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Some Pedagogical Tensions in the Implementation of the Mathematics Curriculum: Implications for Teacher Education in South Africa

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The purpose of this paper is to analyse the pedagogical tensions that interns face during teaching practice. The tensions have the potential to widen their theory-practice gap. Whilst government policies on training to use enquiry methods in the classrooms are explicit, the contexts of schools such as paucity of mathematics and science teachers, makes some interns in these subjects practice teaching without the guidance of experienced teachers. In circumstances where interns are attached to experienced teachers to coach them, the examination system and differences in conceptions on the nature of mathematical content makes traditional rather than learner-centred methods emphasised by experienced teachers. The paper reveals the reasons why reform pedagogy is difficult to be implemented in schools. This revelation presents training institutions with mammoth tasks in educating interns when the enquiry methods that they emphasise are not practised in schools. The paper informs ongoing debate on Higher-Education Institutions (HEI)s in South African schools in particular, and Africa in general, on how to arrange practicum programs for interns that can facilitate the integration of theory and practice.

Introduction

Teaching mathematics effectively is a complex enterprise that involves overcoming a myriad of variables (Even, 2005; Freed-Garrod and McNaughton, 2005). As also noted by Makitalo and Saljo (2002), effective teaching requires attributes such as practical experience, wisdom, common sense, understanding, and good communication skills. On the African continent, the complexity is ubiquitous because some teachers who lack these attributes grapple with additional aspects of limited resources, creating classroom environment that promotes learner active participation as well as challenging and extending learners thinking capacities.

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To reduce the complexity of teaching requires teachers to go beyond employing technical competencies to using their craft knowledge (Brown and McIntyre, 1988) in order to create instructional milieus that change from teacher-centered to learner-centered environments in response to the reform curriculum. Thus, to achieve reform goals it may be necessary to move student teaching of learning how to teach from the "level of ritual to that of principled knowledge" (Russell, 1993: 213). From the reform perspective, to teach mathematics effectively entails equipping learners with "conceptual understanding of the process skills that enables them to individually or collectively develop a repertoire for developing powerful constructions that can concur with viable mathematical knowledge" (Davis, 1990 cited by Nyaumwe and Mtetwa, 2006:35). Sherin, Mendez, and Louis (2004) noted that students' effective learning of the reform curriculum involves activities, reflection, and collaboration in order to socially construct viable conjectures that are in harmony with accepted knowledge of a discipline.

To effectively teach the mathematics reform curriculum, teachers need understanding of the four broad goals of education, namely problem-solving, communication, connections, and reasoning (National Council of Teachers of Mathematics NCTM, 1989) that are the cornerstone of the subject. In pursuing reform expectations, different African countries highlight mathematics goals, at all levels of formal schooling that are stated on the curriculum statements or syllabuses. Examples of such goals are to develop learners' ability to (a) reason mathematically and justify their thinking as well as understand the reasoning of others, (b) apply mathematical knowledge and know-how to analyze and solve both familiar and nonfamiliar problems, (c) organize, interpret, and manage authentic activities using logical mathematical reasoning, and (d) engage responsibly with quantitative arguments relating to issues that arise from learners' environments (Revised National Curriculum Statement, 2005; Ordinary Level Sylabus, 2004). These goals emphasize application of mathematical concepts in learners' environments when the knowledge and skills gained in the classroom are achieved through norms of learner cooperation and social interactions that can lead to both conceptual and procedural understanding of concepts and algorithms.

The National Curriculum Statement for a discipline is usually explicit of the goals to be pursued but teachers' implementation in the classroom vary according to how they resolve pedagogical tensions arising from their conceptions of mathematical content, understanding of the curriculum goals and the complexity of mathematics classrooms that are created by learners. The term "pedagogical tension" is used in this paper to denote the factors that influence or motivate teachers to deviate their teaching from the methods encouraged by the intended curriculum in response to learners' needs and professional decision-making. The paper analyses the

tensions that influence experienced teachers' and student teachers' curriculum implementation strategies. The curriculum implementation tensions are discussed in the context of South Africa using one model of teacher education, Distance and Open Learning (ODL) offered by the University of South Africa (Unisa). The two national documents that are used to monitor the quality of education in South Africa, Norms and Standards for Educators (2000) and The National Policy Framework for Teacher Education and Development in South Africa (2007) are used to show the tensions that sometimes exist between the intended and enacted curriculum. Towards the end of the paper we present some of the tensions of teacher education programs in South Africa to adequately prepare mathematics teachers who are self rejuvenated through learning from self instructional practice and that of others in order to offer effective teaching in the present and future complex instructional environments that are possible in the classroom.

