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Teachers' Attitudes towards Proof of Mathematical Results in the Secondary School Curriculum: The Case of Zimbabwe

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This study investigated teachers' attitudes towards proofs in the secondary school mathematics curriculum. The study was motivated by a desire to fill a gap existing in the literature in relation to teachers' attitudes towards proofs. Thirty-four secondary school mathematics teachers' responses to a Likert type questionnaire and interviews were summarised using the five themes of utility, positive attitudes, methods of proof, negative attitudes, and suitability of level of students to perform proofs. The teachers expressed neutral attitudes on technology as a method of proof and disagreed that verbal proof was a valid method for proving the viability of mathematical claims. The implications of the results are discussed using the context of Zimbabwean classrooms with a view to promote debate on how teachers could implement learner-centred reform.

Successful implementation of student-centred reform in Zimbabwe requires teachers and students to reflect on their attitudes towards the methods they use to establish the viability of mathematical claims. The argument of this paper is informed by von Glasersfeld's (1995) view that mathematical claims are not absolutely true or valid but viable if they prove adequate in the contexts in which they are created. Like the Canadian teachers in the study undertaken by Goldblatt and Smith (2004), teachers in Zimbabwe are guided by their memory of past experiences as students and are sometimes reluctant to consider proof of mathematical results in their teaching. The ultimate value of instruction involving proof of mathematical results depends on students' beliefs on the relevance of proving mathematical results.

Learner-centred classrooms are characterised by student individual and social construction of mathematical claims that develop through experimentation, explanation, justification, and critique. Together these enhance the development of a body of mathematical conjectures. The press for justification of the viability of mathematical conjectures emanating from student constructions leads to proof that will provide adequate grounds for the viability of a conjecture (Hana, 1996). Mathematical proofs can be viewed as logically structured arguments that follow certain established sequences of steps to confirm or refute the viability of mathematical conjectures (Brumbaugh & Rock, 2001).

Like the case for proof in the United States (Peressini, Borko, Romagnano, Knuth, & Willis, 2004), in Zimbabwe proofs are restricted to geometric conjectures where teachers typically use axioms, definitions and theorems to prove their viability. There is a global scarcity of research on secondary school mathematics teacher attitudes towards proofs and teacher preparedness to include proofs in their instructional practice (Herbst, 2002; Peressini et al., 2004). Research connecting pedagogical factors and the learning of proofs is limited in Zimbabwe just as it is in other parts of the world (see Martin, Mcrone, Bower, & Dindyal, 2005).

Attitudes constitute the focus of the present study, particularly for their potential to influence teachers' propensity to prove mathematical claims in the secondary school curriculum. Broadly speaking, such attitudes include beliefs and assumptions about the nature and the place of proofs in the secondary school mathematics curriculum. In exposing teacher attitudes towards proof through research, we may also challenge teachers' existing beliefs about doing, knowing, and validating mathematical results in ways that build their capacity to understand content, pedagogy and student understanding in learner-centred classrooms. Results of the study will also provide insight that necessitates reviewing the methods courses that our university offers to pre-service teachers preparing to teach in secondary schools.

The study contributes to the current debate on teacher attitudes in general, and hopes to reduce the existing gap in research on attitudes towards proofs. It does this by seeking an answer to the research question: Are Zimbabwean teachers' attitudes towards proof of mathematical results in the secondary school curriculum compatible with student-centred classroom environments?

Conceptual Framework from Theoretical Underpinnings

Mathematics may be viewed as a subject in which the viability of claims is not certain until claims are proved. This view presents mathematical knowledge as tentative and therefore not to be taken for granted as viable. Proof of mathematical claims is viewed as a process that involves active justification of the claims rather than a passive process of validating the viability of the claims. As noted by Herbst (2002), proof is an active process because it involves organising previously learned concepts and presenting them as logical arguments that deduce or refute the viability of hypotheses, conjectures or theorems. The process of proving mathematical conjectures involves an understanding of the structure of concepts through selective use of existing knowledge, use of logical reasoning presented at appropriate stages in order to strengthen or weaken arguments for the viability of the mathematical claims. Foresight and appropriate use of axioms are important skills that enhance the presentation of arguments that establish the viability of mathematical claims. Because justification of the viability of mathematical results is an important goal of proof, it is important to explore the pedagogical roles in relation to proof in learner-centred classrooms.

