TEACHERS' PERCEPTIONS OF THE BENEFITS OF CHILDREN WRITING IN MATHEMATICS CLASSROOMS

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This article arises from a broader study that investigates the benefits and forms of mathematical writing and written texts produced by twelve- to thirteen-year-old students in grade seven classes in six junior high schools in KwaZulu-Natal, particularly in the context of major curriculum changes within South Africa. These recent changes in mathematics curricula, both in South Africa and elsewhere, have begun to change the overwhelmingly symbolic nature of mathematics (see, for example, Pimm, 1987, 1995) in schools, promoting more use of the oral and written language

Advocates of 'writing-to-learn' have suggested fundamental changes to the nature of the curriculum and the way students are taught if the introduction of writing activities in mathematics classrooms is to be effective (Clarke *et al.*, 1993; Morgan, 1998, 2001; Waywood, 1992) In contrast to symbolism and specialist vocabulary, which are perhaps the most obviously visible aspects of many mathematical texts (especially school mathematical texts), 'mathematical writing' will be used here to include "grammatical structures and forms of argumentation" (Morgan, 1998, p. 3), for example, those mathematical arguments found in proof and proof writing

South Africa is presently introducing, at all levels and in all subject areas within the school curriculum, radical curriculum changes This educational reform was started by the National Department of Education (DoE) as a result of major political changes in South Africa during the early 1990s that culminated in the first-ever democratic elections in 1994 The new curriculum, which uses an outcomes-based and learner-centred approach to education, was initiated in 1997. Some of the important principles of this outcomes-based education (OBE) include continuous assessment, relevance, integration, learner-centredness, creative thinking and flexibility According to continuous assessment policy documents (DoE, 1997b; DoE, 2000), where summative assessment is concerned, formal tests and examinations can still be used However, emphasis is now being placed on the formative assessment component, within which there is informal assessment and other activities such as *written assignment, investigation, journal, tutorial* (headings taken from DoE, 2000 *emphasis added*).

I believe that the introduction of these various assessment methods into the mathematics classroom has brought an increased demand for writing by students, such as reporting the results of investigative work. This interest in written mathematical communication is a development that is also noticed throughout the mathematics education community world-wide; in the international literature on mathematics education research and in historical curriculum documents such as the *National Curriculum for England and Wales* (DfE, 1995), *Curriculum and Evaluation Standards* in the US (NCTM, 1989) and the *National Statement on Mathematics for Australian Schools* (AEC, 1990). For me, particularly in the context of the curriculum changes in South Africa and now reflected in the *Revised National Curriculum Statement* (NCS) (see, for example, DoE, 2002), this has raised some interesting issues, namely:

- What forms of written mathematics are produced by students in mathematics classrooms and how do teachers assess student's written work?
- What are teachers' perceptions of the learning of mathematics through writing?
- What do the teachers perceive the impact of OBE on writing and assessment to be?

My concern within the South African mathematics education context is a lack of research on students' mathematical writing. What are the experiences of students and the forms of writing that they are likely to produce? Without this research it may not be possible to say to what extent mathematical writing hinders or helps in the learning of mathematics in South African classrooms Furthermore, it may not be possible to inform mathematics teachers, on the basis of empirical research, how they might implement and integrate writing in their classes to ensure that it has positive effects in the learning of mathematics

A further challenge is the fact that the majority of South African classrooms are now multilingual Multilingualism may have implications for the teaching and learning context (see, for example, Adler, 2001), including the introduction of mathematical writing, since the student's language is, in most instances, not the same as the medium of instruction. However, it is beyond the scope and purpose of this article to focus on the interplay between 'code-switching' and the learning of mathematics I will confine my discussion to the issues listed above In mathematics classrooms, students' work, including whether any learning of mathematics has taken place, is ultimately judged and assessed by what each student has written. For me, therefore, the study reported here is important in terms of focusing and raising critical discussion on those aspects of writing that may improve students' performance in and learning of mathematics

One of the stated critical outcomes of the 'new' curriculum is that *all learners* in South African schools, by the end of grade twelve (seventeen- to eighteen-year-old students), should be able to demonstrate successfully their ability to,

> communicate effectively using [...] mathematical [...] skills in the modes of [...] *written presentation* (DoE, 1997a, p. 16, *emphasis added*).

