Attaining and Measuring Knowledge and Beliefs among Teacher Candidates Transitioning to Teaching

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Abstract: *Learning subject matter and developing beliefs consistent with reform-based learning is a current focus of teacher education. This paper reports results from an inquiry on teacher candidates' knowledge and beliefs about mathematics, its learning, teaching and assessment. Test and questionnaire instruments were used. Participants were teacher candidates taking a course that aims to engage them in doing and reflecting on reform-based mathematics learning. I asked: What instruments are suitable for measuring and reporting knowledge and affective characteristics of teacher candidates transitioning to teaching? What characteristics do they have when they join and when they leave teacher education programs?*

Keywords: Learning and teaching practices, beliefs, knowledge, pre-service education

1. Introduction

Learning subject matter for teaching purposes and developing beliefs supportive of mathematics learning is a big focus of teacher education. This is especially the case for elementary mathematics methods courses. In several countries elementary teacher candidates transitioning to teaching are not specialists in mathematics. Several of them profess that they feel uncomfortable with teaching mathematics. I research an elementary pre-service teacher education mathematics course in Canada, which engages teacher candidates in doing and reflecting on reform-based mathematics learning. I study teacher candidates' knowledge and belief characteristics. Their knowledge is measured by a test. Their beliefs are surveyed on a questionnaire. And their comfort levels determined using anxiety scales. The general research questions are: What instruments are suitable for measuring and reporting knowledge and affective characteristics of teacher candidates transitioning to teaching? What characteristics do they have when they join and when they leave teacher education programs? In this paper I focus on knowledge and beliefs of the teacher candidates at the end of the course.

2. Frameworks and Literature Review

2.1. Elementary and Middle School Teacher characteristics

Cooney and Wiegel (2003) observe, "there exists a fairly substantial body of literature on teachers' beliefs and knowledge about mathematics" (p.799). In the past decade this body of knowledge has grown further due to augmented interest in mathematics knowledge needed for teaching. In this section, I briefly present literature that frames my understanding of mathematics teachers' knowledge and belief characteristics as well as of instruments used to measure these characteristics. I also briefly present literature on selection, design and implementation of mathematics tasks that facilitate attainment of these characteristics.

2.1.1. *Knowledge characteristics of mathematics teachers*

Several educators such as Shulman (1987), Ball, Bass, Sleep and Thames (2005), and Ponte and Chapman (2008) provide frameworks for studying the mathematics knowledge that teachers use in teaching practices. Chapman and Ponte classify four major categories of studying teacher knowledge: The first category is on teachers' mathematics knowledge; the second category is on teachers' knowledge of mathematics teaching; the third category focuses on teachers' beliefs

and conceptions; and the fourth component is teachers' practice. I adopt Ponte and Chapman's framework because it elaborates on more than two categories. As well it connects knowledge and beliefs to practices. Researchers note that elementary and middle school teachers in several countries have less sophisticated conceptual knowledge and more procedural mathematics knowledge. Teachers' knowledge is at many times not reform-based. Cooney and Wiegel (2003) define reform-based mathematics knowledge to involve, for instance, providing explanations, using multiple representations, recognizing connections between topics. Cooney and Wiegel define reform-based teaching as student-centred and a process-oriented approach. Traditional-based curriculum and pedagogy, on the other hand, is a content-centred curriculum and procedural-based pedagogy. Thompson (1992) together with other researchers blames the prevalence of traditional-based knowledge and approaches to mathematics on impoverished school mathematics experiences, which have left many teacher candidates with limited knowledge and poor conceptions of mathematics. Thus it is the role of mathematics teacher education to provide experiences of reform-based mathematics learning. Ponte and Chapman identify the need "to allow teachers to understand and reconstruct what they know with more depth and meaning" (p. 230).

