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ABSTRACT

This study describes the ongoing use of a valid and reliable instrument to measure longitudinally teacher candidates' attitudes and beliefs. The instrument, "Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science," was developed for the Maryland Collaborative for Teacher Preparation (MCTP). The MCTP is a National Science Foundation-funded undergraduate teacher preparation program for science and mathematics elementary/middle level teachers. Data were collected from 1995 to Fall 1997. During the Fall 1995 and Spring 1996 semesters the instrument was administered in MCTP classes twice each semester to the study participants (N=104; 100% response). During the Fall 1996 and Spring 1997 semesters the instrument was mailed to the study participants at the end of each semester (N=96; 46% Fall response; 75% Spring response). Since individual responses to the questionnaire were not independent, the unit-of analysis responses from five institutions participating in the program were used. Survey responses within each institution were aggregated and changes analyzed (repeated-measures t-test design). It was determined that the MCTP appears to be affecting participating teacher candidates' attitudes towards and beliefs about mathematics and science in the direction intended. In particular, the MCTP teacher candidates' attitudes and beliefs moved in the desired direction on all five subscales of the instrument. Moreover, the magnitude of change was statistically significant at the .01 level for the subscale measuring "Beliefs about the Nature of Mathematics and Science" and for the subscale measuring "Beliefs about Teaching Mathematics and Science". In addition, the magnitude of change for the subscale measuring "Attitudes towards Mathematics and Science" approached statistical significance. It is believed that these findings make a highly significant contribution to the science and mathematics education research communities interested in documenting the attitudinal and belief journeys of teacher candidates participating in reform-based teacher preparation programs. (Contains 4 tables, 5 figures, and 29 references. (Author/NB)

A Longitudinal Assessment of Teacher Candidates' Attitudes and Beliefs in a Reform-Based Mathematics and Science Teacher Preparation Program

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Abstract

This study describes the ongoing use of a valid and reliable instrument to measure longitudinally teacher candidates' attitudes and beliefs. The instrument, *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science*, was developed for the Maryland Collaborative for Teacher Preparation (MCTP). The MCTP is a National Science Foundation funded undergraduate teacher preparation program for science and mathematics elementary/middle level teachers. Data were collected from 1995 to Fall 1997. During the Fall 1995 and Spring 1996 semesters the instrument was administered in MCTP classes twice each semester to the study participants (N=104; 100% response). During the Fall 1996 and Spring 1997 semesters the instrument was mailed to the study participants at the end of each semester (N=96; 46% Fall response; 75% Spring response). Since individual responses to the questionnaire were not independent, we used as the unit-of-analysis responses from five institutions participating in the program. We aggregated survey responses within each institution, and analyzed changes (repeated-measures t-test design). We determined that the MCTP appears to be affecting participating teacher candidates' attitudes towards and beliefs about mathematics and science in the direction intended. In particular, the MCTP teacher candidates' attitudes and beliefs moved in the desired direction on all five subscales of the instrument. Moreover, the magnitude of change was statistically significant at the .01 level for the subscale measuring "Beliefs about the Nature of Mathematics and Science" and for the subscale measuring "Beliefs about Teaching Mathematics and Science". In addition, the magnitude of change for the subscale measuring "Attitudes towards Mathematics and Science" approached statistical significance. We believe these findings make a highly significant contribution to the science and mathematics education research communities interested in documenting the attitudinal and belief journeys of teacher candidates participating in reform-based teacher preparation programs.

A Longitudinal Assessment of Teacher Candidates' Attitudes and Beliefs in a Reform-Based Mathematics and Science Teacher Preparation Program

This study describes the use longitudinally of a valid and reliable instrument to measure teacher candidates' attitudes and beliefs about the nature of and the teaching of mathematics and science. The instrument, *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science*, was developed for the Maryland Collaborative for Teacher Preparation (MCTP), a National Science Foundation (NSF) funded undergraduate teacher preparation program for specialist mathematics and science elementary/middle level teachers. Sections of the instrument that were verified by factor analysis dealt with beliefs about mathematics and science (a=.76); attitudes toward mathematics and science (a=.81); beliefs about teaching mathematics and science (a=.69); attitudes toward learning to teach mathematics and science (a=.80); and attitudes toward teaching mathematics and science (a=.60). See Table 1 for a listing of all items on the instrument.

Context Of The Study

The MCTP is a NSF funded statewide undergraduate program for students who plan to become specialist mathematics and science upper elementary or middle level teachers. While teacher candidates selected to participate in the MCTP program in many ways are representative of typical teacher candidates in elementary teacher preparation programs, they are distinctive by expressing an interest in teaching mathematics and/or science by making connections between the two disciplines.

