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AUTHOR McGinnis, J. Randy; And Others
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ABSTRACT

The Maryland Collaborative for Teacher Preparation (MCTP) is a National Science Foundation (NSF)-funded statewide undergraduate program whose goal is to promote the development of professional teachers who are confident teaching mathematics and science using technology, can make connections between and among the disciplines, and can provide an exciting and challenging learning environment for students of diverse backgrounds. This paper presents a reflection on the research conducted in a longitudinal, multi-level, multi-dimensional research program charged with documenting and interpreting the development and implementation of the teacher preparation program in mathematics and science education. The intent of the reflection is to contribute toward the researchers' sense-making as the research program enters its fourth year of operation. It is also offered as a case study of research from which interested readers may gain insights to assist their research efforts in diverse contexts. Emergent findings and questions relate to the decisions made in the following areas: the research team; the research design; the research instruments; the data collection; and the data analysis. A call for internal support of research efforts within NSF-funded teacher preparation projects is made to support knowledge growth in this critical realm. Contains 26 references. (JRH)

The Maryland Collaborative For Teacher Preparation: Making Sense Of The Enactment Of Reform In The Preparation Of Specialist Teachers Of Mathematics And Science

J. Randy McGinnis
The Science Teaching Center
Department of Curriculum & Instruction
Room 2226K Benjamin
University of Maryland, College Park
College Park, Maryland 20742
jm250@umail.umd.edu

Tad Watanabe
Department of Mathematics
Towson State University
Towson, Maryland 21204

Amy Roth-McDuffie & Steve Kramer
Mathematics Learning Center
Room 2226 Benjamin
University of Maryland, College Park
College Park, Maryland 20742

Gilli Shama
MCTP Research Group
University of Maryland, College Park
College Park, Maryland 20742

MCTP Homepage (select Research Group) : http://www.wam.umd.edu/~toh/MCTP.html

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Abstract

The Maryland Collaborative for Teacher Preparation (MCTP) is a National Science Foundation (NSF) funded statewide undergraduate program for students who plan to become specialist mathematics and science upper elementary or middle level teachers. Higher education institutions involved in this project include the majority of higher education institutions within the Maryland System responsible for teacher preparation. Several community colleges also participate. In addition, large public school districts are active partners. The primary 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.

This paper presents a reflection on the research conducted in a longitudinal, multi-level, multi-dimensional research program charged with documenting and interpreting the development and implementation of a NSF funded, statewide teacher preparation program in mathematics and science education. The intent of the reflection is to contribute toward the researchers' sense making as the research program enters its fourth year of operation. It is also offered as a case study of research from which interested readers may gain insights to assist in their research efforts in diverse contexts. Emergent findings and questions relate to the decisions made in the following areas: the research team; the research design; the research instruments; the data collection; and the data analysis. A call for internal support of research efforts within NSF funded teacher preparation projects is made to support knowledge growth in this critical realm.

The Maryland Collaborative For Teacher Preparation: Making Sense Of The Enactment Of Reform In The Preparation Of Specialist Teachers Of Mathematics And Science

Introduction

The Maryland Collaborative for Teacher Preparation (MCTP) is a National Science Foundation (NSF) funded statewide undergraduate program for students who plan to become specialist mathematics and science upper elementary or middle level teachers. Teacher candidates selected to participate in the MCTP program are, in general, representative of all teacher candidates in elementary teacher preparation programs. MCTP teacher candidates are distinctive by expressing and interest in teaching mathematics and science. Recruitment efforts have also attracted many students traditionally underserved in the teaching force, most notably African Americans to the MCTP.

Higher education institutions involved in this project include the majority of higher education institutions within the Maryland System responsible for teacher preparation. Several community colleges also participate. In addition, 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. This goal is in accord with the educational practice reforms advocated by the major professional mathematics and science education communities (see, for example, National Council of Teachers of Mathematics [NCTM], 1991; American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC] of the National Academy of Sciences, 1996).

The MCTP was funded in 1993 for up to a five year period to create teacher education programs that contain:

- Specially designed courses in science and mathematics, taught by instructors committed to a hands-on, minds-on interdisciplinary approach.