From a pedagogical point of view, proof can be viewed as a transparent argument in which all the information used, and the rules of reasoning that are used to verify or falsify mathematical results are clearly shown and are open to criticism (Hana, 1996). Proofs show beyond reasonable doubt that a conjecture is indisputably viable or false. Proofs are not simply about justifying why mathematical results are true; they also include discourse that may lead to social construction of mathematical results. Discourses that expose mathematical claims to critique by others enhance student understanding and the construction of mathematical knowledge that characterise learner-centred classrooms (Wheatley, 1992).

Instruction in student-centred classrooms encourages students to construct mathematical claims. In such classrooms, teachers facilitate learning and help students construct mathematical knowledge through interactions with the physical and social environment (Warren & Nisbet, 2000). Successful implementation of learner-centred strategies requires that teachers view mathematical knowledge as tentative, intuitive, subjective, and dynamic (Davis, 1990; Nyaumwe, 2004) and therefore fallible. In this view mathematical knowledge can be revised. When students are encouraged to verify the viability of the claims that they make or encounter in their studies, they may develop alternative views of mathematical knowledge that are not absolute, sacrosanct or infallible.

Traditionally two-column proofs that involve the writing of two adjacent columns of statement and reason (Herbst, 2002) have been widely used in mathematics classrooms. Two-column proofs present logically structured sequence of steps and their justifications to establish the logic and correctness of argument for confirming or refuting a claim. The use of technology generated proofs and the growing recognition given to mathematical experimentation in student-centred classrooms has led to acceptance of other forms of validating the viability of mathematical conjectures such as rigorous and non-rigorous proofs (Hana, 1996).

Similar to findings in the United States (see Ross, 1998), Zimbabwean teachers have traditionally perceived proof as a formal way of showing the validity of theorems rather than a way of student conceptual learning of mathematics. The traditional use of proofs by Zimbabwean teachers for verifying theorems may inculcate in students the notion that mathematical results are absolute truths. Teachers' wide scope of proof as a pedagogical approach or way of validating or falsifying mathematical results may be ideal to promote student understanding of mathematical concepts as tentative. This understanding might develop in students a critical mind that permits an evaluation of mathematical claims that they construct or encounter before accepting them as indisputably true or false.

Methodology

Thirty-four secondary school mathematics teachers attending a day long in-service teacher training workshop on the basic functions on some selected hand-held technologies completed questionnaires during the first 45 minutes of the workshop. These questionnaires were used as the first data source. Teachers who did not understand some questions were free to request clarifications from the researchers who were also present in the workshop hall. Though English is a second language to the teachers, none asked for clarification of any of the questions.

The participating teachers averaged twelve years in teaching experience, with experience ranging from 4 to 21 years. They represented a wide range of mathematics teaching profiles, yet all held a Bachelor of Science Education degree. Twenty-six of them were males while eight of them were female, and they had teaching experience at all levels of the secondary school.[1] It should be noted that mathematics is a male dominated subject in Zimbabwe and the numbers of male and female teachers participating in the study is typical of the gender distribution of mathematics teachers in the country. There is a single mathematics curriculum for each secondary school level in Zimbabwe. Although teachers' curriculum knowledge at a given class level was similar, the teachers differed in pedagogical approach.

The teachers who participated in the study came from different secondary schools situated in rural and urban locations. Some schools were well-resourced and others were under-resourced. As such, the teachers and the schools were representative of the schools in the province and because of this, it is possible to make generalisations about teachers in this province.

