Nurturing Teachers' Intellectual Power for challenging Mathematics: Implications for teacher training institutions in Botswana.

Authors:

Sesutho K. Kesianye

University of Botswana

Department of Mathematics and Science Education

Private Bag 0022

Gaborone, Botswana

kesianyes@mopipi.ub.bw

Paul A. Chakalisa

University of Botswana

Department of Mathematics and Science Education

Private Bag 0022

Gaborone, Botswana

chakalis@mopipi.ub.bw

and

Kgomotso G. Garegae

garegaek@mopipi.ub.bw

University of Botswana

Department of Mathematics and Science Education

Private Bag 0022

Gaborone, Botswana

A proposal to be presented at the ICMI Study 16

Challenging Mathematics in and beyond the Classroom

Trondheim, Norway

27 June to 03 July 2006

Abstract

The study was concerned with the question of the implications of challenging mathematics in the classroom for teacher preparation programmes. Specific focus was on the identification of the challenges and the role of teacher education programmes in efforts geared towards minimising the problems created by the challenges. The findings of the study informed the researchers of the challenging mathematics topics, how these are found challenging and provided some suggestions of

what can be done in teacher education programmes to address the issue. One prominent possible solution was suggested as the inclusion of and deeper coverage of school topics in teacher preparation programmes. A teaching intervention was implemented based on this suggestion and the findings were that this way of working has the potential to enhance teachers' knowledge base.

Introduction

In the discussion document for International Commission on Mathematics Instruction (ICMI) Study 16, the word "challenge" is used to depict two different meanings. On one hand the word is used to mean motivation. In this sense the phrase "challenging maths" refers to mathematics that stimulates students and encourages them to want to do more. This mostly applies in situations such as club competitions, exhibitions, recreational mathematics as well as in mathematics lessons based on progressive approaches to teaching such as the problem solving and investigations. On the other hand, the phrase "challenging mathematics" refers to "difficult and demanding mathematics" — a piece of mathematics that holds someone back and impedes one's progress. In this case, whoever finds the mathematics challenging might think of quitting and abandoning a difficult task. In this paper, we use the phrase *"challenging mathematics"* to mean the latter, unless otherwise stated.

What is challenging mathematics? According to whose perspective is it challenging? Is it teachers? Students? Parents? or the community? Some of these questions directed our research. People react differently when they meet certain challenges. Similarly, one would expect diverse reactions when teachers encounter challenging and difficult mathematical topics. Some would succumb to the situation by skipping the topic; not teaching it at all, others would try to get out of the situation one way or the other without disadvantaging their students. Still others might feel morose and depressed to the extent of contemplating leaving the profession. For whatever scenario, teacher education programmes should both equip and empower aspiring and practicing teachers with the necessary skills and dispositions. It is hoped that once effectively prepared in that manner, they may learn to overcome feelings of helplessness and despair amid the difficulties and challenges in their teaching.

Background

Since independence in 1966, the school curriculum in Botswana has gone through several curriculum innovation episodes. One of these episodes was to change from a Three to a Two-Year Junior Secondary school program in 1986. The reduction of the programme by one year had implications for the content, scope and sequence of the new curriculum. As can be expected some topics were excluded from the mathematics curriculum, and the breadth and depths of topics were not the same as in the preceding curriculum. After ten years of Two-Year Junior Secondary school curriculum, the programme changed back to three years. This change was engineered by unfavouring reports that graduates of the Two-Year junior secondary school were not only immature, but were also having a weak academic background to enable them to pursue further education or join the world of work. Then came the 1996 new Three-Year Junior Secondary school curriculum, which was enriched with more demanding topics as well as the introduction of technology in the form of calculators. The nature of the demands was in twofold. The first being that caused by the introduction of new content areas, and the second, being that of the change in focus in the teaching strategies and methods.

The current cadre of junior secondary school teachers consists of graduates of the Two-Year junior secondary school curriculum. Their dilemma is that they are required to teach topics that they have never learned before, at least when they were at the junior secondary school. In addition, they do not have any teaching experience of some topics in the new syllabus. They are also expected to use the available technology such as calculators and computers in teaching mathematics, something that they had never experienced during their school days.