Curriculum Design and Development

In South Africa, as elsewhere, the school as an institution that is publicly funded by taxpayers is expected to nurture and groom the young generation by imparting to learners a set of values, knowledge, and skills that can enable them to engage responsibly in conducting personal, social, and national duties expected of responsible citizens. Perceived in this context, a curriculum is the set of values, knowledge, and skills usually expressed as statements, courses, and content that learners are expected to achieve during school hours. The contents of a curriculum are debatable. There sometimes does not exists consensus among different stakeholders in a society such as educational, religious, political, commercial, and industrial leaders of what constitutes worthwhile knowledge to be emphasized in a curriculum (Kneeler, 1962). Westbury, Hirsh, and Cornbleth (2002) were not prescriptive of the contents of a curriculum but made some useful suggestions of what could be contained. They suggested that for school leavers to effectively participate in the social, cultural, political, and economic life of their societies and nations, a curriculum should reflect layers of important issues valued by a society. Such layers may include cultural, political, social, and scientific understanding of essential basic knowledge that can provide individual self-esteem and productive disposition to have the potential and flexibility to be taught and quickly master skills for vacations they may choose to take after school.

In their efforts to design a balanced curriculum that reflects national priorities, the South African government has a Curriculum Design and Development Unit within the ministry of education. The Curriculum Design and Development Unit consults stake-holders and decides on the subjects to be offered at different levels of formal school programs. Teams of subject specialists in the Curriculum Design and Development Unit

write the National Curriculum Statements for each of the subjects on offer. The Department of Education hands the national curriculum documents to provinces, which in turn give them to districts and finally to schools for teachers to implement the national vision. Teachers' roles are usually obscured in the curriculum design and development process because high ranking education officials in a province usually appoint a teacher representative to sit in a national subject panel. Feedback on the curriculum development process is usually hard to filter down to teachers because there are no functional structures for teachers to receive feedback from their representative on the national curriculum design and development decisions. Teachers' limited involvement in the curriculum design and development process has potential to make them vary their implementation strategies within the same school and across schools. The variations are acerbated by pedagogical tensions arising from school contexts and individual teacher understanding that often make the intended curriculum being different from the implemented curriculum.

Types of Curriculums

The National Curriculum Statement in the South African is centrally distributed and teachers implement it. Teachers, however, sometimes hold different interpretations in implementing the intended curriculum. Learners, on the other hand, do not always achieve the goals that the teachers plan for them. This gives rise to three types of curriculums, namely, the intended, the implemented, and the attained (Zuzovsky, 2003). The intended curriculum refers to the formal, approved guidelines that provide goals of teaching a subject as well as the breadth and depth of the content that is to be covered at each grade level. The **intended curriculum** can become a reality when teachers are able to deeply understand the goals that learners are expected to achieve, the content learners are to master, and the pedagogies that enable learners to conceptually understand what they learn. Such learners' understanding can facilitate their application of subject matter content in familiar and nonfamiliar situations as well as enable them to become productive members of a society. The **implemented curriculum** emanates from the actual process of teaching a subject content that occurs in the classroom as a result of teachers' interpretations and their perceived understanding of the National Curriculum Statement (Akker van den, 2003). It is reasonable to anticipate variations in the implementation strategies of the same curriculum because the implemented curriculum is influenced by individual teachers' interpretations and understanding. The curriculum implementation variations usually result in the attained curriculum also varying from one teacher to another as well as school to school. The **attained curriculum** embraces the learning goals that are achieved by learners after undergoing a program of study at school.