2.1.2. ***Teacher attitudes, belief, comfort and confidence levels.***

Namukasa, Gadanidis and Cordy (2009) reviewed research on affect characteristics and how these influence learning and teaching. At many times the term beliefs is used to refer to an array of affect characteristics including beliefs, conceptions, attitudes, confidence, comfort levels, self-efficacy and emotions toward mathematics. Affect characteristics are complex systems. They are composed of many dimensions and subsystems. I focus on beliefs and comfort (or, anxiety) levels, specifically how they are formed, how they change, how they relate to reform-based learning. Studies such as Raymond (1997) report varying degrees of inconsistencies among a teacher's beliefs, between a teacher's professed beliefs and their observed beliefs-in-actions as well as between a teacher's professed beliefs and their classroom practices. Several explanations for inconsistencies among beliefs and beliefs-in-practice ranging from inconsistencies that arise from the nature of beliefs to those that arise from teacher education courses have been offered. Cooney and Wiegel (2003) observe that teachers need primarily held and more consistent beliefs about the advantages of reform-based learning. Defining of teacher knowledge characteristics needed for reform-based teaching as well as designing and implementing courses or workshops in which such knowledge is attained is very important; But also is measuring of these characteristics.

2.2. Testing Mathematics Teachers' knowledge and Beliefs.

Research instruments measuring affect of teachers towards mathematics are more widely reported in research than mathematics knowledge tests for teachers. The former are more prevalent in research studies whereas the later such as those in Hill and Ball (2008) and Kajander (2007) are prevalent in teacher evaluation and certification.

2.3. Mathematics for teaching and learning tasks.

The literature on the nature of mathematics learning tasks to be used in teacher education courses identifies several characteristics of mathematics tasks, some of which focus on pedagogical thinking and others on mathematical thinking. In my research I focus on tasks that engage teachers in doing and reflecting on reform-based mathematics. Since 2004-2005, I have designed, implemented and researched ways to get pre-service elementary teachers to engage in doing reform-based mathematics, specifically non-routine problem solving. I use the term non-routine tasks broadly to refer to tasks that have following characteristics: encourage participation by all learners, go beyond routine practice of procedures, enable individuals to gain insight into focal mathematics ideas, and are usable in schools. One such task is the Consecutive Terms task, adopted from Mason, Burton & Stacey (1982/1985). What numbers can be expressed as a string of consecutive addends? What patterns are noticeable? I focus on both teachers' pedagogical and mathematical thinking.

2.4. Learning and Teaching Mathematics Problems Solving.

Although problem solving as a learning approach has a long history in many countries (Schoenfeld, 2007), problem solving as a pedagogical practice (e.g., Crespo & Sinclair, 2008) is a more recent focus of research. Much problem solving research for improving pedagogical practices is still limited to research experiments and courses. Clarke, Goos and Morony (2007) assert that research is needed that connects problem-solving practices to problem solving lessons taught by teachers (e.g., Leikin & Levav-Waynberg, 2008). I designed, implemented, and researched a course on doing and reflecting on reform-based learning through mathematics problem solving.

3. Participants, Research Setting and Methods

The mathematics methods course was designed for elementary and middle-school teacher candidates. we offered it beginning in 2004 at a Canadian University, which offers a one-year long post graduate bachelor's degree in education. At present, in 2012, this course has four components: a) investigating a mathematical task in depth — non-routine problem solving, b) reflecting on the task to consider classroom implications — pedagogical considerations, c) articulating personal affective responses — reflecting on beliefs and affect, and d) writing a summative mathematics essay based on the three preceding dimensions in a, b and c—assessing of teacher learning. Through course interactions and course assignments we encourage teacher candidates to work in small groups whenever it is appropriate. We give each group math materials, activity sheets and online resources. In many sessions, solution strategies are shared in the whole group. In the last five minutes of each session, teachers complete a three-entry learned and felt journal where they describe what they learned and felt, a question they have and one point they would like to make. Six of the 18 days of the course are workshops focusing on each of the provincial curriculum strands, 6 focus on problem solving tasks, one on practicum debriefing and 5 on special topics including assessment and use of technology in mathematics. In this paper I focus on test and survey inquiry on pre-service teachers' mathematics knowledge and beliefs at the end of the course.

The methodology for the study is interpretive for the written textual data, and survey study for the test and questionnaire data. I take our survey to be descriptive (describes characteristics of teacher candidates) (Rosier, 1988). The mixed methods data analysis design adapted involves transformational and multi-level triangulation designs (Day, Sammons & Gu, 2008). I proceed beyond adding a quantitative component to an interpretive stance towards integration through transforming and qualitizing quantitative evidence gathered.