- Internship experiences with research opportunities in business, industrial and scientific settings, and with teaching activities in science centers, zoos, and other institutions.
- Field experiences and student teaching situations with mentors devoted to the interdisciplinary approach to mathematics and science.
- Modern technologies as standard tools for planning and assessment, classroom and laboratory work, problem-solving and research
- Placement assistance and sustained support during the induction year in the teaching profession
- Financial support for qualified students.

Enactment of the Program

In practice, the MCTP undergraduate classes are typically taught by senior faculty and graduate assistants 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. Faculty also strive to infuse technology into their teaching practice, and to employ a instructional strategies recommended by the literature to be compatible with the constructivist perspective (e.g., student-centered, address conceptual change, promote reflection on changes in thinking, and stress logic and fundamental principles as opposed to memorization of unrelated facts) (see, for example, Cobb, Wood, Yackel, McNeal, 1992; Driver, Soko, Leach, Mortimer, & Scott, 1994). Faculty lecture is diminished and student-based problem-solving is emphasized which requires cross-disciplinary mathematical and scientific applications.

The MCTP teacher candidates, selected by using criteria developed at each institution, take the reformed undergraduate mathematics, science, and education classes and have the opportunity to participate in summer internships in mathematics and science rich environments (e.g., museums, zoological parks, and private companies).

Overview of the Paper

This paper presents a reflection on the research conducted in a longitudinal, multi-level, multi-dimensional research program charged with documenting and interpreting the development and implementation of a NSF funded, statewide teacher preparation program in mathematics and science education. The intent of the reflection is to contribute toward the researchers' sense making as the research program enters its fourth year of operation and to offer insights which interested readers may use in their contexts. Key areas examined include:

- The research team
- The research design
- The research instruments
- The data collection
- Data analysis

A call for internal support of research in funded NSF teacher preparation projects concludes the paper. Interested readers are invited to journey to the MCTP's homepage on the internet (http://www.wam.umd.edu/~toh/MCTP.html) to obtain additional text on the MCTP Research Group's efforts (including copies of previous research reports that expand on points alluded to in this paper).

The Research Team

The MCTP project leadership, under the direction of Jim Fey, MCTP Project Director, appointed J. Randy McGinnis (science educator), University of Maryland at College Park (UMCP), and Tad Watanabe (mathematics educator), Towson State University (TSU), to share the leadership of a Research Component of the MCTP. The guiding notion for this decision was to ensure representation of both the mathematics education and the science education research domains in the project's research program (see, McGinnis, Roth-McDuffie, Graeber, & Watanabe, 1995). This notion was extended in the selection and recruitment of the two expert research

consultants to the group (Catherine Brown, mathematics education, University of Pittsburgh, and Kenneth Tobin, science education, Florida State University). Anna Graeber, mathematics educator, University of Maryland at College Park, agreed to serve as a mentor to the Research Group. Amy Roth-McDuffie, Mary Ann Huntley, Karen King, and Steve Kramer, doctoral mathematics education students at UMCP, have served at various times as graduate research assistants to the Research Group. Gilli Shama, a visiting Israeli mathematics educator, assisted the Research Group with quantitative research analysis expertise during the 1995-1996 year.

Balancing the research team between the mathematics and science education research domains has produced a powerful research team with a vision of teacher preparation research arising from the confluence of different research lineages bearing on the same issue, teacher preparation. A significant effect of this complementary research team is the expanded body of literature (and contact individuals within each domain) from which to seek guidance and understanding. Another significant effect is the broadened number of research forums to present and to report the group's research products (including at the annual meetings of the following research associations and in their respective journals: the Association of Educators of Teachers of Science, the National Association for Research in Science Teaching, the National Science Teachers Association, the National Council of Teachers of Mathematics, the Psychological Mathematics Association, the Research Council on Diagnostic and Prescriptive Mathematics, and the American Educational Research Association).

A disquieting realization which has also come as a result of this collaboration in mathematics and science education research has been how difficult it is under even the best of conditions to relax one's identity as a "science education researcher" or a "mathematics education researcher" to create a new identity as a "mathematics *and* science education researcher" or as a more inclusive "educational researcher." We define ourselves in educational research communities in which we were enculturated and can readily envision; we resist replacing those images of ourselves with identities that we create in our local context through the process of research collaboration with the 'other.'

