Mathematics Teacher Education and Development 2004, Vol. 6, 19-30

The Impact of Full Time Student Teaching on Preservice Teachers' Conceptions of Mathematics Teaching and Learning

Lovemore Nyaumwe
Bindura University of Science Education, Zimbabwe

This study investigated the changes in conceptions on mathematics teaching and learning of preservice BScEd teachers after 12 weeks of full time teaching practice. Written answers to open ended questions administered at the beginning and end of student teaching were triangulated with interviews. The preservice teachers exhibited more differences in conceptions on teaching than on learning mathematics. Students' age, class level, the nature of mathematical content and the need to match students' discursive skills with their achievement in written work influenced the preservice teachers' pedagogical and epistemological beliefs. The paper postulates some possible factors that influenced preservice teachers' conceptions on mathematics instruction.

The purpose of this study was to determine the influence of twelve weeks of full-time student teaching on preservice teachers' conceptions of teaching and learning secondary school mathematics. Conceptions are taken here as a preservice teacher's view of the processes and products of mathematics and how students acquire them. That is, conceptions are the personalised ideas and imagination preservice teachers hold about the nature of mathematical knowledge and how it is mastered by students. A preservice teacher's conceptions mould the assumptions, methodology and presentation of mathematical knowledge in ways that are believed to make students understand the subject. Full-time student teaching enables preservice teachers to test and establish the relevance of their conceptions on mathematics instruction and pedagogical theories they learn in teacher education before accepting them as knowledge that guides their practice (Nyaumwe, 2001).

Undergraduate preservice mathematics teachers from Bindura University of Science Education (BUSE) hold a conspicuous tendency to view students and the curriculum as similar factors that must be reconciled instead of viewing them as interacting. Their post lesson reflective text focuses on pedagogical forms in which they deliver content. They pay little attention to how students construct mathematical content during the lesson. Classroom based developments during curriculum implementation influence preservice teachers' conceptions on teaching and learning mathematics. The influences enable them to view students and the curriculum dynamically instead of reconciling them. Preservice teachers implement certain pedagogical approaches for students to achieve certain learning experiences. They cannot fully anticipate how students receive and interact with the mathematical activities they provide. The tension between their pedagogical wishes and students' reception of the approaches, challenge their belief systems on

teaching and learning of mathematics. This dichotomy gives rise to opportunities for preservice teachers to explore and possibly experience a multiplicity of approaches that improve their instruction and students' learning. Changes in teaching approaches caused by demands of students' learning styles enable preservice teachers to adopt innovative instructional practices. As they identify and weigh the levels of success of their instructional practice, preservice teachers are sometimes pressed to study the context in which their educational theories are applicable. Thus contextual classroom based decisions influence preservice teachers' views on conducting effective lessons. Changes in conceptions that emanate from an inquiry perspective towards professional development usually result in a corresponding increase in preservice teachers' ability and inclination to capitalize on students' sense making and processing of mathematical concepts during the learning process.

An assessment of the instructional conceptions that preservice teachers hold before and after student teaching is necessary in order to determine the resonance or dissonance of pedagogical theories and personal conceptions after implementation in the classroom. Some studies are available on teachers' conceptions of mathematical content. Golafshani (2002) and Warren and Nisbet (2000) focused on conceptions on instructional practice. Vacc and Bright (1999) discussed conceptions on the use of students' mathematical thinking during instruction. Lubisi (1997) dealt with preservice teachers' conceptions on how they study undergraduate mathematics. Despite numerous studies on teachers' beliefs and conceptions on mathematical knowledge, little empirical data describe preservice teachers' changes in conceptions on mathematics teaching and learning as a result of full time student teaching. The purpose of the present study is to fill this gap by documenting possible changes on mathematics instruction that preservice teachers attain after practising their ideals of teaching and learning during full time student teaching. The study endeavoured to answer the research question: What is the impact of twelve weeks of full time student teaching on preservice teachers' conception of mathematics teaching and learning? Answers to this question will provide insight on how preservice teachers develop a synergy of professional knowledge and skills whilst on school attachment.

