

**From pre-service to classroom teaching:
A five year longitudinal study investigating the practice of progressive problem
solving and innovation**

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Abstract

This paper presents findings from a five year longitudinal study that follows a group of self-declared math anxious teachers inducted in a two year program (N=20 from a total cohort of 57) and their first three years as elementary teachers when they agreed to participate in a self-directed professional development design experiment known as The MathForum Group. Forms of discourse as promoted in mathematics reform documents, such as the NCTM (2000), and research on Knowledge Building (Scardamalia & Bereiter, 2002) were encouraged to address attitudes toward learning, beliefs of instructional practice and the nature of mathematical knowledge. Findings suggest that for a number of participants, mathematical ideas, questions and problems progressed to deeper levels of complexity and resolution creating conceptual movement. Implications for design research, building community and curriculum decision-making are presented.

Background

This paper describes a five-year longitudinal study that follows a group of teachers enrolled in a two year pre-service program and their first three years as practicing teachers and traces changes in how they understood and taught mathematics over this period. This project supported a reform-based approach to mathematics teaching and learning (Brett, 2002; Brett, Woodruff & Nason, 1997; De Froy, 2002; Woodruff, 2000, 2001; Woodruff, Brett, & Nason, 1999). There were two phases to the study. First, twenty self declared math anxious pre-service teachers were inducted into a learning community as part of an experimental two-year teacher induction program. Brett (2002) determined that this program met with a degree of success, as a shift in how math was understood was shown to varying degrees by all participants. In the second phase, these teachers were invited to participate in a self-directed professional development community modeled as a Community of Practice, (Lave & Wenger, 1991) as they began their elementary teaching careers. The goal was to maintain and develop those more advanced mathematical conceptions gained in the pre-service program.

Theoretical Framework

Researchers have examined how the social context of teachers' school-based interactions supports on-going development leading to improvements in instructional practices (Jarvis, 2006; Kerekes & Botelho, 2006; Stein & Brown, 1997; Secada & Adajian, 1997). Other studies have looked at teachers' development of mathematics in their first year of teaching following a certification program (Brown & Borko, 1992). There is some research taking a self-directed approach to professional development (Harkin, 2000) which also emphasizes the role of dialogue and interaction. Borko (2004) has examined a broad range of professional development and concluded "*Despite recognition of its importance, the professional development currently available to teachers is woefully inadequate ... We are only beginning to learn about exactly what and how teachers learn from professional development or about the impact on teacher change on student outcomes* (2004, p.3).

The study reported here takes a further step in addressing gaps in this literature by focusing on self-directed professional development whereby topics related to teaching and learning of mathematics for conceptual understanding were generated by the participants themselves. Hord and Hall (1987) suggest that such innovations do take time, approximately 3-5 years once teachers are committed to implementing the innovation.

Three frameworks have been used to inform this exploratory study of teachers' thinking. First, problem-solving research informed how teachers resolved challenges faced when teaching mathematics for reasoning and conceptual understanding, second the sociocultural factors influencing development of beginning teachers' thinking and third Knowledge Building research that promotes on-going learning and self-directed professional development.

Methodology

The research is emergent in nature. It examines outcomes from the design and development of a 2-year pilot pre-service program and identifies important factors that contributed to the success of the subsequent 3 year professional development design experiment. The usefulness of design research has been addressed by a number of researchers dealing with complex educational environments (Brown, Collins, & Duguid, 1989). Additionally Borko (2004) comments, "*Design experiments, with their repeated cycles of design, enactment, analysis and redesign can be particularly useful to study the impact on the development of professional community and the learning of individual teachers*" (p. 12).

Participants

The participants were a subgroup of an original cohort of pre-service teachers (N=57) enrolled in an experimental two-year teacher certification program at an urban university in Ontario, Canada, grouped to teach kindergarten to grade 10. Participants from the original cohort who had indicated mathematics to be an area of concern for them in their teaching (N=20) were asked to participate in a more detailed study including annual individual interviews. On completion of their certification program, 10 participants from that group expressed a desire to participate in future discourse about mathematics with their peer group as they embarked on their teaching careers. These 10 'active' members routinely accessed a number of supports, including quarterly workshops and an electronic conference. The remaining 10 participants agreed to participate in the study but in a limited way by receiving the newsletter generated from the workshops and taking part in the annual interviews conducted for this study. This group is identified as 'peripheral' reflecting their level of membership in the community.

