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ABSTRACT

The purpose of the study was to determine the effects of teacher beliefs measured by the Mathematics Beliefs Scales (E. Fennema, T. Carpenter, and M. Loef, 1990) on the problem-solving skills of their fourth and fifth grade students as measured in five areas of mathematics on the Junior Version of the Collis Romberg Mathematical Problem Solving Profiles (K. Collis and T. Romberg, 1992). Participants were 123 teachers from 18 public schools. Student participants were 76 students from classrooms of some of these teachers. The five areas included algebra, chance and data, measurement, number, and space. It was determined that when students were in classrooms of teachers who had constructivist beliefs their achievement in problem solving was higher than that of students of teachers with low constructivist beliefs. (Contains 3 tables and 36 references.) (Author/SLD)

Running head: DEFINING CONSTRUCTIVISM

Defining Constructivism: Its Influence on the Problem Solving Skills of Students

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Abstract

The purpose of the study was to determine the effects of teacher beliefs measured by the *Mathematics Beliefs Scales* (Fennema, Carpenter & Loaf, 1990) on the problem-solving skills of their 4^{th}- and 5^{th}-grade students as measured in five areas of mathematics on the *Junior Version of Collis Romberg Mathematical Problem Solving Profiles* (Collis & Romberg, 1992). The five areas included algebra, chance and data, measurement, number, and space. It was determined that when students were in classrooms of teachers who had constructivist beliefs their achievement in problem solving was higher than students of teachers with low-constructivist beliefs.

Introduction

"One's conception of what mathematics is affects one's conception of how it should be presented. One's manner of presenting it is an indication of what one believes to be the most essential in it...The issue, then, is not, what is the best way to teach? But, what is mathematics really all about?" (Hersh, 1986, p. 13)

Beliefs are the bedrock and cornerstone at the heart of our actions (Corey, 1935). These beliefs are the best indicators of the decisions individuals make throughout their lives (Dewey, 1933). Teacher beliefs are instrumental in defining teacher pedagogical and content tasks and for processing information relevant to those tasks (Nespor, 1987). Pajares (1992) proposed that beliefs are often initiated early in life and maintained in the face of strong contradictions. These entrenched beliefs serve as a filter through which teachers view the world and interpret information. All teachers possess beliefs about their profession, their students, how learning takes place, and the subject areas they teach.

Teacher attitudes and beliefs are the essential components in changing the ways of teaching mathematics in schools. The National Council of Teachers of Mathematics (NCTM) in *The Principals and Standards for School Mathematics* (2000) advocated the constructivist approach enabling students through mathematical tasks and activities to construct their own knowledge enthusiastically through investigation and discourse.

Constructivist teachers are educators whose beliefs and practices allow students to construct their own knowledge through active investigation and meaningful discourse (Vacc, 1995). Beliefs are essential influences on how and whether teachers acquire constructivist knowledge in the first place, and on how and whether teachers would be inclined to implement constructivism in the classroom (Nespor, 1987). When there is an agreement in the constructivist beliefs and practices of teachers, improved teaching should occur. This alignment is referred to as consonance between teacher objectives, plans, and practices. Conversely, when there is dissonance or a discrepancy in beliefs and practices, ineffective teaching results (Pokola, 1984; Thornton, 1985).

Teacher Beliefs

Long-lasting instructional changes only result from essential modifications in what teachers believe, know, and practice (Putnam, Wheaten, Pratt, & Remillard, 1992). The National Institute of Education (1975) in their document entitled, *Teaching as Clinical Information Processing* posited a close relationship between beliefs and practices stating "what teachers do is directed in no small measure by what they think" (p.1). Moreover, it is "necessary for any innovations in the context, practices and technology of teaching to be mediated through the minds and motives of teachers" (p. 1).

Teacher beliefs play a crucial role in developing students' mathematics power in problem solving. "Like a piece of music, the classroom discourse has themes that pull together to create a whole that has meaning. The teacher has a central role in orchestrating the oral and written discourse in ways that contribute to students' understanding of mathematics" (NCTM, 1991, p. 35). Teachers' beliefs and practices essentially mold classroom teaching, including discourse.

Substantial improvements occur in classroom achievement when teachers shift their beliefs along with their practices (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996; Putnam, Wheaten, Pratt, & Remillard, 1992). Studies have centered on teachers' beliefs concerning mathematics and mathematical pedagogy and learning. In general, these researchers have worked from the hypothesis that " to understand teaching from teachers' perspectives we have to understand the beliefs with which they define their work" (Nespor, 1987, p. 323).

