Factors Influencing Computer Use in Mathematics Teaching in Secondary Schools

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The reluctance of many mathematics teachers to embrace the use of computers in their teaching has been well documented. This paper report on a study that attempts to identify and describe the major factors that have effected some teachers' decisions to use or not to use this innovation. Rich case study data has been summarised in a concept map. This map illustrates that central to teachers responses are their beliefs about mathematics, beliefs about students, pedagogical knowledge, knowledge about using technology in teaching, cultural press and perceptions of assessment. The interactions are complex. The findings indicate that a pronged approach to syllabi reform and professional development is recommended.

Both nationally and internationally, education researchers have expressed high expectations for the potential of computer technology to improve the teaching and learning of mathematics (Kissane, & Kemp, 1998). This has included the use of use of graphics calculators (McRae, & Kendal, 1999), generic software such as spreadsheets (Abramovich, 1995), specialist mathematics software such as DERIVE 2.55 (Pierce, 1999), and *Cabri geometry* MS-DOS (Vincent, & McRae, 1999). A number of studies have indicated that teachers have been slow to introduce and use computers in their teaching even when hardware and software has been accessible (Norton, McRobbie, & Cooper, 2000; Becker, 1994). Studies on teachers' reluctance to engage in the use of computers in their mathematics teaching have examined teachers' beliefs about how students learn (Sarama, Clements, & Henry, 1998) and the mismatch between their beliefs and teaching practices (Norton, 2000). Further, the importance of peers and school micro-culture in influencing teachers' implementation of innovative teaching strategies has been reported (Rosen, & Weil, 1995).

The purpose of this paper is to present a model of the variables that were found to have an important influence on teachers decisions to use computers in their teaching of mathematics. This paper summarises and syntheses the author's previously publications on this topic. (Norton, 1999a & b; Norton, Cooper, & McRobbie, 2000 & in press; Norton & McRobbie, 2000; Norton, McRobbie, & Cooper, 2000).

Method

The methodology is described in detail in Norton, McRobbie and Cooper, (2000). In essence the study involved a series of embedded case studies involving a hermeneutic and naturalistic approach (Denzin, & Lincoln, 1994).

Subjects and Contexts

The study was carried out in two technology rich schools. The first being a mid sized (650 students) private girls school known by the pseudonym of "Hill View" and the second a State secondary school (1200 students) known as "Forest Glen."

Data Gathering Methods

There were three phases of data collection. The first phase involved surveying the mathematics staff and selecting teachers as case-study subjects for in-depth study. The survey covered: (a) demographic data, (b) use of computers, (c) factors limiting classroom computer usage, and (d) beliefs about mathematics, teaching mathematics and the effectiveness of computers in mathematics teaching. Eleven teachers were selected, 5 from Hill View and 6 from Forest Glen. The teachers selected met the criteria of being the senior and most influential teachers in each school. The second phase explored the case-study teachers' beliefs and practices through interviews and classroom observations. The third and final phase involved the author conducting a teaching intervention in the teachers' classes and interviewing the teachers about their responses.

Analysis and Model Construction

The individual case-study results have been summarised in Norton (1999b), the Hill View teachers (Eva, Peter, Julie, Emm and Mary) have been discussed in detail in Norton, McRobbie and Cooper (2000) and Norton and McRobbie (2000), and the Forest Glen teachers (Jan, Kurt, David, Sasha, Will and Simon) have been described in Norton McRobbie and Cooper (in press). In this paper, a synthesis of the results of the case studies is modelled as a concept map. To do this, eight major concepts were identified from the case studies and fourteen relationships (called effect factors) showed the relationships between the major variables. Discussion of the interactions between variables and effect factors is used to explain teachers' use of computers in mathematics teaching.