The challenges facing formal education in South Africa, as elsewhere, emanate from the failure to reduce the myriad of tensions that divide the intended and implemented curriculum so that the attained curriculum produces national cadres, who can do problem-solving, communicate, make connections, reason. and apply academic knowledge (NCTM, 1989) in spearheading the cultural, industrial, and technological development of the country. Teachers play a vital role in the reduction of the gap between the intended and implemented curriculums. For instance, recognizing the role of teachers in curriculum implementation, the South African government sets the criteria for one to qualify as a teacher.

Government Policy on Practicing Teachers

The South African government policy currently dictates that a person must hold a minimum of a Bachelor's degree in a subject that is offered in the school curriculum for one to qualify as a teacher. Those teachers in the service with Certificates in Education continue teaching but are encouraged to study for an Advanced Certificate in Education (ACE). Possession of a Bachelor of Education degree (B.Ed) or Post-Graduate Certificate in Education (PGCE) is the current minimum requirement for practicing as a teacher in public schools. Teacher education on both the B.Ed and PGCE programs are required to meet the standards set by the government as stipulated in the South African national policy documents for interns to be accredited as teachers. The Norms and Standards for Educators (2000) and The National Policy Framework for Teacher Education and Development (NPFTED) in South Africa (2007) stipulate the minimum standards that pre-service teachers must have before they can be accredited as teachers in the country. NPFTED (2007) recognizes that the art of teaching can only be developed through experience in the classroom and that schools are the only suitable places for the relevant learning of how to teach. In line with this recognition, the policy document requires that HEIs, schools, and student teachers should form partnerships, which monitor student teachers' acquisition of professional skills and knowledge. For instance, HEIs collaborate with schools to determine whether a student teacher has successfully attained Qualified Teacher Status (QTS). In order to achieve QTS, student teachers have to demonstrate to the partnership that they have reached a particular level of professional competence by displaying satisfactory synergies of teaching knowledge and skills.

The NPFTED document expects the HEI-school partnerships to benefit student teachers in their learning to teach. For instance, HEIs are encouraged to have a full-time teaching practice model that pairs a student teacher and an experienced teacher in an attachment school. This model enables student teachers to learn the art of teaching under the assistance of experienced teachers. The pairing can also enable student teachers to share

the expertise and craft knowledge of experienced teachers through imitative interactions (Nyaumwe, 2001). When experienced teachers coach student teachers the art of teaching, they can easily monitor a student teacher's ability to handle a lesson alone. Depending on a student teacher's capacity to handle a lesson alone, the number of lessons that a student teachers can teach per day can be increased and targets of the teaching skills that they can implement in a lesson can mutually agreed upon. This model can enable student teachers to systematically implement the pedagogical theories that they learn during teacher education and whilst receiving constructive feedback of how successful they implement them from their hosting teachers. The feedback from hosting teachers, who understand the unique school contexts that they teach in, can be more professionally enriching than lecturers' supervision feedback, which is sporadically made and not focused on teaching skills that are mutually agreed upon with the student teachers. Continuous presence of hosting teachers in student teachers' lessons can enable them to make more valid assessment grades than a lecturer who visits student teachers "once and for a short time" (Connelly, 1994, p. 166). Due to limited financial resources a lecturer on supervision of student teachers' teaching practice competencies normally assess all of them in one school or in a confined geographical location that the supervision is sometimes hurriedly conducted in order to attend to the next student teacher.

The NPFTED's intended curriculum for student teachers are implemented by HEIs. We show below how one HEI, Unisa, implements this curriculum.

Teaching Practice Model in Use

Unisa is an Open Distance Learning (ODL) institution. The institution, with a main campus based in Pretoria, offers undergraduate and graduate studies accessible to students who can study at their pace, choice of time, and place without distractions of having to sacrifice some important activities in their lives such as working in formal jobs. Distance education can provide students with challenges to engage with independent study packages and to manage their own studies with minimal face to face tuition.

The two respective departments of teacher education and further teacher education at Unisa offer programs for undergraduate and post graduate students using ODL. Teachers who obtained certificates in education from teachers' colleges can upgrade themselves by studying Advanced Certificate in Education (ACE). People with passes in Matric examinations, gainfully employed or otherwise, who have a passion for teaching and can meet the entry qualifications, can enroll for a B. Ed degree. Those people with an undergraduate degree and passion for teaching can enroll for the PGCE program.