We used a Likert type questionnaire. The construction of the closed five point Likert type scale of *Strongly Agree* (SA) through to *Strongly Disagree* (SD) was guided by the literature (Hana, 1996; Herbst, 2002; Knuth, 2002) as well as the authors' personal experiences of teaching mathematics. After identifying the end points of the negative-positive attitude continuum (see Boone, 2006), eighteen items between the end points were constructed. The items were later shuffled so that they could be randomly distributed on the questionnaire. The authors and four heads of mathematics departments from four different schools analysed the items on the questionnaire for construct validity. The questionnaire was first trialled on a cohort of in-service mathematics teachers attending a residential course at the university where the authors are based.

After piloting, some items were rephrased to enhance comprehension. For consistency and comprehension, the statements were presented in continuous present tense rather than past tense. For instance, "identities were proved graphically" was rephrased to "identities are proved graphically." The remaining items were similarly rephrased.

The second source of data comprised interviews with six teachers, each from a different secondary school. The interviews enabled the teachers to expand on their attitudes towards proof in the secondary school mathematics curriculum. As part of our university course pre-service teachers experience practicum teaching in some selected schools in the province. Interviews were conducted with teachers who filled in the questionnaire and were found at our affiliated schools of our student teachers during appraisal and supervision visits made by the researchers. The teachers who were interviewed can be viewed as randomly selected because it was by chance that a teacher was found at an attachment

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[1] The formal educational system in Zimbabwe comprises of the primary school (6-12$^{\pm}$), junior secondary school (13-14$^{\pm}$), middle secondary school (15-16$^{\pm}$), and high school (17-18$^{\pm}$).

school on the day of a visit and that a visited school sent a teacher to participate in the workshop in which teachers completed the questionnaires for this study.

The interviews were semi-structured and lasted for approximately one hour each. They focused on the five issues discerned from the questionnaire themes of utilitarian values, positive attitudes, methods, negative attitudes, and suitability of proofs. The interviews started with general questions and progressed into specific questions when interviewees had gained confidence in answering questions (Hobson, 2003). For instance, the interviews could start with general questions and lead to specific questions such as: Do you think students should be encouraged to prove mathematical results? What motivational and self-regulatory issues influence your choice of validating mathematical claims? Should technology be used to prove mathematical results? The interviews were transcribed in full and duely analysed. The analysis entailed assigning relevant pieces of text to one of the five categories delineated in the questionnaire items.

Results

The results of this study are presented according to the methods used for data collection. Results of the questionnaires are presented first followed by those from interviews.

Results from the Questionnaire

To facilitate understanding of the teachers' attitudes on proof, the questionnaire items were grouped in themes that best represented the main idea in an item. For instance, "Students are encouraged to prove mathematical conjectures" and "I enjoy proving mathematical results" portray positive attitudes. The authors discussed and agreed on the words that summarised the items belonging to the same theme. The themes were determined after compiling the questionnaire items and before administering them. Colleagues in the mathematics methods section became peer editors offering insights into grouping items into respective themes.

A Cronbach alpha reliability coefficient of 0.82 on the questionnaire makes the instrument satisfactorily internally consistent and reliable to measure teachers' attitudes towards proofs. Descriptive statistics were used to gain insight into the teachers' attitudes towards proof in the secondary school mathematics curriculum. Frequencies of responses and their means were arranged in descending order in order to determine the popularity of the teachers' responses on each theme. Table 1 displays the teachers' responses on the items in the questionnaire.