In addition to the new curriculum demands, teachers encounter some problems that are embedded in the education system. Researchers report an ambiguous teacher-centred approach in schools, and this style of teaching is attributed to among other things, the examination system, large class sizes, a wide ability range in mathematics classes (Taole and Chakalisa 1995, Garegae-Garekwe, Chakalisa

and Taole 1995, Garegae 2005). Since these structural challenges are here to stay, teachers need to be empowered to live beyond them. They need not succumb to the situation, but rather use opportunities as stepping-stones to improve their situation. However, other factors may be associated with the preparation of teachers which in most cases is also teacher-centered (Deurwaarder 2000, Kesianye 2002) and do not develop desired qualities for learning in student-teachers (Kesianye, 2005). We argue for a teacher education programme that will equip teachers with adaptive skills, relevant dispositions and professional attitudes. We posit that if teacher educators could regard their clientele as transformative intellectuals and teach them as such, the situation in school may be abated.

The aim of this study was to find out how teacher education programmes can be designed to empower secondary school teachers for teaching topics identified as challenging to both the teacher and students. Questions that directed the enquiry were:

1. Which topics do junior/senior secondary school teachers find challenging?
2. To whom are these topics a challenge?
3. What action, if any, do teachers take to alleviate the problem/challenge?
4. How can teacher education institutions enable teachers to cope with the problem of teaching difficult topics?

Theoretical Framework

Teachers need to be empowered to meet diverse situations in the classrooms and outside the classroom. In the classroom, teachers in general, and in particular mathematics teachers, meet students who are not motivated to learn; students who want to learn but have difficulties in understanding what is being presented. Also, the teacher might find him/herself having to teach difficult and challenging topics. Regardless of the situation, the teacher has to teach and produce good results, failing which he/she is labelled incompetent, hence tarnishing his/her career image. Since teacher education institutions cannot provide all scenarios and situations that teachers are likely to encounter in their career lifetime, the kind of dispositions during training should instil lifelong learning attitudes. We argue that training that is based on 'transformative' learning is of paramount importance.

Using Giroux's (1988) concept of teachers as transformative intellectuals, we claim that teachers can be prepared for the challenges and difficulties as enumerated above. Giroux's critical pedagogy of learning posits that both teachers and learners must be active co-participants in the teaching and learning process. Teachers are to educate learners to be active critical citizens. This calls for teachers to be involved in the process of action, reflection and reflexiveness at the same time. To enable teachers to reflect and act simultaneously, teacher education programmes should instil in them appropriate dispositions. First, teachers should be self-actualised, and then they will have the desire to know and understand (Maslow, 1970). Second, they should be treated as human beings who can think. The way they are taught should not resemble Freire's (1970) "banking" concept where they become passive recipients of knowledge. As much as they are expected to engage learners at secondary schools, student teachers at institutions of higher learning should be engaged in their learning. Because the teacher would be well-groomed, self-actualised, he/she can squarely face challenging mathematics with a positive attitude. He/she is likely to take the initiative of wanting to know more about the topic so that next time he/she will be able to teach it. He/she could also look for a resource person without having feelings of both incompetence and insignificance for his/her self-concept is not wanting.

Design and Methodology

A qualitative case study was employed to explore teachers' views and experiences with regard to challenging mathematics topics. A qualitative research approach was deemed appropriate because of the kind data needed and the size of the sample. The focus group approach was used in order to get "information (we) would otherwise not access" (Babbie and Mouton 2002:291). Because of the space they get when in a group, individuals in a focus group are free to contribute to the discussion.

When making contributions about a phenomenon, members of the focus group have a sense of belonging that they are not alone in the struggle when similarities and differences in opinion surface. Our experiences indicate that teachers are usually uncomfortable with being interviewed especially by lecturers. They usually suspect that they are being evaluated. Besides, this comfort factor, we also considered the role of teachers in what and how they can learn. As experienced teachers they can draw from their experiences to enrich their preparation programmes. It is from these points of view that we choose the case-study focus group approach.