Unisa, as a committed ODL centre, makes every attempt possible to reach out to all students by using various modes of communication. Chief among the modes of studying are study guides that cover a comprehensive content of a course. Other modes of study materials offered are assignments, the e-library, week-end discussions, regional literacy centers, counselors to assist with study skills, peer groups, and *myUnisa* (an online learning management system that is accessible on the website of the university) are at students' disposal.

Unisa envisages producing effective teachers who can display teaching competencies in different educational contexts that characterize the rainbow nation. South Africa is considered to be a rainbow nation because of its multicultural nature with eleven indigenous languages. The teachers are expected to be self-rejuvenated in their teaching competencies by continuously developing understanding of what teaching is all about in school environments through reflective practice. In pursuing this vision, pre-service teachers are provided with a well-rounded and systematic knowledge base in a discipline and a detailed knowledge of a specialist subject. For instance, the pre-service teachers concurrently study a minor and major subject in addition to an indigenous African language that is different from their first language. The inclusion of an extra indigenous language during pre-service teacher education is to enable the prospective teachers to be able to code-switch during their teaching because the multilingual classrooms in the country present language barriers to most students learning in English as their second language (Setati, 1998). The skills of coping with teaching in multilingual classrooms can enable prospective teachers to develop the ability to present and communicate subject matter using their knowledge of the learners, content knowledge, and pedagogical content knowledge that form well-structured arguments. This would show awareness of the ternary relationship between content, learners, and the teacher. The prospective teachers practice these skills under the guidance of the university when they go for teaching practice.

Teaching Practice

Student teachers do teaching practice for a minimum period of 5 weeks (25 school days) per semester. They are required to prepare and present at least 5 lessons in the minor and major subject respectively. They spend the rest of the teaching practice period observing lessons taught by the host teacher or performing some professional duties assigned to them. The choice of the five lessons that student teachers can teach in a subject is determined by host teachers who balance student teachers' observations of demonstration lessons (taught by host teachers) and teaching lessons to practice implementation of pedagogical strategies mutually agreed upon. For the lessons that they teach, student teachers write a detailed lesson plan. The template of the detailed lesson plan, among other things,

highlights essential professional aspects such as lesson outcomes, manipulatives to be used during instruction to develop concepts, learners' prior knowledge, lesson stages, time management, and reflection on the lesson taught. A summary of the five lessons taught by a student teacher in a subject together with the evaluation comments made by the hosting teacher and supervisors are sent to the University for grading.

Teaching practice in the ODL model of teacher education inherently is wrought with challenges in terms of implementation logistics. ODL institutions are accessible to unlimited number of students because they do not face constraints of teaching space and staff. As a result, the number of students enrolled at Unisa for teaching practice each semester is extremely high. Challenges are exacerbated by the sparse geographical locations of schools within the vicinity of student teachers' home bases. Because student teachers seek attachment to schools within their home vicinity, Unisa student teachers on teaching practice are spread throughout South Africa and for university lecturers based in Pretoria to realistically visit all of them for the purposes of assessment of classroom practice during the twenty-five weeks of teaching practice is logistically a nightmare. For standardization of student teachers' classroom practice, the university appoints supervisors in the districts where attachment schools are located. These supervisors, also referred to as tutors, are professional educators with experience in the teaching of subject areas that they are hired to assess. The district supervisors are trained by the university on how to interpret the assessment template in order for them to conduct uniform assessments of student teachers' classroom practice on a regular basis.

Nyaumwe and Mavhunga (2005) noted the contestable nature of the validity of assessment instruments and the ramifications for reliability and marker agreement. Connelly (1994), on the other hand, dismissed supervisor training in the use of assessment instruments arguing that classroom assessments were judgmental and colored by personal values, interests, and choice of words that no amount of training can iron out the interpretive and subjectivity involved in the process. Given the nature of ODL practices where the university cannot bring student teachers to do their teaching practice at satellite schools close to it, the classroom assessments made by host teachers and supervisors have to be accepted as proxy of university lecturers' assessments. The discussion thus far has shown a perspective of the intended curriculum of schools and teacher education institutions with intentions to achieve reform curriculum goals of learner reasoning, communication, problem-solving, and making connections. We present in the next section the tensions that sometimes influence achievement of these reform curriculum goals.