3.1. Adaptation of Mathematics Knowledge Test, Belief Questionnaire and Comfort Scales

I developed and piloted: a math knowledge test; a questionnaire on beliefs about mathematics teaching, its learning and teaching; and a scale on teacher's comfort levels at learning mathematics and at taking mathematics assessment. A majority items on these instruments were derived from existing instruments, several of which are psychometrically validated. The mathematics knowledge test items were adopted from grades 3, 6 and 9 provincial and international standardized tests. I classified questions on these tests into procedural knowledge (PK), conceptual knowledge (CK) and specialized pedagogical content knowledge (PCK). New questions were constructed from research for the PCK category. 13 selected response (SR) questions measured PK, 8 SR questions measured CK, and each of the 5 constructed responses (CR) measured CK, PK and PCK. Aspects of process skills (e.g., communication and representing) were considered to ensure a wider sampling of process standards. Three research assistants and one researcher scored the tests. Reaching inter-rator liability for PCK questions posed difficulty. SRs were scored on a 0-1 scale and CRs on a scale of 0 to 15. Total scores on SRs and CRs were then converted to a 0 to 5 scale. By using a scale of 1 to 5 we sought for comparisons among mathematics knowledge component scores and affect scores rated on a Likert scale of 1 to 5. Figure shows sample questions.

1. Ruth works as a translator. She charges her customers a fixed consulting fee of $20, plus 23¢ per word. Which expression shows Ruth's charges, in dollars, for translating a document with *n* words?

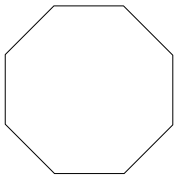
A $(20 + 0.23)n$

B $(20 – 0.23)n$

C $20n - 0.23$

D $20 + 0.23n$

2. How many lines of symmetry does a regular octagon (8-sided) polygon, as the one shown below, have?



Explain which shape has more lines of symmetry: A circle or an Octagon?

3. Please circle the response that best described their belief about the statement. SD = Strongly Disagree, D = Disagree, N = Neutral/No opinion, A = Agree, SA = Strongly Agree

What are your views about each of the statements below?

I. Mathematics learning is being able to get the right answers quickly.

SD (1) D (2) N (3) A (4) SA (5)

Figure 1 Sample Test and Beliefs Questions.

The Mathematics beliefs questionnaire and comfort scale were adopted from published research such as that on anxiety scales (Plake & Parker, 1982). The questionnaire consisted of three factors, each understood as a spectrum ranging from traditional based to reform-based beliefs: Factor 1, consisted of 10 questions focused on Beliefs about Mathematics, BAM. It, for instance, measured a spectrum of views ranging from platonic views of mathematics as an immutable subject to experiential views of mathematics as a human construction; Factor 2, consisted of 12 questions focused on Beliefs about Learning Mathematics, BLM, represented as a spectrum of learning mathematics as internalizing knowledge on one extreme to learning mathematics as constructing knowledge on the opposite side; Factor 3, 33 questions, focused on Beliefs about Teaching Mathematics, BTM. It measured a spectrum from teacher tells to teacher orchestrates. The scale consisted of two factors ranging from not comfortable at all (extreme anxiety) to very comfortable (no anxiety): Factor 4, 18 questions focused on Learning Mathematics Comfort-Anxiety levels, LMC-A, a spectrum from extreme anxiety to very comfortable with learning mathematics; and Factor 5, 8 questions focused on Mathematics

