secondary school as low ability learners [9]. Furthermore, failure in 2009-2012 CSEE was associated with lack of understanding the concepts of shift from content based to competence based teaching and from content-

based to methodology-based tutoring [9]. Instead of training teachers to master both the content of the subject that they will teach and methodology, tutors focused mainly on how to teach, leaving the content that entails the competence. This made teachers to fail understanding of the concepts of the subject as well as failing to set exams that measure the learners' ability of understanding the concepts over memorizing [9]. Educators' pedagogy did not aid deeper understanding of science content due to bad environments of teaching, failure to manage thousands of teacher candidates joining degree courses, and aspirant teachers missed the chance for doing practical to learn the use of concepts, hence not capable to apply the knowledge on [10].

Ball & Cohen (1999) suggested that teachers must have deeper understanding of the subject content, deeper beyond the level they were taught in schools [11]. Leaving the subject content was therefore improperly if preparation of teachers was to be expected for outstanding performance of learners in science subjects. Goode (2007) examination of enrollment revealed that more Los Angeles Unified school district students whose teachers got a 2-weeks training to in-service teachers and regular tutoring for pre-service teachers to acquire more skills on relative challenging topics, studied more the optional subject than California students whose teachers got no training [12]. In two years, optional subject student enrollment rose to 75% in Los Angeles Unified school district but decreased to 17% in California. So the guess for increasing teachers' skills for attracting and retaining the weak and minority learners in optional subject was successful. PD intervened teachers/peers on how to prepare non-dull tasks for igniting the interest of learners in the subject, and to collaborate in preparing lesson plans so as to build the culture for helping each to overcome isolation. Teachers were introduced to the more difficult topics to build them the knowledge of the subject matter that they will teach, and deepened in pedagogy to counteract their observed pedagogical approaches working to the loss of handful of minorities in the class [12]. Learned aspects involved PD needs related with improving learning and learners' interest in the subject. So there was association between aspects of training and teachers' knowledge. The two-week initial training was too little to master the content of some topics and the aquatic biology simulation study, teachers with least prior subject knowledge wanted more training chances to support their teaching, inexperienced teachers needed extra mentoring/coaching from senior who could help them realize the difficult topics [12]. Therefore, there was a difference in the needs for improving teachers' skills. Saturday sessions were started to provide extra help and networking events for teachers to get more instruction for teaching in preparation for optional subject exams [12].

South Africa, Botswana, Swaziland, Zimbabwe and Tanzania take on cluster workshops as common PD for teachers. However, they are faced by a challenge of little emphasis of introducing teachers to integrate Information and communication Technology (ICT) in teaching [13]. South Korea, Singapore, Ireland and Poland as civilized PD tradition emphasize the exposure for integrating ICT in teaching to both pre-service and in-service teachers for skills to elaborate the concept which cannot be understood by text alone [13]. According to Dadi (2015) teachers graduated with little content knowledge due to reduced duration of college programme and the dilemma for what content to put in the teacher education course that would fittingly deserve to produce teachers in short time possible to meet the demand [14]. However, most of the aspects in Pedagogical Knowledge were not addressed in PD [15]. There was no significant difference for use of skills for assessment as both project and non-project school pupils' notebooks bore no teachers' comments; observed lessons revealed that teachers were reluctant to provide assignments; hence no room for adjustments and next plan in teaching [15]. Anney (2013) noted that licensed science teachers had poor PCK and exams set by licensed teachers did not comply with all levels of skills as per Bloom's classification of knowledge [16].

It is clearly spelt that teachers lack adequate subject content knowledge as a crucial component for professional knowledge of teachers. Scholars have well articulated the need for professional development of teachers in subject content matter and pedagogy skills but only a few like Mtebe, et al (2015) developed multimedia enhanced subject content topics for developing science and mathematics teachers to improve the teaching of science in secondary schools [17]. Despite implementing PD projects for improving the teaching of science subjects in Tanzanian secondary schools, there is extended use of traditional ways of teaching such as lecturing due to a shortage of qualified teachers and lack of good skills for teaching and experimenting [18, 19]. Consequently, the lessons delivered are partial in transferring the intended skills;

learners perform poorly in exams, drop science subjects and quit them in next levels [18, 20, 21, 19, and 9]. The reason involves lack of subject content and pedagogy knowledge for teaching. PD seems not addressing pedagogy and subject content areas related to needs for teachers to refine the skills [18, 14, 22, 15, and 23].

According to Shulman (1986), teacher professional knowledge comprises a range of knowledge.

a. Pedagogical knowledge (PK)

PK is a broad knowledge of procedures and methods of teaching and the way by which this integrates the general teaching purposes, standards and plans, to discern skills acquisition and learners' sorts of attitude to learning [24]. Pedagogies are applied as technical rule, observation and assessment techniques, and lesson plan points to meet the objectives of the lesson [25]. In United States Goode (2007) found that intervention successfully developed teachers with varied academic origin on the skills for attracting and retaining underrepresented students in science and preparation of science exams. Intentionally students were recruited into subject through their counselors' invitation, guidance and counseling, hence 2 years later enrolment in computer science in Los Angel raised by 75% [12]. In reality, teachers learned how to draw pupils' interest into science subjects and teaching [26].

Anney et al., (2012) studied the deficit of licensed science teachers; and found that they needed PD for classroom organization, lesson planning, assessment and test construction [18]. These skills ensure learning to converge to common goal and integrate with evaluation to adjust the teaching process. Student discipline/behaviour, assessment practices, counselling and classroom management are basic development needs, and skills for teaching special need learners assist teachers to develop competence for teaching learners in mainstream classes [27]. Guidance and counseling as for Kiwhele (2014) is insisted for students to help them raise motive for science and choose subject/career by service demand. Teachers should be well built in these areas to include effective guidance to attract, recruit and retain pupils in science streams [12].

b. Pedagogical content knowledge (PCK)

