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AUTHOR	McGinnis, J. Randy; Parker, Carolyn	
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ABSTRACT

This study reports the use of a valid and reliable instrument, "Attitudes and Beliefs About the Nature of and the Teaching of Mathematics and Science," to measure teacher candidates' attitudes and beliefs about the nature of mathematics and science teaching. This paper examines how teacher candidates felt over 3 years. Teacher candidates were from the Maryland Collaborative for Teacher Preparation (MCTP), a National Science Foundation-funded undergraduate teacher preparation program for specialist mathematics and science elementary/middle school teachers. The student teachers completed the instrument in MCTP classes twice each semester for two semesters, then completed it by mail over three more semesters. The instrument had five subscales: beliefs about the nature of mathematics and science; attitudes toward mathematics and science; beliefs about the teaching of mathematics and science; attitudes toward using technology to teach mathematics and science; and attitudes toward teaching mathematics and science. Data analysis indicated that the MCTP was affecting participants' attitudes toward and beliefs about mathematics and science in the intended direction on all five subscales of the instrument. The magnitude of change was statistically significant for three of the subscales and approached significance for one other. (Contains 5 tables, 5 figures, and 34 references.) (SM)

Running head: TEACHER CANDIDATES' ATTITUDES AND BELIEFS OF SUBJECT MATTER AND PEDAGOGY

Teacher Candidates' Attitudes and Beliefs of Subject Matter And Pedagogy Measured Throughout Their Reform-Based Mathematics And Science Teacher Preparation Program

J. Randy McGinnis & Carolyn Parker
Science Teaching Center
Department of Curriculum & Instruction
Room 2226K Benjamin
University of Maryland, College Park
College Park, Maryland 20742
301-405-6234
jm250@umail.umd.edu

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Abstract

This study reports 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 used, *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 funded undergraduate teacher preparation program for specialist mathematics and science elementary/middle level teachers. In this analysis, we report how MCTP teacher candidates' attitudes toward and beliefs about mathematics and science evolved over a three year period. 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, Spring 1997, and Fall 1997 semesters the instrument was mailed to the study participants at the end of each semester (46% Fall 1996 response; 75% Spring 1997 response; 78% Fall 1997 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. 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 .05 level for the subscales measuring "Beliefs about the Nature of Mathematics and Science," "Mean Attitudes Toward Mathematics and Science," and "Beliefs about Teaching Mathematics and Science." In addition, the magnitude of change for the subscale measuring "Attitudes Towards Teaching Mathematics and Science" approached statistical significance (0.8). These findings make a highly significant contribution to the science and mathematics education research communities interested in charting the attitudinal and belief journeys of teacher candidates participating in a reform-based teacher preparation program.

Teacher Candidates' Attitudes and Beliefs of Subject Matter And Pedagogy Measured Throughout Their Reform-Based Mathematics And Science Teacher Preparation Program

Introduction

This study reports 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. It is not at all common for investigations in the affective domain to focus simultaneously on these two content disciplines. However, there is a urgent need for this type of study as attempts are made to make connections among mathematics and the sciences in both teacher preparation programs and in the schools. 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 (McGinnis, Watanabe, Shama, & Graeber (1997). Sections of the instrument that were verified by factor analysis dealt with beliefs about mathematics and science (α=.76); attitudes toward mathematics and science (α=.81); beliefs about teaching mathematics and science (α=.69); attitudes toward using technology to teach mathematics and science (α=.80); and attitudes toward teaching mathematics and science (α=.60).

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 within 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 investigated 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 wanted 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 was:

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

Method

Instrumentation

Between September, 1995 and October, 1997 MCTP teacher candidates periodically completed a questionnaire crafted for this study, *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science.* The questionnaire contains 37 statements to which students responded on a Likert scale (Likert, 1967). That is, each item had five possible responses, ranging from "A-strongly agree" to "E-strongly disagree". We used student responses to these 37 items to compute their scores on five subscales intended to measure their attitudes and beliefs.

We originally developed the subscales with the aid of a factor analysis, as described in McGinnis, Watanabe, Shama, & Graeber (1997). The questionnaire, as well as the subscales used to report its results, was intended for several purposes. We used it, for example: to compare the attitudes and beliefs of teacher candidates enrolled in the MCTP program to those of teacher candidates not enrolled in the program (McGinnis, Shama, Watanabe, & Graeber, 1997); to see if students' attitudes and beliefs change between the beginning and end of a single MCTP course; to identify "outlier" MCTP courses which seemed to have a particularly strong impact on students' attitudes and beliefs; and to periodically examine and report on changes in the MCTP teacher candidates' attitudes and beliefs over time (McGinnis, Kramer, Roth--McDuffie, & Watanabe, 1998).