Theoretical framework

Preservice teachers come for teacher education with their own conceptions of mathematics teaching and learning. The instructional conceptions they hold are usually shaped by the methods they use to master mathematical concepts and the teaching methods used by teachers during their school days (Lubisi, 1997). Teacher education courses inject new pedagogical ideas that influence preservice teachers' conceptions on teaching and learning (Vacc & Bright, 1999). Thom (1973, p. 204) posited that "all pedagogy, even if scarcely coherent, rests on a conception of knowledge acquisition." In a similar way preservice teachers go for student teaching with a conception of mathematics instruction that is explicit in the way they design and conduct lessons.

Shapiro (2000), Matthews (1994) and Davis and Hersh (1981) generally agree on three conceptions of mathematics teaching and learning that influence preservice teachers' practices. These were identified as Platonism (static view), formalism (mechanistic view) and constructivism (contemporary view). In the Platonist conception of teaching and learning, mathematics is viewed as a universal and static subject whose concepts reside outside human senses. Preservice teachers who hold formalist conceptions of teaching believe that sources of legitimate mathematical processes are axioms, definitions and theorems (Davis & Hersh, 1981; Lubisi, 1997). The products of mathematical activities in formalism arise from logical mechanistic use of accepted procedures that a preservice teacher demonstrates to students (Warren & Nisbet, 2000). Rule and Lassila (2003) and Davis and Hersh (1981) concur that Platonist and formalist conceptions are not mutually exclusive. There is a thin line that divides them in that they both employ transmission principles of teaching mathematics.

Preservice teachers holding constructivist conceptions of teaching believe that mathematical knowledge is tentative, intuitive, subjective, and dynamic. They believe that it originates from observations, experimentation and abstraction using senses (Davis, Maher & Noddings, 1990). Their conceptions of teaching mathematics is equipping students with conceptual understanding of the process skills that enable students to individually or collectively develop a repertoire for constructing powerful mathematical constructions that concur with viable mathematical knowledge.

The polemic issue of which conception of teaching and learning of mathematics is effective is outside the realm of the present paper. Learning to teach mathematics using any one of the three conceptions mentioned above is a complex process. The learning process is determined by a continual assessment of instructional preferences that promote the construction of new pedagogical knowledge from classroom practices (Ball, 1994). The curriculum, resources available in schools and the nature of students provide unique challenges to preservice teachers to assess the effectiveness of their conceptions on teaching and learning mathematics.

Teaching practice arrangements for preservice teachers at BUSE

BScEd preservice teachers at BUSE go for twelve weeks of full-time student teaching in their final year of a four-year degree in Education with two science subjects. Faculty members visit preservice teachers three times at their attachment schools for the purposes of clinical supervision and assessment. Although the model of school attachment the university adopts is mentoring, situational constraints in schools present unique problems that prohibit the correct implementation of the model. Factors such as school heads choosing mentors, allocating classes and teaching loads influence the quality of mentoring that preservice teachers receive. Preservice teachers usually have a teaching load of twelve hours per week to enable them to have enough time to plan their lessons, sit in classes taught by other teachers in their departments and hold debriefing sessions with mentors. To a large extent, the preservice teachers practice teaching

alone because their mentors have parallel full teaching loads (Taruvinga & Museva, 2003). Whatever limitations are inherent in this type of school attachment, it provides preservice teachers with opportunities to experience the four categories of mathematics teachers' work delineated by NCTM (1991).

Methodology

The design for assessing changes in preservice teachers' conceptions on mathematics teaching and learning was adapted from teachers' conceptions on instructional practice to meet the goals of the present study (Glencross et al, 1997; Lederman & Zeidler, 1987; Lubisi, 1997; Vacc & Bright, 1999).

Data were collected in four chronological stages. Part A involved the administration of eight open-ended questions. Of the eight questions, four covered conceptions on teaching and the remainder were on learning. Preservice teachers majoring in mathematics completed the open-ended questions for the first time at the end of the semester before full-time student teaching. Writing their names on the answer sheets made it possible to locate them at their placement schools in Part B of the study. Lack of anonymity in the data supplied did not appear to influence the responses towards pedagogical approaches extolled in lectures (See Table 1).