PCK is special for teaching particular subject content and right approach to teach a specific concept [24]. In USA Chval et al. (2008) found that science teachers need PD for six common skills in same order, that would lead to growth of developing learners' critical thinking skills in science/math (68%/73.1%), integrating technology in teaching science/math (63.1%/68.9%), relating science/math to real life situations (55.8%/60.5%), employing problem based teaching approach (55.7%/67.2%), how do students learn picky topics in science/math (50.8%,63.9%) and developing conceptual understanding in science/math (48.4%/47.1%) [28]. This knowledge assists designers to set PD material. Chi-square (X^2) test uncovered that there was no significant difference in proportions between science and math teacher groups, except the need for understanding of how pupils learn picky topics in science/math: $X^2 = 4.189$, $P < 0.05$; employing problem-based teaching and inquiry: $X^2 = 9.131$, $P < 0.01$ and collaborative learning in science/math: $X^2 = 4.596$, $P < 0.05$; in which math teachers accounted larger needs than science teachers [28]

Involving girls or marginal pupils in science/math (25.4%/22.7%) and designing instruction for English as Second Language students in science/math (23.0%/13.5%) ranked the most bottoms. However, these aspects were the most significant difference in the results of science teachers with 0-2 years of teaching, since they ranked among their top five needs [28]. Spearman's rank correlation index (r_s) indicated a significant correlation in the ranking of needs of the 0-2 years of teaching to those with 6-10 years ($r_s = 0.490$, $p < 0.05$) and 11-15 years ($r_s = 0.482$, $p < 0.05$) for science teacher groups by experience; but there was less correlation between teachers with 0-2 years of teaching and others for math teacher groups [28]. The findings are suggestive that teachers' qualifications and experiences, to include their training status lead to different perception of the needs regarding PD. Teachers account high-level development needs on content and presentation standards, subject areas and teaching practices both across and within countries [27]. There is difference in the development needs between countries due to varied teacher preparation and exploitation.

c. Technological knowledge (TK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK) as technological skills (TS)

According to Mishra and Koehler (2006), TK is knowledge about typical technologies that run in parallel with subject CK and PK to deliver teaching [24]. TCK is concerned with the relationship between content and technology sides in ways to represent them interchangeably to easily visualize the concept. TPK is the intersectional between TK and PK for perceptive of existing components and capabilities of distinct technologies for use in teaching and learning, and the awareness on how teaching and learning might be altered upon use of particular technologies. Technological skills (TS), particularly integrating ICT skills in teaching is next requirement for PD after skills for teaching special need learners [27]. The North Carolina Biology teachers managed to carry out the syllabus objectives following integration of wet and dry laboratory tasks during PD [26]. Some 68.9% of math teachers compared to 63.1% of science teachers ranked their PD need about using technology to teach math/science [28]. Thus, suggesting that technology skills are critical to teach science.

Cimer (2012) suggested that to overcome learning difficult areas in biology, teachers need to develop skills for teaching by use of visual materials in topics that involve human body such as respiration and practical works [29]. There has been a problem for technology use to unqualified/under-qualified teachers; they fail to improvise to conduct less expensive lab tasks [18, 4]. PD should be focused on integrating ICT in pre-service education courses and In-Service Trainings (INSETs) leading to improvement of teachers' subject content and how to teach [13, 22].

d. Subject content knowledge (CK)

Content Knowledge (CK) is the knowledge of science subject that the teacher is to teach [24]. It has both procedural aspects about knowing how of science and conceptual aspects about knowing why we use of science, hence different experiences for teachers to teach it (Shulman, 1986). Statistical concepts of mode, median and mean, graphical design and interpretation, and analysis of distribution shapes were reported difficult to teach for pre-service teachers due to failure in addressing procedural and conceptual aspects [30]. Therefore, they had no skills for teaching curricular content.

In US, Chval et al. (2008) surveyed teachers' needs for PD and revealed that while physics and chemistry topics were ranked top needs, genetics and evolution ranked the fifth by 45.9% of teachers selecting it [28]. The top four topics were electricity and magnetism (55.7%), energy and chemical change (50.8%), climate and weather (49.2%) and modern physics (46.7%). More math teachers wanted development in topics for technology in support of math (60.5%), discrete mathematics (54.6%), probability (51.3%), statistics (45.4%), patterns and relations (43.7%). Likewise, PD for learning to Singaporean math teachers involves courses for enhancing their deeper understandings of important topics such as calculus as it is a basis to most math topics [13].

In the biology content-based PD institute, energy and matter, evolution and DNA were reported causes of student failure [26]. A quantitative and qualitative analysis of what makes biology difficult to learners in Turkey, marked and held matter cycles, endocrine system and hormones, aerobic respiration, cell division, genes and chromosome as difficult due to nature of topics, teaching styles, students' learning or studying habits and students' negative feeling/attitudes towards the topic [29].

Mtebe et al. (2015) reported that there are 20 physics, 20 chemistry, 14 biology and 16 mathematics topics (sum of 70) and 34 physics, 47 chemistry, 34 biology and 32 math subtopics (sum of 147) relatively difficult for teachers to teach [17]. 2500 Digital Video Disks (DVDs) for developed multimedia enhanced content thought of increasing learners' understanding of the difficult ideas during teaching by deep clarification. Knowledge of common areas of difficulty is instrumental toward improving teaching through focused PD to them.

According to Sirhan (2007), curriculum content (logical order of chemistry knowledge) is one of the learning difficulties as it requires the chemical knowledge to be taught, learned and understood at three levels, namely sub-atomic (micro level), descriptive (the macro level), and symbolism (representational) as well as the interplay between the three levels [31]. Passing examinations without a correct conception of chemical knowledge is a result of traditional emphasis for teaching at only one level, the descriptive (macro) level. It means that teachers must explicitly understand chemistry concepts at the three dimensions and the related interplay in order to teach the concept at the microscopic, macroscopic and representational levels at once for correct concept formation.

In connection to that, abstractions in the content of chemistry require much logical thinking and understanding in order to (teach) learn. Understanding of concepts such as dissolution, particulate nature of matter and chemical bonding is fundamental to teaching and learning units of reaction rate, acid and bases, electrochemistry, chemical equilibrium and solution chemistry. These link new knowledge on the accommodated idea in the learner's mind. Concepts develop as new ideas link jointly to old. If learners do not always make such links, they develop misconceptions [31]. So teachers must have a deeper understanding of fundamental concepts to capably teach them.