Possible Tensions Encountered

HEIs face mammoth tasks to produce the desired teachers capable of implementing the reform curriculum in ways that can enhance the production of school leavers who are capable of applying academic knowledge in national and technological development that is anticipated by curriculum planners. Some of the tensions that HEIs face, which makes it doubtful whether student teachers can ever implement the theory of the reform curriculum covered in course materials manifest during teaching practice. The NPFTED document, which guides Unisa's teaching practice model of attaching student teachers to host teachers in an attachment school, is implemented at the school level with variations depending on peculiar contexts and needs. From the perspective of NDFTED, student teachers should do teaching practice under the guidance of an experienced teacher so that learners are not used as experimental objects by student teachers who use trial and error to implement pedagogical theories in real classrooms. On the HEIs' part, attachment to experienced teachers is very important to enable student teachers to learn how to teach, using the craft knowledge of experienced teachers and their pedagogical theories in implementing the reform curriculum through making viable interpretations of student learning. Based on the effectiveness of combining experienced teachers' craft knowledge and educational theories extolled in study modules student teachers can modify their implementation strategies to enact effective teaching.

The practical realities faced by schools makes them at times perceive putting "two teachers" in the same classroom a luxury they cannot afford. A peculiar situation in South Africa and Africa in general, is the paucity of mathematics and science teachers. Due to this paucity, mathematics and science classes are sometimes taught by underqualified teachers. In showing this paucity Soobrayan (2010), the acting Director General of Basic Education in South Africa, confessed to a parliament select committee on education that "too many school teachers cannot pass the tests their pupils sit at Grade 12" (South African News, 2010: paragraph 1). Mathematics and science student teachers on attachment in such schools are usually given full loads to teach on their own from the onset of teaching practice. The student teachers who faced this situation complain that they were turned into "relief teachers" (Nyaumwe, 2001).

In circumstances where student teachers were attached to a competent experienced teacher, the full potential of their combination were sometimes not easy to achieve. Like in the case of Unisa, where the geographical location of teaching practice schools are sparsely scattered in the country, it is sometimes not possible to train experienced teachers to mentor students teachers they are attached to. Where training is done, the exercise is futile because student teachers make independent choices of teaching practice schools. For example, student teachers may choose to go

to schools where training was not done. The independent student teacher choices of attachment schools can drastically change from one semester to the other. Moreover, when a student teacher is deployed at a school, it is the prerogative of the Principal or Head of Department to assign an experienced teacher. These two scenarios make it economically impossible for Unisa to train experienced teachers to mentor student teachers because that exercise has to be done every semester in the countless attachment schools. In the absence of experienced teacher training in mentoring duties, the quality of mentor coaching varies from one student teacher to the other (Portner, 1998). On the extreme cases student teachers have lamented of experienced teachers who supervised rather than mentored them because they only appeared in the classrooms being taught by student teachers when they wanted to make assessment reports required by the university (Nyaumwe, 2001). This scenario epitomizes mentoring programs in which experienced teachers are qualified but may lack knowledge of how to mentor student teachers because they may fear to clash with university expectations (Portner, 1998).

The success of student teachers' learning of how to teach from experienced teachers sometimes depends on the degree to which their instructional conceptions match. Teachers' conceptions on mathematics instruction play an important role in how they implement a curriculum reform (Nyaumwe, 2004). This in turn can influence their choice of pedagogy. For instance, teachers with a traditional conception of mathematics content take the discipline as static, rule driven and their teaching emphasize regurgitation of rules through drill and practice. On the other hand, teachers with a constructivist conception believe that mathematical content is tentative, originates from human activities, and can change depending on the context in which they are constructed. Teaching mathematics in the constructivist conception, entails creation of learning environments that are conducive for learners to use their intuitions to experiment, search for patterns, reason logically, generalize, and make conjectures individually or socially with others. Most teachers' conceptions are sometimes not strictly fixed at one end of the traditional—constructivist continuum, but fluctuate with an inclination tilted towards one end.