Part B of the study involved matching responses of the preservice teachers by names and their placement schools. Case studies on the professional development of teachers are usually qualitative in nature and involve a small number of teachers (Lubisi, 1997; Vacc & Bright, 1999; Warren & Nisbet, 2000; Wiersman & Weinstein, 2001). Case studies were appropriate for this study because they provide thick documentary evidence that describes the behaviours demonstrated by the preservice teachers. Four (three males and one female) preservice teachers (13.3% of the total cohort class) from different high schools falling within a limited radius from the research base provided data for this study.

Part C of the study involved the re-administration of the questions during the 12th week of school attachment. Re-administration of the questions was necessary in order to evaluate the exit conceptions on teaching and learning that the preservice teachers were holding after student teaching.

Part D involved interviews lasting about 40 minutes conducted immediately after the preservice teachers had answered questions in the second round. The interviews enabled them to elaborate the new conceptions on mathematics teaching and learning that they were holding after student teaching. Each interview was transcribed verbatim to facilitate interpretation and analysis of responses.

The processes of data analysis involved placing preservice teachers' conceptions on teaching and learning into the three categories - Platonism, formalism or constructivism. In cases where responses were difficult to place, a Faculty member was consulted in order to discuss and locate the conception that best described the response. Preservice teachers who held an absolutist static, teacher-centred view of mathematics teaching or learning were placed under Platonism (Thompson, 1984). Those who believed in teaching mathematics using fixed and infallible algorithms conformed to formalism. Formalism conceptions on

learning were expressed in views that students need external motivation to mechanically master symbols and procedures to produce mathematical solutions. Responses giving preservice teachers supervisory roles to determine whether students were following the right procedures belonged to the formalism conception of teaching (Rule & Lassila, 2003). Preservice teachers who believed in organizing activities that facilitate students' construction of mathematical knowledge, who used students' wrong answers as rich sources of understanding their current knowledge, or who set differentiated work were categorized in the constructivist conception of teaching. Responses that showed preferences on student-centred approaches were placed in the constructivist conception of learning.

Due to limited space and the need to avoid repetitions of similar themes expressed by preservice teachers, only transcripts that were representative of responses in the same conception are quoted verbatim in the results.

Results

Many similarities exist in the preservice teachers' responses. Changes in preservice teachers' conceptions on learning mathematics were minimal (9 conception changes and 7 unchanged conceptions - Table 1). The preservice teachers showed many changes in conceptions on teaching mathematics (13 conception changes and 3 unchanged conceptions) from subject centred to student centred approaches. For instance, changes were observed in conceptions from content transmission to students' explorations, from ignoring students' wrong responses to probing students' responses, from treatment of students as empty of mathematical content to accepting them as possessing prior knowledge that is valuable to construct alternative procedures. As a result of full time student teaching, all the preservice teachers believed that intrinsic not extrinsic motivation enables students to persevere on mathematical tasks in and outside the classroom (Question 6). The four preservice teachers' conceptions on teaching and learning mathematics before and after full time student teaching are summarised in Table 1.

Table 1
Changes in preservice mathematics teachers' conceptions on teaching and learning of mathematics

Question	Name	Responses at the beginning of student teaching.	C1	Responses at the end of student teaching.	C2
1T. What is the role of the teacher during maths instruction?	Mike	Demonstrates methods.	F	Supervises working.	F
	Jones	Selects content.	P	Derives formulae.	F
	Mary	Explains procedures.	P	Organizes activities.	C
	Chris	Selects content.	P	Guide students.	C

2[L]. How do students learn maths?	Mike	Memorize formulae.	F	Constant practice.	F
	Jones	Constant practice.	F	Through discussions.	C
	Mary	Imitate procedures.	F	From environment.	C
	Chris	Memorize procedures.	F	Individual practice.	F
3[L]. Should solutions focus on processes or products?	Mike	Correct answers.	P	Correct use of procedures.	F
	Jones	Answers.	P	Underlying processes.	C
	Mary	Procedures to answers.	C	Processes to products.	C
	Chris	Answers.	P	Processes.	C
4[L]. Do maths problems have more than one solution?	Mike	Unique solution.	F	One solution.	F
	Jones	One solution.	F	One solution.	F
	Mary	One solution.	F	Equivalent solutions.	F
	Chris	One solution.	F	Equivalent solutions.	F

Table 1 (continued)