In constructing this map, the teachers' responses to using computers in their teaching were classified according to Norton's (1999b) three categories. The first was *rejection* where teachers did not believe that it was appropriate to use computers in mathematics teaching. The second was *calculationa*l where teachers saw the potential for computers to carry out routine computations and display mathematical data as tables or graphs. The third was *conceptual*, where teachers' believed that computers could be used to reveal underlying mathematical structures to students.

Results

The map is presented in Figure 1. The key contributing processes that link the effect factors in this map are described below.

Effect Factors 1 to 6: Direct and Indirect Influence of the Senior Syllabi

The Senior Syllabus in Mathematics B (Board of Senior Secondary Schools Studies, 1992, p. 1) acknowledged the role of technology in changing the nature of mathematics and "encouraged teachers to give their students the opportunity to experience the power which has been given to mathematics by technology." Some teachers appeared to be quite conscious of the intention of the syllabi in regard to using computers in learning. This effect is recognised as Effect Factor 1. This was not the case with most case-study teachers. The senior syllabi exerted indirect effects upon teachers' use of technology. First, it indirectly influenced teachers' beliefs about the nature of mathematics (Effect Factor 2). In some cases this may have contributed to the formation of teachers' falliblist beliefs about the nature of mathematics (Ernest, 1991).

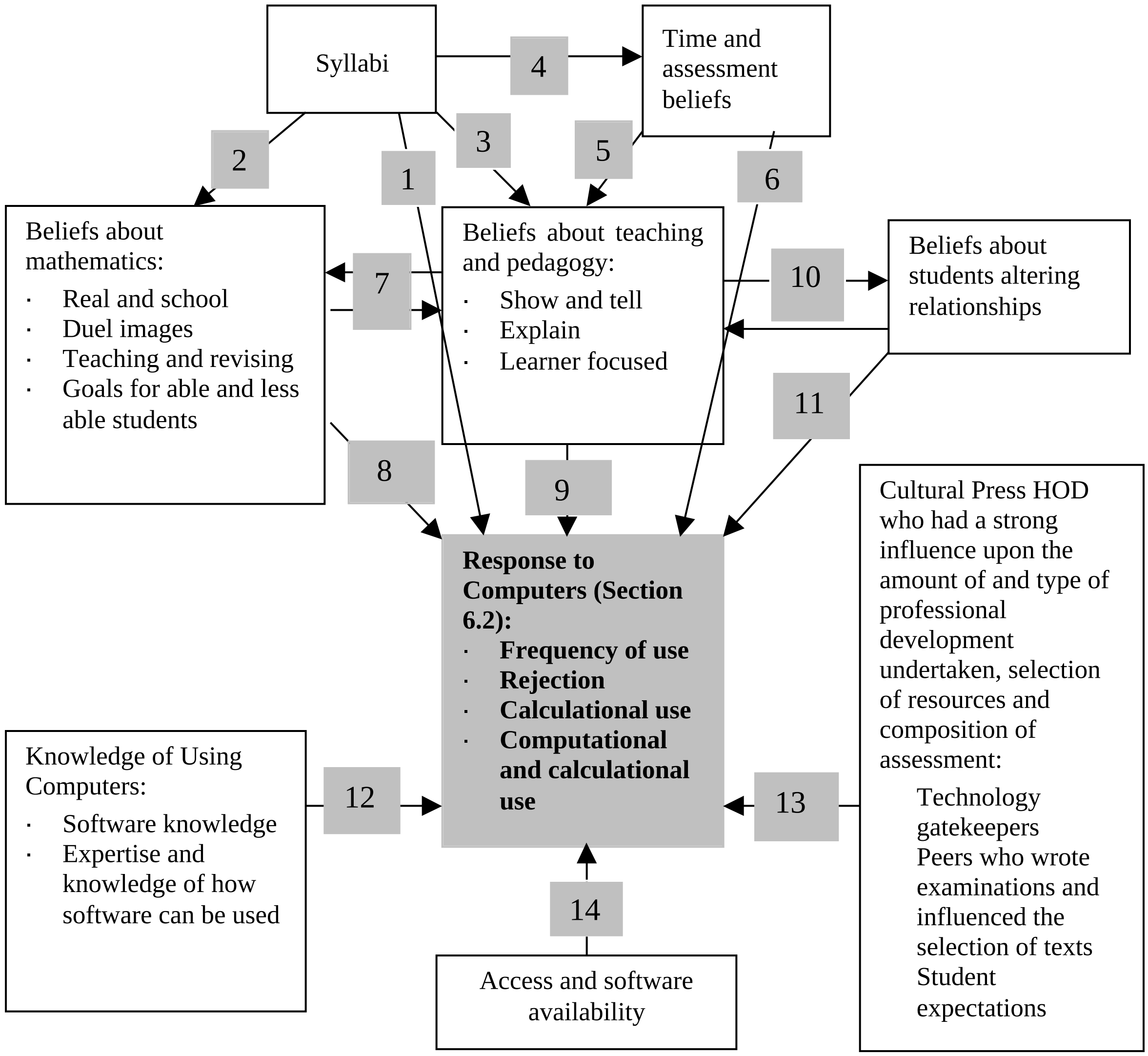

Figure 1. Model summarising factors influencing teachers' responses to the use of computers in their mathematics teaching.

Second, the syllabi contributed indirectly to teachers' pedagogy by influencing teachers' formation of different goals for able and less able mathematics students (Norton, McRobbie & Cooper, in press). For example, 9 of the 10 case study teachers had mostly instrumental goals for mathematically less able students and all teachers claimed to have understanding goals for more able students. Third, the syllabi indirectly influenced teachers' pedagogy in relation to strategies (Effect Factor 3), particularly by countenancing the use of *show and tell* and *explain* teaching strategies. These strategies are described in detail in Norton, McRobbie and Cooper (in press). Essentially *show and tell* refers to a focus on instrumental learning where the teacher models procedures and sets practice activities, while *explain* involves demonstration accompanied by the provision of detailed cognitive scaffolding in order to lead students to understanding. Interestingly, this effect on strategies by the syllabi is in opposition to the intention expressed in the syllabus rationale, which recommended a move towards investigative, problem solving and learner-focused teaching strategies.