Kay and Yiin (2010) found that teachers had misconceptions in content knowledge of chemical bonding, chemical kinetics, inorganic chemistry [electronic structure, properties of elements, periodicity, trends in properties, transition elements, complex compound, compounds of metal], electrochemistry, acids and bases, chemical reactions and energetic [32]. Behind concept formation and misconception is familiarity of the language and communication about how to talk chemistry in second language instruction [31]. High skills in language use and communication that correctly enable students to develop correct chemical knowledge minimize noise in the student's working memory space. The language and communication are major to enable teachers deliver correct concept to learners in all science subjects upon appropriate use.

Deeper chemical knowledge and PCK integrate as central to set tasks and tests that develop students' science content, socio-scientific reasoning skills and scientific reasoning skills. Surveying the impacts of longitudinal PD to students' aspects of scientific and technological literacy, Laius and Rannikmae (2014) found that, while students' knowledge in biology had impact on socio-scientific reasoning but not on scientific creativity, test results of chemistry had no significant influence in any of the gauged skills [33]. Commentators noted that content of the test did not gauge the skills of creativity and reasoning. Modern teachers must set tasks and tests that link scientific literacy skills.

Not only skills of internal structure of science knowledge is critical, but also setting to nurture pupils is significant for teachers to analytically unpack own material to build in pupil's mind. Ejidike and Oyelana (2015) surveyed 20 teachers and 100 students about ease of use of laboratory and enough periods for teaching chemistry [3]. Chi-square (X^2) tests revealed no significant relationship in the response of teachers and students about sufficient and insufficient chemistry textbooks, periods, and laboratories at α 0.05. Scarce practical periods and laboratory facilities made the teaching of chemistry ineffective.

Investigating on options to enhance 'O' level teachers' pedagogical skills and content knowledge; heredity, organic evolution, coordination and classification; safety, health and diseases were difficult to teach, difficult for students to understand and difficult to obtain teaching aids so that teachers needed to learn them and how to find and use teaching aids [34]. Teachers encountered difficulty in teaching qualitative analysis, electrolysis, mole concept and chemical equilibrium [34]. Both Mugizi (2010) and Mushi (2007) found that topics that were difficult for teachers to teach were also difficult for learners to understand [34, 35]. Qualified physics teachers have to master a wide range of matter like classical mechanics, electromagnetism, thermodynamics/mechanics, wave motion, optics, modern physics and integrated science; with inquiry based laboratory activities and research skills to link the theory and practice [36]. However, improper learning support and unreliable retention effort for better teaching result into fall of student learning yields [21].

e. Technological pedagogical content knowledge (TPCK)

The knowledge is useful any time one is teaching. “This knowledge would not typically be held by technologically proficient subject matter experts, or by technologists who know little of the subject or of pedagogy, or by teachers who know little of that subject or about technology [24].” That is to say specialist teachers have mastered skills in every aspect of professional knowledge and apply during teaching by interacting suitable skills that clearly build up correct concept in learners’ mind. It can be summarized that good teaching is a function of TPCK.

2 Purpose of the study

The study intended to develop the subject content needs for professional development to improve the teaching and learning of science and mathematics subjects in secondary schools in Tanzania. In sight of that, this study was guided by the specific objective:

- i. To develop the content needs for professional development (PD) to improve teaching and learning science and mathematics subjects in secondary schools

2.1 Research hypothesis

The study was guided by the following research hypothesis

- i. Ho: there is no significant difference in the content needs for PD to improve teaching between teachers who teach science subjects and mathematics subject in secondary schools

3 Methodology

In this study a cross-sectional survey was considered suitable. The researcher intended to collect raw data at once from the sample of teachers so as to study their responses about questionnaire items that tapped teachers’ needs about subject content and pedagogy topics for which they wanted to have PD to improve their skills. Selection of the design based on the varying subjects that were occupied in teaching, their teaching experience, education qualifications and category of schools where they worked. This design was suitable and less expensive to get the variety of data which were to be collected at once from many respondents who had variable attributes of interest to the study. Also, the collected data were processed, management and investigation was done by analyzing the statistical data using statistical programmes that used mathematical measures.

In this study, questionnaire was used for data gathering. The questionnaire was developed from the reviewed literature of the study to construct both closed ended and open ended questions that tapped information pertinent for the study. Furthermore, Likert scale items and checklist items were developed by adapting the skills from Vigias (2006) and OECD Teaching and Learning International Survey (TALIS) Teacher Questionnaire [37]. The questionnaire was advantageous as it made it less expensive to get details involving background information, teachers’ levels (extent) of need regarding pedagogy needs for PD, their selection of subject content topics for PD and supplying response topic concepts for which they wanted PD. The questionnaire consisted of three questions in two sections. The first section for background details on gender, education level, level of teaching, working experience, in-service training status, and school ownership. The second section for variety of items in a scale of Likert to tap teachers’ needs for pedagogical knowledge, pedagogical content knowledge and technological skills; including a checklist for subject content. Questionnaire forms were distributed and elaborated to them. The researcher waited until respondents had replied and handled back the survey form. Preface checkup for response bias and preparing data analysis by coding the details from tools into a computer profile continued. Checkup for response bias assisted in resetting the checklists for relative difficult topic items.

With the help of Mbeya rural District Secondary Education Officer and Mbeya urban District Secondary Education Officer, the target population was known to consist of 869 secondary school science and mathematics teachers consisting of 523 and 346 teachers who worked in Mbeya urban and rural district respectively. Out of 869 teachers, 273 were teaching in 31 public secondary schools and 250 in 23 private schools located in Mbeya urban while 173 were teaching in 28 public schools and 173 in 19 private schools located in Mbeya rural district. Thus, 446 teachers worked in 59 public schools and 423 in 42 private schools. The target population included teachers who taught physics, chemistry, biology and math subjects in secondary schools. These were included because they attend PD programmes and apply knowledge and experiences to improve teaching [38, 39]. Therefore, they were source of facts about research inquiries.

In this study, the sample size of respondents was estimated according to Krejcie and Morgan (1970) sample size formula because it regards the statistical test that was used in analysis [40]:

$$n = \left[\frac{x^2 NP(1 - P)}{D^2(N - 1) + x^2 P(1 - P)} \right]$$

Where n = sample size, x^2 = is the tabled value of chi-square for one degree of freedom at the preferred confidence level, N = the target population, P = the population proportion, D = the level of accuracy.