Nine higher education institutions responsible for teacher preparation within the University System of Maryland, including community colleges, participate in the MCTP. In addition, several large public school districts are active partners. The goal of the MCTP is to promote the development of professional teachers who are confident teaching mathematics and science using technology, who can make connections between and among the disciplines, and who can provide an exciting and challenging learning environment for students of diverse backgrounds (University of Maryland System, 1993). This goal is in accord with the educational practice reforms advocated by the major professional mathematics and science education communities (National Council of Teachers of Mathematics [NCTM], 1989, 1991; American Association for the Advancement of Science [AAAS] 1989, 1993; National Research Council [NRC] of the National Academy of Sciences, 1996).

In practice, the MCTP undergraduate classes are taught by faculty in mathematics, science, and education who make efforts to focus on "developing understanding of a few central concepts and to make connections between the sciences and between mathematics and science" (MCTP, 1996, p. 2). Faculty also strive to infuse technology into their teaching practices, and to employ instructional and assessment strategies recommended by the literature to be compatible with the constructivist perspective (i.e., address conceptual change, promote reflection on changes in thinking, and stress logic and fundamental principles as opposed to memorization of unrelated facts) (Cobb, 1988; Driver, 1989; Tobin, Tippins, & Gallard, 1994; von Glasersfeld, 1987, 1989). Faculty lecture is diminished and student-based problem-solving is emphasized in cross-disciplinary mathematical and scientific applications.

Theoretical Assumption And Research Question

A fundamental assumption of the MCTP is that changes in pre-secondary level mathematics and science educational practices require reform within the undergraduate mathematics and science subject matter and education classes teacher candidates take throughout their teacher preparation programs (NSF, 1993). One of the ways reformed undergraduate classes can change teaching practices is by changing the attitudes and beliefs of teacher candidates. The MCTP Research Group is investigating whether enrollment in MCTP classes encourage teacher candidates to adopt more positive attitudes towards mathematics and science, and towards the teaching of these subjects. We also want to determine whether the MCTP fosters beliefs about the nature of mathematics and science, and about the best ways to teach mathematics and science, that are compatible with the program's goals: use of constructivist instructional strategies, emphasis on connections between mathematics and science, appropriate use of technology when teaching mathematics and science, and encouragement of students from diverse backgrounds to participate in challenging and meaningful learning.

Specifically, the research question investigated in this study is:

> Do MCTP teacher candidates' attitudes toward and beliefs about mathematics and science change over time as they participate in the MCTP?

We have designed a documentation system to address this and other research questions. The documentation system includes a regularly administered reliable and valid attitudes and beliefs survey (see, e.g., McGinnis, Kramer, Roth-McDuffie, & Watanabe, 1998; McGinnis, Kramer, Shama, Watanabe, & Graeber, 1997; McGinnis, Watanabe, Shama, Graeber, 1997). In this study, we describe 1995/1996 and Fall 1997 data available from the attitudes and beliefs survey.

Findings

Only responses from MCTP students at the five institutions which participated in all six surveys are used in this analysis. In the December, 1996 mail-in survey, 104 of the MCTP students who were sent questionnaires attended one of the five universities analyzed in this study. Of those surveyed, 48 returned a completed questionnaire, yielding a 46% response rate. In the May, 1997 mail-in survey, 96 of the MCTP students who remained in the program were sent questionnaires attended one of the five universities analyzed in this study. Of the 96 teacher candidates surveyed, 72 returned a completed questionnaire, yielding a 75% response rate. We attribute the higher response rate in the May administration of our questionnaire to our extensive efforts at that time to ensure surveys were returned, following recommendations made by Dillman (1978).

MCTP teacher candidates generally take at least one MCTP course each semester. Therefore, the data from each of the in-class surveys conducted during the 1995-96 academic year generally reflect the attitudes and beliefs of the majority of teacher candidates enrolled in the MCTP program at that time.

The teacher candidates responding to the two mail-in surveys during the 1996-97 school year were generally from the same group who had completed surveys in-class during the 1995-96 school year. This is because MCTP courses and recruitment during 1995-96 were geared to first-year and second-year undergraduate teacher candidates. (The MCTP planned to develop upper-level courses during the subsequent two years.) Therefore, few MCTP teacher candidates graduated at the end of the 1995-96 school year. Most remained and became part of the cohort whom we began surveying by mail in December, 1996.

In summary, although a few of the MCTP teacher candidates who attended MCTP classes in 1995-96 were not part of the cohort surveyed by mail, and although some of the teacher candidates in the cohort surveyed by mail were new to the program in 1996-97, the majority of those surveyed were in the program throughout the two years investigated by this study. For this reason, our decision to use survey responses to draw conclusions about how MCTP teacher candidates' attitudes and beliefs evolved as they remained in the program over a 2-year period is legitimate statistically.

Table 2 presents an itemized description of the number of students participating in each survey administration. Table 3 shows the results of a statistical analysis (repeated-measures t-test using 5 institutions of higher learning as unit-of-analysis) of the change in the MCTP students' attitudes and beliefs over 2 years. Table 4 demonstrates that the changes in MCTP teacher candidates' attitudes and beliefs have substantive significance. For each subscale, we computed the effect size of the change between the fall of 1995 and May, 1997 in student attitudes or beliefs. "Effect size" is defined as the number of standard deviations the score has changed. In computing effect size, we used the student-level standard deviation among MCTP teacher candidates who took the fall, 1995 pretest survey at the five institutions of

Figures 1 through 5 display graphically the mean attitude and beliefs scores for MCTP teacher candidates at each of the six administrations of the survey analyzed in this report. The figures were prepared using data aggregated to the institution/college level. Each score is the mean of the college means.