Question	Name	Responses at the beginning of student teaching.	C1	Responses at the end of student teaching.	C2
5[T]. How should a teacher handle wrong responses?	Mike	Ignore wrong responses.	F	Let student explain.	C
	Jones	Ask another student.	P	Probe response.	C
	Mary	Probe to find sources.	C	Probe response.	C
	Chris	Tell student s/he is wrong.	P	Refocus & guide	C
6[L]. How may students be motivated to learn maths?	Mike	Give motivations.	F	Challenging work.	C
	Jones	Give easy work.	F	Differentiated work.	C
	Mary	Encourage them to work.	P	Set interesting work.	C
	Chris	Though motivation.	F	Link experience & work.	C
7[T]. Which method best promotes the learning of maths?	Mike	Discovery.	C	Demonstrations.	F
	Jones	Demonstrations.	F	Discovery.	C
	Mary	Guided discovery.	C	Group work.	C
	Chris	Problem-solving.	C	Demonstration.	F
8[T]. Can students teach maths to each other?	Mike	No.	F	Yes.	C
	Jones	No.	P	Yes.	F
	Mary	Yes.	F	Yes.	C
	Chris	Yes.	F	In group work.	C

Key:- [T] Questions assessing conceptions on teaching mathematics.
[L] Questions assessing conceptions on learning mathematics.
C1: Initial conceptions on mathematics teaching and learning held before teaching practice.
C2: Exit conceptions on mathematics teaching and learning at the end of teaching practice.
P – Platonism. F – Formalism. C – Constructivism.

Changes in preservice teachers' conceptions on teaching mathematics

Questions 1, 5, 7 and 8 assessed preservice teachers' conceptions on teaching mathematics. Responses on question 1 show that Mary and Chris changed their conceptions from Platonism to constructivism. During the interview Mary

explained why she stopped explaining procedures (Platonism) and used manipulatives that promote students' construction of mathematical concepts (constructivism).

> At the beginning of school attachment I thought students would understand mathematical procedures that were demonstrated by the teacher followed by application in related exercises. A Form 1 class enjoyed establishing the value of π from finding the ratio of the radius and the circumference [Interview: 3 December 2002].

Mike constantly believed that a teacher takes supervisory roles during mathematics instruction (Question 1). Jones on the other hand, changed his conception on teaching from showing fixed mathematical relations (Platonism) to deriving and applying them when solving given exercises (formalism). Jones' and Mike's conceptions on the role of the teacher during instruction remained in the transmission paradigm. Jones' static conception is explicit when he said "Most calculus concepts are not easily derived from physical objects." [Interview: 5 December 2002].

One preservice teacher (Mary) had conceptions on handling students' wrong responses (Question 5) constantly constructivist (students' inappropriate responses as rich sources of their misconceptions). The other three preservice teachers changed their conceptions from ignoring inappropriate answers (Platonism) or guiding their thinking (formalism) to probing student's responses (constructivist). Chris who changed his conceptions on teaching from telling students that an answer was not viable (Platonism) to rephrasing the question or providing hints to guide the student's thinking process (constructivism) elaborated:

> If a student is told that an answer is wrong s/he may lose confidence and withdraws from the lesson. This prevents the teacher from diagnosing the source of the student's errors. Students' wrong answers should be redirected by simpler or rephrased questions to facilitate their construction of new frames. [Interview: 4 December 2002].

Three quarters of the responses on ideal methods for teaching mathematics (Question 7) were in favour of constructivist methods (discovery or problem solving) at the beginning of student teaching. However, preservice teachers who taught calculus at Advanced Level (Mike and Jones) changed their conceptions on teaching from constructivist (at the beginning of student teaching) to formalism (at the end of student teaching).

One preservice teacher (Jones) wavered on his conception of students teaching mathematics to each other in the transmission paradigm throughout student teaching (Question 8). Initially Jones believed that students could not teach each other new concepts because they were not knowledgeable of the procedures (Platonism). After full time student teaching he changed his conceptions to believing that students could correct each other's errors or could teach each other mathematical procedures during revision of content previously covered in class (formalism). His conceptions on students teaching each other were guided by the

perspective that "students cannot teach each other mathematical content because they do not know them until they are told" [Interview: 5 December 2002].

Mike, Mary and Chris changed their conceptions on students teaching each other mathematics from consolidation exercises using laid out procedures (formalism) to students' cooperation in constructing alternative methods, exploring patterns or socially constructing mathematical knowledge (constructivism).