In this study, the magnitude of the population was 869 science teachers; the predetermined population proportion was 0.5 to get the maximum sample size. The level of accuracy used was 0.05 at which the chi-square for one degree of freedom is approximately 3.841. Values of variables were substituted into the formula; the expected sample size of the study was computed to be equal to 267 respondents. Exact 54 and 47 Mbeya urban and Mbeya rural district secondary schools rank first and third respectively in the region for being many, and sum to 101 schools. The actual sample was 256 respondents comprising 197 male teachers and 59 female teachers (See Table 1).

According to Ary et al., (2010), sampling is the technique of picking a sample whereby all objects of the target population are picked by chance procedures. From the sample size of expected 267 respondents; the researcher assumed that each randomly selected school could have at least one teacher who taught physics, chemistry, biology and mathematics subjects. Thus, a total of 67 schools (267 divide by 4) were required. Schools were stratified into ownership and the required sample schools in a stratum was obtained by proportion of the schools under stratum in a target population of 101 schools

Number of school in each stratum, $[S] = \left[\frac{Ns}{TNs} \right] \times [Ss]$. Where Ns = Number of schools in a stratum, TNs = Total number of schools in target population, Ss = Sample size of schools in target population. Thus, sample size of public schools $SG = \frac{59}{10} \times 67 = 39$; Sample size of private schools $SP = \frac{42}{10} \times 67 = 28$

Number of public school in Mbeya urban district $S1 = \frac{31}{59} \times 39 = 20$; Number of public schools in Mbeya rural district $S2 = \frac{28}{59} \times 39 = 19$; Number of private schools in Mbeya urban district $S3 = \frac{23}{42} \times 28 = 15$; Number of private schools in rural district $S4 = \frac{19}{42} \times 28 = 13$

By simple random sampling, 20 out of 31 public schools were selected from Mbeya urban district, 19 out of 28 public schools were selected from Mbeya rural district. Some 15 out of 23 private schools were selected from Mbeya urban district, and 13 out of 19 private schools were selected from Mbeya rural district. In each case, a school by name was numbered. Then, slips of papers each bearing identification number of the school were prepared and folded. The folded slips were then placed in a container. The researcher shook the closed container vigorously and drew one fold of slip. The researcher repeated shaking the closed container and drawing the folded slip several times until the drawn number of folded slips was equal to the stated number of schools from that group. The actual number of schools contacted was 47: 15 public schools (urban district), 15 public schools (rural district), 10 private schools (urban district) and 7 private schools

(rural district). This was because the needed number of respondents reached before all the 67 secondary schools were contacted.

Respondents were selected through stratified sampling technique. Use of stratified sampling technique assured the researcher that a representative sample of teachers is selected from each section since the target population consisted of groups of private and public school teachers, and teacher who teach science and mathematics subjects. Representativeness of sample was crucial for getting different experience from teachers about subject content and pedagogy topics for PD; which is central knowledge to meet the objectives of this study.

Teachers were stratified into individual’s teaching subject as physics, chemistry, biology and mathematics. The number of respondents from stratum was determined in relative amount to the size of the stratum in the target population so as to study the characteristics of entire mass of teachers regarding needs for PD. Since 446 (51.3%) and 423 (48.7%) teachers worked in public and private schools respectively, proportionally, 137 (51.3% X 267) and 130 (48.7%X 267) respondents were needed from public and private schools respectively. Subject groups in target population consisted of:

Some 169 teachers of physics whereby 47 worked in public schools and 54 worked in private schools (urban district); and 27 worked in public schools and 41 worked in private schools (rural district). Some 206 teachers of chemistry whereby 55 worked in public schools and 68 worked in private schools (urban district); and 45 worked in public schools and 38 worked in private schools (rural district). Some 211 teachers of biology whereby 70 worked in public schools and 56 worked in private schools (urban district); and 48 worked in public schools and 37 worked in private schools (rural district). 270 teachers of mathematics whereby 97 worked in public schools and 66 worked in private schools (urban district); and 51 worked in public schools and 56 in private schools (rural district).

Number of respondents was computed by summing up $[R] = \left[\frac{NSg}{TNc} \right] \times [NSgc]$ where; R = number of respondents in a subject group, NSg = number of teachers in the subject group in the target population, TNc = total number of teachers in school type in the target population, NSgc = number of teachers in the subject group in the school type. The actual number of respondents is indicated in Table 1.

Table 1. Actual sample size of respondent science teachers

School	Science Teachers												Total		
	PH			CH			BL			MT			M	F	T
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
Private	27	1	28	23	4	27	20	7	27	28	5	33	98	17	115
Public	22	2	24	22	9	31	17	21	38	38	10	48	99	42	141
Total	49	3	52	45	13	58	37	28	65	66	15	81	197	59	256

Source: Fieldwork October–November, 2017. PH=Physics, CH=Chemistry, BL=Biology, MT=Mathematics, M=Male, F=Female, T=Total

The accuracy ‘D’ was calculated from the sample size formula

$$n = \left[\frac{x^2 NP(1 - P)}{D^2(N - 1) + x^2 P(1 - P)} \right]$$

The variables N = 869, n = 256, P = 0.5, X² = 3.841 were substituted to give estimated D = 0.051, which means the level of confidence in the results of statistical test was 0.051.

3 Results

Research Hypothesis one: Ho: there is no significant difference in the content needs for PD to improve teaching between teachers who teach science subjects and mathematics subject in secondary Schools

Three steps of analysis were done. First, the researcher studied the association between pedagogy topics for PD and teachers by subject or qualifications or experience or INSET status groups. For purpose of analysis, the researcher re-coded into same variable: “high level of need” and “moderate level of need” as “*Needed*”; “neutral,” “low level of need” and “no need at all” as “*Not needed.*” 14 topics were studied.