In addition, the syllabus also influenced teachers' perceptions of whether it was appropriate to spend time getting students to use computers. This was because of perceived time constraints imposed by the syllabus and the assessment format it supported. This influence is recognised by Effect Factors 4 and 5. Teachers' responses showed that they were concerned with covering the syllabi in the allocated time. A number of them expressed the opinion that they did not have time to spend getting students "up to speed" with software or to engage their students in lessons based upon the use of computers. This appeared to be associated with a belief that getting their students to use computers was less time efficient than traditional teaching strategies. Finally, the syllabi strongly influenced the two schools' internal assessment programs. For at least four of the case-study teachers, the assessment regimes adopted by their schools worked against the introduction of computers in their mathematics teaching. This influence is identified as Effect factor 6.

Effect Factors 7, 8 and 9: Beliefs About Mathematics Teaching and Pedagogy

Teachers' beliefs about the nature of mathematics had a direct effect upon their use of technology (Effect Factor 8). This occurred because some teachers believed that computers hid the processes of mathematics when the computers were used for calculations and procedures and that this could hinder students' mathematical growth. These teachers believed that calculations were the essence of secondary school mathematics and, therefore, the students should be doing these calculations themselves. Teachers' beliefs about mathematics also had an indirect effect upon their response to computer technology by effecting their pedagogy (Effect Factor 7). This, in turn, effected their responses to the use of computers (Effect Factor 9). In brief, teachers with essentially absolutist images of mathematics (Ernest, 1991), particularly school mathematics, believed in transmission theories of learning (Atweh, & Cooper, 1995) and used *show and tell* and *explain* teaching strategies. These teachers either rejected the use of computers, or used them only in a *calculational* way. By contrast, teachers with essentially fallibist images of school mathematics (for able students) favoured learner-focused teaching strategies and considered that student use of computers could assist in the process of developing student conceptualisation. The research literature supports the influence of teaching practice upon teachers' beliefs about mathematics (Buzeika, 1996; Cuban, 1984). Thus, the two arrows in Figure 1-indicating effect are two ways for Effect Factor 7.