Scores / TCs	**BAM Factor 1**	**BLM Factor 2**	**BTM Factor 3**	**LMC-A Factor 4**	**MEC-A Factor 5**	**ORs Factor 6**	**CRs Factor 7**
TC 1	4/5	4.1/5	3.9/5	4.7/5	4.3/5	4.8/5	4.1/5
TC 2	3.8/5	4.7/5	4.2/5	4.8	3.3/5	4.8/5	3.1/5
TC 3	3.6/5	3.8/5	3.9/5	3.6/5	3.8/5	4.8/5	3/5
TC 4	4.3/5	4.4/5	4.2/5	4.2/5	2.8/5	4.6/5	2.7/5
TC 5	3.2/5	4.5/5	4.5/5	4.1/5	3.0/5	4.6/5	2.7/5
TC 6	3.8/5	4.3/5	3.9/5	4.3/5	3.6/5	4.0/5	3.9/5
Mean S	3.78	4.3	4.1	4.2833	3.4667	4.6	3.25
Variance	0.138	0.1	0.06	0.190	0.303	0.096	0.367
SD	0.3710	0.316	0.245	0.436	0.550	0.310	0.606

Table 2: *Summary Results on Knowledge test, Beliefs Questionnaire and Comfort Scale*

Evaluation Comfort-Anxiety levels, MEC-A, a spectrum of extreme evaluation anxiety to no evaluation anxiety. I selected to use an odd scale and utilize reverse and repeat coded items on the questionnaire for validating respondents. The psychometric properties of both the knowledge test and the affect questionnaire were improved upon by carrying out two smaller scale studies in 2007 and 2008 before two studies with over 150 teacher candidates in two subsequent years, 2009 and 2010. Construct validity was further improved by carefully selecting items that fit the constructs of teacher

characteristics defined in the literature. The results presented in this paper are from the smaller study with 17 grades 4 to 10 teacher candidates (4 male, 13 females) who volunteered to complete the test and the survey at the end 2008, and consented to have their reflection forms copied for research purposes.

4. Results and interpretation

Data from six teacher candidates (2 males and 4 females) who completed and retuned the instruments and passed the random guessing test is summarized in Table 1. Scores on the SR part of the knowledge test formed Factor 6, whereas the CR part formed Factor 7. The participants were coded Teacher Candidate, TC 1 to TC 6, according to their rank at the SRs part of the test.

4.1. Quantitative Analyses

I quantitatively analyzed scores on the 7 factors. I further carried out item analyses of the items in light of teacher candidates' scores, that is to say I qualitatively analyzed (qualitized) quantitative data. I also qualitatively analyzed participants' reflection forms in light of the quantitative results. To form hypotheses for a large study I carried out factor analyses and analyzed the data shapes on scatter plots for this small set of data.

4.1.1. Belief and values about mathematics, its learning, and teaching, Factors 1, 2, 3

As seen in Table 2, varied Teacher Candidates, TCs ranked highest on each of factors 1 to 3 respectively: TC 2 ranked highest on Factor 2 and highest on all factors 1-3 combined implying that he professed moderate to high reform-based beliefs about mathematics, its learning and teaching. Whereas TC 3 ranked lowest on factor 2 and 3 and lowest on all factors 1-3 combined, implying that she professed neutral to moderate beliefs about reform. All 6 TCs scored far above neutral on factors 1-3, implying that their beliefs about mathematics teaching, its learning and teaching at the end of the course were more on the reform-based side than the traditional based side. Mean scores on factors 2 and 3, beliefs about learning mathematics (BLM) and beliefs about teaching mathematics (BTM), were high (4.3 and 4.1 on Factors 1 and 2, respectively), much toward the reform side than mean scores on Factor 1, beliefs about mathematics, BAM (3.78). Scatter plots of BTM and BLM show similar shapes, implying that participants maintained their ranks within the group on these two factors. Factor 1, BAM shows the greatest variance of 0.13 whereas Factor 3, BTM registered the lowest variance of 0.06 on all 7 factors. On scatter plots for Factors 1 plotted against Factors 2 and factors 2 plotted against factors 3, TC 5 appeared as an outlier on would be strong correlations. In addition to greater variance on Factor 1, BAM, TC 3's responses on this and on the other two factors (and on factor 4) varied scoring 1, 2, 3, 4 or 5. A closer look at the questionnaire in relation to the results, the item analysis, revealed clusters of questions with consistent responses on Factor 1, including: 3 questions (out of 10) focusing more on the *value* of mathematics than on *what* mathematics and its content are defined as per se; 3 questions focusing more on what mathematics activity such as doing math involves, and on 4 questions on the nature of mathematics itself. TC 3's average scores on each of these subcategories varied considerably. Her scores were inconsistent on BAM but consistent on the three emergent sub categories of BAM. Her scores were much lower on the nature than on value of mathematics, for instance. This implied that TC 3 highly valued mathematics but his/her belief about mathematics were more on the traditional side.