In this final analysis of this three-year study, we report how MCTP teacher candidates' attitudes toward and beliefs about mathematics and science evolved over a three-year period. To do this, we found it necessary to modify one of the five subscales described in McGinnis, et. al. (1997). Specifically, one of the subscales, which we originally labeled "X_4: Attitudes towards learning to teach mathematics and science" contained two items which we dropped. These items asked teacher candidates to rate their agreement with the statement "I expect that the college courses I take will be helpful to me in teaching mathematics in elementary or middle school," and "I expect that the college courses I take will be helpful to me in teaching science in elementary or middle school". As MCTP students filled out the questionnaire during multiple occasions over a 3-year period, many of them completed a significant portion of their undergraduate classes, and their responses to these two items, instead of measuring the attitudes we intended, began to reflect their expectation that they did not need to take many more college courses to complete their teacher preparation program. This precipitated a reliability issue. Therefore, we dropped the two items from the "X_4" subscale. The remaining two items on the subscale focused rather narrowly on students' attitudes towards learning to use technologies to teach mathematics and science. Consequently, we have renamed the subscale to more accurately reflect its new emphasis "Attitudes toward using technology to teach mathematics and science."

Table 1 describes the five subscales in detail. For each subscale, the Cronbach's alpha reported is based on the original sample of students who completed the questionnaire in the fall of 1995. All 535 students enrolled at that time in mathematics and science classes influenced by the MCTP completed the first section of the questionnaire, and their responses were used to compute reliabilities for subscales X_1, X_2, and X_3. Only those of the 535 students who identified themselves as teacher candidates--a total of 313 students--completed the items on the questionnaire contained in subscales X_4 and X_5, so only their responses could be used to compute reliabilities for these two subscales. (Note: in subsequent administrations of the questionnaire reliabilities were generally similar to those reported here.)

Data collection

During the fall semester of the 1995-96 school year, each MCTP course administered the *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science* questionnaire twice: once near the beginning of the semester, and once near the end. The same process was repeated during the spring semester of that same (1995-96) school year. The majority of MCTP courses in which the questionnaire was administered were either mathematics or science content courses, containing a mixture of undergraduate teacher candidates enrolled in the MCTP program, teacher candidates who were not enrolled in the MCTP program, and students who did not identify themselves as teacher candidates. The questionnaire was administered in-class to all students present, and we did not collect information that could be used to identify individual students who completed the questionnaire.

In December, 1996 (i.e., the end of the fall semester of the 1996/97 school year) we began to use the questionnaire for a periodic mail-in survey of MCTP students. This mail-in survey strategy was selected in response to instrument administration fatigue voiced by many of the MCTP faculty. We identified 113 students enrolled in the program who had been in the MCTP program for at least a year, and mailed a survey to each of them. The response rate to the December, 1996 survey was lower than for our goals and standards. Of the 113 MCTP students sent surveys, 52 completed and returned them (46% response rate).

In May, 1997 (i.e., during the spring semester of that same academic year) we mailed 103 surveys to those of the original 113 who remained in the MCTP program. To increase the response rate, we used ideas from the "Total Design Method" (Dillman, 1978). These ideas included a follow-up postcard mailed to each survey participant, an additional certified mailing of the instrument to non-respondents, and the possibility of a modest stipend for three randomly selected respondents. Of the 103 MCTP students sent surveys in May, 1997, 72 completed and returned them (75% response rate). This process was repeated in the fall semester of 1997 when 65 surveys were sent out to those who remained in the program. Fifty-two completed and returned them (78% response rate).

In addition to the larger-scale surveys of MCTP students described above, we have used the questionnaire for several smaller-scale surveys. Each summer, a small number of MCTP students participate in a special internship in the science or business community. These interns were surveyed by mail at the end of the summer in 1996 and in 1997. In addition, one MCTP professor used the survey during the fall of 1997 to measure the attitudes and beliefs of all students in his Science Pedagogy Methods class.

Data Analysis

In this study, we are investigating how MCTP students' attitudes towards and beliefs about mathematics and science changed over time as they remained in the program. Two years of data are available to us. The simplest question to ask, and the one we address statistically, is "Were MCTP students' attitudes and beliefs different in the fall of 1997 from what they had been in the fall of 1995?"

In addressing this question, a simple t-test with individual surveys as the unit-of-analysis was not appropriate. Within each institution of higher learning, individual responses to the questionnaire were not independent. Each of the nine institutions implemented its own unique "flavor" of the MCTP program, depending on the preferences of the faculty and the needs of the student body. Moreover, MCTP teacher candidates within each institution took courses together and were encouraged to interact with each other extensively. T-tests have been shown to be highly inaccurate unless the data being used for the analysis consists of *independent* observations.

In such a situation, an acceptable solution that preserves statistical accuracy was to use the institution as the unit-of-analysis (Stevens, 1996, pp. 238-241). Of the nine institutions involved in the MCTP, only five participated fully during the period from the fall of 1995 through the fall of 1997. (Three institutions joined the program on a rather small scale later than 1995, and a fourth institution did not implement the MCTP program fully.) Therefore, we aggregated survey responses (i.e., computed the average response) within each of these five institutions, and analyzed changes in these aggregated scores. This enabled us to use a "repeated-measures" t-test design, with each of the five institutions having a repeated measure of its students' responses to the attitudes and beliefs questionnaire.

Because we were using a repeated measures t-test on multiple subscales, we used a Bonferonni adjustment, requiring a significance level of .01 in order to declare differences on a subscale statistically significant. This preserved an overall-experiment type I error rate of 5%. (If we had tested each of the five subscales separately at, for example, the .05 significance level, the probability of making at least one inaccurate rejection of a null hypothesis would have been $(1-(.95)^5) = 22.6\%$.)