Teachers in the study showed positive attitudes towards utilitarian values of proof to train students to reason logically ($M = 4.6$) and understand mathematical concepts ($M = 4.5$) on a five-point Likert scale of 1 for strongly disagree to 5 strongly agree (Table 1). The teachers agreed, but not strongly, on three items with means of 4.2, 4.1, and 3.9 that belong to the positive attitudes theme (Table 1). The three items in the positive attitude theme depict teacher encouragement of student proofs, teacher enjoyment of proof, and encouragement of inclusion of

Table 1
Attitudes of Teachers on (N = 34) Proofs by Themes Rank Ordered using Means and Standard Deviations

Item	Narration	SD	D	N	A	SA	*M*
Utilitarian values of proofs							
5	Proofs train students to reason logically.	0	0	4	5	25	4.6
12	Proving results enhance student understand of the structure of mathematical concepts.	0	0	2	13	19	4.5
Positive attitudes							
4	Students are encouraged to prove maths results.	1	1	3	13	16	4.2
11	I enjoy proving mathematical results.		5	3	12	14	4.1
8	The secondary school curriculum should include proof of mathematical results.	1	2	5	17	9	3.9
Methods of proof							
15	Technology is used to prove mathematical results.	1	4	12	13	4	3.4
18	Identities are proved graphically.	7	18	4	3	2	2.2
16	Two column deductive proofs are the only valid way of proving mathematics results.	8	13	12	1	0	2.2
3	Proofs can be done through paragraph explanations.	23	7	2	2	0	1.5
Negative attitudes							
17	Students do not enjoy proving mathematical results.	5	9	5	14	1	2.9
19	Proofs are time consuming.	5	12	5	9	3	2.8
10	Proofs make mathematics difficult for students.	5	12	6	7	4	2.8
9	Proofs are boring to teach.	10	13	6	3	2	2.2
14	The secondary school curriculum should avoid proofs.	14	15	3	1	1	1.8
7	Secondary school students have no reasoning capacity to prove mathematical results.	15	10	6	2	1	1.9
13	Female students find difficulties in proving mathematical results.	19	11	1	1	2	1.7
Suitability							
1	Students should accept mathematics results as correct.	3	9	7	12	3	3.1
2	Teachers should prove theorems only.	13	7	6	6	2	2.3
20	Proofs should be done by bright students only.	14	14	2	3	1	1.9
6	Proofs should start at the undergraduate level.	15	12	4	1	2	1.9
	Overall Mean = 2.78	Cronbach alpha = 0.82					

Note. SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SD = Strongly Agree.

proof in the secondary school curriculum. The teachers revealed different opinions on the theme that related to methods of proof. These opinions ranged from *Strongly Disagree to Neutral* (Table 1). They were neutral on technology as a device for proving mathematical results, disagreed that identities can be proved graphically and that two column proofs are the only valid methods for proving mathematical results. The teachers strongly disagreed that explanatory paragraph proofs were legitimate methods for proving the viability of mathematical results.

The teachers who participated in the study were neutral on student acceptance of mathematical algorithms as true (M = 3.1). From this finding we can conclude that the teachers were not sure of students' views on the nature of mathematical knowledge, whether they were true or not.

The teachers disagreed, but not strongly, on three items: "Teachers should prove theorems only" (M = 2.3), "Proofs should be done by bright students only" (M = 1.9), and "Proofs should start at undergraduate level" (M = 1.9). These items reveal that teachers should prove other mathematical results besides theorems, that teachers believe that gender has no influence on student ability to prove mathematical results, and proof of mathematical results should start before undergraduate studies. The questionnaire results were corroborated by the interview transcripts presented next.

Results from Interviews

Verbatim transcripts on the five themes (viz., utilitarian values, positive, methods, negative and suitability of proofs) are presented in this section. Some transcripts contain more than one theme. Commonly expressed statements are summarised by a teacher's[2] verbatim statements.

Generally the teachers expressed positive attitudes on the utilitarian values of proofs. The teachers expressed the belief that utilitarian values of proofs can verify the viability of mathematical results and can help train students to reason logically. These attitudes are illustrated by the following quotations "...proofs are important to demonstrate the correctness of mathematical assertions" (Lameck). "Proofs are important in order to verify that a mathematical result is true" (Susan). "Proofs train learners to think logically and present their arguments sequentially" (Munashe).

