Exploring the Effects of Teacher Research Experiences (RET's) on Classroom Inquiry

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Rationale and Related Research

It is argued that scientific inquiry should be a central principle of science curricula (25) as well as a central strategy for science teaching and learning (32). Low levels of scientific knowledge, poorly taught science courses, few women and minorities participating in science, and too few citizens prepared to use scientific knowledge in decision-making provides the impetus for this focus (2,17,32). The argument further holds that teaching science through inquiry will lead to increased motivation (students would enjoy *doing* science more than being *told* scientific facts) and increased science learning (28,29). It has been widely assumed that, with sufficient professional development and materials, classroom teachers can implement this approach in public school classrooms (1). As a result, considerable resources and efforts have been expended to develop inquiry-based science curricula and assist teachers in implementing it.

The focus on teachers as central to bringing reform-based practice into the classroom has intensified in recent years (3,20,40). Indeed, in *Inquiry and the National Science Education Standards*, a critical follow-up analysis of inquiry in the *Standards*, the National Research Council (NRC) states "For students to understand inquiry and learn to use it in science, their teachers need to be well-versed in inquiry and inquiry-based methods." (33, p. 87). It is thought that teachers need to experience all steps of scientific inquiry *and* to concurrently develop an understanding of what those steps are and how they can be taught (11). One of the most prominent vehicles for addressing both these needs has been the NSF Research Experiences for Teachers (RET) programs. But, although considerable resources have been expended in providing RET's, there is scant research investigating the effectiveness of such programs in terms of teacher knowledge, teaching practices, or subsequent student learning (6). This omission is a serious one. Sustained, systematic educational research into the RET professional development process is critical.

Science education reforms, such as the introduction of inquiry into the classroom, represent second order educational changes (12,13). Although first order changes require small alterations of existing practices, second order changes challenge the structures and rules of schooling. Research on second order change has shown that, despite best efforts, most reforms are "either adapted to fit what existed or sloughed off, allowing the system to remain essentially untouched" (12, p. 343). RET's seem to hold the most promise for supporting second order changes as represented by inquiry; however, given the difficulty in achieving and sustaining second order changes, the need for research into their influence is clear. This research project will focus on analyzing RET programs through description of their essential features, their efficacy in fostering teachers' understanding and enactment of inquiry, their interaction with the personal characteristics of participating teachers, and an examination of the influence of teaching through inquiry on student learning in science.

Florida State University (FSU) finds itself well positioned to conduct such systemic research in a rigorous, controlled fashion *within one institution*. Two completely separate groups at FSU have developed two distinct RET models and each has at least six years of experience implementing its program. The Center for Integrating Research and Learning (CIRL) at the National High Magnetic Field Laboratory (NHMFL) at FSU developed a traditional-format RET program in which teachers are placed in individual NHMFL faculty laboratories to participate in on-going, authentic research projects. The teachers also come together daily for round-table discussions and activities focused on pedagogical issues. The CIRL RET model closely resembles the structure of many RET's nationwide. In contrast, the Office of Science Teaching Activities (OSTA) in the College of Arts and Sciences at FSU employs a very different RET model, in which two scientists and two master teachers devote *full-time* to a group of teacher participants, engaging them in scientific research of each individual teacher's *own* devising. Concurrent with this research is "inquiry on the process of inquiry." The concept in the latter format is for each teacher to engage in a concurrent pedagogical research project on the essential features of inquiry and what they mean in terms of classroom teaching. Throughout this pedagogical research project teachers are assisted in reflecting on the structure of their own, ongoing science research experience in an effort to allow them to develop a deep pedagogical content knowledge about scientific inquiry.

These two separate models, the CIRL and the OSTA, present an ideal research context for analyzing the questions posed by the NRC: "What do teachers need to know and be able to do to use inquiry effectively? What kinds of professional development can help prospective and practicing teachers both develop and use inquiry effectively?" (33, p. 87).

A third, separate unit at FSU, the Science Education Program in the College of Education, has *not* participated in the development of either of these programs, though two of their students have completed some preliminary research on the OSTA RET model as a part of their MS and PhD research. Dr. Sherry Southerland from the Science Education Program has expertise in teacher change research and the requirements of second order change in schooling. She is also currently directing research into how science learning is influenced by inquiry teaching and editing a text on inquiry in science teaching. Thus, she is ideally suited to direct research that answers NRC's call (33).