In addition to checking for significant differences between MCTP students' attitudes and beliefs at the time of the first survey and their attitudes and beliefs at the time of the last survey, we analyzed the data graphically to get a qualitative impression of how MCTP students' attitudes and beliefs evolved. To remain consistent with our statistical analysis, we prepared the graphs using only data from the five institutions that participated fully throughout the 3-year period covered, and we used data that had been aggregated to the institution level.

<u>Administrations of the Instrument</u>

This study analyzes MCTP students' responses to the questionnaire on seven occasions:

1) the "pretest" given in all MCTP classes at the beginning of the fall semester, 1995;

2) the "post test" given in all MCTP classes at the end of the fall semester, 1995;

3) the "pretest" given in all MCTP classes at the beginning of the spring semester, 1996;

4) the "post test" given in all MCTP classes at the end of the spring semester, 1996;

5) the mail-in survey, conducted in December, 1996;

6) the mail-in survey, conducted in May, 1997.

7) the mail-in survey, conducted in October, 1997.

Participants

Only responses from MCTP teacher candidates at the five institutions which participated in all six surveys are used in this analysis. Table 2 summarizes how many MCTP students from each institution responded to each survey administration.

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). In October 1997 we sent out the survey for the final time to the 65 teacher candidates who remained in the program, yielding a 78% response rate.

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 three mail-in surveys during the 1996/97 and 1997/1998 school years were nearly all 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, only a very few MCTP teacher candidates graduated at the end of the 1995-96 school year. Almost all 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, almost all of those surveyed were in the program throughout the three 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 3-year period is legitimate statistically.

Results

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. (For comparison purposes, we also prepared similar graphs using disaggregated data. The resulting graphs were very similar to those contained in this report.)

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 3 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 .05 level for the subscales measuring "Beliefs about the Nature of Mathematics and Science" (X_1), "Beliefs About Teaching Mathematics and Science, " 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 Teaching Mathematics and Science" (X_5) approached statistical significance (0.08) This can be seen by examining Table 3.

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 October, 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 higher learning analyzed in this study.

Cohen (1977) has suggested as a rough rule of thumb that an effect size around .20 is small, an effect size around .50 is medium, and an effect size greater than .80 is large. As noted by Stevens (1996, pp. 174-5), most evaluations of social science programs find "small" effect sizes, as defined by Cohen. In contrast, Table 4 shows that effect sizes on three of the five subscales reported in this study achieved the "moderate" level and on one subscale achieved the "large" level (X_2).

<u>Alternate explanations.</u>

As noted above, the positive changes in MCTP students' attitudes and beliefs on three subscales are statistically significant. Therefore, the MCTP program claims to be influencing students' attitudes and beliefs in the ways it intended.

However, the timing of students' changed attitudes did raise one possible doubt about this conclusion. As can be seen in Figures 1 through 5, a large positive change occurred on four of the five subscales between when the questionnaire was administered in class at the end of the spring, 1996 semester, and when the questionnaire was first administered as a mail-in survey in December, 1996. On two of the subscales (X_1: Beliefs about the nature of Mathematics and Science and X_2: Attitudes towards Mathematics and Science) average scores on the questionnaire increased more between those two administrations than at any other time. Could the apparent improvement in students' attitudes and beliefs be attributable merely to the difference between how students respond to an in-class survey, and how they respond to a mail-in survey? Perhaps students respond more positively to a questionnaire if the fill it out at home than if they fill it out in a classroom setting. Or, perhaps those who didn't have attitudes and beliefs desired by MCTP were disproportionately among non-respondents to the mail-in questionnaire. Finally, is it possible that the in-class sample of "MCTP students" was contaminated by some non-MCTP students in the same class, who mistakenly identified themselves as being enrolled in the MCTP? However, such explanations seem rather unlikely. Even before the switch to a mail-in survey, average scores had increased on four of the five subscales.

We also tested whether the apparently improved attitudes and beliefs were likely due to the less than 100% response rate for the mail-in surveys. As noted above, the May, 1997 survey which we used for our statistical analysis achieved a 75% response rate. What if the 25% who didn't respond tended to be the MCTP students whose attitudes and beliefs least resembled those desired by the program? To control for this possibility, we modified the pretest Fall, 1995 data to eliminate the 25% lowest responders. We computed the average of the five subscales for each of the 97 students who completed the in-class questionnaire for the Fall pretest, and eliminated the 25% with the lowest average scores. We then aggregated scores for the remaining 73 students to the college level, and repeated our comparison with results of the May, 1997 mail-in survey. As shown in Table 5, the results still indicated a gain on all five subscales, with a statistically significant gain on X_3 and a nearly significant gain on X_1.

We were unable to eliminate the possibility that the sample of students who completed the questionnaire in-class was contaminated by non-MCTP students who incorrectly responded that they were in the MCTP program. MCTP students are special, in that they take a large number of MCTP classes, they have special seminars and internships, and special relationships with advisors. In any given MCTP class, however, there were often a number of non-MCTP preservice teachers who may have mistakenly believed that, since they were in an MCTP class, they should call themselves MCTP students. This possible contamination, though it is unlikely to explain our results, should nonetheless be kept in mind when considering our conclusions.