In preparing Figures 1 through 5, we marked the vertical scale for each variable in units of approximately one-fourth of a standard deviation. (For this purpose, we used student-level standard deviations. In normally distributed data, a movement of .25 standard deviations is enough to move a student's score from the 50th percentile up or down by 10%. Computing standard deviations on data aggregated to the institution level would have produced an artificially shrunken number, exaggerating the apparent importance of changes in the mean.)

As is apparent in Figures 1 through 5, over the 2 year period during which we administered the survey, MCTP teacher candidates' attitudes and beliefs moved in the desired direction on all five subscales. Moreover, the magnitude of change was statistically significant at the .01 level for the subscale measuring "Beliefs about the Nature of Mathematics and Science" (X_1), and for the subscale measuring "Beliefs about Teaching Mathematics and Science" (X_3). In addition, the magnitude of change for the subscale measuring "Attitudes towards Mathematics and Science" (X_2) approached statistical significance.

Conclusion

Many researchers have suggested that a teacher's attitudes towards and beliefs about mathematics and science are key influences on how they teach those subjects. (See, Ball, 1990a, 1990b; Brickhouse, 1989, 1990; Lederman, 1992; Moreiri, 1991; Peterson, Fennema, Carpenter, & Loef, 1989; Schoenfeld, 1985,1989; Silver, 1985; Thompson, 1992). The MCTP appears to be having a positive affect on the attitudes and beliefs of prospective mathematics and science teachers participating in the program. A complementary study that examines the perspectives of MCTP teacher candidates via extensive analysis of semi-structured interviews (Watanabe, McGinnis, & Roth-McDuffie, 1997) supports this assertion along with documenting how the MCTP teacher candidates come to see the possibility of different ways of teaching mathematics and science. It is hoped that these attitudes, beliefs, and new perspectives of teaching and learning mathematics and science will be maintained and strengthened as the MCTP teacher candidates complete their teacher preparation program. Moreover, one new component of the MCTP program is to assist graduates as they move into actual teaching positions. The emerging literature on the induction of new teachers (see, Huling-Austin,1990) suggests that ongoing support during the first few years of teaching practice will help the MCTP teachers maintain their positive attitudes and beliefs. The hope is that, as suggested by the literature, the MCTP's graduates' attitudes and beliefs will positively affect their teaching and their learning. At the point the MCTP teachers' students benefit from their teachers' participation in the MCTP, the project will have achieved its primary goal.

Educational Significance Of The Study

There are a dearth of reported longitudinal studies which strive to document longitudinally the struggles teacher candidates and others confront when participating in reform-based, constructivist-informed instruction that attempts to make connections between science and mathematics. The findings from this phase of our study investigating the impact of reform-based undergraduate classes and other professionally enhancing experiences (such as summer internships in science and mathematics rich environments) in science, mathematics, and methods classes directly contributes to this targeted knowledge base. Our instrument, *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science*, is proving to be useful in providing a "longitudinal topography" of the attitudes and beliefs of MCTP teacher candidates. We believe that we are documenting the attitudinal and belief journeys of an identifiable group of mathematics and science teacher candidates throughout their teacher preparation program. The findings from this type of study is a significant contribution to the science and mathematics education research communities interested in understanding all aspects of the impact of implementing reform-based practices in teacher preparation.

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Table 1

The Five Subscales

Description	Cronbach's a
X1. Beliefs about the nature of mathematics and science	**a=.76**

In grades K-9, truly understanding mathematics requires special abilities that only some people possess.[1]
In grades K-9, truly understanding science requires special abilities that only some people possess.
The use of technologies in mathematics is an aid primarily for slow learners.
The use of technologies in science is an aid primarily for slow learners.
Getting the correct answer to a problem in the mathematics classroom is more important than investigating the problem in a mathematical manner.
Getting the correct answer to a problem in the science classroom is more important than investigating the problem in a scientific manner.
The primary reason for learning mathematics is to learn skills for doing science.
The primary reason for learning science is to provide real life examples for learning mathematics.
Mathematics consists of unrelated topics (e.g., algebra, arithmetic, calculus and geometry).
Science consists of unrelated topics like biology, chemistry, geology, and physics.
To understand mathematics, students must solve many problems following example provided.
To understand science, students must solve many problems following example provided.
Theories in science are rarely replaced by other theories.
Science is a constantly expanding field.

X2. Attitudes towards mathematics and science — **a=.81**

I am looking forward to taking more mathematics courses.
I am looking forward to taking more science courses.
I like mathematics.
I like science.
I enjoy learning how to use technologies in mathematics classrooms.
I enjoy learning how to use technologies in science classrooms.