In this article, I will argue for a more holistic and integrated approach to mathematics curriculum development. More importantly, I will show that there is a need to use research and its findings to enable classroom teachers, subject advisors, policy-makers and curriculum developers to make informed decisions about the successful implementation of new curriculum developments, such as the introduction of mathematical writing in classrooms.

Teacher benefits from using writing-to-learn activities

The idea that writing is a powerful aid to learning has found much support from cognitive psychologists. The argument that writing may contribute to the learning process seems to arise from the Vygotskian view of the relationship between language and thought as dialectical, with language and thought both being transformed in the act of representation (Vygotsky, 1962). Vygotsky argues that writing requires particular demands from the writer who has to engage in the "deliberate structuring of the web of meaning" (p. 100). This structuring is critical because, for Vygotsky, writing could be seen as an extension of inner speech which is "maximally compact" (p. 100), whereas written speech is "maximally detailed" (p. 100). Vygotsky maintained that writing seems to increase the cognitive actions executed by students and that inner speech is critical in the writing process. In fact, when students use writing as a communication tool, they depend quite heavily on the formal meaning of the written words. As a result they will use a lot more words than they would use to state the same ideas orally.

Research evidence (Borasi and Rose, 1989; Davison and Pearce, 1990; Phillips and Crespo, 1996; Rudnitsky *et al.*, 1995; Swinson, 1992) emanating from using writing activities in mathematics classrooms seems to suggest that the effectiveness of the activities and the students' performance in mathematics may increase substantially if the writing is done in a regular and systematic manner, and over an extended period.

Miller (1992) criticises past studies related to writing-to-learn and says that they have primarily been focused on the cognitive and affective benefits that the student might derive as a direct result of being involved in the writing. In her own study, Miller (1992) sought to determine any potential benefits to teachers when using writing prompts at the beginning of each lesson. Miller's main observation was that teachers could learn about their students' understanding of a particular topic from reading their responses to the writing prompts. She also noted that teachers had an improved awareness of their students' state of understanding of the work, and this awareness influenced the teachers' instructional practices. Nevertheless, one limitation pointed out by Miller was that the extent of the benefits derived by the teachers from reading students' responses depended on the ability of the students to express themselves in writing. It was noted in the study that many of the written responses were rather brief and sometimes "more confusing than informative" (p. 337).

In another study, Davison and Pearce (1988, 1990) conducted a survey to determine the amount, kinds, and uses of writing in junior high school mathematics classrooms. For purposes of analysis, the researchers developed different categories of writing within which certain aspects of students' written work could be classified:

1. *Direct use of language* - copying and transcribing information, e.g. copying information from the board, the text or a worksheet.

2. *Linguistic translation* - translation of mathematical symbols into words, e.g. writing in a complete sentence the meaning of the formula.

3. *Summarizing/interpreting* - summarizing, paraphrasing and making personal notations about material from texts or other source, e.g. explaining how to solve a problem in students' words.

4. *Applied use of language* - situations where a mathematical idea was applied to a problem context, e.g. having students write their own story problems.

5. *Creative use of language* - using written language to explore and convey mathematically related information, e.g. having students write a report on a mathematics project (Davison and Pearce, 1988, pp. 10-11; *emphasis added*)

Davison and Pearce (1990) concluded, amongst other things, that if teachers used writing activities frequently and systematically, for example, at least once a week, with prewriting sessions, the performance of students improved substantially.