Conclusion

The MCTP affected participating teacher candidates' attitudes towards and beliefs about mathematics and science in the direction intended. In particular, the MCTP teacher candidates' beliefs about the nature of the two disciplines, and their beliefs about how one ought to teach them, are becoming more in line with beliefs advocated by current reform efforts in mathematics and science education. This positive result is particularly striking given the fact that, during the majority of the three-year period MCTP teacher candidates were surveyed, the majority of them were completing their MCTP-influenced mathematics and science content courses, and had not yet begun to take their MCTP-influenced pedagogy courses or their MCTP-influenced student teaching.

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, 1984, 1992). The MCTP had 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. In the long run, the hope is that, as suggested by the literature, our graduates' attitudes and beliefs will positively affect their teaching and their learning. This is currently being investigated by McGinnis and Parker who are conducting both a large-scale survey study of all the MCTP new teachers and a case study of five new MCTP teachers in their first years of teaching.

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. Studies which are emerging (see, for example, McGlamery, Edick, & Ostler, 1999), generally are not encouraging in the impact of the reform--based undergraduate teacher programs on new teachers. The findings from our longitudinal 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*, proved to be useful in providing a "longitudinal topography" of the attitudes and beliefs of MCTP teacher candidates. We believe that we charted the attitudinal and belief journeys of an identifiable group of mathematics and science teacher candidates throughout all if not most of their teacher preparation program. The findings from our study is encouraging in that it supports the efforts made to institute reforms in mathematics and science teacher preparation programs. We therefore believe that this type of study makes 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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Correspondence concerning this report of research should be addressed to the first author.

Table 1
Factor Analysis of the Survey Instrument

Description	Item index		Avg. load
X1. Beliefs about the nature of mathematics and science			**α=.7596***
In grades K-9, truly understanding... requires special abilities that only some people possess.	10	24	.57
The use of technologies in ... is an aid primarily for slow learners.	12	31	.56
Getting the correct answer to a problem in the ...classroom is more important than investigating the problem in a ... manner.	16	23	.55
The primary reason for learning ... is to ... for learning ...	19	35	.53
... consists of unrelated topics like ...	13	33	.48
To understand ..., students must solve many problems following examples provided.	14	28	.33
Theories in science are rarely replaced by other theories.		27	.41
Science is constantly expanding field.		26^{-}	.30
X2. Attitudes towards mathematics and science			**α=.8070**
I am looking forward to taking more ... courses.	5^{-}	21^{-}	.73
I like ...	7^{-}	29^{-}	.69
I enjoy learning how to use technologies in ... classrooms.	6^{-}	30^{-}	.68
X3. Beliefs about the teaching of mathematics and science			**α=.6900**
Using technologies in ... lessons will improve students' understanding of ...	18^{-}	22^{-}	.55
Calculators should always be available for students in science classes		34^{-}	.51
Students should be given regular opportunities to think about what they have learned in the ... classroom	17^{-}	25^{-}	.48
Students should have opportunities to experience manipulating materials in the ... classroom before teachers introduce ... vocabulary	15^{-}	32^{-}	.51
Small group activity should be a regular part of the ... classroom.	20^{-}	36^{-}	.47
X4. Attitudes toward using technology to teach mathematics and science			**α=.80**
I want to learn how to use technologies to teach ...	38^{-}	44^{-}	.80
X5. Attitudes towards teaching mathematics and science			**α=.6014**
The idea of teaching scares me.	43	40	.69
I prefer (feel prepared) to teach mathematics and science emphasizing connections between the two disciplines.	42^{-}	45^{-}	.56

$^{-}$ Item is reversed.

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	Fall '96 Survey	Spring '97 Survey	Fall '97 Survey
A	9	8	3	3	8	15	9
B	23	13	22	26	5	11	2
C	10	10	8	10	9	12	9
D	34	22	18	20	11	18	17
E	20	8	6	5	15	16	14
Total	96	61	57	64	48	72	51

Table 3
Change In MCTP Students' Attitudes And Beliefs Over 3 Years: Significance Tests

variable	Fall '95 pretest mean	Fall '97 mean	s.e. of mean	t-value	df	95% CI of difference	2-tail significa e
X_1	3.95	4.34	.102	3.80	4	(.105, .671)	.019*
X_2	3.81	4.42	.165	3.69	4	(.151, 1.069)	.021*
X_3	4.11	4.41	.079	3.87	4	(.087, .525)	.018*
X_4	4.66	4.87	.122	1.80	4	(-.119, .559)	.146
X_5	3.51	4.07	.237	2.37	4	(-.096, 1.220)	.077

Notes: Repeated measures t-test using 5 institutions of higher learning as unit of analysis.
* significant at the .05 level.

Table 4
Change In MCTP Students' Attitudes And Beliefs Over 3 Years: Effect Sizes.

variable	Fall '95 pretest mean	Fall '97 mean	change	student-level st. deviation (fall '95)	effect size	student at 50th percentile would move to
X_1	3.96	4.34	.38	.50	.76 st.dev.	78th percentile
X_2	3.81	4.42	.61	.75	.81 st.dev.	79th percentile
X_3	4.11	4.41	.30	.49	.61 st.dev.	73rd percentile
X_4	4.66	4.87	.21	.62	.34 st.dev.	63rd percentile
X_5	3.51	4.07	.56	.79	.71 st dev.	76th percentile

Note: Effect sizes based on student-level standard deviation on Fall '95 pretest.