The Research Design

In essence, the primary purpose of research in the MCTP is directed at knowledge growth in undergraduate mathematics and science teacher education. The unique elements of the MCTP (particularly the instruction of mathematical and scientific concepts and reasoning methods in undergraduate content *and* methods courses that model the practice of active, interdisciplinary teaching) are being documented and interpreted from two foci: the faculty and the teacher candidate perspectives. The research design is longitudinal, extending throughout the entire four-year undergraduate teacher education preparation program and the first induction year of the MCTP specialist teachers. Also, since the scope of the MCTP is statewide, the design of the research is multi-level (state, higher education institution, and individual). And finally, since the researchers composing the MCTP Research Group are diverse in research discipline backgrounds (mathematics education and science education) it is multi-dimensional (both research domains are investigated and a new fusion area, mathematics *and* science education, is documented and interpreted). Implementation of all components of the research design are contingent upon the research questions crafted for the research program.

The following questions served as the *a priori* research questions that were presented to the National Science Foundation in the MCTP grant proposal:

1. What is the nature of the faculty and teacher candidates' beliefs and attitudes concerning the nature of mathematics and science, the interdisciplinary teaching and learning of mathematics and science to diverse groups (both on the higher education and upper elementary and middle level), and the use of technology in teaching and learning mathematics and science?
2. Do the faculty and teacher candidates perceive the instruction in the MCTP as responsive to prior knowledge, addressing conceptual change, establishing connections among disciplines, incorporating technology, promoting reflection on changes in thinking, stressing logic and fundamental principles as opposed to memorization of unconnected

facts, and modeling the kind of teaching/learning they would like to see on the upper elementary, middle level?

Upon NSF funding, some additional first-year emergent research questions gained interest in the MCTP Research Group:

(1) Does the integration of mathematics and science content and pedagogical preparation in their college teacher preparation program lead to curricular integration of those subjects in teaching opportunities by the specialist teacher candidates?

(2) Does the strengthened content and pedagogical preparation of the specialist teacher candidates help them to focus instruction on student conceptual growth, rather than factual and procedural learning? Also, does it prepare them to make deeper assessments of the learner's thinking and to choose instructional responses from an array of options?

(3) Do the science and informal education experiences assist he specialist teacher candidates in engaging learners in authentic learning investigations? Do they provide them with pedagogical knowledge and resources for meaningful motivation of students?

These research questions have served the MCTP Research Group as identifiable landmarks in a sea of collected data as the research program has progressed over the last three and a half years. While valuing and employing a liberating and creative "emergent and contingent" research *modus operandi* (K. Tobin, personal communication, November 10, 1995), the early conceptualization of a relatively few research questions within the MCTP Research Group have kept us focused on clear targets upon which to direct our energies and upon which our efforts can be evaluated.

The Research Instruments

Crafting instruments to assist in collecting relevant data that promise to inform the key research questions requires extensive energy from the MCTP Research Group. Developing a valid

and reliable questionnaire to measure teacher candidates' attitudes and beliefs toward mathematics and science and about the teaching of those disciplines became necessary once an exhaustive review of the literature did not identify any one extant instrument which had that focus or could efficiently do so within a 15-minute time constraint (a constraint insisted upon by the project leadership). The final 48-item instrument took two years to develop in order to ensure its validity and reliability as a research tool. It is named *Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science* and is especially appropriate for use with prospective teachers of mathematics and science (see, e.g., McGinnis, Shama, Graeber, & Watanabe, 1997a; 1997b).

Multiple interview protocols for teacher candidates and college faculty (content specialists and method specialists) also needed to be developed, peer reviewed, and field tested over the years of the research program's operation. An additional instrument to use for classroom observations was also developed and field tested before implementation. A current identified need within the MCTP Research Group is for valid and reliable content and process assessments in mathematics and science to administer at periodic points to the MCTP teacher candidates.