On the positive attitudes theme, the teachers expressed a desire to have learners prove mathematical assertions that they make irrespective of the method of proof that they adopted. This attitude is illustrated by Bernard's quote presented below:

> In learner-centred classrooms it is ideal that students prove the assertions that they make. It ... does not matter whether they use a deductive proof, use technology to verify results or ... explain verbally. Accepting results that students construct without proving to the class how they obtained solutions

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[2] Pseudonyms are used for moral and professional reasons to protect the identities of the participants.

> encourages them to be individualistic and neglecting that learning is a social enterprise. (Bernard: February, 2006)

Some positive attitudes were expressed on the inclusion of proofs in the secondary school curriculum for their potential to develop argumentation skills among students but they noted that the summative examination system was a barrier. Due to examination demands learners tend to dislike proofs in mathematics classrooms. Shamiso's interview transcript below depicts both positive perceptions on proofs and barriers to full implementation:

> Proofs should be included in the secondary school curriculum for the obvious reasons of promoting argumentations in learner-centred classrooms where learning mathematics is a social activity. Given the nature of ... the examination systems that evaluate candidates' skills to apply theorems, perform computations and encourage speed and accuracy, it is difficult at times to convince students of the need to prove mathematical conjectures. Students are usually concerned about preparations for summative examinations and not anything that is not examinable. (Shamiso: March, 2006)

Some of the teachers' attitudes towards mathematical teaching were informed by formalist conceptions rather than social constructivist theories that encourage students' construction of mathematical results and proving them. Cecil's sentiments on the suitability of proofs to secondary school students, given below, are typical of some teachers' sentiments:

> I think (pause) secondary school students should accept mathematical results in text-books and those given by teachers as correct. Some students are not mature enough to reason in ways that can produce meaningful proofs, unless one wants them to cram or reproduce results proved elsewhere. Moreover,...encouraging students to prove mathematical results might make them develop negative attitudes towards the subject, especially girls. Girls in my class are generally challenged by mathematical problems because they take mathematics as a male domain and giving them the burden of proving results will...certainly drive them out of mathematics classes at the earliest time they are allowed to drop some subjects. (Cecil: March, 2006)

Discussion

The teachers in the study expressed positive attitudes towards utilitarian values of proving mathematical results such as pedagogical values in verifying mathematical claims and promotion of student understanding. As also noted by Knuth (2002) and Mudaly (1999), proving mathematical results facilitates students' deep understanding of concepts, through a responsibility to participate in generating and justifying mathematical knowledge. The other utilitarian value of proof of mathematical results noted by the teachers was the potential to promote student argumentation skills in learner-centred classrooms where learning mathematics is a social activity (Shamiso). Argumentation would facilitate learner understanding of the interrelatedness, structure and logic of mathematical concepts. This attitude was prompted by the teachers' beliefs that during proof of mathematical results, students recall significant topic-specific concepts and formulate viable steps and justifications to prove or refute a mathematical claim in ways that enhance understanding. Recalling previously learned concepts, axioms or theorems facilitates student revision, applications, and assessment of the internal consistency of mathematical concepts in ways that enhance student understanding and retention.

The teachers also perceived proofs as important to promote students' logical reasoning that leads to presentation of arguments sequentially (Munashe). Asking students to prove mathematical results has the potential to train them to reason logically through selecting and connecting concepts that build a strong argument for a case. Successful proof of unseen or unfamiliar conjectures that are possible in learner-centred classrooms requires independent thinkers to develop insight into choosing relevant results, and relies on precise language, definitions and axioms to show why and how different concepts work and connect to build a new result (Brumbaugh & Rock, 2001). Independent thinkers that student-centred classrooms thrive to produce, construct claims, explain, justify, and critique each other's results in a social context of learning and they do this to build a body of mathematical knowledge that is viable.