Table 5
Significance Tests With Lowest-Scoring 25% Thrown Out From Fall Ô95 Pretest

variable	Fall '95 pretest mean	Fall '97 mean	standard error of the mean	t-value	df	95% CI of the difference	2-tail significance
X_1	4.06	4.34	.084	3.34	4	(0.047, 0.517)	.029*
X_2	4.09	4.42	.098	3.33	4	(0.054, 0.598)	.029*
X_3	4.27	4.41	.051	2.84	4	(0.003, 0.285)	.047*
X_4	4.81	4.87	.087	0.71	4	(-0.181, 0.305)	.518
X_5	3.69	4.07	.218	1.74	4	(-0.226, 0.986)	.157

Notes: Repeated measures t-test using 5 institutions of higher learning as the unit of analysis.
* significant at the .05 level

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

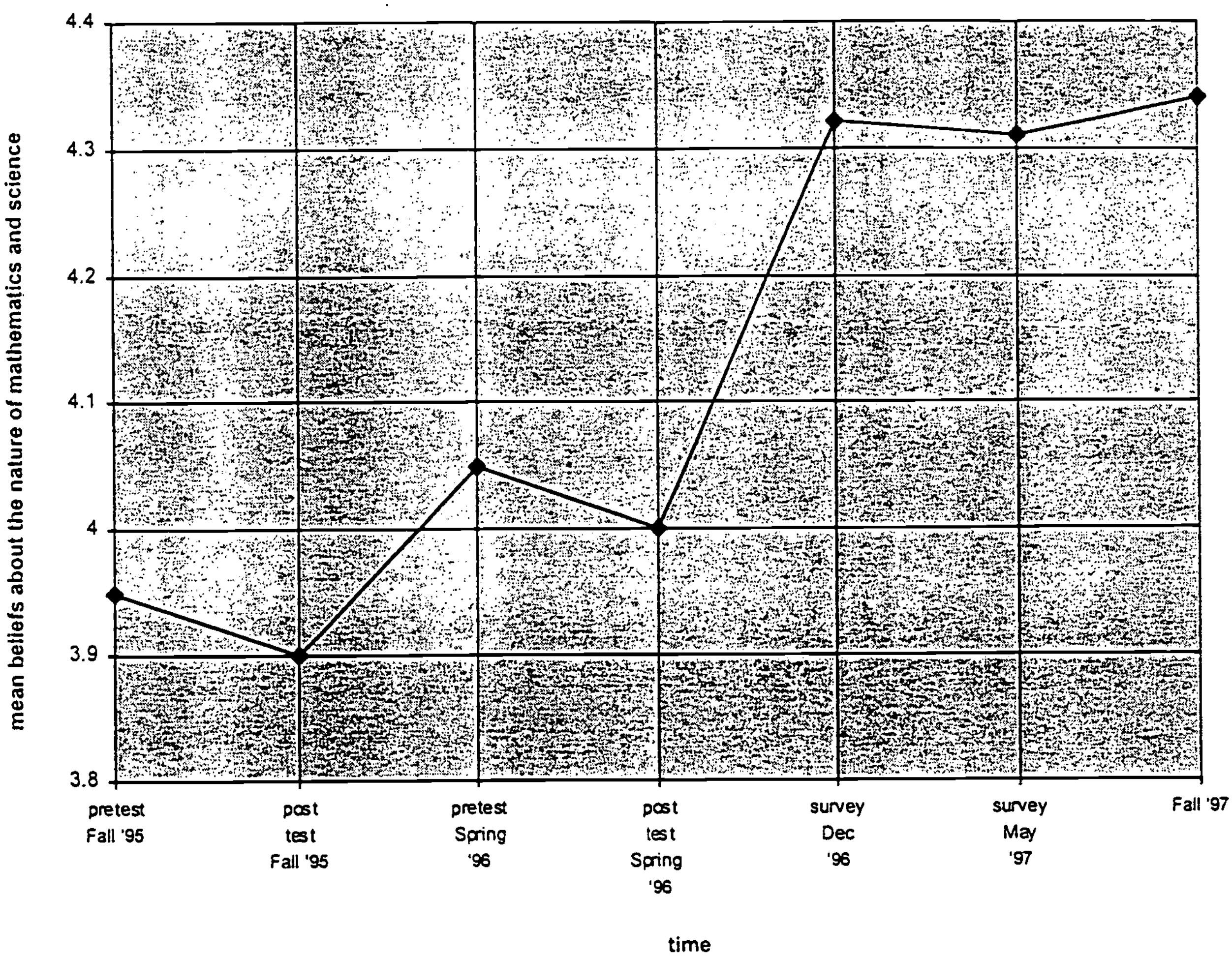

Figure Caption

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

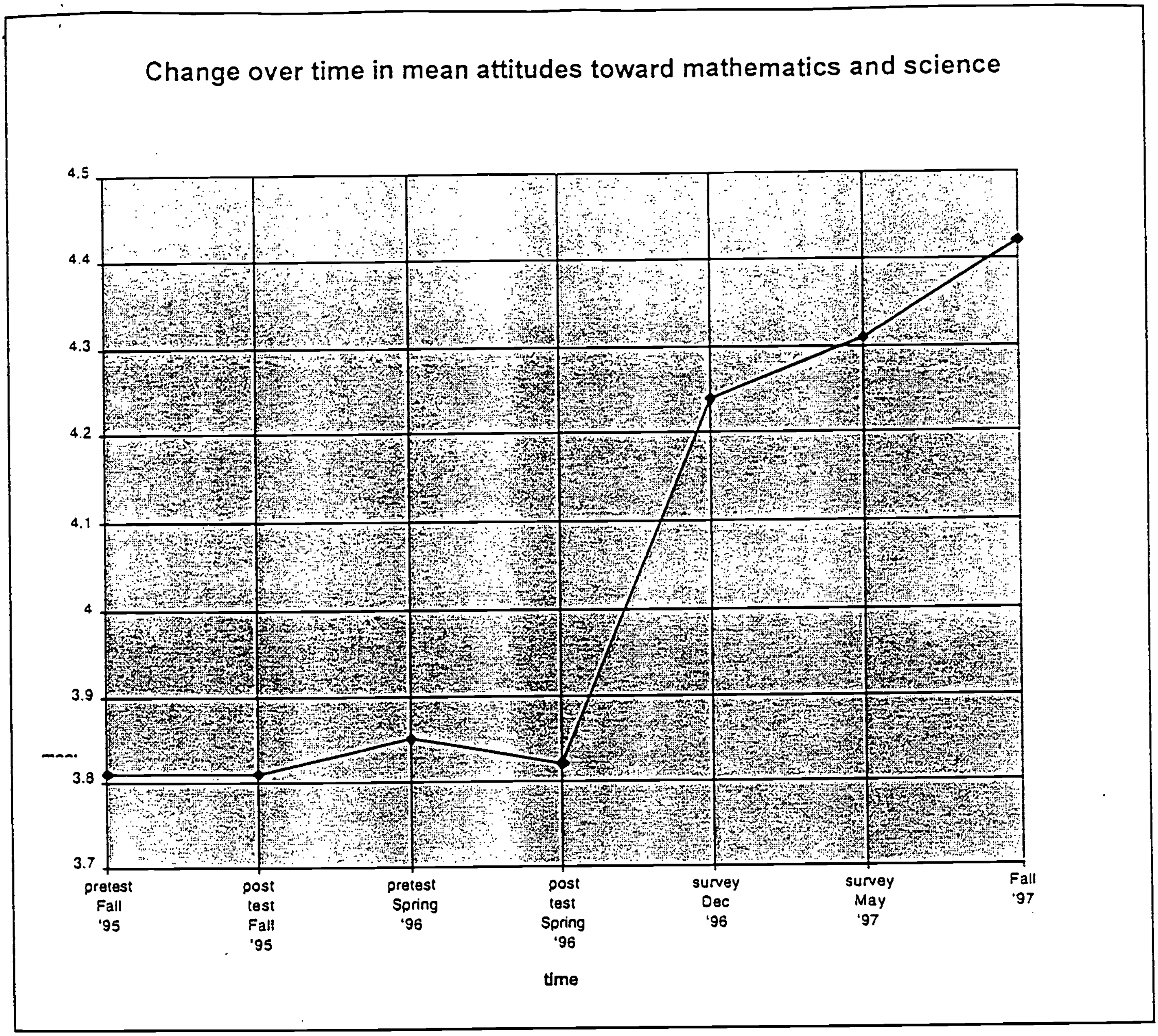

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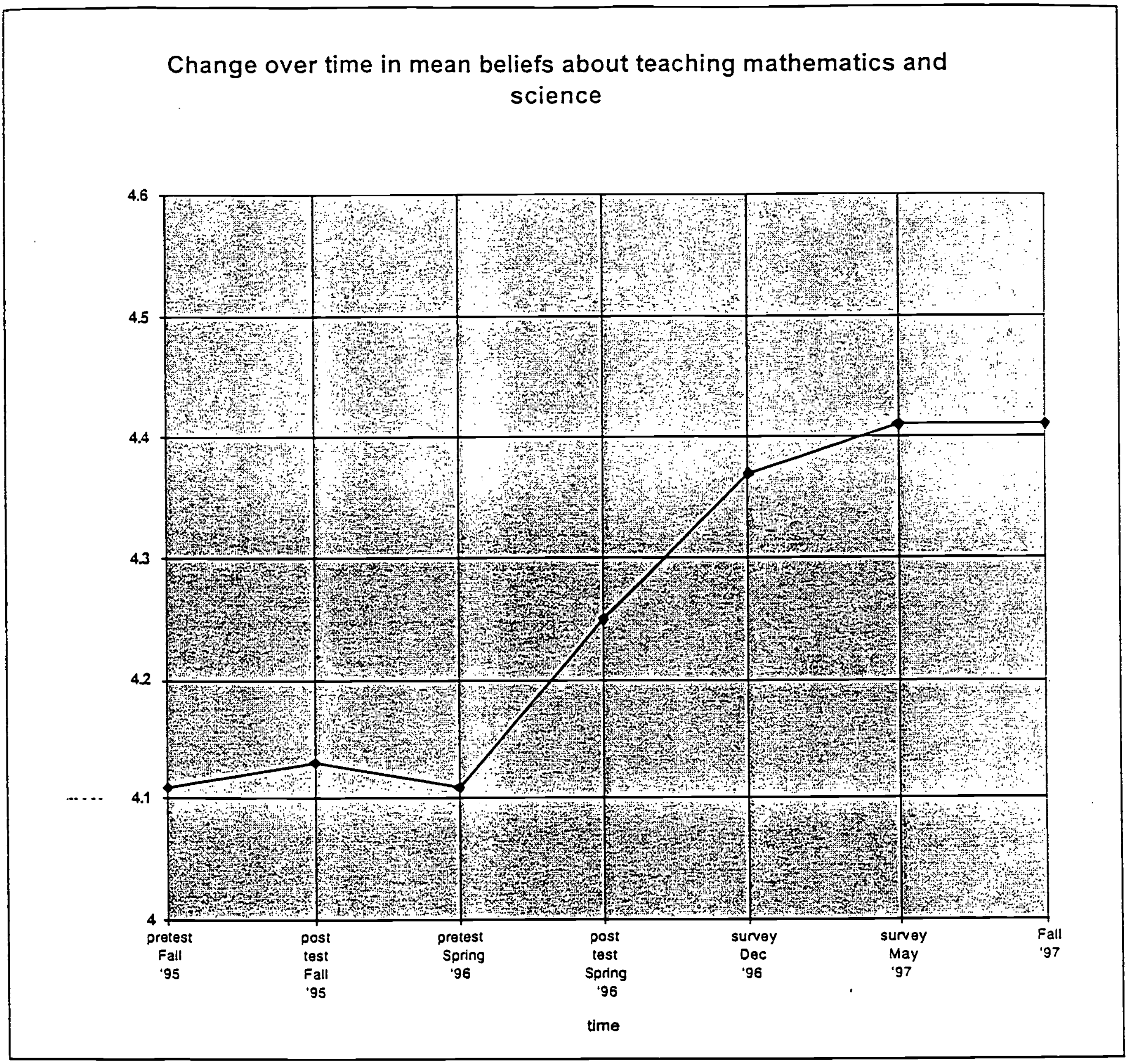
Figure Caption