Table 2. Association between pedagogy needs and teachers by subjects

Topic	% Respondents for “Needed”				X ²	P
	PH n=52	CH n=58	BL n=65	MT n=81		
Pedagogical Knowledge	78.8	79.3	84.6	87.7	2.576	0.462
How to assess and evaluate learning, construct test and standard exams						
How to manage student discipline, behaviour and learning habits in science	76.9	81.0	87.7	84.0	2.557	0.465
How to counsel students so as to enhance their interest in sciences	78.8	84.5	81.5	85.2	1.083	0.781
How to carry out academic, career guidance and advice to students	65.4	72.4	75.4	82.7	5.348	0.148
How to timely give support to students at risk to drop sciences/schooling	75.0	69.0	81.5	85.2	6.005	0.111
How to obey morals on the relationship between teacher and students	78.8	74.1	83.1	81.5	1.749	0.626
Pedagogical Content Knowledge	80.8	79.3	76.9	82.7	0.796	0.850
How to prepare lesson activities for low, average and high performing students						
Preparing lesson plan to meet diverse learning needs to all students	69.2	75.9	83.1	77.8	3.193	0.363
How to use concept map to solve students' confusion of idea interrelations	76.9	77.6	54.4	77.8	0.134	0.987
How to use collaborative learning and real life problem solving in teaching	76.9	84.5	83.1	80.2	1.233	0.745
How to use inquiry to enhance students' critical thinking	78.8	81.0	78.5	85.2	1.354	0.716
How to engage less motivated girls and boys in science and mathematics	69.2	74.1	80.0	76.5	1.915	0.590
Technological skills	75.0	77.6	80.0	81.5	0.907	0.824
How to present lessons and analyze learning results by computer tools						
How to use lab tools or improvise to prepare reagents for lab lessons	84.6	86.2	76.9	75.3	3.597	0.308

*Values are significance at * $P \leq 0.05$. n= no. of respondents, PH=Physics, CH=Chemistry, BL=Biology, MT=Math

Data in Table 2 show that the result in each topic of pedagogy is not significant as P value is larger than the alpha value of 0.05 using chi-square test for independence. There is no statistically significant association between the needed pedagogy topics and teachers by physics, chemistry, biology and mathematics groups. The proportion of teachers in group, ranking “needed” on the studied pedagogy topics is large but not

significantly different from each other. Thus there is no association between pedagogy needs for PD and teachers of particular subjects. In that regard all subject teacher groups needed PD for pedagogy.

Table 3. Association between pedagogy needs and teachers by qualifications

Topic	% Respondents for "Needed"				X ²	P
	NEd. n=10	D.Ed n=79	B.Ed n=152	MD n=15		
Pedagogical Knowledge (PK)	90.0	82.3	82.9	86.7	0.518	0.915
How to assess and evaluate learning, construct test and standard exams						
How to carry out academic, career guidance and advice to pupils	80.0	77.2	73.0	80.0	0.856	0.836
Pedagogical Content Knowledge (PCK)	100.0	78.5	78.3	93.3	4.571	0.206
How to prepare lesson activities for low, average/high performing students						
how to engage less motivated girls and boys in science/mathematics	60.0	75.9	76.3	73.3	1.394	0.707
Technological skills (TS)	100.0	74.7	79.6	80.0	3.575	0.311
How to present lessons and analyze learning results by computer tools						
How to use lab tools or improvise to prepare reagents for lab lessons	90.0	73.4	80.9	100.0	6.613	0.085

*Values are significant at $P \leq 0.05$. n = no. of respondents, Ned.=Non-education, D.Ed.=Diploma in education, B.Ed.=Bachelor degree in education, MD=Master degree

Data in Table 3 show the topics in each of pedagogy in which the percent for respondents for "needed" are relatively low or high. From each of components of PK, PCK, and TS two items in the range where one scored the highest and the other the lowest percentages have been taken to represent others that fall between these. Statistically there is no significant association between each pedagogy topic studied for PD and teaching qualifications as P value is larger than alpha (α) 0.05 using chi-square test for independence. Thus there is no significant difference in proportion of teachers by qualifications who need PD for pedagogy topics.

Table 4. Association between pedagogy needs and teachers by experience

Topic	% Respondents for "Needed"				X ²	P
	< 3 yr n=42	3-5 yr n=61	6-9 yr n=56	10+ n=97		
Pedagogical Knowledge(PK)	81.0	72.1	78.6	72.2	1.858	0.602
How to carry out academic, career guidance and advice to students						
Pedagogical Content Knowledge(PCK)	85.7	77	83.9	80.4	1.564	0.667
How to use inquiry to enhance students' critical thinking						
How to engage less motivated girls and boys in science/mathematics	78.6	70.5	83.9	72.2	3.762	0.288
Technological Skills(TS)	85.7	67.2	80.4	82.5	6.993	0.072
How to present lessons and analyze learning results by computer tools						

*Values are significant at $P \leq 0.05$. yr = years

Data in Table 4 show from each of component of PK and TS one item in the range where one scored the lowest percentages and from PCK two items in the range where one scored the highest and the other the

lowest percentages, have been taken to represent others that fall above and between them respectively. There is no significant association between each pedagogy and experience since $P > 0.05$. Thus there is no significant difference in proportions of teachers by experience who needed those pedagogy topics.

Table 5. Association between pedagogy needs and training status

Topic	% Respondents for "Needed"				X ²	P
	Never had training n=87	2011 and before n=29	2012 to 2014 n=88	2015 to 2017 n=52		
Pedagogical Knowledge (PK) How to carry out academic, career guidance and advice to pupils	80.5	89.7	70.4	67.3	*8.083	0.044
Pedagogical Content Knowledge (PCK) Prepare lesson activities for low, average/high performing students	89.7	86.2	71.6	73.1	*10.289	0.016
Concept mapping to solve pupils' confusion of concept interrelations	78.2	79.3	77.3	73.1	1.059	0.787
Technological skills (TS) How to present lessons/analyze learning results by computer tools	83.9	79.3	75.0	76.9	2.171	0.538

*Values are significant at $P \leq 0.05$

Data in Table 5 show from each of component of PK, PCK and TS one item in the range where one scored the lowest percentages have been taken to represent others that fall above them. There is a statistically significant association between how to carry out academic guidance/career guidance/advice to pupils and teachers' status of INSET since $P\text{-value} \leq 0.05$. Likewise, there is a statistically significant association between how to prepare lesson activities for low/average/high performing pupils and teachers' status of in-service training since $P\text{-value} \leq 0.05$. Thus, proportions ranking needed on the two topics are significantly different from each other group. The percentages of teachers who had latest INSETs within less than 5 years ago are smaller compared to those who had latest INSETs in 6 and above years ago or never had in-service training.