The existence of three, separate units at one institution, each embedded in separate, in-depth work on teacher inquiry and pedagogical change, presents a perfect opportunity for rigorous, controlled, yet *economically* feasible, research to be conducted. By this we suggest that the research required to answer NRC's questions requires intensive study and such study will be much more thorough and cost effective if the unit responsible for the research is located near the RET sites themselves. The RET models we propose to study present a unique examination of the process of science inquiry described in current calls for science-education reform as they have incorporated many of the features that the research literature indicates as essential for successful teacher professional development. Namely, they include immersion in inquiry, they are intensive

(6-weeks, full-time with classroom follow up), they seek to engage teachers in concrete teaching tasks, and they seek to deepen teachers' content knowledge (e.g., 11,45).

The Teacher-Centered Systemic Reform Model (TCSR) will guide much of the research (20,47). This model is important for our efforts as it simultaneously recognizes the influence and interaction of the teaching context, teacher characteristics, and teacher thinking as means to understand attempts to implement second-order reform. This theoretical frame will guide our efforts to describe teachers' understanding of inquiry-based pedagogy after their RET's, the manner in which they enact this pedagogical approach, as well as focus on the factors that shape their long-term usage of this reform-based approach to teaching science, and ultimately its effects on student learning.

RET Models to be Examined

FSU has a long history of sustained partnerships with the K-12 science teaching community. In 1983, the College of Arts and Sciences established OSTA in response to the publication of *A Nation At Risk (31)*. The mission of OSTA is to provide sustained support for science teaching and learning partnerships throughout the K-12 and University educational systems. By connecting partners with effective strategies, practices, and resources, OSTA seeks to foster and maintain their active engagement in high-quality science instruction. In 1992, the NHMFL was moved to FSU; the NHMFL established CIRL as its educational outreach arm. The mission of CIRL is to expand scientific literacy and to encourage interest in and pursuit of scientific studies among educators and students of all ages. Each of these two entities within FSU have designed and administered their own RET model. The existence of these two contrasting models is one of the strengths of this proposal as it enables a comparison and contrast of the professional development approaches of each model in order to tease apart the essential features of successful RET's and their effects on change in teachers' conceptions of inquiry, teaching practice, and student learning.

CIRL RET Programs Description: Since 1999, the CIRL has provided authentic science research experiences for 102 elementary-, middle-, and high-school teachers through their residential program. Funded by NSF (supplement to DMR-0084173), this RET program has attracted teachers from 8 states. Over the 7 years of the program, 56 scientists and researchers have served as mentors and many graduate and post doctoral students have contributed to the mentorships. For many teachers this is a first experience in a real-world science laboratory and the rigors of authentic science research is both daunting and exhilarating. The clear emphasis of the CIRL RET program is participation in authentic, engaging scientific research; the translation of this experience into teachers' practice remains a challenge that is largely the responsibility of the teachers. The staff of CIRL are part of a national network of RET programs and attend annual meetings and workshops to explore best practices.

The CIRL program has evolved over its lifetime to include structured elements designed to provide new strategies for teaching, to develop a network of colleagues, to assist teachers to articulate how the experience changed their views of science, and to promote classroom inquiry. One feature of the program is that all teachers are placed in one facility, the NHMFL. This facilitates daily, 2-hour sessions in which all participants and staff meet for content-rich science lectures and sessions focused on pedagogical issues. Thus, a typical day consists of 6 hours in the laboratory and 2 hours in one of the following activities: seminar (shared with NHMFL Research Experiences for Undergraduates--REU), colloquium (shared with REU), workshop-type sessions, strategy sharing, and peer mentoring. Sample topics conducted in theseactivities include incorporating reading and writing in science, Socratic seminars and other strategies addressing issues in teaching science, infusing technology in the science classroom, presentation skills for teachers and students, and visiting local informal science education sites.

Although interpreting the research experience in pedagogical terms is a focus of the CIRL program, it is important to recognize that like most RET's around the nation, the research experience itself takes priority over all other activities. Clearly, having teachers participate in authentic, on-going scientific research is the primary goal for the program, and because there is such a wide variety of research conducted at the NHMFL, teachers are exposed to diverse research areas. Research at the NHMFL spans all disciplines of science–biology, chemistry, physics, medicine, earth science–and, while teachers work in only one lab, they are exposed to research from all areas of the laboratory. Due to this diversity of research, the daily group sessions provide a needed way to maintain a sense of cohesion to the participants' experiences. A full reporting of all years can be found at http://ret.magnet.fsu.edu.

Recognizing that there is scant published research on how RETs effect teachers once they return to their classrooms, as well as on the effect on students in classes taught by teachers who have participated in RETs, CIRL established a research agenda. Qualitative data collected yearly for program evaluation purposes indicates that the program is largely successful: there is clear evidence that teachers leaving the program intend to incorporate content strategies from the experience in their own teaching. Too, they leave the program with an increased understanding of the nature of science and motivation for including discussion of real-world science in their classrooms. The CIRL staff also has collected data on students' attitudes toward science. In this research, elementary-, middle-, and high-school students in classes taught by CIRL RET teachers were compared to students with non-RET teachers. Results indicate a statistically significant difference in attitude between students taught by the two types of teachers and the results were linked to RET teachers' program experiences (15).