Changes in preservice teachers' conceptions on learning mathematics

Questions 2, 3, 4 and 6 were focused on evaluating changes in preservice teachers' conceptions on learning mathematics. Mike and Chris had conceptions on learning constantly formalist, that is, students learn mathematics by memorizing algorithms followed by application (Question 2). They believed that procedural learning which involves the recall and application of an algorithm was an ideal way to learn mathematics. Chris perceived the hallmark of learning mathematics as "entailing logical reasoning and application of formulae" [Interview: 4 December 2002]. Jones and Mary changed their conceptions on learning mathematics from constant practice using an algorithm (formalism) to students' use of manipulatives to socially generate mathematical concepts (constructivism).

Mike's beginning and exit conceptions on assessment of students' mastery of mathematical skills remained in the traditional paradigm. He constantly viewed assessment in mathematics as focusing on showing laid out procedures that lead to correct solutions (Question 3). The influence of examinations persuaded Mike to believe that "students need to master the procedures that lead to correct answers in ways prescribed by the curriculum" [Interview: 2 December 2002].

Chris, Mary and Jones changed their conceptions on learning mathematics. The changes were from products focused assessment (transmission paradigm) to conceptual understanding of processes focused assessment (constructivism). Jones explained his new conception:

> A focus on answers is not enough because some students may get correct answers from wrong approaches. Step by step working shows a student's mastery of procedures. The logical steps help the teacher to identify misconceptions should solutions produced be unacceptable [Interview: 5 December 2002].

All the four preservice teachers did not change their formalist conceptions on mathematical problems having more than one solution (Question 4). Mary and Chris believed that mathematics solutions were unique but could be expressed in equivalent forms. Jones and Mike believed that equivalent answers might be expressed in different forms. Mike was convinced that "if solutions to the same question differ then there are errors approach used" [Interview: 2 December 2002].

The four preservice teachers changed their conceptions on maintaining students' interest to learn mathematics from extrinsic to intrinsic incentives (Question 6). Before student teaching the preservice teachers believed that

mathematical knowledge was sacrosanct and fixed (Platonism) or students need external motivations to be focused on mathematical tasks (formalism). Student teaching influenced the preservice teachers to favour interesting and challenging differentiated problem solving tasks (constructivism). Mary succinctly explained:

> I believed that students work hard when they are given motivations by a teacher. I now realise that extrinsic motivations are not effective to keep students working on mathematical tasks on their own [Interview: 3 December 2002].

Discussion

The preservice teachers in this study concentrated on professional areas of planning, teaching and classroom management in order to cope with teaching practice. As a result, their conceptions changed more on teaching than on learning mathematics. The preferential changes can be explained in terms of a desire to identify pedagogical strategies that help them to improve their practice (Spalding & Wilson, 2002). Student learning was assessed in terms of how they accomplished laid down procedures. Perspectives on learning mathematics seemed to be influenced by the examination system.

> The need to prepare students to pass summative examinations persuaded the preservice teachers to believe that successful learning of mathematics entails correct applications of formulae and procedures (Chris: 4 December 2002).

> Coaching students for summative examinations was perceived as exposing them to consolidation exercises that enable students to "master procedures that lead to correct answers" (Mike: 2 December 2002).

Changes in conceptions on teaching mathematics varied by age of students, nature of mathematical concepts and level of classes taught (Junior or Advanced Level). Preservice teachers who taught elementary and middle secondary school (13 -15 year olds-Chris and Mary) changed their conceptions on teaching from transmission to constructivist approaches.

> The changes in conceptions on teaching were influenced by the desire of students at this level to enjoy learning mathematics through manipulation of physical objects in attempts to establish mathematical concepts (Mary: 3 December 2002).

Adaptations to students' learning styles gave rise to good teaching habits. The good teaching habits were nurtured by reflection on one's practice in the light of students' reception of decisions and actions made during lessons. Students' receptions of preservice teachers' approaches influenced their instructional conceptions from teacher-centred to student-centred. The reception of junior students (13 - 15 year olds) to transmission methods convinced preservice teachers that they (students) do not learn mathematics well by watching and listening to the teacher's demonstrations but by constructing their own mathematical knowledge. Reflection on students' behaviours in response to pedagogical approaches enabled preservice teachers to actively monitor their own practice through thinking and developing proficiency of their instructional practice.