Secondly, the researcher studied the hypothesis, H_0 : there is no significant difference in the needs for pedagogy topics for PD to improve teaching between teachers who teach science subjects and those who teach mathematics subject. Range of scores were re-coded 1.0000-3.999 as "Low demand" and 4.0000-5.0000 as "High demand"

Table 6. Score for pedagogy between teacher groups of science and mathematics

Pedagogy Scale	Scale Score for Science Teachers				t-value	P-value
	Teach Physics, Chemistry or Biology (n=175)		Teach mathematics (n=81)			
	Mean	SD	Mean	SD		
Pedagogical Knowledge(PK)	4.1419	0.85696	4.3313	0.82052	-1.666	0.097
Pedagogical Content Knowledge (PCK)	4.1000	0.80190	4.2016	0.80005	-0.944	0.346
Technological skills(TS)	4.1514	0.84499	4.0988	0.89589	0.455	0.650

*Values are significant at $t \leq 0.05$. SD=Standard Deviation

Data in Table 6 show that the mean scores on PK and PCK for teachers who teach math are higher than those for teachers of science subjects. The mean score on TS for teachers who teach science subjects is higher than that for math. Since $P > 0.05$, H_0 is accepted. There is no significant difference in the mean scores between the two groups using independent samples t-test. Both teacher groups have high demand on pedagogy.

Thirdly, the researcher studied the frequencies of teachers in selecting a subject content topic that they perceived challenging to teach to the extent that they needed re-training. This area responds to question items in section B No. 2.2 subsection 2.2.1 and 2.2.2 of the survey questionnaire form.

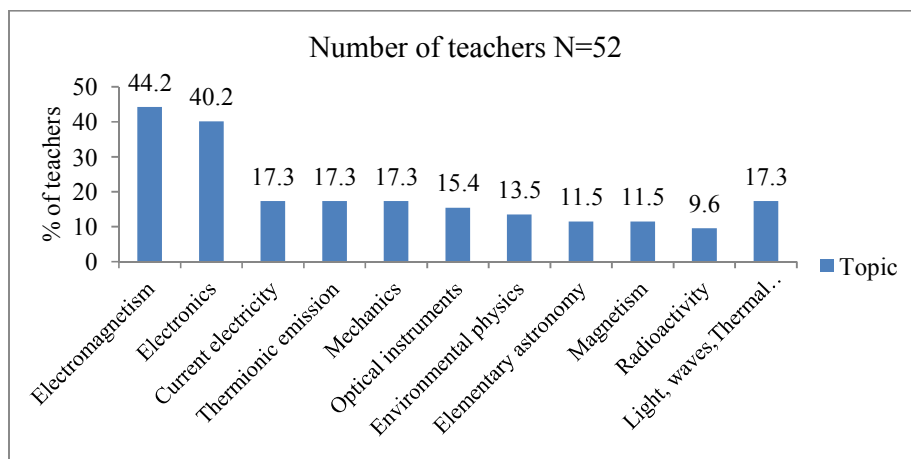


Fig. 1. Challenging physics topics by percentage of physics teachers selecting the topic for re-training and support

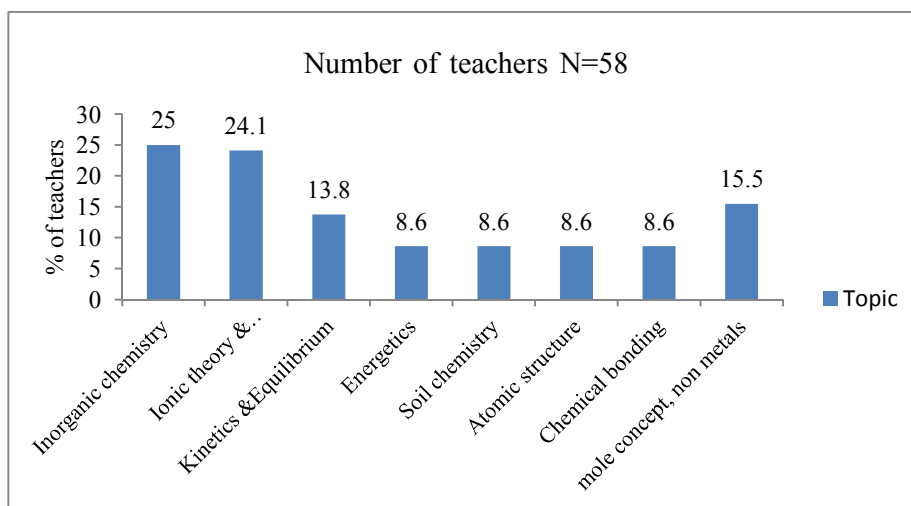


Fig. 2. Challenging Chemistry topics by percentage of Chemistry teachers selecting the topic for re-training and support

Data in Fig. 1. indicate that electromagnetism was selected by 23(44.2%) teachers, and electronics by 21(40.2%) teachers. These were top two topics in which teachers needed training or support. Other topics are picked by fairly equal percents. In electromagnetism the following were identified by response:

electromagnetic induction 15(28.8%), magnetic field 6(11.5%), magnetic field of the earth 4(7.7%), magnetic force 3(0.06%). In electronics responses identified: operational amplifier 10(19.2%), telecommunication 6(11.5%), transistors 6(11.5%), semiconductors 2(3.8%), logic gates 2(3.8%) and LASER 1(0.02%).

Fig. 2 indicates that inorganic chemistry was selected by 15 (25%) teachers, and ionic theory & electrolysis by 14 (24.1%) teachers. These were top two topics in which teachers need re-training and support. Other topics were selected by relatively equal percents. In inorganic chemistry, the following were identified by responses: extraction of metals 6 (10.3%), periodic classification 3 (5.2%), compounds of selected elements 3 (5.2%), and periodic trends in physical properties of elements 2 (3.2%). In ionic theory and electrolysis, responses identified laws & application of electrolysis 4 (6.9%), ionic theory 2 (3.4%), mechanism of electrolysis 1 (0.02), electrode potential 1 (0.02%).