X3. Beliefs about the teaching of mathematics and science — **a=.69**

Using technologies in mathematics lessons will improve students' understanding of mathematics.
Using technologies in science lessons will improve students' understanding of science.Calculators should always be available for students in science classes.
Students should be given regular opportunities to think about what they have learned in the mathematics classroom.
Students should be given regular opportunities to think about what they have learned in the science classroom.
Students should have opportunities to experience manipulating materials in the mathematics classroom before teachers introduce mathematics vocabulary.
Students should have opportunities to experience manipulating materials in the science classroom before teachers introduce science vocabulary.
Small group activity should be a regular part of the mathematics classroom.
Small group activity should be a regular part of the science classroom.

X4. Attitudes towards using technology to teach mathematics and science — **a=.80**

I want to learn how to use technologies to teach mathematics.
I want to learn how to use technologies to teach science.

X5. Attitudes towards teaching mathematics and science **a=.60**

The idea of teaching mathematics scares me.
The idea of teaching science scares me.
I prefer to teach mathematics and science emphasizing connections between the two disciplines.
I feel prepared to teach mathematics and science emphasizing connections between the two disciplines.

1. Note: items in italics have been reversed, so that a response of "strongly agree" is scored as a "1" and a response of "strongly agree" is scored as a "5".

Table 2

Number of Students Participating in Each Survey Administration

Institution	Pretest Fall '95	Post test Fall '95	Pretest Spring '96	Post test Spring '96	Dec '96 Survey	May '97 Survey
A	9	8	3	3	8	15
B	23	13	22	26	5	11
C	10	10	8	10	9	12
D	34	22	18	20	11	18
E	20	8	6	5	15	16
Total	96	61	57	64	48	72

Table 3

Change in MCTP Students' Attitudes and Beliefs over 2 Years: Significance Tests

(Repeated-measures t-test using 5 institutions of higher learning as unit-of-analysis.)

variable	Fall '95 Pretest mean	May '97 Survey mean	SE of mean	t-value	df	95% CI of difference	2-tail significance
X1	3.96	4.31	.072	4.83	4	(.149, .551)	.008**
X2	3.81	4.31	.172	2.94	4	(.028, .985)	.042*
X3	4.11	4.41	.044	6.96	4	(.184, .427)	.002**
X4	4.66	4.83	.099	1.73	4	(-.103, .444)	.159
X5	3.51	3.90	.254	1.57	4	(-.305,1.104)	.191

* significant at the .05 level

** significant at the .01 level

Table 4

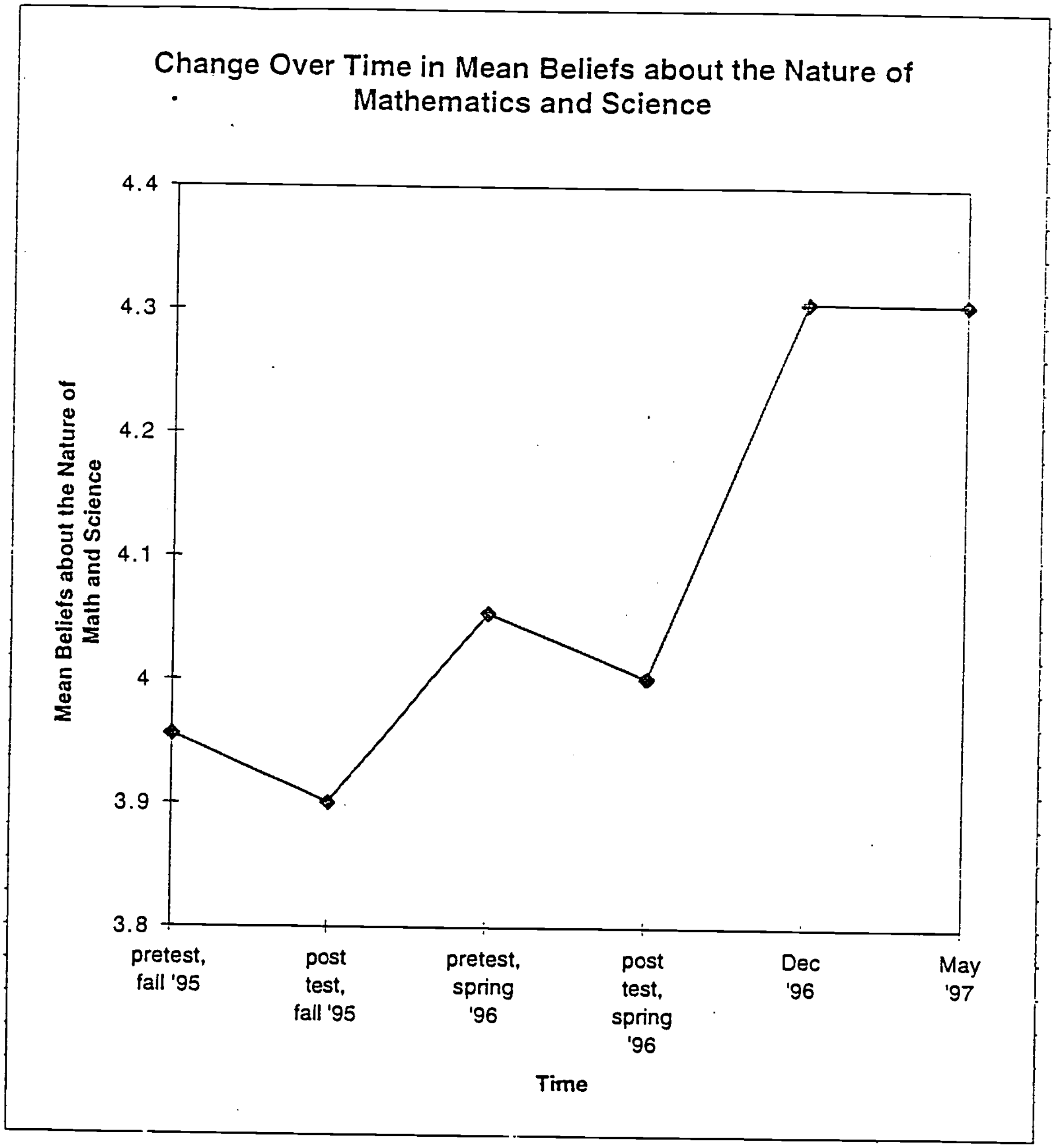
Change in MCTP Students' Attitudes and Beliefs over 2 Years: Effect Sizes