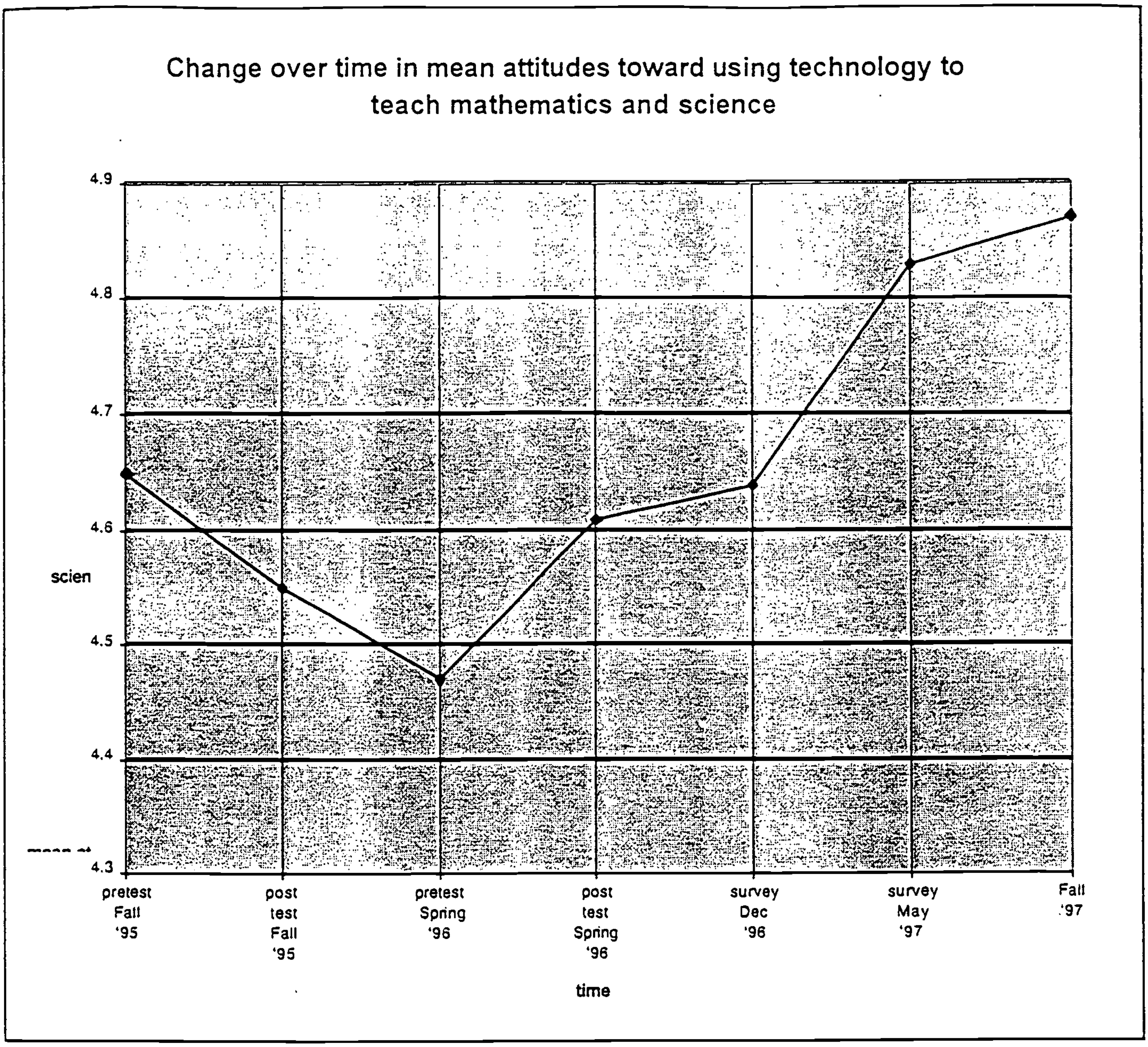
<u>Figure 3</u>. Change over time in mean beliefs about the teaching mathematics and science.