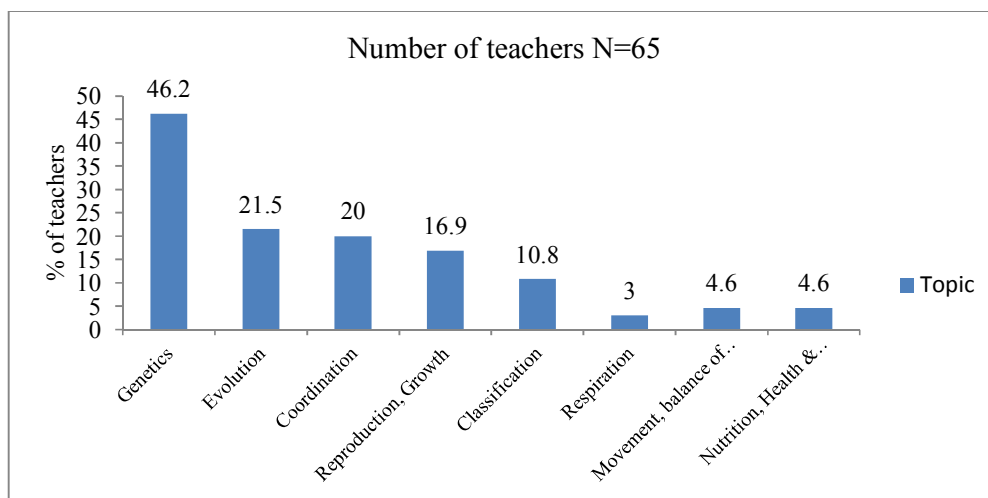


Fig. 3. Challenging Biology topics by percentage of Biology teachers selecting the topics for re-training and support

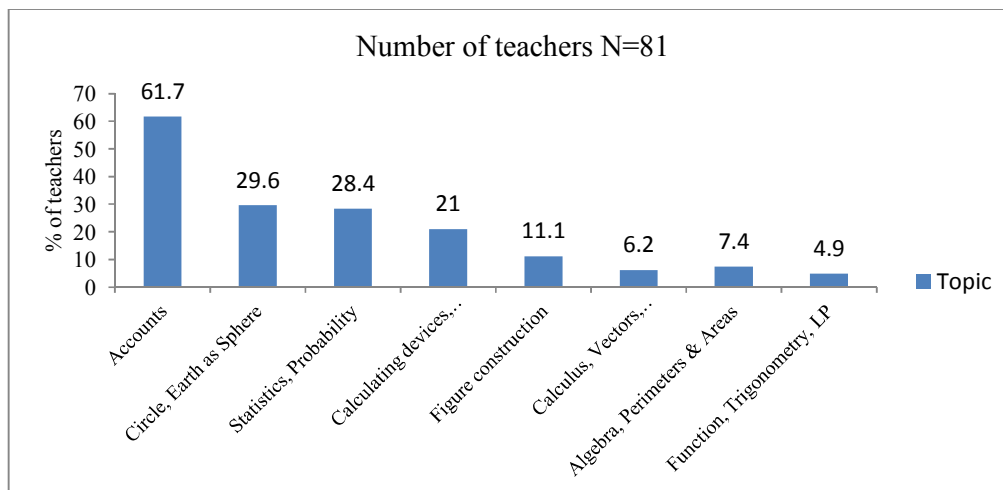


Fig. 4. Challenging mathematics topics by percentage of mathematics teachers selecting the topic for re-training and support

Fig. 3 indicates that genetics is selected by 30 (46.2%) teachers, hence the top topic in which teachers need training and support. Other topics were selected by fairly close percent to each other. In genetics, the following were identified by responses as follows: hereditary 11(16.9%), Mendelian principle of inheritance 10 (15.4%), mutation 7 (10.8%) and non-mendelian inheritance 3 (4.6%). Responses identified others as follows: theories of the origin of life 11(16.9%), evidence for evolution 3(3.1%) in evolution; nervous coordination in mammal 9 (13.8%), receptors 4(6.2%), coordination in plants 4 (6.2%), hormonal coordination in mammals 3 (4.6%) in coordination; meiosis 5 (7.7%), mitosis 5 (7.7%), reproduction in mammals 2 (3.1%), reproduction in plants 1(1.5%) in reproduction, growth & development; comparative studies of natural groups of organisms 6 (9.2%) and principles of classification 1 (1.5%) in classification.

Fig. 4 indicates that accounts was selected by 50 (61.7%) teachers, hence the top most topic in which teachers need training and support. Other topics were selected by fairly close percents. Identified by responses were: principle of double entry 27 (33.3%), trial balance 30 (37%), and final accounts 42 (51.9%) in accounts; theorem of circles or sphere 15 (18.5%) and application of theorem and formulae in solving problems 14 (17.3%) in circles & the Earth as sphere; mutually inclusive events 12 (14.8%), conditional probability 11 (13.6%), dependent and independent events 8 (9.9%), combination & permutation 8 (9.9%), discrete probability distribution 7 (8.6%), continuous probability distribution 7 (8.6%), mean, median, mode, standard deviation, graphs & interpretation, estimation of mode and median 7 (8.6%) and fundamental principle of counting 6 (7.4) in probability and statistics; application of logarithms in solving real problems 11 (13.6%), application of mathematical tables in computation 9 (11.1%), application of calculator in math computation 3 (3.7%), and application of computer software in solving math problems 3 (3.7%). Three dimensional figures, congruence & similarities of polygons and solving allied problem 10 (11.1%). The lowest responses, 4.9% for functions, trigonometry and linear programming (LP).

4 Discussion

Findings (Table 5) suggest that large proportion of teachers who never got INSETs and those who had once gotten in-service training but stayed at least six years without any training need PD. They need PD for skills on how to carry out academic guidance and career guidance to students; and how to prepare lesson activities for low, average and high performing students compared to teachers who attended INSETs within the past five years. It can be said that frequent trainings is essential for teachers to adapt and manage the changing learners and preparing materials that increase student learning. On the other hand, data in Tables 2, 3 and 4 indicate that statistically there is no enough evidence to support that there is difference in proportion of teachers who need PD for pedagogy topics. So, there is no relationship between studied pedagogy topic for PD and teachers' qualification, subject, and experience; and training status, except two topics. This is in line with what the UNESCO Need Assessment study for Tanzania's Science Education stated that during college programme, teachers did not have had adequate knowledge and practice to be able to apply the skills in job, but also graduated with little professional knowledge [14, 10].