The teachers in the study pointed out that the examination system posed barriers that limited proof of mathematical results in their teaching (Shamiso). The summative examination system in Zimbabwe relies heavily on recall and procedural application of mathematical results. It emphasises correct computations at the expense of logical reasoning and thinking that is nurtured by proof of mathematical results. As a result, non-examinable skills that students can develop during their learning are usually not prioritised by teachers and this leads to the marginalisation of proof in mathematics classrooms in secondary schools. This marginalisation is not unique to teachers in Zimbabwe but is also reported to exist in other countries such as the United States (Knuth, 2002), South Africa (Mudaly, 1999), and the United Kingdom (Solomon, 2006). The marginalisation of proof can be explained by teachers' old habits and prejudices. Explaining Zimbabwean teacher preference of logarithm tables over scientific calculators, Nyaumwe (2006) concluded that teachers' find it difficult to relinquish traditional habits and prejudices and/or that curriculum change breeds teacher resistance to change.

Some of the teachers in the study, Bernard for instance, were not concerned about the method that students used as long as they proved mathematical results other than using verbal explanations. Such teachers expressed neutral attitudes on whether technology can be used to prove mathematical results. The teachers' neutral attitudes on the use of technology for proving mathematical results stem in part from their limited use of scientific calculators as classroom resources. Without exposure to the visual and exploratory features of graphing calculators it is difficult for Zimbabwean mathematics teachers to accept that student-centred classes using technology can formulate claims which they can test and prove using technology. The teachers' denial that traditional two-column proofs are the only valid means of proving mathematical results leads one to surmise that the teachers in the study were aware that there are other means of proving the viability of mathematical results.

The teachers in the study objected to the use of verbal proofs that are usually expressed in paragraph form to explain the viability of a mathematical conjecture. For them, a viable proof uses consistent mathematical symbols, definitions, axioms or theorems. The teachers' rejection of verbal proof as a valid method for testing mathematical results is inconsistent with views expressed by Martin et al. (2005) who advanced verbal proofs as legitimate methods for proving the viability of mathematical results. Martin et al. (2005) perceived verbal proofs as the medium for proving mathematical results that are possible from open-ended student tasks, characteristic of those used within learner-centred classrooms. Open-ended tasks engage students in dialogue that encourages them to reason and produce multiple strategies that lead to multiple solutions. Martin et al. (2005) argued that in responding to open-ended tasks, students have the opportunity to test their contributions and justify them through verbal means in classroom discourse. Verbal proofs determine the extent to which students' claims are consistent with acceptable reasoning.

The findings that teachers believed that introducing proof in the secondary school might make the learning of mathematics difficult to students, especially to girls, needs further exploration. Whilst traditionally females in Zimbabwe avoided scientifically oriented trades in favour of professions that involve caring such as secretarial work, nursing, and primary school teaching, it remains to be determined whether these attitudes still prevail, given that recruitment criteria in most professions and trades includes passes in mathematics and science courses.

Conclusion

The examination system in Zimbabwe that evaluates students' competence to find correct answers to mathematical problems using standard procedures leads teachers to the view that students should be coached to recognise mathematical problems in their routine form and should master the procedures to solve problems correctly. This encourages teachers to develop a formalist view of teaching mathematics — one that involves imparting to students mechanistic skills to solve problems using standard procedures. This view makes Zimbabwean teachers' attitudes towards proofs in the secondary school mathematics curriculum incompatible with student-centred reform in the country. In-service and pre-service teacher programs in the country have a mammoth task ahead to encourage new attitudes in teachers. The view is towards an understanding of mathematical knowledge as fallible, context based, value-laden, and changing, and an acceptance of the importance of proving results as the key to successful implementation of learner-centred teaching methods that are gaining popularity world wide.