Data Sources

In total, five data sources were used for this study: 1) database contributions 2) portfolio entries on self selected topics considered significant 3) quarterly workshop transcriptions and/or written minutes 4) annual semi-structured individual interviews, and 5) journal reflections of the writers as researchers and participant observers for the TMG project. The data include quantitative measures such as frequency tables to illustrate patterns of interaction as a result of overall qualitative ratings.

Data Analysis

Research suggests that active participation reflecting a commitment to teach for conceptual understanding creates the possibility for conceptual movement (Wenger, 1998). To illustrate a progressive trajectory, Bereiter (2002) identified *deep level constructivism* as a way to describe how people work with ideas in a Knowledge Building community. Building on this research the following framework was developed to analyze the data:

Coding Framework: Categories of how teachers worked with ideas

Code	Sub-Category	Description
1.1	Foundational Knowledge	Finding out what is already known, acquiring mathematical language, accessing resources, learning "how-to-do-it"
1.2	Sub-skills Of Research	Practicing critical thinking, using scientific method. Thinking often uses sets of step-wise procedures, teacher-designed activities, assessing results. Incorporated collaboration, provided emotional support and encouragement. Over time they learn to assemble information into competent original research and curriculum design.
1.3	Shallow Constructivism	<i>Participating</i> in learning communities, project based learning, guided discovery. Saw knowledge as socially constructed, used collaboration, shared knowledge based in real world content, and varied information sources to understand the deeper meaning behind the language of mathematics
1.4	Deep level Constructivism	Active goal of improving knowledge. Instructional strategies include the identification of unsolved problems of understanding, theorizing, building models, monitoring, evaluating progress and reporting, refining ideas at deeper levels.

Data was analyzed first by coding nominal data with corresponding quotes for each participant. Second, a group of events designated as significant incidents for individual participants were identified. Third tracking files from the online participation data were used to capture common recurring themes. Excerpts from the database, portfolio and interview data are used to illustrate changing conceptions of mathematics, teaching and learning. Evidence of movement on specific concepts representative of the subjects' thinking is represented as 'trails' reflecting a form of trajectory. (Hutchins, 1996; Scardamalia & Bereiter, 2002; Wenger, 1998).

Results and Discussion

The following table illustrates the total number of statements that fell into these four categories. Statement totals within categories were averaged as a percentage of the total number of statements in all categories (displayed in the column 'Frequency of Mention'). If there was no data for a participant in a particular year no score was given so it would not impact the overall rating. In this way, the data were biased toward finding the highest reflective level reached for each participant, regardless of the quantity of entries. Co-rater reliability was $r = .87$

Table 2: Results: How teachers worked with ideas

Categories of Teachers Emerging Idea Focus					
	Foundational Knowledge	Sub-skills of Research	Shallow Constructivism	Deep Level Constructivism	Frequency of Mention
Peripheral					Peripheral
Year 1	22%	71%	8%	0%	51
Year 2	32%	61%	7%	0%	28
Year 3	78%	21%	0%	1%	25
Year 4	71%	27%	2%	0%	98
Year 5	69%	30%	1%	0%	138
Active					Active

Year 1	27%	52%	21%	0%	52
Year 2	33%	44%	18%	5%	39
Year 3	42%	40%	16%	2%	54
Year 4	40%	34%	22%	3%	151
Year 5	29%	30%	35%	7%	149

Foundational Knowledge and Sub-skills of Research

In Years 1 and 2, both groups were primarily focused on building foundational knowledge around mathematics. Importantly, both groups additionally became adept at using research sub-skills, and shallow constructivism in order to learn ‘how to’ teach elementary mathematics. For the ‘peripheral’ group, references to research sub-skills dropped off in Year 3 and never regained pre-service levels. Instead, interaction was predominantly characterized by foundational knowledge behaviours. By comparison the ‘active’ group’s statements increasingly reflected shallow and deep level constructivism.