This component of the MCTP Research Group's efforts has taken everyone in the research group by surprise. The time and energy required to develop valid and reliable research instruments is enormous and an oftentimes taxing exercise in patience, both among the researchers, the participants, and the project leadership. The alternative, however, of using research instruments justifiably open to peer criticism as not being valid or reliable or not appropriate to address the research questions is not viable within a professionally run educational research program. Hard decisions on what needs to be done, in which order, and by whom within the research group are necessary to make and can generate tensions among the collaboration of researchers. There is also the danger of losing sight of the point of the research program--to answer the research questions--and to myopically focus exclusively on the development of the research instruments as if that were the main point of the research program. The MCTP Research Group has progressed through these issues by carving out the research into areas of mutual

responsibility (instrument development and data collection) and areas of individual research interests (i.e., faculty discourse analysis, faculty modeling, faculty and teacher candidate case studies) with some sense of equity guiding individual time and energy expenditure. Periodic reviews of the research program by the NSF and the project leadership have also served to reorient the direction of the research group so that answering the landmark research questions remain the central focus of the research. And, although it has not been possible up to this point within this research program, the use of previously developed, appropriate, and valid and reliable research instruments is highly recommended to free up the researchers' time and energy that can be redirected to data analysis.

The Data Collection

Since this was a statewide research effort, with eight institutions of higher learning participating in the project, obtaining permission to collect data and then enacting implementing strategies to collect the data also required much energy and ongoing attention. Procedures for administration of the questionnaire, the interview protocols, and collection of data artifacts also needed to be developed and approved for use by multiple committees charged with ensuring the safety of human subjects throughout the University of Maryland Higher Education System. Ongoing instructor cooperation to administer the project's questionnaire in MCTP classes at the beginning and at the end of each semester was essential. Sending the materials out to them from the MCTP office with an accompanying letter that emphasized the commitment the project made to engage in continuous research efforts facilitated this data collection. Interviewers to conduct teacher candidate interviews twice a semester were recruited from the pool of practicing teachers participating in the project. The NSF project's funding was essential to remunerate them for their participation and to pay for the voluminous taped data to be transcribed.

Data Analysis

Since this study employed complementary research methods (Jaeger, 1988), quantitative, qualitative, and discourse, data analysis in each domain was required. Each is summarized below.

Qualitative.

The interpretative research methods employed in this on-going five-year study are guided by Alasuutari (1995), Erickson (1986), and LeCompte, Millory, & Preissle (1992). The intent is to focus on "the meanings of actions, as defined by the actors' points of view " (Erickson, 1986, p.119). It is conducted within a constructivist paradigm which is guided by an associated set of ontological, epistemological, and methodological beliefs (Guba & Lincoln, 1989). Namely, as investigators, we assume that there are multiple realities which can be socially constructed, ours would be but one. And, we believe that our findings will be knowledge claims or constructions which we negotiate among ourselves by using the data we collected in the setting in which we worked.

Data are currently being analyzed throughout the study by the principal investigators and multiple doctoral education students. The analysis and interpretation process consists of reading and examining collected data placed in the NUD.IST environment and formulating tentative assertions that are being negotiated among the investigators. These tentative assertions are being tested by many sources in the data set. This iterative process of phases of interpretation, critique, and reanalysis is a hermeneutic cycle that results in the emergence of joint constructions of one possible view of the intending teachers' discussion and actions during their science methods class.

Preliminary analysis of the wealth of data from the first two years of this research study (there exists approximately a year's delay in the analysis of data due to the time needed to collect and then process the data into formats amenable to analysis tools and strategies) indicates that there are intriguing regularities in the participants' attitudes, beliefs, and performances. These findings have been reported in depth in other research reports (see, e.g.). In addition, several manuscripts based on these findings are under review, or in the process of being edited, for journal publication in the *Journal of Research in Science Teaching*, the *Journal of Mathematics Education*, and *School Mathematics and Science*.

The use of this research methodology has been particularly effective in providing the researchers with participant voices from throughout the project. These voices are used to construct a coherent story of the project in general to share with those interested in this NSF teacher preparation project. The voices are also used in case studies of individual faculty members and college students participating in the project. Themes of how the faculty perceive each other's role in teacher preparation, how they perceive making connections between mathematics and science, what constraints they see in implementing courses that emphasize connections between mathematics and science, and how individual faculty members and teacher candidates perceive the enactment of MCTP reforms are some of the analytical constructs that have emerged (see, e.g., King & Roth-McDuffie, 1996; Roth-McDuffie & McGinnis, 1996, Watanabe, Huntley, & McGinnis, 1996).