This study analysed mathematics teachers' attitudes towards proofs in the secondary school curriculum in Zimbabwe. The importance that the teachers placed on proof was influenced by their beliefs on the utilitarian values of proofs and by examination demands. Changing teachers' understanding of the nature of mathematical knowledge might broaden their understanding of the importance of coaching students to prove the viability of mathematical results in ways that might more closely resemble the tasks and actions that characterise student-centred classrooms. Further studies may establish specific strategies for Zimbabwean mathematics teachers that are conducive to the implementation of student-centred reform.

References

Boone, W. J. (2006, January). *Designing and analyzing mathematics/science surveys and tests in Ohio*. Paper presented at the 14th South African Association for Research in Mathematics, Science and Technology Education annual conference. University of Pretoria, South Africa.

Brumbaugh, D. K., & Rock, D. (2001). *Teaching secondary mathematics*. London: Lawrence Erlbaum Associates.

Davis, R. B. (1990). Constructivist views on the teaching and learning of mathematics. In R. B. Davis, C. A. Mahler, & N. Noddings (Eds.), *Constructivist views on the teaching and learning of mathematics* (pp. 1-6). Reston, VA: NCTM.

Goldblatt, P. F., & Smith, D. (2004). Illuminating and facilitating professional knowledge through case work. *European Journal of Teacher Education, 27*(3), 335-354.

Hana, G. (1996). The ongoing value of proof. In L. Puig & A. Gutierrez (Eds.), *Proceedings of the 20th conference of the International Group for the Psychology of Mathematics Education* (Vol. 1, pp. 21-34). Valencia, Spain: PME. Retrieved 8 April, 2002, from http://fcis.oise.utoronto.ca~ghanna/pme96prf.html

Herbst, P. G. (2002). Engaging students in proving: A double bind on the teacher, *Journal of Research in Mathematics Education, 33*(3), 176 - 203.

Hobson, A. J. (2003). Student teachers' conceptions and evaluations of theory in initial teacher training. *Mentoring & Tutoring, 11*(3), 245-261.

Knuth, E. J. (2002). Proof as a tool for learning mathematics. *Mathematics Teacher, 95*(7), 486-490.

Martin, T. S., Mcrone, S. M. S., Bower, M. L. W., & Dindyal, J. (2005). The interplay of teacher and student actions in the teaching and learning of geometric proof. *Educational Studies in Mathematics, 60*(1), 95-124.

Mudaly, V. (1999). Who said that proof was boring? *Proceedings of the 7th SAARMSE conference* (pp. 303-308). Harare, South Africa: SAARMSE.

Nyaumwe, L. J. (2004). The impact of full time student teaching on pre-service teachers' conceptions of mathematics teaching and learning. *Mathematics Teacher Education and Development, 6*, 23-36.

Nyaumwe, L. J. (2006). Investigating Zimbabwean mathematics teachers' dispositions on the 'O' Level calculator syllabus. *South African Journal of Education, 26*(1), 39-47.

Peressini, D., Borko H., Romagnano, L., Knuth, E., & Willis, C. (2004). A conceptual framework for learning to teach secondary mathematics: A situative perspective. *Educational Studies in Mathematics, 56*(1}, 67-96.

Ross, K. (1998). Doing and proving: The place of algorithms and proof in school mathematics. *American Mathematical Monthly, 3*, 252-255.

Solomon, Y. (2006). Deficit or difference? The role of students' epistemologies of mathematics in their interactions with proof. *Educational Studies in Mathematics, 61*(3), 373-393.

Von Glasersfeld, E. (1995). *Radical constructivism: A way of knowing and learning*. Washington DC: Falmer.

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* (Proceedings of the 23rd annual conference of the Mathematics Education Research Group of Australasia, Vol. 2, pp. 632-639). Sydney: MERGA.

Wheatley, G. H. (1992). The role of reflection in mathematics learning. *Educational Studies in Mathematics, 23*(5), 529-541.

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