Similarly Kiwhele (2014), Mkumbo (2011) and Ndalichako and Komba (2014) emphasized for students to be guided and counseled to help them raise their motive and interest for science, and choose subjects by ability [41, 32]. In other words, today's students demand extensive guidance in order to commit learning. Therefore PD for knowledge that affords teachers with guidance skills and teaching learners with mixed learning ability is critical.

A significant larger proportion for mathematics teachers needed PD about how to use inquiry in teaching, how to use collaborative learning and problem solving in teaching compared to the proportion of teachers for science subjects [28]. There is no significant difference in the findings where respondent teacher groups (like physics, chemistry, biology, math in Table 2) are more homogeneous. By using independent samples t-test, there is no significant difference in mean scores between mathematics and science teacher groups regarding the needs for skills such as PK, PCK and modern technological skills for teaching (Table 6). Thus, findings (Table 6) implies that both mathematics and science subject teacher groups have high demands for PD in:

- PK detailed on assessment and evaluation, constructing standard tests and exams, managing student discipline/behaviour in sciences, student counselling to enhance their interest in science, academic/career guidance and advice, supporting students at risk to drop science, and ethical teacher-student relationship.
- PCK detailed on preparing lesson activities for mixed ability learners, preparing lesson plan to meet diverse learning needs, concept map to solve students' confusion of concept interrelations, using collaborative learning/problem solving in teaching, using inquiry to enhance students' critical thinking, and engaging minorities in learning science/math.
- Technological Skills detailed on how to present lessons and analyse learning results by computer technologies and how to use standard laboratory tools or improvise to prepare reagents for laboratory lessons.

Teachers with high level of education like master degree wanted more development than bachelor and diploma holders but the difference was not statistically significant; also, teachers who did not get any training wanted more development to have their more gaps about teaching filled [27]. Teachers may be qualified by grades on basis of diploma/bachelor/master degree (Table 3), but not expert. Therefore, science teachers are qualified if have appropriate practice that affords them to present understanding of many aspects of PK, PCK and technology use in teaching [36].

Physics/chemistry concept formation require perceptive of the sub-atomic nature of particles (Sirhan, 2007), in the ideas for example in such topics as electromagnetism and electronics (Fig. 1) so as to visualize the descriptive part of such ideas and the symbolism and representational part. Hence, PD should engage the use of devices and chemicals.

Some topics in science for example inorganic chemistry are basis to build others (Fig. 2). There is high degree of teachers' and students' misconception in chemical knowledge on such ideas as electronic structure, physical properties of elements, transition element or complexes, chemical kinetics and bonding [32]. So PD must enable teachers to understand their misconceptions in teaching such ideas and examining students' works to know the likely misconceptions. Teachers' ideas on dissolution, particulate nature of matter and chemical bonding must be deepen, as they are basic for teaching kinetics, equilibrium and electrolysis [31]. More biology teachers want PD for genetics (Fig. 3). Lowest proportions wanted PD for topics of movement, balance of nature, regulation, nutrition, cytology, health & diseases. Concept understanding in biology need more refined teaching/learning aids, particularly the suggestion to use multimedia enhanced content, especially in biology concepts where virtual experiments can be used in place of real practical and experimentation [17, 26]. PD should focus on deepening teachers' understanding of nature of the topic concepts, teaching styles, strategies to motivate learners, guidance and advice; all of them aimed at freeing learners from negative feelings and attitudes towards the topics [29].

There is a difference in the subject content needs for PD between the four teacher groups (Figs. 1, 2, 3 and 4). Teachers who teach biology/ math specified more ideas that needed support and the percent of teachers in the top one challenging topic was above 46. Percent of Physics/Chemistry subject teachers in their top two topics were fairly lower especially in chemistry. Research indicates that more physics/ chemistry topics were reported for PD but only genetics was ranked by large percent for biology teachers; also, technology in support for math and teaching came first for math teachers as a development need [28]. The differences in findings of the current study suggest that either teachers are competent and familiar with subject content areas or the syllabus is partially implemented or topics skipped following the local context of school. Teachers' frequencies on picky topics, is a suggestion that they needed PD for;

- Mathematics subject; concepts in account 50 (61.7%), circles and the Earth as sphere 24 (29.6%), statistics and probability 23 (28.4%).
- Biology subject; concepts in genetics 30 (46.2%).
- Physics subject; concepts in electromagnetism 23(44.2%) and electronics 21 (40.2%)
- Chemistry subject; concepts in inorganic chemistry 15 (25%) and ionic theory & electrolysis 14 (24.1%).

5 Conclusion

Based on the research findings, science and mathematics teachers need PD for pedagogy knowledge and selective subject content topics. High demand on pedagogy knowledge informs that teachers are qualified by education level but re-training is required to afford them the strategies to win teaching the ever changing learners with changes of curriculum and technologies of instructions. Regular training is necessary to afford teachers with the skills for preparing lesson activities for mixed ability learners as well as student guidance and advice. The following are therefore recommended in this research study:

1. Private agencies and the Government should sponsor urgent intervention to train teachers in their areas related to improving teaching. Variation of development needs should be well recognized to make relevant improvements. This should also include special training to heads of schools to orient and build them the capacity to oversee school-based PD.
2. In order to study teachers' need for PD to improve teaching at the national level; similar studies should be conducted in other district of other regions
3. Longitudinal survey studies on biasness to some content areas or topics in the teaching of science/mathematics subjects should be conducted to add knowledge of what subject content for PD to improve teaching.
4. This study investigated teachers' needs for PD with limited data collection instruments. Similar studies at district levels should integrate multiple data collection methods.

Consent

As per international standard or university standard, participant's written consent has been collected and preserved by the author(s).

Ethical Approval

Ethical considerations were taken into account to secure appropriate data of the study.

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Competing Interests

Authors have declared that no competing interests exist.

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