Selection and Sampling

The study employed purposive sampling. According to Maxwell (1996: 69), purposive sampling is "a strategy in which peculiar settings, persons or events are selected deliberately". Thus, participants of this study were chosen basing on both their availability and ability to inform the study in terms of providing rich experiences they have gained from several years of field work.

Participants

Two sets of teacher participants were selected basing on their availability. The first group were eleven (11) in-service teachers who had enrolled in the Bachelor of Education programme at the University of Botswana after teaching at junior secondary school level for at least five (5) years. Because they were housed in the institution where researchers work, cost and distance constraints were eliminated. Researchers could easily arrange with this group of participants for further probing. In addition, one of the researchers was teaching them two core courses. This was a significant advantage with regard to the practice of how to teach some of the topics identified. All these teachers hold a three-year Diploma in Secondary Education (DSE) certificate. The second set of participants was twenty-three Mathematics Senior Teachers Grade 1. These were drawn from twenty-three out of twenty-seven senior[1] secondary schools in the country. These participants had convened to the capital city for a national in-service workshop organized under the auspices of DMSE-INSET[2]. The workshop was within reach of the researchers, thus issues of the cost and distance were reduced.

Instruments and data collection

Data was collected from two groups of teachers at different times. Participants were told, at the time of questionnaire administration, how their contributions would be used. The questionnaire was administered to the junior secondary school teachers by one of the researchers and she made clarifications where necessary. Those who took the questionnaire away for reference to other resources such as the syllabus returned them as arranged. Upon returning questionnaires, focus group discussions were held. Teachers from senior secondary schools were given the questionnaire on the second day of the workshop. The other instrument of data collection involved reflections of teachers in how teacher education programmes can prepare them to teach the identified challenging mathematics topics. The reflections extended to after the implementation of the teaching intervention where the in-service teachers noted aspects of both the subject-content knowledge and the pedagogical content knowledge that they acquired from the intervention.

The teaching intervention

As an ongoing study, feedback from the questionnaire and Focused group discussions were used to modify the study by incorporating the findings in a related course for the in-service teachers. This related course, ESM 392 has as a topic on '*Teaching Difficult Topics'*, which gave the researchers an opportunity to incorporate in-service teachers' suggestions. The in-service teachers suggested, among other things, that they should be prepared in the subject content and pedagogical content knowledge on these difficult or challenging topics in a manner that these topics can be taught at the secondary school level. In other words, they wanted to be assisted in understanding the subject content and in how they can teach the topics. Therefore, groups of two to three in-service teachers were assigned to prepare to teach a 40 minutes lesson on one of the four topics. The in-service

[1] The curriculum for senior secondary school BGCSE is equivalent to IGCSE and was introduced in 1997 and it is the amendment of COSC.

[2] DMSE-INSET stands for Department of Mathematics and Science Education In-service programme.

teachers were requested to note their reflections from lesson discussions that followed and these reflections are discussed under the results section later in the paper.

Data Analysis

A qualitative approach to data analysis was employed to interpret the responses and to identify emerging themes about how teacher education can empower teachers for mathematical challenges in their teaching. The Framework Analysis (Ritchie and Spencer, 1994) was employed to analyse data in this study. It shares many of the common features of much qualitative analysis methods, particularly the "thematic analysis" level of qualitative analysis as observed by Lacey and Luff (2001). Framework Analysis allows for the inclusion of a priori as well as emergent concepts. In contrast to the Grounded Theory Analysis (Glaser and Strauss, 1967), where the resulting theory emerges from the data, Framework Analysis is developed for research aimed at meeting specific information needs and providing outcomes or recommendations on policy or practice matters, usually within a short time scale. In this approach to data analysis data can be collected before the analysis, which was done in this study. The five key stages of Framework Analysis being, Familiarisation; Identifying a thematic framework (initial coding); Indexing (applying codes); Charting; and Mapping and interpretation, were then employed. As Framework Analysis allows for the inclusion of emergent issues and it is conducted for purposes of meeting specific information needs to provide outcomes or recommendations, this study took on board the findings from the questionnaire to plan and implement a teaching intervention. Data collected from the intervention was also analysed to ascertain the effectiveness of the intervention programme for further development of the preparation of teachers accordingly to be envisaged. The main focus of the analysis was to ultimately develop strategies for empowering teachers in teaching mathematically challenging topics. However, further analysis can be employed towards theory formulation and testing in future extensions to the study.