(Effect sizes based on student-level standard deviation on Fall, 1995 pretest.)

variable	Fall '95 Pretest mean	May '97 Survey mean	Change	student level sd. dev.	effect size	Student at 50th percentile would move to
X1	3.96	4.31	.35	.50	.70 std. dev.	76th percentile
X2	3.81	4.31	.51	.75	.68 std. dev.	75th percentile
X3	4.11	4.41	.31	.49	.63 std. dev.	74th percentile
X4	4.66	4.83	.17	.62	.27 std. dev.	61st percentile
X5	3.51	3.90	.40	.79	.51 std. dev.	70th percentile

Figure Caption

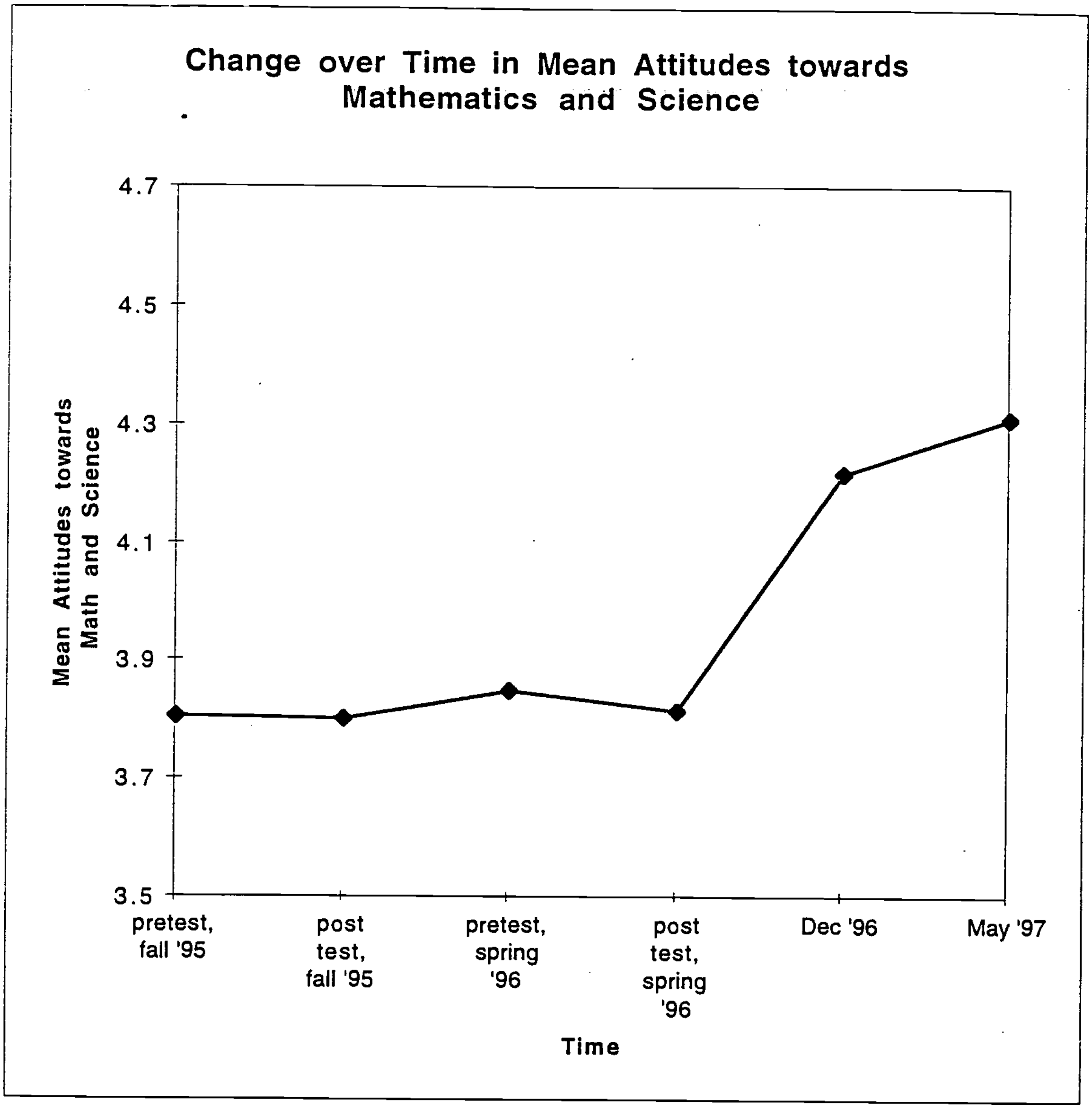
Figure 1. Change over time in mean beliefs about the nature of mathematics and science.