Teachers who have attended inservice professional development and implemented reform-minded instruction influence the attitudes of their students. Through a study of students enrolled in classrooms implementing Cognitively Guided Instruction (CGI), Franke and Carey (1997) concluded that the students saw mathematics not just as moving numbers around on paper to get the answer, but as a variety of solutions that may be equally correct. Students participating in the study realized that they, together with the teacher, were responsible for their own learning.

In another aspect of the same study, some of the same researchers focused on the effect of professional development on teachers' beliefs. Through a series of inservices, spanning four years and using the CGI teacher-training program, Fennema, Carpenter, Franke, Levi, Jacobs, and Empson (1996) used children's thinking in mathematics instruction to show teachers how students thought about the problem-solving processes. The goal of the inservice program was to encourage reform-minded mathematics teachers to provide many opportunities for their students to solve many different types of problems and share their thought processes with other classmates. Ultimately these teachers used information from the inservice program to reform their curriculum. Classrooms became living laboratories where teachers could implement the strategies learned during the workshops. At the end of the four-year period, 18 of the 21 teachers had attained a reform-minded constructivist level and the students of these teachers showed greater improvements than the students in the non-reform teacher' classrooms in their mathematics application skills.

Additional studies revealed a definite relationship between teacher beliefs, actual classroom content, and how students learned in individual classrooms (Grant, Hiebert & Wearne, 1994). Clarke (1997) looked at how the beliefs held by teachers were reflected in the roles of the teachers – what the teachers did. The two teachers studied by the researcher were involved in a *Maths in Context* unit. The qualitative case-study approach yielded strong results for inservice providers. When there was dissonance between prior teachers' beliefs and what they had learned through their involvement in the unit, changes began to happen. When teachers witnessed positive results from student performance, change definitely took place. A strong plus was the availability of the researcher, inservice provider, and/or fellow colleague to serve as a "sounding board" for support.

Several researchers looked at the beliefs of preservice teachers. Emenaker (1995) reported that preservice teachers' mathematical beliefs changed after being enrolled in a course that focused on students learning mathematics through a problem-solving approach. These future teachers worked in a small group, problem-solving environment for a semester. These future teachers observed their classmates obtaining multiple solutions through different approaches. The results of the Likert scale indicated, with statistical significance, that their mathematical beliefs improved positively. This research emphasized the importance of quality instruction in mathematics methodology courses at the university level.

Vacc and Bright (1999) worked with preservice teachers with the CGI project. They found that although these preservice teachers' beliefs changed positively over two years, they did not fully implement the theories into practice during student teaching. The researchers attributed this to possible lack of support from the university observers and cooperating teachers.

Battista (1994) stated that teachers who are presently teaching mathematics learned from teachers who used traditional curriculum fostering beliefs dissonant from those proposed by the reform movement. The researcher depicted teachers as educators in a vicious cycle, teaching the same way that they were taught in school. These teachers held a view that was in direct contrast to the reform movement. "Teachers who see mathematics as following set procedures invented by others will have little experience making sense out of mathematics" (p. 467). Only universities can assume leadership in changing the way professors teach mathematics.

Problem Solving

Many teachers feel that mathematics is mainly computation and, therefore, postpone problem solving until students master their facts or pass all "timed tests". This narrow conception of mathematics deprives students of problem-solving experiences that can help them gain deeper mathematical understandings. Teachers should not look at problem solving as a topic to teach but a process that is an umbrella under which all other mathematical concepts and skills can be learned. The essential component steps of the problem – setting up, organizing, discourse, drawing a picture, connecting to the real world – do not need to be postponed until students can do twenty workbook pages of subtraction (NCTM, 2000).

Since 1980, the NCTM has promoted the need for teachers to incorporate problem solving as part of the total mathematics curriculum and not as a set of individual skills to be taught to students at the end of each chapter. In the *Agenda for Action*, the NCTM (1980) proposed that problem solving should be the focus of school mathematics in the 1980s (Kilpatrick, 1985). Problem solving, according to the update to the new *Principles and Standards for School Mathematics* (2000) published by the National Council of Teachers of Mathematics, means getting involved in a task for which there is no immediate answer. Problem solving needs to be an integral part of all mathematics learning and " not be an isolated part of the mathematics program" (NCTM, 2000, p.52)." When teachers maintain an environment in which the development of understanding is consistently monitored through reflection, students are more likely to learn to take responsibility for reflecting on their work and make the adjustments necessary when solving problems" (NCTM, 2000, p.55). These teachers must understand that in order for their students to improve their problem-solving skills, they must "systematically teach problem solving strategies... with varying complexities.... with different types of problems" (Kulm, 1984, p. 2). Problem solving in these classrooms will then become an important curriculum tool as well as a goal itself.