These stories, while cogently telling the MCTP story, have also produced some tensions within the Research Group and within the project. The selection of case study individuals is difficult. Should only the "success" stories be told or should also the less than ideal situations be documented and interpreted? Who gives permission to being revealed among peers as a teacher in need of assistance in a teacher preparation program, less than successful in implementing the project's reforms? What researcher desires to have colleagues unhappy with their depiction in a case study? How can the researchers resist the prevailing hope of the project leadership that this project will be successful? Insisting upon the use of pseudonyms for faculty to protect the confidentiality of them and their students strikes some as unnecessary, even counter to their goal of being recognized by their peers, yet needs to be done. These are some of the salient issues which must be expected to arise in research projects of this scope. Maintaining a vision of conducting oneself as an ethically bound professional researcher oftentimes is the only guidance one has in these matters, as insufficient as that may sound, or feel, in particular situations.

Quantitative.

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. A second assumption is that MCTP teacher candidates who take reformed undergraduate mathematics, science, and method classes that are informed by the constructivist epistemology (i.e., learners actively construct knowledge through interaction with their surroundings and experiences, and learners interpret these experiences based on prior knowledge) (see, for example, von Glasersfeld, 1987, 1990) develop more positive attitudes and beliefs toward mathematics and science and the teaching of those subjects. A third assumption is that throughout the MCTP teacher preparation programs the active collaboration among college faculty, public school personnel, and colleagues in work environments rich in mathematics and science will prepare the teacher candidates to successfully teach diverse students in an authentic manner.

To test these assumptions, the documentation of the MCTP teacher candidates' attitudes and beliefs toward and about the learning of and the teaching of mathematics and science throughout their undergraduate years was recognized as essential to perform. In addition, since a major component of the MCTP includes a commitment to infuse technology in the teaching and learning of mathematics and science, the documentation of how this is enacted on the college-level and how this influenced the teacher candidates' attitudes and beliefs also became crucial to report. The documentation system designed includes on-going teacher candidate interviews, classroom observations, and a regularly administered instrument in all MCTP classes to all students.

Therefore, the following research questions using quantitative methodologies are being investigated:

1. Is there a difference between the MCTP teacher candidates' and the non-MCTP teacher candidates' attitude toward:

(i) mathematics and science?

(ii) the interdisciplinary teaching and learning of mathematics and science?

(iii) the use of technology in teaching and learning mathematics and science?

2. Is there a difference between the MCTP teacher candidates' and the non-MCTP teacher candidates' beliefs toward:

(i) the nature of mathematics and science?

(ii) the interdisciplinary teaching and learning of mathematics and science?

(iii) the use of technology in teaching and learning mathematics and science?

Answers to these questions are particularly relevant to two domains of widespread interest in mathematics and science teacher preparation. The first domain is in documenting what attitudes and beliefs elementary/middle level teacher candidates typically hold throughout their undergraduate college programs toward the nature of and the learning/ teaching of subject matter. This information will enable those interested in mathematics and science teacher preparation to construct a more valid attitudinal and belief profile of a typical major. The second domain is in better understanding the effect of systemic effort throughout the entire undergraduate subject matter and pedagogy teacher preparation program to institute reforms advocated by current thinking in the mathematics and science professional societies. This information will enable those interested in mathematics and science teacher preparation to more accurately predict the consequences of enacting advocated reform practices.

Items for the instrument needed to measure constructs within the affective, belief, and epistemological areas to inform the research questions: attitudes toward and beliefs about mathematics and science, interdisciplinary teaching and learning of mathematics and science, and the use of technology to teach and learn mathematics and science. Sections of the instrument that were verified by Factor Analysis dealt with beliefs about mathematics and science; attitudes toward mathematics and science; beliefs about teaching mathematics and science; attitudes toward learning to teach mathematics and science; and attitudes toward teaching mathematics and science.