Shallow and Deep Level Constructivism:

The key distinction between shallow constructivism and deep constructivism is the ability and willingness to identify unsolved problems of understanding and work towards producing a new resolution that advanced group understanding. Evidence of constructivist thinking was apparent for both groups during the induction program in their questioning of practices in their practicum schools and in sharing experiences of using the strategies they were learning in their teaching. The database and face to face classroom conversations provided opportunities to debrief and build on their learning. As beginning teachers in Years 3, 4 and 5, the ‘peripheral’ group focused predominantly on acquiring foundational knowledge and use of research sub-skills, typically with another teacher in their school. In comparison, the ‘active’ group produced more constructivist thinking, including ideas that could be traced back to discussions during the pre-service program and TMG. A number of ‘active’ participants focused their efforts on a conceptual problem that they really cared about, creating a trail of evidence, and took it to deeper levels while contributing to community knowledge. The following example highlights such an effort.

Yr5-A- I wanted to ‘go beyond’ binary language,,,, I wanted them to realize that there could be other math bases out there that they could play with and work with. So I wrote a paper interviewing a computer person about computers, in particular about binary code to explain it. He helped me to develop a worksheet where students could start looking at a relationship between numbers.... where they were able to explore a relationship on why binary works and how it works. We only have four bits of ones and zeros. What would the next zero or one be if you kept adding? So let’s say I wanted to go beyond four bit language,...What value would that fifth bit be and why? It was published. Yeah! First time ever. (James-A Yr5p8)

Overall, the findings suggest that 9 out of 10 ‘active’ participants developed an enhanced conception of themselves as both math learners and teachers, as they moved from developing foundational knowledge and sub-skills of research to engaging in deeper levels of constructivism. Additionally, in Year 3, 4 and 5, all the participants declared their intent to teach for conceptual understanding. This further supports Brett’s (2002) findings that overall, participants broadened their conceptions of what math pedagogy involves, and saw the process as rooted in the understanding of the learner. The persistence of those changes can be seen in the limitations

participants identified in pre-packaged programs such as a textbook series. These limitations included a) needing to explain the rationale *behind* a mathematical objective, b) identifying the source of difficulty when there were problems of understanding, and c) creating support materials to solve students' difficulties beyond providing additional worksheets. Specifically, the 'active' participants did not abandon the resources sanctioned by their schools or boards, but rather went beyond them in order to address those limitations.

Deleted:

Educational Implications

The researchers had a number of goals, one of which encouraged teachers to rethink mathematics as an inquiry based domain. Four key principles of knowledge building as advanced by Bereiter and Scardamalia (2001) were evidenced throughout the study as a shift in thinking took place over time. In order to be willing to cognitively engage, a high degree of epistemic agency was required. The researchers addressed this by acknowledging anxiety as a common factor for many teachers and providing ongoing supports to overcome the fear. The situated activity was represented as real ideas and authentic problems of conceptual understanding in the pedagogy of mathematics, reflecting the real world of innovation as suggested in another principle of knowledge building. It was through the discourse that participants reflected a shared responsibility and commitment to not only advance their personal knowledge but that of their classroom and the wider professional community.

This study attempted to identify the affordances of community interaction that impacted on changes in teachers' thinking and their practice and the resulting contributions to the collective understanding of key mathematical concepts:

Yr 5-A It [the math community] did a lot of stuff but probably the most important thing was making it all right to play with math, and making it all right to be a co-investigator with kids on problems. I didn't necessarily have to always understand the concepts like I had a Bachelor of Mathematics but that together we could work through things and make discoveries. I think some of the most fun I had teaching math was when I was trying to figure something out and so were the kids, and we did it together. (Wendy-A Yr5p2)

In efforts to promote a shift away from a traditional view that expects teachers to assume the role of expert, these teachers acquired a willingness to engage in self-directed professional development and improve their levels of mathematical understanding. Fundamentally, accepting oneself as both a learner and a teacher is a conception that holds considerable promise for extending and deepening understandings of the complexities of teaching and professional knowledge of participants.

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