Change over time in mean beliefs about teaching mathematics 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
survey Dec '96
survey May '97
Fall '97
time

Figure Caption

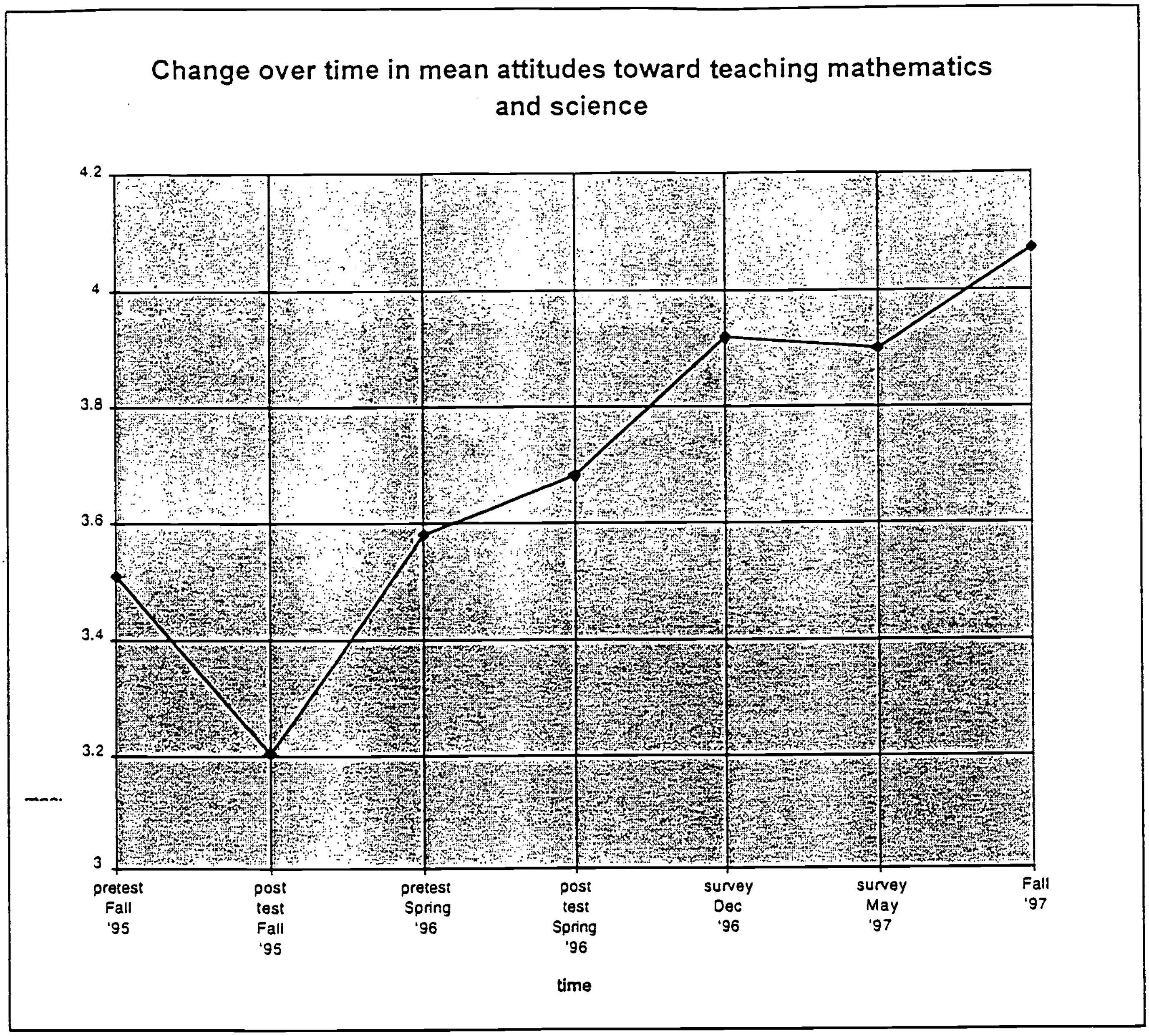
Figure 4. Change over time in mean attitudes toward using technology to teach mathematics and science.



Change over time in mean attitudes toward using technology to teach mathematics and science
4.9
4.8
4.7
4.6
scien
4.5
4.4
4.3
pretest Fall '95
post test Fall '95
pretest Spring '96
post test Spring '96
survey Dec '96
survey May '97
Fall '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
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
survey Dec '96
survey May '97
Fall '97
time

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Organization/Address: Science Teaching Center, Dept. of C&I University of MD/College Park, MD 20742	Telephone: 301-405-6234	FAX: 301-314-9055
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