The instrument includes two groups of items. One group consists of thirty-two items that are to be answered by all students. The other group consists of nine items that are to be answered only by those intending to teach. The pre-planned sub-scales were verified on each group of items

separately, using principle-components factor-analysis, with varimax rotation. The reliability of each of the five sub-groups in the instrument was examined by Cronbach's alpha ($\underline{n}$ =486, α=.76). For each of the five groups, a variable X_i was defined as the mean of scores on items in the group.

Another factor that was further extracted from each of the five groups is linked to the classification of most items into pairs. Each pair included two corresponding items, one from the mathematics discipline, and the other from the science discipline. Paired items were then also examined for reliability.

The use of this research methodology, while initially viewed as a necessary yet unexciting area of research by members of the research team, is proving to be essential in painting a landscape scale picture of the attitudes and beliefs of college students in Maryland (both of teacher candidates and other majors) toward the disciplines of mathematics and science and the teaching of those disciplines. In addition, the instrument development was exhaustive and rigorous and offers both the mathematics and the science education research communities with a valid and reliable instrument that is available for use in differing contexts. The recommendation is to recruit associate members to the core research team who have the specialized expertise in questionnaire development and quantitative data analysis *early* in the research program. This is a structured research strategy with highly developed rules and procedures that requires expert attention to be successful and not excessively tax the energy of the research team.

Discourse.

Discourse as used in this study is defined as the dynamic interplay of dialogue between individuals that includes the use of rules developed by certain groups of people (Gee, 1990). The focus on discourse in this study is the result of recent theoretical views that stress the importance of the context in which members of a community communicate (Greeno, 1991; Rogoff, 1990; Roth & Tobin, 1996). Conversations, or `talk,' is recognized as a particularly revealing resource in analyzing social interactions for patterns of sense-making in a community (Lemke, 1990; McCarthy, 1994).

In the MCTP, the large speech community consisted of college faculty members who taught revised mathematics and science undergraduate content classes at universities, colleges, and community colleges in Maryland. Mathematics and science content expertise and an expressed interest in reforming content classes for MCTP teacher candidates defined the criteria membership in the teaching faculty speech community. Sharing ideas on the role of mathematics and science in MCTP undergraduate content was a consensus conversation referent. In each of these speech, or discourse communities there were two groups: discipline content experts (termed 'mathematician or science content specialists' by the conversants in this study's speech community) and pedagogy content experts (termed 'mathematics or science methods specialists' by the conversants in this study's speech community) (see, McGinnis & Watanabe, 1996).

The use of this emergent research methodology has assisted the researchers in conceptualizing the components of the community which defines the MCTP. It is used to two-dimensionally represent the discourse landscape college mathematics and science teachers inhabit when the referent in their thinking is science and mathematics, two disciplines the MCTP project hopes to connect. The assumption is that this form of analysis will particularly assist in understanding the college teaching faculty's beliefs and actions taken in designing and teaching undergraduate teacher preparatory science classes in which connections between mathematics and science is a major goal. A similar analysis is currently being conducted focusing on the college student participants. Research in teacher beliefs and actions have been a major focus of teacher education research since Clark and Peterson (1986) and Munby (1986) alerted the research community to its importance in understanding teaching practice. Researchers should be prepared, however, upon sharing a discourse interpretation with the participants as a member check strategy to elicit much discussion from individuals within the discourse communities, some of it in disagreement with statements made by other individual members in the discourse communities. These reactions should be included in the discourse analysis.

Conclusion

This paper presents compelling evidence that the MCTP Research Group has been active in carrying out a much needed research program in a NSF funded mathematics and science teacher education education. While conducting research within the MCTP project, the researchers have oftentimes collaborated with individuals representing other NSF Collaboratives and funded teacher enhancement projects. Surprisingly, the MCTP is distinguished among its peer NSF projects in its organizational chart by including an internal Research Group and by budgeting ongoing financial support for its operation. This ongoing funding, no more than 5% of the entire project's funding, has enabled this project to develop a research program that is actively contributing to the knowledge base on teacher education in mathematics and science. The research products from the Research Group will serve as one of the lasting legacies of the MCTP. This strongly suggests that the MCTP's model of a NSF funded project supporting research within itself is a viable model that calls for replication throughout the NSF, particularly in critical areas such as mathematics and science teacher preparation projects.

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