Schoenfeld (1992) indicated that students' problem-solving failures are many times attributed not to a lack of mathematical content knowledge but to the unproductive use of what they do know. He suggested giving students strategies such as searching for patterns, drawing diagrams, listing all possible answers, trying unique values or special cases, making up equivalent problems, and making an easier problem. If each teacher continued and modeled these processes from early elementary school to high school, students would develop a repertoire of strategies and thus be able to choose the appropriate strategy to match the problem-solving task at hand.

Goldin (1998) suggested that despite all the emphasis on promoting increased problem solving, classroom practices have been slow to change. Teachers continue to teach giving the most importance to computational skills and algorithms. The researcher concluded that even when teachers did present problem solving, the experiences were shallow and students followed algorithmic notations rather than true understandings. Recommendations included having students construct their own mathematical meanings.

The National Assessment of Educational Progress (NAEP) results indicated that less than 20% of fourth grade students were able to solve beginning word problems. Not surprisingly, these same students reported that most of their class time was spent listening and watching teachers solve problems rather than they themselves working problems in small groups (Dossey, Mullis, Lindquist, & Chambers, 1988; Reese, Jerry, & Ballator, 1997). These dissonant practices were in direct contrast to descriptors of the NCTM constructivist classroom where teachers placed students in problem solving situations and students worked on a daily basis solving problems in collaborative groups (Kersh & Masztal, 1998).

The focus of the present study was to investigate the effects of teachers' beliefs on the problem-solving skills of their students. More specifically the purpose was to investigate the differences in problem-solving skills in the five areas of algebra, chance and data, measurement, number, and space of 4th – and 5th–grade students when their teachers had constructivist beliefs compared to the problem-solving skills of students when their teachers had low constructivist beliefs.

Participants

The teacher sample for this study consisted of 123 4th- and 5th-grade teachers from 18 public schools in five school districts in a southern state. The demographic composition of the five districts surveyed ranged from a high of 89% to a low of 14% for the white population, from 83% to 10% for the black population, and 12% or less for populations categorized as other non-specified respondents which included Asian, Hispanics, and Native Americans. The student participants for this study included 76 fourth-and fifth-grade students enrolled in the classrooms of these teachers.

Methods

A Likert-type instrument entitled, *Mathematics Beliefs Scales* (Fennema, Carpenter, & Loef 1990) measured the mathematical beliefs of teachers. Teachers (n =123) were surveyed using this scale to determine those with high and low constructivist beliefs. The scale was either sent by mail or hand-delivered to 176 teachers, with 123 returned in person or by mail. Each of the responses to the 48 items of the *Mathematics Beliefs Scales* was entered in 48 separate columns. Numerical data were entered from 5 to 1 based on the Likert scale responses of A to E respectively. Negative statements were then recoded. An average scale score on the total scale was obtained and on this score teachers were divided into two categories. Teachers whose mean score was less than 2.5 were considered low constructivist in their beliefs and those whose mean score was greater than 3.5 were considered constructivist in their beliefs.

Seven teachers placed in the low constructivist belief category and 25 in the constructivist belief category. The coefficient-alpha reliability of the scores on the 48-item belief scale for the 123 teachers was .68. This reliability is marginally acceptable according to Shavelson (1988). Reliability was lower than the published reliability of .93 obtained by Fennema, Carpenter, and Loef (1990) using a sample of 39 teachers in a Mid-western state. This difference possibly suggests this researcher used a more homogeneous sample of teachers rather than those used by the previously mentioned researchers.

76 students from six of the teachers (three with constructivist beliefs and three with low constructivist beliefs) were then administered the *Collis-Romberg Mathematical Problem-Solving Profiles* (Collis & Romberg, 1992). Only those students who had been with the same teachers since the start of the school year and returned permission slips were tested. The profiles of the students were scored and analyzed comparing students in the three teacher groups in each of the five subtests: algebra, chance, measurement, number, and space. Each of the subtests contained three parts (a, b, and c). The coefficient-alpha reliability of scores is illustrated in Table 1.

INSERT TABLE 1 ABOUT HERE

"Items" on the table refer to the first letter of the subtest and the question part. For example, the three items on the algebra subtest are referred to as a1, a2, and a3. The total test score alpha reliability was .72 on 13 items, not 15 (total test) since two of the items had zero variance and were dropped. Reliability for each of the subtests was found lower than the total test: chance (.40), measurement (.49), number (.22), and space (.56). "Since reliability is a function of test length, the reliability of a given subtest is typically lower than the total test reliability" (Gay, 1992, p.169). Two of the test items, a2 and a3 had zero variance, therefore, a reliability on the scores for the algebra subtest could not be obtained. No students got either a2 or a3 of the algebra subtest correct. This suggests that those specific questions need to be rewritten to measure more accurately the algebra skills of 4^{th}- and 5^{th}-graders. A score was also obtained on each of the five subtests and on three learning outcome levels (unistructural, multistructural, and relational) for each student. Scores on the outcomes ranged from unistructual to relational. A total summary score was calculated for all students ($\underline{N}$=76).. Scores on the overall test ranged from students with a low of 1 to a high of 10.