Preservice teachers who taught pure mathematics at Advanced level (Mike and Jones) changed their conceptions within the transmission paradigm or from constructivist to transmission paradigm. The changes were influenced by the difficulties they faced to derive calculus concepts from manipulatives (Jones). As a result of the nature of Advanced Level concepts, the preservice teachers who taught calculus demonstrated applications of algorithms so that students could imitate the steps when solving related problems. The preservice teachers who taught Advanced Level behaved like many teachers who defend the use of ubiquitous demonstrations of mathematical procedures followed by consolidation exercises. They believe that demonstrations of mathematical algorithms followed by applications give students familiarity and confidence in applying them (Grouws & Cebulla, 2002; Lubisi, 1997).

The realisation that a synergy of mathematics instruction entails tracing sources of students' misconceptions underscores the fact that the art of teaching is best mastered by real teaching. Teaching practice provided preservice teachers in this study with opportunities to build personalized teaching knowledge and skills using classroom contexts. It also enabled them to perceive that students' wrong responses provide insight into their thinking processes. The insight derived from students' inappropriate responses help preservice teachers to establish levels of students' understanding of mathematical content and procedures. Behaviours exhibited by students in real classroom situations have stronger impacts on preservice teachers' beliefs than theory alone. Students' withdrawal during instruction when their inappropriate responses were ignored gave preservice teachers opportunities to probe wrong answers. Merits of probing students' inappropriate responses include provisions of insight on students' understanding of the structure and inter-relatedness of mathematical knowledge. Real teaching experience enabled preservice teachers to form appropriate psychological habits like reflection on one's practice with mentors and peers. Reflective discussions on lessons taught with mentors and peers give preservice teachers a rich understanding of teaching and student learning of mathematics. The reflective discussions with mentors and peers enable preservice teachers to assess and refine their philosophies about the nature of mathematical knowledge and how it is learned. Reflection committed to mastering professional skills strengthens preservice teachers' decision-making and learning how to teach. Without forming appropriate psychological habits rooted in practice, preservice teachers' changes in conceptions on teaching and learning mathematics may be superficial (Stueben, 2003).

Conclusion

The present study was limited to the entry and exit conceptions on mathematics teaching and learning of preservice teachers. The study did not assess the extent to which the appraised conceptions were implemented in their instructional practice. The changes in conception on teaching and learning resulted from a need to model pedagogies to suit students' mathematical understanding and dovetail their prior knowledge with content. Golashani (2000) and Clarke

(1994) concur that learning to teach from experience in the real classroom context enables preservice teachers to make important changes in their perspectives on pedagogical approaches. Reflections with mentors and peers centred on instructional practice provide fresh avenues for preservice teachers to learn how to teach (Ferraro, 2000). From classroom experience and reflection with mentors and peers, preservice teachers make fundamental changes in their conceptions on teaching and learning that usually improve their instructional practices.

Overall it can be concluded that theory on instructional practice can never be a substitute for practice. As a result of teaching experience the four preservice teachers in this study changed their conceptions on teaching mathematics from the transmission paradigm (Platonism / formalism) to constructivism although it cannot be inferred that they equally changed their classroom practice. Some preservice teachers used a fallible reason of procedural assessment methods to defend their continued use of traditional methods, when in fact doubts about their capacity to implement modern approaches could have been a stumbling block. On the other hand, preservice teachers who taught calculus at Advanced Level found transmission methods plausible. This finding poses a challenge to teacher education to design a pedagogy course that facilitates preservice teachers to employ constructivist methods for teaching abstract concepts at an Advanced Level.

Results of four case studies of preservice mathematics teachers in four secondary schools may not represent or make extensive claims of the impact of full time student teaching on pedagogical and epistemological conceptions. A further study is needed to establish whether the changes in conception on teaching and learning that these preservice teachers exhibited are fundamental or superficial and whether or not they impacted on their mathematics instruction.

References

Ball, D. L. (1994). Developing mathematics reform: What don't we know about teachers learning but would make good hypotheses? Paper presented for Conference on Teacher Enhancement in Mathematics K - 6. National Science Foundation: Washington, DC.