Effect Factors 10 and 11: Beliefs About Teacher/Student Relationships

Effect Factors 10 and 11 refer to the influence teachers' beliefs about teaching and teachers' relationships and patterns in their interactions with students has on computer use. The interactive nature or these relationships was seen in the different goals and practices that teachers had for different ability students (Norton, McRobbie, & Cooper, in press). The two directional arrows in relation to these effect factors are recognition of teachers' expressions of their beliefs about what students wanted from them as teachers. There was evidence from both computing coordinators and case-study teachers that concerns about altering these relationships were factors working against the use of computers in mathematics teaching (Effect Factor 11).

Effect Factor 12: Knowledge of Using Computers

Effect Factor 12 refers to teachers' knowledge of suitable software, confidence, expertise and knowledge of support material that could be used with software. In some cases it appeared that lack of expertise on how to use computing technology in mathematics teaching limited teachers' vision of how computers could be integrated into their classroom teaching. This may have been one explanation why some teachers modified their statements about the potential of computers over the life of the case study. Of all the variables this study has shown to have an influence upon teachers' use of computer technology in their mathematics teaching, teachers' knowledge of the use of computers may be the easiest to change through professional development. On the other hand numerous studies have indicated that beliefs (Alexander, 1996; Thompson, 1992) and teaching practices (Cuban, 1984; Ernest, 1991; Rosen, & Weil, 1995) are difficult to change.

Effect Factor 13: Cultural Press

Effect Factor 13 refers to the cultural press that existed among the mathematics staff of the study schools, which facilitated or hindered the use of computers in mathematics teaching (Norton, Cooper, & McRobbie, 2000). This cultural expression was related to the support the principal gave to the integration of computers in mathematics teaching, the beliefs and management style of the HODs and the support for or rejection of the role of computers by peers. Two very different staff cultures influenced teachers' responses to the potential of computers in their mathematics teaching. At Forest Glen essentially absolute images of school mathematics and teacher-centred pedagogy were associated with a restricted image of the potential of computers in mathematics teaching. However, the teachers were encouraged and supported to explore the potential of computer technology in mathematics teaching. It appeared that the head of the mathematics department supported his staff in exploring all options in teaching, this was evidenced by the much greater professional development taken up by Forest Glen teachers. In contrast, at Hill View, essentially absolutist images of school mathematics and teacher-centred pedagogy were linked more strongly to the rejection of computers in mathematics teaching and learning. Incidentally this school adopted a much more democratic approach to professional development and this was reflected in much less attendance at mathematics professional development. In short the Hill View teachers availed themselves to a much lesser degree for professional development, including investigating the role of computers in mathematics teaching and learning.

Effect Factor 14: Access

These schools from which the major case studies were selected were technology rich. Access to computers was not considered to be a significant problem by the HODs of the mathematics departments, and by several teachers at Forest Glen and one teacher at Hill View. However, a number of teachers at both schools may not have used the computer resources available at their schools because they may not have been fully aware of the resources that were available and how to access these resources. An alternative explanation is that they stated that access was a problem because they did not want to use computers.