Change Over Time in Mean Beliefs about the Nature of Mathematics and Science
Mean Beliefs about the Nature of Math and Science
4.4
4.3
4.2
4.1
4
3.9
3.8
pretest, fall '95
post test, fall '95
pretest, spring '96
post test, spring '96
Dec '96
May '97
Time

Figure Caption

Figure 2. Change over time in mean attitudes towards mathematics and science.



Change over Time in Mean Attitudes towards Mathematics and Science
4.7
4.5
4.3
4.1
3.9
3.7
3.5
Mean Attitudes towards Math and Science
pretest, fall '95
post test, fall '95
pretest, spring '96
post test, spring '96
Dec '96
May '97
Time

Figure Caption

Figure 3. Change over time in mean beliefs about the teaching mathematics and science.

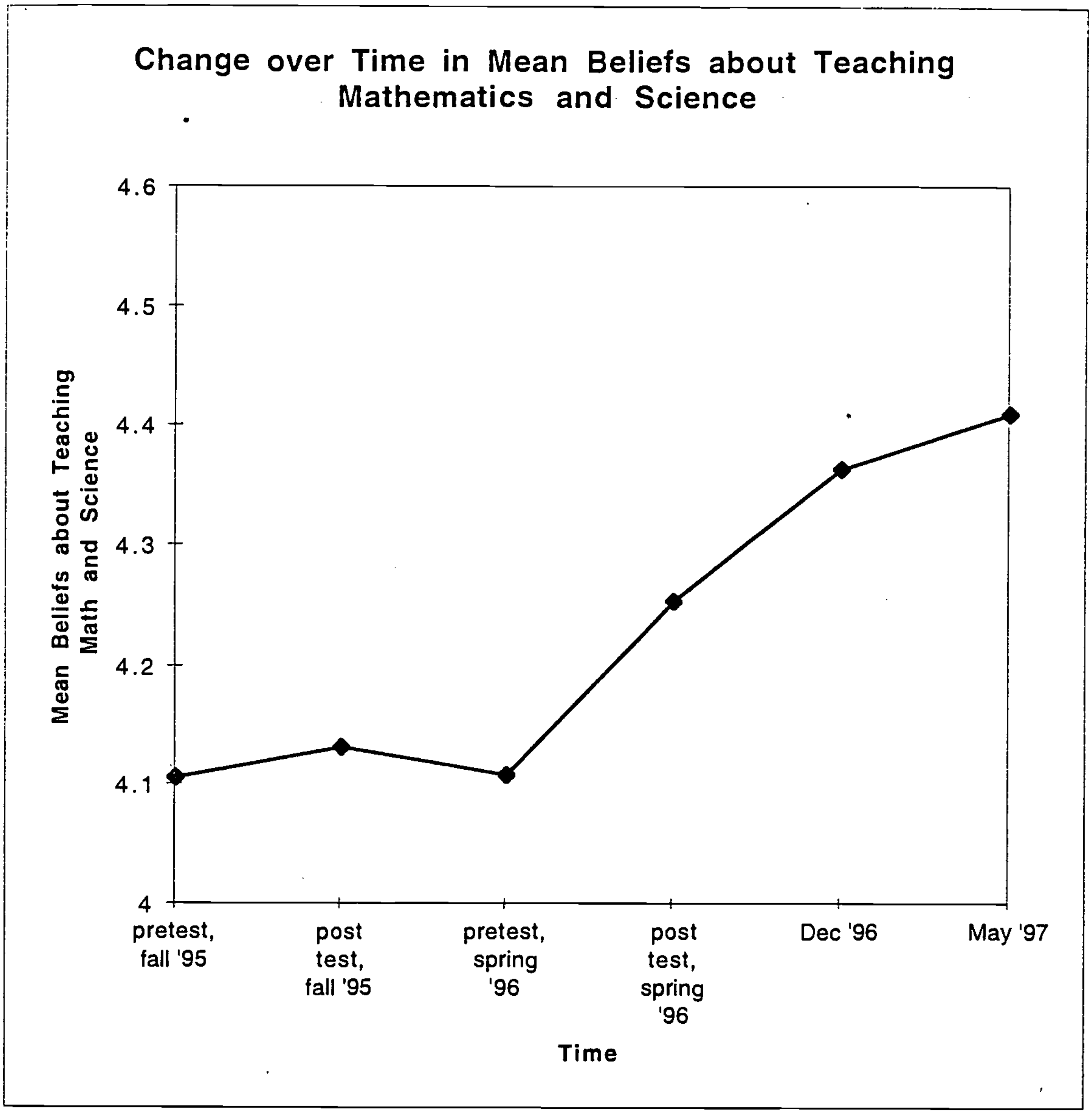
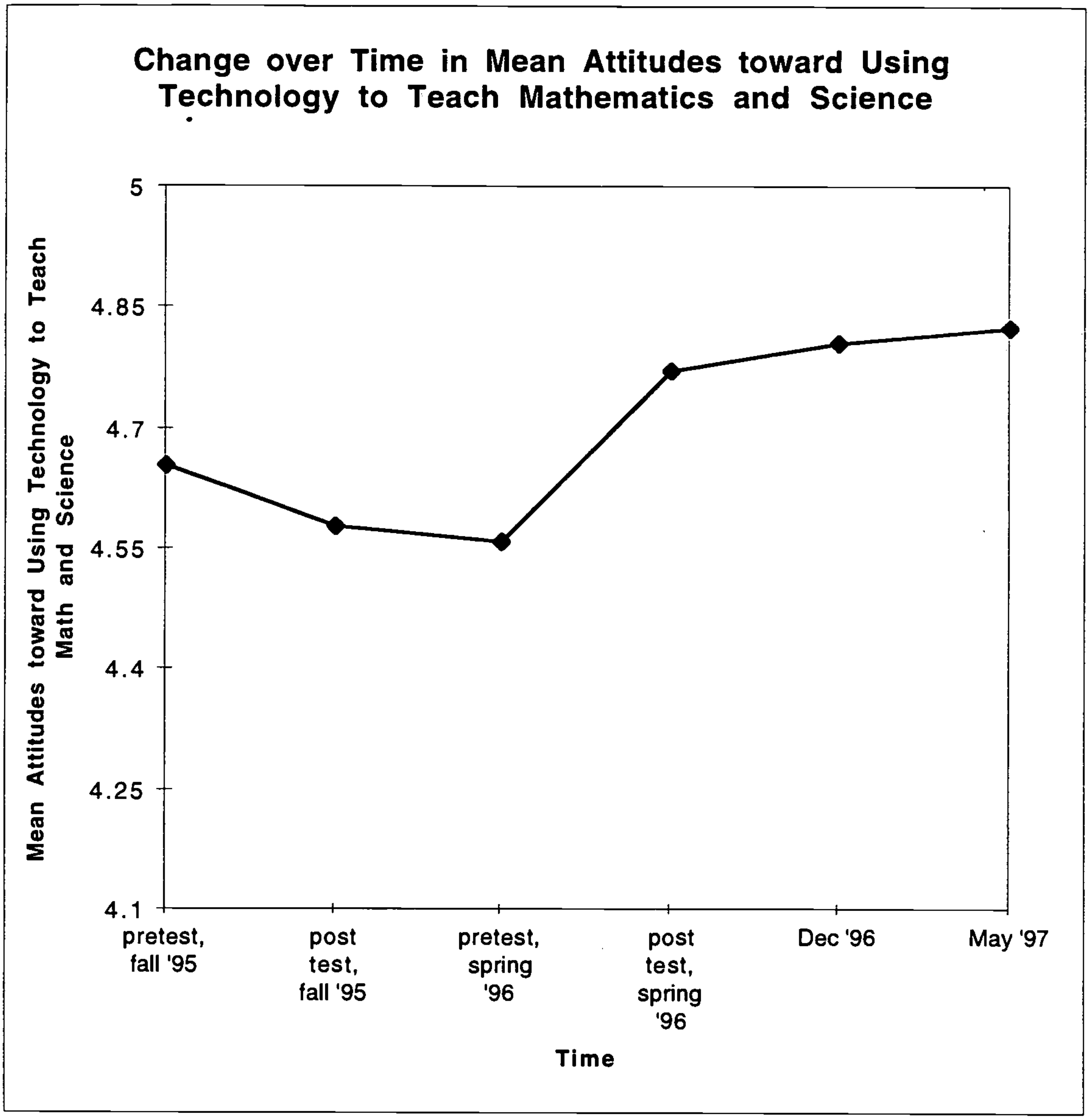