Clarke, D. (1994). Epistemologies, beliefs and conceptions of mathematics teaching and learning: The theory and what is manifested in mathematics teachers' work in England, France and Germany. *TNTEE Publications, 2*(1), 127-146.

Davis, R. B., Maher, C. A., & Noddings, N. (Eds.). (1990). Constructivist views on the teaching and learning of Mathematics. Reston, VA: NCTM.

Davis, P., & Hersh, R. (1981). The mathematical experience. Boston: Houghton Mifflin.

Ferraro, J. M. (2000). *Reflective practice and professional development* (ERIC Digest ED449120). Washington, DC: ERIC Clearinghouse on Teaching and Teacher Education. Retrieved July 22, 2004, from http://www.ericfacility.net/ericdigests/ed449120.html

Glencross, M., Kentane, L., Njisane, R., Nxiweni, J., & Mji, A. (1997). Conceptions of science subjects and how they are learnt: Views of first year students. In M. Sanders, (Ed.), *Proceedings of the 5th annual meeting of SAARMSE* (pp. 114-118). Johannesburg: University of Witwatersrand.

Golafshani, N. (2002). Teachers' conceptions of mathematics and their Instructional Practices. Retrieved March 26, 2002 from file://A:\Pome15.htm

Grouws, D. A., & Cebulla, K. J. (2002). *Improving student achievement in mathematics, Part 1: Research findings.* ERIC Digest. Retrieved April 9, 2002 from http://www.ericse.org/digests/dse00-09.html

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behaviour? *Science Education, 71*(5), 721-734.

Lubisi, R. C. (1997). Beliefs on the nature and assessment of mathematics: A case of preservice teachers. In M. Sanders, (Ed.), *Proceedings of the 5th annual meeting of SAARMSE* (pp. 247-251). Johannesburg: University of Witwatersrand.

Matthews, M. R. (1994). *Science teaching*. London: Routledge.

National Council of Teachers of Mathematics (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

Nyaumwe, L. (2001). A survey of Bindura university of science education student teachers' perceptions of the mentoring model of teaching practice. *Zimbabwe Journal of Educational Research, 13*(3), 230-256.

Rule, L. C., & Lassila, K. E. (2003). *Innovative teaching approaches to improve science education*. Retrieved from http://www.iitapilastate.edu/reports/stafrica/rule.html

Shapiro, S. (2000). *Thinking about mathematics: The philosophy of mathematics.* New York: Oxford University Press.

Spalding, E., & Wilson, A. (2002). Demystifying reflections: A study of pedagogical strategies that encourage reflective journal writing. *The Teachers College Record*, *104*(7), 1393-1402.

Stueben, M. A. (2003). A way of teaching. *Mathematics Teacher, 96*(6), 390-392.

Taruvinga, C., & Museva. S. (2003). Mentoring and supervision. In F. Zindi, B. Batidzirai & M. Nyota (Eds.), *Improving teacher preparation: Teaching practice guide*. Harare: SAPES Books (1 -5).

Thom, R. (1973). Modern mathematics: Does it exist? In A. G. Hawson (Ed.), *Development in mathematical education.* Cambridge: CUP.

Thompson, A. G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics, 5*(2), 105-127.

Vacc, N., & Bright, G. W. (1999). Elementary preservice teachers' changing beliefs and instructional use of children's mathematical thinking. *Journal for Research in Mathematics Education, 30*(1), 89-110.

Warren, E., & Nisbet, S. (2000). Factors in primary school teachers' beliefs about mathematics and teaching and learning mathematics. In J. Bana & A. Chapman (Eds.), *Mathematics education beyond 2000* (Proceedimgs of the 23rd annual conference of the Mathematics Education Research Group of Australasia. Freemantle, pp. 632-639). Sydney: MERGA.

Wiersman, L., & Weinstein, G. L. (2001). Mathematics sophistication and educational philosophies among novice mathematics teachers. Retrieved July 13, 2001 from http://www.ex.ac.uk/~PErnest/pome14/wiersma.htm

---

Author

Lovemore Nyaumwe, Bindura University of Science Education, Box 1020, Bindura, Zimbabwe.
Email: <ljnyaumwe@yahoo.co.uk>