Results Presentation and Discussion

This study explored teachers' views pertaining to challenging mathematics in junior and senior secondary mathematics syllabi. The findings of the study are presented under the following thematic titles: (1) Identified challenging topics, (2) Suggested possible solutions, (3) Perceived role of Teacher education institutions and (4) In-service teachers' reflections on the teaching intervention.

1. Identified challenging topics

The first research question concerned itself with identification of challenging topics in the syllabus. Junior secondary school teachers identified twelve topics. These are: plans and elevations, basic trigonometry, quadratic and simultaneous equations, matrix multiplication, civic arithmetic, transformations, three-dimensional figures, directed numbers, scale drawing and maps, conversion of units, time, sequences and proportion. The rating by junior secondary teachers was as follows (See Table 1): 'Plans and Elevations' was the most challenging topic to teach followed by Civic Arithmetic topics. Out of the 11 in-service teachers, 5 found Plans and Elevations to be challenging to the teacher, while 6 found the topic to be challenging to both the teacher and students. Probability is found challenging for the teacher by 2 out of 3 in-service students who identified the topic. Three out of five who identified Civic arithmetic found it challenging to both the teacher and students. It should be noted that 'Plans and Elevations' and the 'Civic Arithmetic topics' identified as challenging, were introduced in the curriculum for the first time by the new Mathematics syllabus in 1996.

Table 1: Challenging topics from junior secondary school teachers.

Topic	Teacher Challenged	Students challenged	Both teacher and students challenged
Plans and Elevations	5		6
Trigonometry	2		1
Probability			
Quadratic and simultaneous		1	

equations			
Matrix multiplication		1	
Civic arithmetic		2	3
Transformations		2	1
Three-dimensional figures	1	1	
Directed numbers (Subtraction)		1	
Scale drawings and maps		1	
Conversion of units		1	
Time		1	
Sequences		1	
Proportion		1	

These are some of the reasons for these difficulties grouped into categories: Incompetence in the subject matter; Incompetence in pedagogical content knowledge; Lack of resources; and Negative attitudes towards some topics by both teachers and students.

Senior secondary school teachers identified about 15 subtopics that are challenging to both teachers and students (See Table 2). Identified topics with high frequencies are those in the extended[3] section of the curriculum and *additional mathematics*. In the core section of the syllabus, statistics, probability and estimations were popular with frequencies of 10, 7, and 6, respectively. Other challenging topics identified with frequencies less than 6 were: 3-D trigonometric functions, loci in 2-D, inequalities/linear programming, money transactions, geometry, 3-D shapes, as well as linear and quadratic equations.

Table 2: Challenging topics for senior secondary school teachers

Topic	Frequency	How/Why challenging
Statistics (Interpolation + sampling)	11	- Difficulty in explaining to students - Lack of resources
Reflexive velocity	8	- Material new to most of teachers - Difficulty in explaining to students
Probability	7	- Content new to most teachers - Difficulty in explaining to students
Permutations and Permutations	7	- Not able to explain concepts
Scale Drawing	6	- Lack of material
Limits of accuracy	5	- Not confident in the content - Difficulty in explaining to students
Trigonometry in 3-D figures	3	- Difficulty in communicating concepts to students
Linear programming	3	- Difficulty to explain - Lack of materials
Estimation and approximations	3	- Not sure as to when to use 1dp or 2dp - Lack of resources
Symmetry of circle	2	- Lack of material