Test of Hypotheses

H_{1-6} There is a difference between the algebra (H_1), chance (H_2), measurement (H_3), number (H_4), space (H_5), and total test (H_6) problem- solving skills of upper elementary students whose teachers are constructivist in their beliefs as compared to those whose teachers have low constructivist beliefs.

The results indicated that hypotheses H_1 – H_6 were partially supported. The Wilk's Lambda of .692 associated with the multivariate test was statistically significant ($\underline{p}$< .001). The effect size (1- Lambda) (Huberty, 2000, p.194) of .31 indicates a medium to large effect size (Buchner, Faul, & Erdfelder, 1997; Hair, Anderson, Tathem, & Black, 1998, p.353). The discriminant function and the structure coefficients are presented in Table 2.

INSERT TABLE 2 ABOUT HERE

Based on examination of the structure coefficients, the variables of chance, measurement, and space were found to be the major contributors to group differentiation. Students whose teachers had constructivist beliefs had higher mean scores on all of the subtests than students whose teachers had low constructivist beliefs as shown in Table 2. A t-test on the total test scores (t (74) = 4.56, $p < .001$) showed that the students whose teachers who had high constructivist beliefs had higher mean scores than students whose teachers had low constructivist beliefs as shown in Table 3.

INSERT TABLE 3 ABOUT HERE

Summary of Major Findings

Through a discriminant analysis (H_1-H_5) and ANOVA (H_6) it was found that students who were in classrooms with teachers who had constructivist beliefs scored higher in the five subtests and on the total test of problem solving than those who were in classrooms of teachers who had low constructivist beliefs. This study showed that when teachers (n = 3) had high constructivist beliefs their students scored higher in problem solving than when teachers (n = 3) had low constructivist beliefs. The mean scores of those students whose teachers were constructivist in their beliefs were higher when compared to those students whose teachers have low constructivist beliefs. On every subtest, students (n= 35) whose teachers had high constructivist beliefs had a higher mean score than those students (n= 41) whose teachers had low constructivist beliefs. Mean scores on the subtests ranged from 0 to 3. The lowest mean score was .6286 for algebra and the highest mean score was 1.8286 for space. The largest range was between students whose teachers had high constructivist and low constructivist beliefs was on the space subtest (.7554).

Discussion

Teacher attitudes and beliefs are the essential components in changing the ways of teaching mathematics in schools. The National Council of Teachers of Mathematics (NCTM) in *The Principles and Standards for School Mathematics* (2000) advocated the constructivist approach enabling students through mathematics tasks and activities to construct their own knowledge enthusiastically through investigation.

Teacher beliefs play a crucial role in developing students' mathematical power in problem solving. Studies have centered on teachers' beliefs concerning mathematics and mathematical pedagogy and learning. In general, these researchers have worked from the hypothesis that " to understand teaching from the teacher's perspective we (researchers) have to understand the beliefs with which they define their work" (Nespor, 1987, p. 323).

This study supports these findings, when students whose teachers had constructivist beliefs as determined by the survey, took the problem solving test they scored higher on each of the five subtests and the total test than those students whose teachers had low beliefs as determined by the survey. The *Mathematical Beliefs Scales* (Fennema, et.al, 1990) which was employed by this researcher was used to partition teachers into the two categories of high-constructivist beliefs and low-constructivist beliefs. Constructivist teachers are educators whose beliefs and practices allow students to develop (construct) their own knowledge through active investigation and meaningful discourse (Brooks & Brooks, 1993; Vacc, 1995). This survey, although developed before educators popularized the term constructivist, contained statements, which in the opinion of this researcher measured constructivism. Originally when used by Fennema (1990), its purpose was to answer four research questions dealing with pedagogical beliefs about curriculum and instruction, approaches to teaching, relationships between pedagogical beliefs and students' achievement, and relationships between beliefs and content knowledge. Although this researcher felt that many of the statements lent themselves to measuring constructivist to low constructivist beliefs, over 70% of the teachers were not classified and remained uncategorized as either high constructivist or low constructivist in their beliefs. This teacher group (70%) remained "in the middle" since they placed between a 2.5 and 3.5. This researcher felt that there needed to be at least a one-point difference been high and low beliefs in order to discriminate adequately. Perhaps on a six-point Likert scale, these same teachers would have been forced not to "ride the fence." Further research in the area of factor analysis is needed to distinguish items on the *Mathematics Beliefs Scales*.