Change over Time in Mean Beliefs about Teaching Mathematics and Science
Mean Beliefs about Teaching Math and Science
4.6
4.5
4.4
4.3
4.2
4.1
4
pretest, fall '95
post test, fall '95
pretest, spring '96
post test, spring '96
Dec '96
May '97
Time

Figure Caption

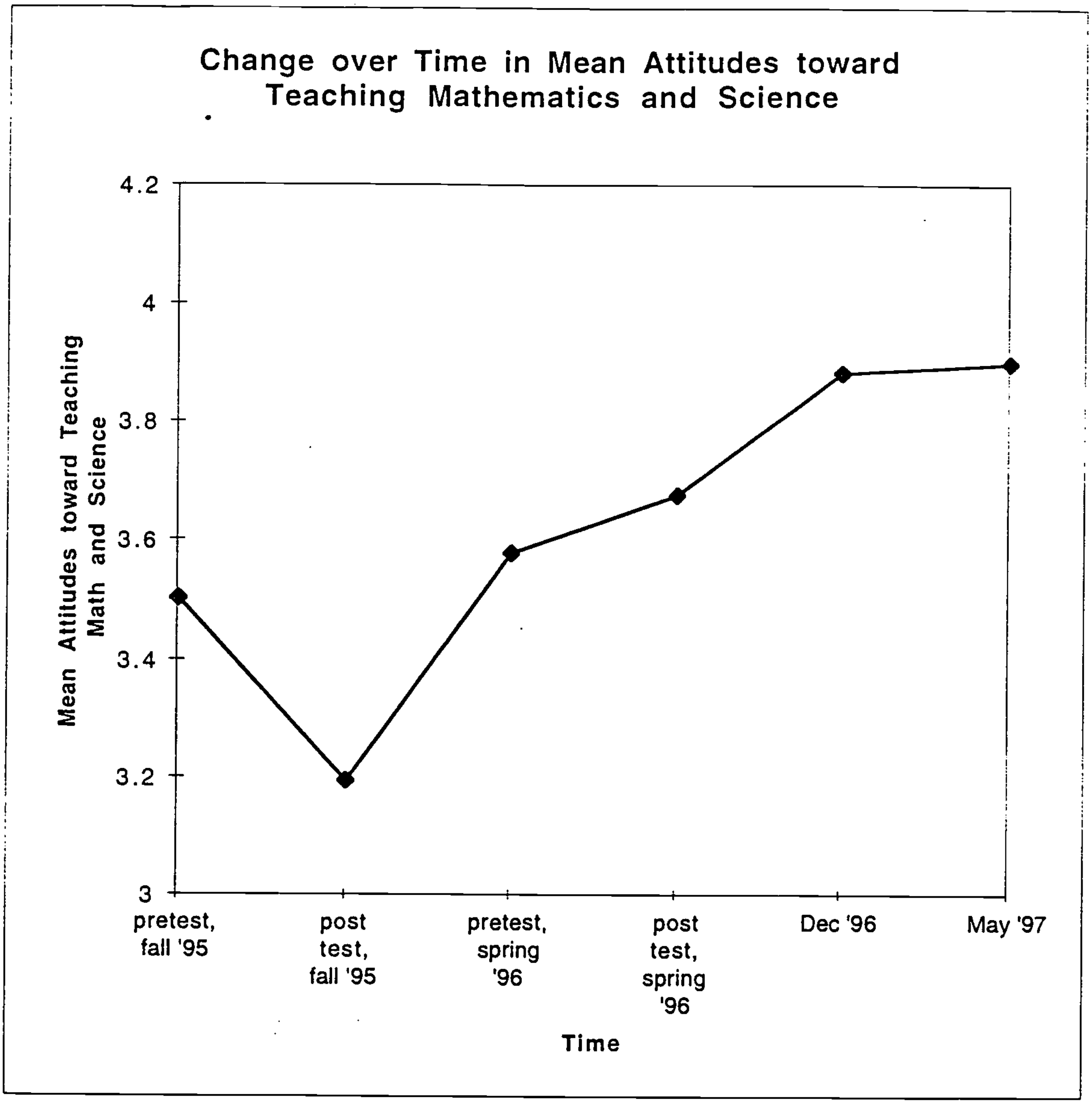
Figure 4. Change over time in mean attitudes toward using technology to teach mathematics and science.



Change over Time in Mean Attitudes toward Using Technology to Teach Mathematics and Science
Mean Attitudes toward Using Technology to Teach Math and Science
5
4.85
4.7
4.55
4.4
4.25
4.1
pretest, fall '95
post test, fall '95
pretest, spring '96
post test, spring '96
Dec '96
May '97
Time

Figure Caption

Figure 5. Change over time in mean attitudes towards teaching mathematics and science.


Change over Time in Mean Attitudes toward Teaching Mathematics and Science
Mean Attitudes toward Teaching Math and Science
4.2
4
3.8
3.6
3.4
3.2
3
pretest, fall '95
post test, fall '95
pretest, spring '96
post test, spring '96
Dec '96
May '97
Time

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