There is a clear indication that both junior and senior secondary school teachers are challenged by topics that are interrelated and are mainly about geometrical ideas. The majority of participants indicated that most of the topics in the secondary school curriculum are new to them. They did not learn such topics during their secondary schooling period. Because of lack of this exposure, they are unable to teach these topics and the recommended textbooks do not adequately, and in some cases do not at all, cover these topics. Participants in this study also indicated that some mathematics topics are challenging to students. The difficulty of topics to students is attributed to lack of foundational concepts from the preceding level. Some of the topics are introduced for the first time at each level without specific connections being made to previously covered topics, and this, teachers argue, disadvantages students. They find these topics difficult to understand and thereby taking much of teaching and learning time.

[3] The BGCSE mathematics curriculum is divided into core and extended. The core section is compulsory, and the extended is taken by those who obtained very good grades for mathematics and other pure sciences at Junior Secondary School Examinations.

2. Suggested possible solutions

Teachers say they find it difficult to explain certain topics because of their incompetence in pedagogical content knowledge or in the subject content knowledge, as well as shortage of material. On the other hand, students find such topics difficult because they lack basic pre-requisite concepts. In their attempts to handle these challenges, teachers engage in six strategies. These are (a) teamwork within the same department, (b) forming a liaison across subject departments, (c) making connections, (d) indoctrination by drill and practice and (e) Employment of progressive approaches such as group work.

3. Perceived role of teacher education programmes.

The following suggestions were made addressing both pre-service and in-service programmes:

- Cover entire content to be taught in schools in detail at teacher training
- Workshops in clusters for mathematics teachers on how to handle these topics
- Other subject teachers to be used to resource mathematics teachers
- Workshops in topics identified by teachers to be difficult
- Workshops when new topics are introduced in the syllabus
- The programmes can be made to include such topics so as to give the teachers more information than is required by the J.C. syllabus
- Education officers to visit schools more frequently to assist where possible
- The identified topics to be used for peer teaching at teacher training institutions so that teachers can get help right away

The last thought was adopted in a teaching intervention whereby in-service teachers were asked to prepare lesson plans for some identified difficult topics, and teach such to their colleagues.

4. A case study of exemplary lesson plans

Coverage of some of these challenging topics in one of the courses, which directly deals with teaching difficult topics, was attempted. During the course sessions, the progressive approach to teaching was discussed and the in-service teachers were given an opportunity to practice teaching these topics from discussed learner-centred and conceptual development approaches to teaching. The preparations for these lessons focused on teaching approaches and methods that would enable relational understanding, which derives from active involvement of the learners. The participants were urged to search the literature with the hope of producing lesson plans which have learner-centred activities and meant to promote conceptual understanding rather than procedural understanding. The specific topics taught were Plans and Elevations, Connection between Plans and Elevations and the Construction of 3-D figures, Trigonometry, and Subtraction of a negative number from another negative number. Lesson plans (See appendices) were produced, implemented and reflections made after the lessons. The in-service teachers commented about learnt mathematical ideas and pedagogical issues as follows:

(a) subject-content knowledge:

"I learnt that projections can be made in two ways e.g. 1st angle and 3rd angle projections. I also learnt the difference between the terms orthographic and isometric in relation to Plans and Elevations. I learnt that an orthographic object can be transformed into an object in the form of isometric and vice versa. "

"Transformation from 3-D to 2-D and vice versa as well as the fact that views and plan must have proportionality (e.g. in height, length and width)."

"The Loop and pipe cleaners method [of subtracting negative numbers] was new to me."

"The difference between a plan and the elevations."

"Angles of observations, ie. Vertically for the plan and horizontal observation for other views."

"Linkage of plans and elevations to 3-D figures."

(b) pedagogical-content knowledge

"Words are [to be] explained and not just left to students to find out their own meanings"

"Directed numbers - the use of visual representation on addition and subtraction of directed numbers"

"The use of manipulatives, cooperative learning.."