Background and context: schools and teachers

I selected six schools; three urban schools, one township school and two rural schools. The choice of the schools represents two broadly different categories:

previously-advantaged school: schools advantaged prior to the democratic elections in South Africa in 1994 - well-equipped in terms of human and physical resources

previously-disadvantaged school: rural and township schools -very limited facilities and resources

There are some schools in rural and township areas which have well-qualified teachers and some good teaching facilities. Nevertheless, in terms of physical and human resources these schools are still lagging behind compared to the urban schools. For example, in rural schools as many as 50% of the teachers are unqualified and/or under-qualified to teach mathematics, and there is usually a shortage of mathematics teachers (Arnott and Kubeka, 1997).

Six mathematics teachers of grade seven students were identified in each of these schools, namely, Bridget, Chris, Makhosi, Wendy, Xolile, and Zwide [1]. Bridget, Chris, and Wendy teach in urban schools that have small classes, an average of 25 to 35 students. Xolile and Zwide teach in rural schools and Makhosi teaches in a township school, with all their classes generally ranging between 40 and 65 students. I interviewed the teachers, examined students' written work,

observed mathematics lessons, examined lesson plans and analysed the mathematics textbooks used by the teachers.

The mathematical writing described by the six teachers was analysed with respect to the five categories identified by the Davison and Pearce study. I found these analytic tools useful for my own study because they consider the relationship between "symbolic thought and written language activities" (Davison and Pearce, 1988, p. 10) that can happen in the mathematics classroom. It is worth noting that the five categories are hierarchical. Davison and Pearce regard the first category, "direct use of language", as the lowest level of mathematical writing. The last category, "creative use of language", is regarded as the highest level of mathematical writing in which a student may operate.

Teachers' understanding of mathematical writing

One major point that seemed to come out clearly from the interviews was that teachers were not yet 'ready' to implement fully the continuous assessment policy as directed by the Department of Education. This was never explicitly said by any of the teachers I interviewed, but I was able to infer this conclusion from the way the teachers said they performed their work of teaching and assessment. As I will show later, teachers indicated that, as far they were concerned, a test or examination was always necessary to see if a student understood a mathematical concept. It seems that these teachers rely heavily on the summative aspect of assessment.

However, it is also possible that the teachers are not using the formative assessment methods simply because they may not have received adequate support in how to implement such methods. One of the initial findings in this study is that teachers do not have full access to information, for example, about the formative components of continuous assessment and how they might be implemented to benefit students. In the following sub-sections I organise the discussion of the data around the three issues that I raised at the beginning of the article letting the teachers' voices speak.

Forms of written mathematics produced by students

Davison and Pearce (1988) have argued that the most-valued form of writing is the 'creative use of language', which happens if students are encouraged to write a report on a mathematics project. I found that some teachers give students written assignments or investigative reports but for a variety of other reasons other than to allow students to use language in a 'creative' way. This point is illustrated by the following extract from the interview with Wendy:

> You set them an assignment, perhaps to solve a problem and then they have to explain to the class how they went about it and getting their fellow pupils to actually assess, "Have they achieved their task?"

My interpretation here is that Wendy is not just interested in the written work of the students but she seems to want to ensure that students are able to give fellow students an explanation of the work produced. Her emphasis is on both the written and oral aspects of mathematical writing. The other students are also given an opportunity to ask questions and critique the work that has been produced, hence allowing for peer assessment. This is what Wendy said in connection with the difficulty that some of her students have with access to facilities for doing investigative reports, written assignments, or project work:

> It also depends on the home environment. And the facilities and what they have been brought up with. Some children find that it's something foreign, so you have to help them overcome that problem first [...] (Wendy)

The facilities she is referring to here could be the use of the Internet to search for information to do a project or assignment. Wendy's school has a fully equipped library and a computer room connected to the Internet, although students have a limited use of the Internet facilities. However, finding a computer, let alone a computer connected to the Internet, in many South African homes is rare, in particular for those students coming from disadvantaged communities.