A combination of their craft knowledge and training many years ago during apartheid era makes some host teachers and student teachers hold contradictory ideas on choices of teaching methods to use in a lesson. During colonial years in South Africa the "chalk and talk" method of teaching was the dominant method in order for the education system to produce subservient citizens who are capable and eager to comprehend and execute the orders of the colonial masters without an inquiring mind. After self-rule, teacher education advocated for inquiry teaching methods

informed by constructivist theories in order for schools to produce informed citizens who are critical of a host of issues that take place in their environments.

Informed by their craft knowledge of the ternary relationship between the student, content, and the curriculum, most host teachers prefer using traditional methods of teaching mathematics. Such host teachers often use the examination system and the nature of learners to defend their choices of teaching methods. The pencil and paper form of assessment that is widespread in South African education system is a social phenomenon that is fraught with tensions with the reform curriculum (Field, 1991). In attempts to implement the reform curriculum the South African education system emphasizes learner achievement of affective, psychomotor, and cognitive domain goals. The practical reality of assessment methods on the ground is an emphasis on low order cognitive processes that require memorization of standard algorithms in order to "achieve high regurgitation score" (Pesek and Kirshner, 2000). No matter how much effort is put on the development of affective goals in the classroom, learners can only concentrate on memorizing the mathematical algorithms that are transmitted by their teachers and regurgitate them during assessments in order to increase their chances of passing high stake examinations. Knowledge that learners are not interested of achieving other goals in the curriculum other than those examined makes host teachers pay lip-service to conceptual learning through problem-solving and concentrate on procedural memorization of rules and algorithms.

The examination system that focuses on the cognitive domain only persuades teachers to expose content to learners in forms that the learners can easily retrieve during summative assessments. The retrievable content is mostly learnt though rote and problem-solving pedagogical methods that are extolled in theory lectures of student teachers remain the rhetoric of teacher education. As noted by McInerney and McInerney (1998), most student teachers learn to teach through observing experienced teachers and modeling their teaching practices. Such student teachers tend to imitate, in their teaching, the teaching practices of their mentors rather than implement the pedagogical approaches that are taught to them during teacher education. This observation makes the gap between theory and practice widen to such an extent that the reform curriculum may remain rhetoric rather than a reality in South Africa, in particular, and educational systems on the African continent.

The theory–practice divide that is evident during teaching practice can make co-operative learning, which is at the heart of reform learning and national goals in South Africa appear trivial in the implemented and the attained curriculum because the goal is not examinable. This failure may make the envisaged benefits of small groups of offering enquiry based learning with a focus on learner development of competencies and skills

of team work and collaboration not coached to learners. The skills of team work and collaboration are the cornerstone of indigenous African maxim of Ubuntu. Developing Ubuntu values in learners during school days is critical for good citizenry that schools as miniature societies will be failing in their national duties if they continue to ignore these and other important goals due to their non-examinable in summative assessments.

Conclusion

That some student teachers on teaching practice find theory covered in teacher education courses not applicable in host teachers' practices has serious implications on the theory–practice dichotomy. Even if the university–school coherence improves, the theory–practice gap may remain wide unless the summative assessment system refrain from examining learners' ability to regurgitate content memorized to include tasks on problem-solving. Research on why teachers teach for examinations rather than per the demands of the intended curriculum may go a long way to inform debate on how to persuade teachers to pursue the four pillars of the reform curriculum, namely: reasoning, problem-solving, connection, and communication. When teachers correctly implement the reform curriculum goals, South Africa and other African countries may begin to reap the benefits of the huge investments they make in education. The reaping would manifest when school leavers begin to reason mathematically; apply mathematical knowledge and know-how to analyze and solve both familiar and nonfamiliar problems; organize, interpret, and manage authentic activities, using logical mathematical understanding; and engage responsibly with quantitative arguments relating to national issues. This may be possible only when tensions encountered by student teachers on teaching practice are reduced and the theory–practice gap is kept minimal. This possibility may give hope for schools that produce job creators rather than job seekers.

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