"Trigonometry- the sequencing of concepts"

The in-service teachers' reflections indicate that they acquired new knowledge with regard to these topics from the teaching intervention. Their previous teaching of these topics was obviously done with lack of understanding of some basic concepts such as the difference between a plan and the

elevations. The new understanding of these topics and how to teach them was a direct result of the in-service teachers taking an active part in the preparations for the lessons and the actual teaching of these topics during training. Although, the effectiveness of the intervention cannot be judged based on this case study, there is indication from the participants that working in this fashion has the potential for enhancing their knowledge base.

Conclusions and Recommendations

It is evident from the results that the inclusion and deeper coverage of school Mathematics content in Teacher Education programmes is called for by teachers who have experienced the difficulties of teaching these challenging topics. However, one aspect of teacher preparation that in-service teachers do not seem to comprehend is related to capacity building of lifelong learning skills for themselves. Their suggestions on minimising the problems of challenging topics seem to be focusing on others at the exclusion of what they can do for themselves. Issues of attitudinal change and self-reliance do not seem to have any bearing on how they teach as none of the suggestions were along these directions. We are aware that both pre-service and in-service teacher preparation cannot cover every challenge that teachers are likely to encounter in their teaching of mathematics. Instead, we advocate for the development of lifelong learning skills such as self-autonomy in their initial preparation. Engagement in discussions with other teacher educators is perceived to have the potential for empowering the researchers to develop programmes that nurture teachers' intellectual capabilities and produce 'transformative' teachers.

References

Babbie, E. and Mouton, J. (2002). The Practice of Social Research. Cape Town: Oxford University Press Southern Africa.

Deurwaarder, J. (2000). *Keeping of Diaries by Student-teachers in a Constructivist Learning Environment to enhance the development of a constructivist learning and teaching view and practice.* Paper presented at National Conference on Teacher Education, Gaborone

Freire, P. (1970). *The pedagogy of the oppressed*.

Garegae, K. G. (2005). *The impact of junior secondary school terminal examinations on classroom dynamics.* In J. Adler (ed.), Proceedings of the 12th Annual conference of the Southern African Association of Mathematics, Science and Technology Education. Windhoek, Namibia.

Garegae-Garekwe, K. G. (1999). *Pre-service teacher education program for secondary school teachers at the University of Botswana*. A working paper. University of Manitoba, Winnipeg, Canada.

Garegae-Garekwe, K. G., Chakalisa, P. A, & Taole, J. K. (1995). *Renegotiating the preparation of mathematics teachers: call for a shift in paradigm*. A paper presented at the Second National Conference on Teacher Training. Molepolole, Botswana.

Giroux, H. A. (1988). *Teachers as intellectuals.* New York: Bergin & Garvey.

Goldin, G. & Shuteingold, N. (2001). Systems of representations and the development of mathematical concepts. In A. Cuocos (ed.), *The roles of representations in school mathematics.* Pp. 1-23. Reston, Virginia: NCTM.

Kesianye, S. (2002). *Teachers learning to Assess students' mathematics: An Investigation with Botswana Pre-service Teachers*. Doctoral Thesis, The University of Leeds, Leeds.

Kesianye, S. (2005). *Developing Desired Student-Teacher Qualities for Learning through Interactive and Reflective Teaching/Learning Methods*. Paper presented at The 1st African Regional Congress of the International Commission on Mathematical Instruction. Johannesburg. South Africa.

Kesianye, S. and Deurwaarder, J. (1997). *Graduates' views on the Pre-service Professional Studies component in the Mathematics Programme at Tonota College of Education.* Paper presented at the Third Biennial Conference on Teacher Education. Gaborone Botswana.

Lacey, A. and Luff, D. (2001). *Trent Focus for Research and Development in Primary Health Care: An Introduction to Qualitative Analysis*. Trent Focus.

Maslow, A. (1970). *Motivation and personality.* 2nd ed. New York: Harper & Brothers.

Maxwell, J. (1996). *Qualitative research design: an interactive approach.* Thousands Oaks: SAGE.

Taole, J. K. & Chakalisa, P. A. (1995). *Implications of the National Commission on Education for mathematics.* Mosenodi 3 (1&2): 15 –22.