For Bridget, the written assignments or investigative reports were seen as optional or for enrichment, rather than as part of a policy on continuous assessment that was already being implemented. She only gave a written assignment or investigative report to those students who wanted to explore the concepts that had been dealt with in the classroom further:

> We looked at the Fibonacci sequence, we looked at Pascal's triangle, and I said to them if they can, you know, I'd given them some information but I said, go home, it wasn't a formal assignment, it was for those children who wanted to. I said go home, look on the Internet, look in books, look in encyclopaedias and I did give kids [...] saying this is what we have discovered, this is what they have found. But I haven't done any formal maths assignments

Other teachers thought that the traditional, routine exercises done over an extended period were a form of written assignment. These teachers did not see the significance of the classification that I was using from my point of view as a researcher, which raises questions about the congruency between the language of description of the researcher, myself, and the language of description of the research participants, the teachers. For example Xolile argued her position, which is representative of the teachers in schools with minimal teaching facilities, as follows:

> Most of the time the assignments that I give [...] are things like questions that you get in a test but I give them out as assignments. So they have to refer to their exercise books to what they have done [...] I mean I can't give them something that would make them go to the library because they won't have any library

In those schools with good teaching facilities, such as access to the Internet and a library, teachers can set a written assignment or investigative report. Therefore, some students from these schools have a better chance of using the language in a 'creative' way than students from rural and township schools. I say 'some students' because, for example, Bridget only

gave the investigative report to those students who wanted to explore the concepts that had been taught in her classroom further. As indicated by Xolile in the last comment, if students do not have access to a library, for example, then it is no use giving them an assignment or investigative report which may require access to the library

However, the overall situation in the six schools indicates that there is very little mathematical writing taking place beyond the third level of the hierarchy developed by Davison and Pearce (1988) Most of the teachers who were interviewed involved their students in quite a lot of copying and transcribing of information from the board This is what Bridget, a deputy-principal in her school, and teaching just one grade seven class, says about copying and transcribing of information by students, whenever a new topic or section in mathematics is started:

> [...] What I'll do is I'll explain, I'll give them examples on the board, we'll go through them as a class to give [solutions]. I'll give questions and [get] answers from them and then I'll always give them an example to do and they have to put like a little red star in the margin to say this is an example [...].

It seems that Bridget requires that all examples, solutions, and procedures for finding the solutions done on the board with students must be copied and then marked with a red star in the margin of the students' exercise books. The red star next to the problem and solution indicates to her that it is an example and she does not have to check or mark it

Teachers' perceptions of learning mathematics through writing

My analysis now looks at linking teachers' perceptions about mathematical writing with the notion that it can affect the learning of mathematics. Again, Davison and Pearce (1988) claim that teachers must set writing tasks that will begin to move students' writing towards an 'applied' or 'creative' use of the language, and such work needs to be regularly and systematically given if students' performance in mathematics is to improve. What is critical in what Davison and Pearce suggest is that it is imperative to integrate mathematical writing within the mathematics curriculum The following extracts are illustrative comments from some of the teachers on the possibility of writing affecting the learning of mathematics and also on how assessment of mathematical writing could be undertaken:

> I think the only way is to set a test on that particular concept. That is the only way because some of the children will copy direct and it goes in one ear and out the next. So one would have to test (Wendy)

> You give them a whole load of tests [...] continuous assessment are the tests that you'll do [...] (Chris)

> [...] we do continuous assessment because I know all our tests are fair on maths. And I do continuous assessment and then we have June exams, we have December exams and I [...] test to see if the kids understood their maths and understood the concept. (Bridget)

These responses indicate the weight and importance a test or examination still has, at least in the schools that took part in this study, in determining if students have learnt certain mathematical concepts. These teachers did not seem to note any relationship between writing and learning mathematics. For them, the students' performance in the test was the only means of showing that they (the students) understand, know, and have learnt the mathematical concepts that are being taught However, there were other teachers in the study who were collecting evidence of students' understanding of mathematical concepts by employing some of the suggestions from the continuous assessment document, in particular, the formative aspect of the assessment methods:

> [...] we are using tests most of the time [...] and on top of that we have another kind of assessment. We assess them on their - not exactly writing in the sense that they write properly, but how they work the problems out [...] including homeworks [...] and the language that they use. And the input they use in class We combine all those things in a certain kind of assessment. (Zwide)

Zwide seems to be using other assessment methods such as considering the homework completed by students and the students' input or participation in the classroom activities Zwide is, however, not quite specific how these methods are applied and I was not able to ascertain from his response how the different assessments are combined to determine the formative assessment component To a certain extent this might be said to indicate that Zwide had obtained some limited information on continuous assessment and he was now trying out some of the suggested assessment methods other than using only a test or examination

Makhosi, in her classroom, experimented with journal writing, which is one of the 'new' assessment procedures suggested by the outcomes-based curriculum. For her, journal writing meant involving students with writing on their experiences and on activities related to the teaching and learning that happened in previous lessons. This writing would fall under the third category in the Davison and Pearce (1988) classification since students are afforded some opportunities to make personal overviews about material that has been taught. Makhosi believes that the journal writing she sets for her students affects their learning of mathematics:

> In the process they learn mathematics and even to talk about mathematics. It's not only [...] know[ing] how to find the solution but they even come up with other methods of finding a solution in their own words. [...] They even come up with other methods of doing it.

Makhosi claims here that her students also showed that they could do some of the problems using their own methods. However, I did not find any corroborative evidence of these claims in the students' written work or journals. Makhosi also said that she read all the students' journals and went to the extent of giving marks up to a maximum of ten marks and a minimum of two marks for a badly written journal. I did not, however, find out from Makhosi what criteria she would use to award a mark within the range of two to ten

that she had set On probing why she gives marks for journal writing, her response was:

> I give them marks because most of the time pupils know that if they are doing something they have to get marks [. .]

In the earlier part of the interview with Makhosi I had asked her if she had encountered any problems from the students when she told them that she was going to introduce journal writing in her mathematics classes Her response was:

> They asked many questions about the writing of mathematics [. . .] how is it going to help them in the passing of mathematics? [. . .] they are concerned about the final results in maths.

I think that Makhosi may have decided to award marks to those students who wrote entries and handed in their journals to ensure that students took journal writing 'seriously' Students are not used to this kind of mathematical writing It seems to me that students wanted to know whether doing this kind of work, i.e. 'journal writing', would help them in passing mathematics at the end of the year Therefore, to encourage journal writing, the teacher marks the written work and the marks contribute towards the continuous assessment component at the end of the year

Most of the teachers interviewed still rely on the test and examination as a means of determining if students have learnt a mathematical concept A research study conducted by Lubisi (2000), into mathematics teachers' perceptions and practices of classroom assessment in South African junior high schools, found similar practices. One of Lubisi's findings was that testing, in the schools that participated in the research, dominated as a method of collecting evidence of students' understanding of mathematical concepts. However, within my own study, there were other teachers (for example, Bridget and Zwide) who used different assessment methods other than the test as a way of collecting evidence on students' understanding of mathematics. Nevertheless, the assessment methods tried by Zwide, for example, were not clearly defined, whilst the methods of assessment tried by Bridget were seen as optional and for enrichment As a result, these teachers were not concerned with any possible relationship between writing and learning mathematics, a relationship that would arise if students produced more written text than before.

Teachers' perceived impact of OBE on writing and assessment

Davison and Pearce (1988) and other researchers (for example, Clarke *et al.*, 1993) have consistently emphasized the point of changing the nature of and approach to the mathematics curriculum in relation to the integration of writing into activities in mathematics classrooms Most of the teachers I interviewed felt that the new mathematics curriculum, though they wholly supported it, required them to do more work, such as filling in many forms in connection with students' assessment and record-keeping (*cf.* DoE, 2001, p 130) Basically, the new South African curriculum is referred to as "a learner-centred educational process" (*ibid*, p. 4) because it promotes the notion that the learner is the most important component in learning and teaching For this reason, the NCS suggests that teachers have to:

> choose a variety of assessment strategies to provide learners with a range of opportunities to show what they have learnt (*ibid*, p. 124).