Conclusions

From the study, the following conclusions can be made:

1. Constructivist beliefs held by teachers have a major influence on whether their students scored higher on problem-solving tests than students whose teachers had low-constructivist beliefs.
2. Educators must take the responsibility for changing their own beliefs to align their beliefs with the *NCTM Principles and Standards* (2000).
3. Preservice providers need to spend more time in assisting preservice teachers in developing and supporting their constructivist beliefs.
4. Math methods professors need to model constructivist lessons that demonstrate for preservice teachers the benefits for students when they are allowed to construct their own knowledge through problem-solving activities.
5. Inservice providers need to assist classroom teachers in understanding how their beliefs influence student achievement. Inservice providers need to take the time to understand the prior knowledge of teachers and determine their beliefs before presenting workshops in areas where teachers have no intention of changing their practices in the classroom because of firm-held beliefs in areas that are in opposition to the direction of the workshop presenter. In addition, Sparks (1999) found that purposeful teacher inservice could change classroom practices and improve student learning.

Mathematical methods instruction for preservice teachers should focus on constructivist activities. Preservice teachers need to be actively involved to discover the meaning of mathematics through using a problem-solving approach. Rather than being taught about the *NCTM Principles and Standards,* these preservice teachers should be provided models of how to implement these problem-solving constructivist activities on a daily basis in their methods courses. Some of these students enter math methods classes with trepidation. This modeling of activities might make them feel more comfortable and assist in changing beliefs. When these preservice teachers feel more comfortable in the safe environment of their university classrooms where the students are active learners, they will be better prepared to provide a constructivist environment rather than a transmission approach when they actually get involved in their field-based practicum and assigned classrooms.

Educators must take the primary responsibility for changing their own beliefs. Sparks (1999) found that improvement in student achievement can be 50% attributed to changes in teacher behavior and practices. Most teachers, according to Pokala (1984), want their students to achieve. According to this study, higher student achievement in problem solving is associated with teachers who posses high constructivist beliefs. Although the *NCTM Principles and Standards* (2000) does not identify itself with the label "constructivist", many of it's recommendations and suggestions encourage teachers to provide varied experiences for students whereby they form their own solutions and strategies.

In summary, teachers must align their constructivist beliefs and teach mathematics through a problem-solving approach if their goal is students who can problem solve. If this really took place the next National Assessment of Educational Progress (NAEP) evaluation would hopefully report that 50% or more of fourth-grade and above students would be able to solve beginning word problems rather than the 20% who now can do this.

Further research in the form of directed action-research should be conducted to substantiate this study. This classroom-based research will continually perpetuate the benefits of constructivist beliefs in the area of problem solving. At the grassroots level, it will allow teachers to see more readily the rewards of their efforts in the higher problem-solving skills of their students.

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Table 1

Reliability of Test Scores

Tests	Items	Alpha
Algebra	a1, a2, a3	Unobtainable
Chance	c1,c2,c3	.40
Measurement	m1,m2,m3	.49
Number	n1,n2,n3	.22
Space	s1, s2, s3	.56
Total	All except a2 and a3	.72

Table 2

Standardized Discriminant Function Coefficients and Structure Coefficients on Beliefs for Function 1

Variable	Discriminant Coefficients	Structure Coefficients
Algebra	-.337	.140
Chance	.678	.749
Measurement	.351	.490
Number	.049	.282
Space	.487	.727

Table 3

Results of Means and Standard Deviations of Students Whose Teachers Had High Constructivist Beliefs and Those Students Whose Teachers Had Low Constructivist Beliefs on the Five Subtests and the Total Test

Beliefs	Variable	Mean	SD
High Constructivist	Algebra	.63	.49
Low Constructivist		.54	.50
High Constructivist	Chance	.89	.83
Low Constructivist		.24	.43
High Constructivist	Measure	1.51	.78
Low Constructivist		1.00	.81
High Constructivist	Number	1.49	.66
Low Constructivist		1.22	.76
High Constructivist	Space	1.83	.75
Low Constructivist		1.07	.82
High Constructivist	Total Test	6.34	1.92
Low Constructivist		4.07	2.35

Note: a) mean on the subtests ranged from 0 to 3

b) mean on the total test ranged from 0 to 15

c) n = 35: Constructivist Beliefs

d) n = 41: Low Constructivist Beliefs

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