4.1.2. Comfort-Anxiety levels at mathematics learning and its assessment, Factors 4 and 5

Overall, all TCs rated their comfort level with math learning and evaluation on the higher end of the scale (4.2, 3.5 mean scores respectively). All TCs with the exception of TC 3 registered a higher mean score on Factor 4, learning mathematics comfort levels, LMC-A. TCs 1 and 2 scored very high on Factors 4 and 5 implying that they perceive themselves to be very comfortable with learning math and at taking mathematics tests. TC 4 scored very low (2.8) on Factor 5 implying that she perceives her self to be less comfortable at taking math tests. TC 2 scored high on Factor 4, LMC-A but low on factor 5, MEC-A.

4.1.3. Mathematics procedural, conceptual, pedagogical content knowledge for teaching, Factors 6, 7

With mean scores of 4.6 and 3.3, participants scored high on selected response items (SRs), PK and CK combined (Factor 6) and moderately high on the constructed response items (CRs), PK, CK and PCK combined (Factor 7). An item analysis of the SRs revealed that teacher candidates frequently failed 8 specific questions. Four of these questions were CK questions, half of the CK questions on the test. CK questions which the participants frequently failed mostly involved numerical or geometric estimation skills or were visual-graphic questions asking for measurement or statistical inferences rather than computations. Further, a closer look at the CRs reveals that only two TCs, TC 1 and 6 scored as high on specialized PCK as they did on PK and CK components of both the SRs and CRs, the rest performed much lower on PCK.

On all factors 1 to 7, only four pairs (out of 21 possible pairs) appeared to have high correlation coefficients: Factor 3/Factor 6 = 0.974; Factor 2/Factor 4 = 0.942 correlation; Factor 1/Factor 5 = 0.916 correlation; and Factor 1/Factor 7 = 0.859 correlation. The graph of knowledge (factors 6 and 7 combined) overall has a close shape to that of comfort levels overall (factors 4 and 5 combined), implying that teacher candidates appeared to have maintained their ranks on the knowledge overall and comfort levels overall. For this group of participants the higher they scored on knowledge the more they professed being comfortable with mathematics.

5. Discussion and conclusion

Contrary to what is indicated in the literature (e.g., Thompson, 1992), our findings show that the participants, to a larger extent, professed high reform-based beliefs, in the following descending order: beliefs about learning mathematics, beliefs about teaching mathematics and beliefs about mathematics itself. The participants did not profess debilitating anxiety at learning mathematics. This finding is not surprising given that the data was collected from grades 4 to 10 (not, grade K to 4) teacher candidates at the end (not at the beginning) of a course on reform-based mathematics learning. Also the participants represent teacher candidates who voluntarily consented (not a random sample) and followed through to return completed test and survey instruments. The following findings are in line with the literature: In spite of the their professed high comfort, of their high achievement on procedural and content knowledge, and of their reform-based beliefs about learning and teaching mathematics, participants still scored low on pedagogical content knowledge and on mathematics evaluation comfort. In line with the literature on beliefs, our findings show inconsistencies among scores on beliefs: specifically, the mean score on beliefs about mathematics lying between neutral to moderate agreement whereas the mean scores on beliefs about learning and about teaching mathematics lying between moderate and high agreement with reform-based mathematics. The finding, which emerged from closely examining the instrument items and responses of participants with either outlier or widely spread responses, offers a novel explanation, of existence of sub categories such values of mathematics on a factor on beliefs about mathematics. This might account for inconsistencies among a participant's beliefs scores. This raises the need to further define the belief factors so as to design more precise instruments. For instruction, aggregated data on a group's areas of weaknesses and strengths on any of the factors could inform programs and instruction. The study generates hypothesis on correlations that could be further refined by analyzing qualitative data on the participants' reflection forms.

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