The NCS has re-emphasised the importance of including formative assessment, defined as:

> assessing the strengths and weaknesses of learners by assessing *different kinds of written and oral work* (p 13, *emphasis added*).

It is clear from these official statements that written work and assessment are now inextricably linked

Wendy believes that the OBE assessment principles, which include continuous assessment as the recommended model for the assessment of learners (DoE, 2000; DoE, 2002) are time consuming:

> The only problem I do find with this OBE is that it's time consuming and to give every child the same amount of time - there's no time for the other subjects. So I have a really bad feeling with that aspect.

Wendy's dilemma is that she teaches all the subjects in her grade seven class With the introduction of the OBE she now seemingly has to spend more time filling in assessment forms, doing record-keeping and writing profiles for each and every student in her (mathematics) class She has to do the same for the other subjects she teaches and this causes her to be unhappy with the situation. Bridget was more forthright in her response. She felt that the formative assessment aspect of the OBE, which was bringing in more mathematical writing, meant that students were unlikely to learn important and basic mathematical concepts:

> [. .] what worried me initially with OBE, and I actually voiced my opinion at one of our meetings [.] I said [.] I was worried that the actual content of maths was going to be ignored. [. .] And you know, we spoke about doing these various units or themes [. . .] they would do [ ] they'd bring in a bit of maths here and a bit of maths there And I said, I can't do that, because to me if you haven't got a concept and you haven't learnt it for the next year or whatever, or for the next section, they're going to be lost So I've stuck to the maths concepts that I think are important and they've got to build up from before they get to high school

Bridget has already indicated earlier on that any investigative reports or written assignments she gives to learners are informal because she regards these as enrichment work for students My interpretation of Bridget's statement here is that she believes that mathematics content can only be learnt in a typical classroom situation. She does not seem to believe that students can learn mathematical concepts by working on their own, for example, through doing investigative reports, written assignments and research projects. This clearly indicates conflict and tension for Bridget between implementing the OBE curriculum, which suggests that evidence of mathematical learning can be collected using various assessment tools, and preserving the status

quo. Xolile, who has large classes, ranging between 49 and 52 students, says that she already finds it difficult to cope with the current situation, which requires that she does summative assessment. Her opinion on the OBE curriculum assessment demands is that:

> With the big numbers [of students in each class] that I am having at the moment, I am finding it very difficult to add more work. I mean so far, what I am doing, I think it's too much. But now if I think that I'll have to do more than this, I don't know whether I would be able to cope. But maybe I'm over-estimating, I don't know. Maybe I'm over-estimating.

My interpretation here is that when Xolile says, "[...] what I am doing, I think it's too much", she is referring to tasks such as the marking of classwork, homework, tests, examinations and generally teaching large classes. If she has to introduce mathematical writing, as required by the OBE curriculum, in the form of investigative reports, projects, or written assignments, then this will add more work because she has to check, assess and keep records of this work for each student. Although Xolile thinks she may be "over-estimating" the amount of work suggested by the OBE assessment principles, I can, however, detect unhappiness about doing more work when she says, "[...] I am finding it very difficult to add more work"

Concluding remarks

The mathematical writing in these six classrooms is predominantly in the forms of writing that are seen by Davison and Pearce (1988) as being of a low level. The fifth, and highest, level of mathematical writing described by Davison and Pearce is the 'creative' use of language. In the context of my study only one teacher, Bridget, involved students in the creative use of language, or as Swinson (1992) puts it, in "creating knowledge or in reflecting on knowledge [...]" (p. 43). Bridget gave an investigative report to some students who wanted to explore mathematics concepts learnt in the classroom further. Bridget did not, however, 'officially' assess the written work produced by the students in the investigative report. This practice, by Bridget, is also noted from the research done by Lubisi (2000) in South Africa which, amongst other findings, concluded that:

> [...] the alternative assessments were [...] seen as no more than 'enrichments' that were designed to 'extend' students, especially those in high achieving classes. (p. 276)

The teachers I interviewed also did not seem to appreciate the relationship between writing and mathematics, or between writing and the learning of mathematics for that matter. Davison and Pearce (1988) voiced similar concerns in their research. The outcomes-based curriculum that is being introduced in the South African education system now includes formative aspects of continuous assessment, most of which require students to produce more written work. However, this study shows that teachers may be avoiding some of these alternative assessments. As inferred earlier on it is possible that these teachers have not acquired the necessary skills to carry out the suggested alternative assessments.

Another interpretation I am putting forward is that the teachers have probably not reached a common understanding amongst and within themselves on how to collect evidence of students' learning through writing - understanding of and knowledge of a particular mathematical topic through using the alternative assessment strategies. To further compound teachers' problems, Morgan's (1998) research shows that even experienced mathematics teachers can come up with widely different interpretations of the mathematics from students' written work (*cf.* Watson, 2001). Hence, an algorithmic or traditional, routine problem, with specific steps or a specific procedure to follow, and a specific solution, could be seen by some of the teachers who participated in the study as easier to assess than the alternative assessment strategies.

To a certain extent I was surprised by some of the findings. The OBE has had a definite impact on the way teachers approach their classroom practice. The introduction of the continuous assessment principles (DoE, 1997b) in South African schools since 1997 from grades four to eleven, means that there is a formative assessment component, which includes written assignments, investigative reports, journal writing and projects. I would have thought that if the policy on continuous assessment was implemented effectively, then most of the mathematics students in schools would already be involved in the production of extended writing.

Obviously, this is not yet the case. It seems that the teachers who participated in the study were not sure of how they could implement the various suggested assessment methods, particularly those that required the inclusion of writing activities, in their classrooms. These mathematics teachers have other 'bigger' problems to deal with in their classrooms than worry themselves with the new emphasis on writing. Therefore, the successful implementation of writing in mathematics classrooms may, indeed, be rather limited in the short to medium term.

The findings I have noted seem to suggest that there is a need to involve mathematics teachers in more intensive and extensive in-service courses, workshops, professional development programs and seminars in order to improve their classroom skills in relation to how they could incorporate writing activities into their classes as a means of supporting the learning of mathematics.

More importantly, however, the findings from the study suggest to me that it is imperative, at least within the current curriculum development initiatives, for curriculum developers to ensure that writing is integrated into the mathematics curriculum, to allow curriculum materials and mathematics textbooks to reflect these changes. The rationale here is that if writing is to be successful as a vehicle for the learning of mathematics, then the structure of the mathematics classroom, the nature of the mathematics curriculum, and the approach to mathematics materials development have to change radically.

Furthermore, the dynamics of a multilingual classroom may play a critical role in the success or failure of the introduction of mathematical writing as learners need to have relevant vocabulary to express their ideas. As Vygotsky (1962) has pointed out, to articulate one's thought processes

in writing requires more words, in particular, to clarify and explain the meanings and understandings of ideas and concepts.

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Notes

[1] All teacher names are pseudonyms

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> In contrast to what one may consider the approximate neutrality of right-left direction in the horizontal dimension [...] Johnson and Lakoff point out the universality of *more is up* and *less is down*. They offer the examples in English such as: *prices rose, the Dow hit bottom, turn up the thermostat*; and they note that this bias occurs in many languages. Even more telling is that there is no language for which the opposite is true: none in which more is down and less is up. To be sure, we have no end of experience, from childhood on, that helps to entrench the metaphor *more is up*; for example, every time we pour water into a glass the level goes up.
>
> (Mazur, 2003, pp. 59-60)