Conclusions and Implications

The model presented in Figure 1 indicates that there are many of factors that influence teachers' responses to the potential of computers in secondary mathematics teaching and learning. This suggests that in order to help teachers to better utilise the potential of computers in their mathematics teaching an integrated and multi-dimensional approach is needed. This approach needs to consider the effects and interactions between the syllabi, beliefs about mathematics and teaching, knowledge and staff culture. The study illustrates the influence of the syllabus upon the formation of teachers' goals and ultimately upon their practices including their responses to computers. Attempts to influence teachers' responses to computers by manipulating the syllabus are top down in nature. A number of authors have noted that such approaches have been resisted by teachers (Cuban, 1984; McDonald, & Ingvarson, 1995). There was some evidence of resistance to top down reform in this study. One way by which teachers avoided implementing new syllabi was to modify the new syllabus to make it compatible with their own beliefs. That is, they interpreted the syllabi in ways that supported their beliefs and practices. For example they pointed to assessment criteria and used this to maintain absolutist images of mathematics and used the syllabi to justify *show and tell* and *explain* teaching strategies rather than move towards the recommended investigative and learner focused approaches. On the other hand, there was evidence that some of the teachers were relatively unaware of the rationale and learning strategies recommended by the syllabi.

Clearly syllabi can be used to alter teachers' goals. The obvious place where this process can be implemented is assessment criteria, these can be altered to encourage teachers to adopt goals consistent with the syllabi rationale. The importance that assessment criteria held for most of the case study subjects indicates that if it is clearly articulated in the syllabi that students will be assessed in their ability to use technology to construct mathematical knowledge, many teachers are likely to alter their goals and subsequently practices even if this causes some tension with their beliefs. In this regard, the study supports the finding that assessment can strongly influence teaching practice (Barnes, Clark, & Stephens, 1996; Ernest, 1991). Figure .1 also illustrates that teacher knowledge and expertise in the use of computers in mathematics teaching and learning is an important consideration (Effect Factor 12). Clarke and Peter (1993) refer to this as part of teachers "personal domain." Improving teachers' knowledge of software can be accomplished using traditional in-service (Guskey, 1985, cited in Clarke & Peter, 1993) and this can empower teachers to begin experimentation (Clarke, & Peter, 1993). That is, external sources of information such as those provided in a short in-service session have the potential to empower teachers to experiment in their classrooms and this can cause them to modify their beliefs and practices. On the other hand, it can be argued that the case study data has indicated that 7 out of 10 case-study teachers had limited images of the potential of computers, that is, their images were based upon their beliefs that computers were not as efficient or as effective as traditional teacher-centred approaches particularly in developing student understanding. Thus, since there is evidence that teachers' responses to computers are strongly constrained by their beliefs about mathematics and teaching (Figure 1), simply providing them with technical knowledge is likely to have a limited impact upon their practices.

Research has noted the need for teachers to engage in sustained reflection in order to change their beliefs and practices (Becker, & Pence, 1996; Clarke, & Peter, 1993). Getting teachers to engage in sustained reflection is not a trivial task, and in attempting to do so, models of professional development of teachers have emphasised the dialectic between practice and beliefs that is illustrated in Figure 1 (e.g., Clarke & Peter 1993). As discussed above, one way of trying to do this is by altering teachers' goals by altering the syllabi. However, an alternative approach has been suggested by Atweh and Ochoa (in preparation). They have recommended that teachers engage in classroom based research. That is, by experimenting with the use of computers in mathematics teaching, teachers might experience the "break through" described by Hyde Ormiston and Hyde (1994) and alter their practices. Figure 1 also shows that beliefs about students and their relationships with students influence teachers' responses to the potential of computers in mathematics teaching and learning. Concerns about changing teachers' roles are well-documented (Buzeika, 1996; Crawford, 1994; Simonsen, & Dick, 1997). One way around this problem is to develop programs where teachers are encouraged to move slowly away from their existing practices without changing their relationships with students. That is, teachers need to be supported to adopt new practices which initially do not greatly alter the balance of relationships between them and their students. Finally, Figure 1 illustrates the importance of cultural press. Thus, the study supports the recommendations of other authors (Becker, & Pence, 1996; Hyde et al., 1994) that effective professional development needs to involve the entire mathematics staff community.

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