The latest research into the CIRL experience began in Spring 2005 and focuses on 4 case studies of the nature of change in elementary teachers' thinking and instruction as a result of the CIRL RET. Data from classroom observations and interviews were collected before the 2005 summer research experience and post program collection is ongoing. Document analysis is also being conducted on materials collected during the summer program. Specific changes to thinking and instruction that resulted from the research experience and how such changes differ between beginning and experienced elementary teachers will be identified (14).

OSTA RET Program: Over the past 6 years, over 120 elementary-, middle-, and high-school teachers have participated in the OSTA RET program. The OSTA professional development team designed this RET to facilitate teachers' understanding about inquiry both as a method for scientific research *and* as a strategy for teaching science. The resulting methodology, developed with funding from the NSF (ESI-9819431), engages teachers in scientific research *and* a concurrent in-depth study of what this means for their teaching practice. Through emphasis on this intersection of knowledge about doing science and knowledge about teaching science, teachers are supported in developing the necessary pedagogical content knowledge for teaching through inquiry (19,39). This RET design was mindful of the research that suggests that research experience offered in tandem with reflection on the teaching of inquiry is essential for teachers to internalize aspects of inquiry (11).

In the OSTA model, two scientists and two master teachers are involved *full-time* for the 6-weeks working alongside the group of teachers in all aspects of science research and pedagogy sessions. One of the premises underpinning the science research portion of this model is that teachers need to experience *all* stages of scientific inquiry including the original observation of a scientific phenomenon; development of their own research questions and hypotheses about it; development of the research methodology to test their hypotheses; the research process itself; data organization and analysis; and reporting of results. This differs from the traditional RET model, and that employed by the CIRL RET, in which a teacher joins a research project already in progress in the laboratory of a scientist. Specifically, the OSTA RET provides teachers with experience in making original observations on marine organisms, a setting that effectively and nearly universally arouses their curiosity. They perform short-term research in ecology and ethology, research that does not require extensive expertise on their part or complicated instrumentation. Structured inquiry, facilitated by program staff of scientists and master teachers, begins with the teachers' observations, extends through hypothesis development and testing, data analysis, interpretation, and reporting of results. The scientists guide but do not prescribe the research process, so each individual makes full intellectual investment in the discovery of new knowledge. The model is based on the premise that this complete participation in the performance of science as a "way of knowing" is very effective in instilling in the participants a working understanding of how science can be done by *anyone* at *any level* of prior knowledge. It is argued that teachers' confidence as scientists will increase and with it the desire and capacity to transmit the inquiry process to their students.

Concurrent with the science research, teachers engage in reflection upon the pedagogical features of their research experience using a hermeneutic dialectic (discussion/journal writing/written instructor responses/discussion/journal clarification/written instructor responses) process (23). The series of reflective journaling sessions was "designed to facilitate conceptual change learning about inquiry and to support participants [teachers] in the process of constructing meaning of their experiences in inquiry, both as a method for research and as a strategy for teaching science. Systematically addressed through explicit and context-based science instruction, the details contained in the teachers' journals represent a stage-by-stage descriptive account of their individual constructions of the pedagogical features of inquiry as a product of a systematic analysis of their own experiences in scientific research." (16). The two master teachers primarily support this reflective process of analyzing the *research as teaching*. OSTA developed this bifurcated yet intermingled process because in early iterations of the program that employed traditional "translation-to-practice" methodology, the quality of the teachers' scientific research was exemplary, yet their translation of inquiry to classroom practice was lacking (16). (This finding that teachers can gain useful science inquiry experience without a concomitant gain in knowledge of teaching through inquiry, has important implications for many current RET projects.) Thus, the program was redesigned to make explicit how full engagement in authentic scientific research also represents an exemplary model of inquiry-based teaching. The use of the hermeneutic dialectic process as a vehicle for teachers to *actively* "extend their own inquiries to the implications for their teaching" was developed through 6 years of program formative evaluation and refinement (33, p. 101). As constructed now, offerings of the OSTA RET engage teachers in an *inquiry* on *inquiry-based instruction* that is concurrent with and draws upon what they are doing in their scientific research. Ongoing research into the program evaluation shows this bifurcated approach is a promising model for helping develop understandings of both the scientific research process and its implications for design of classroom inquiry lessons (6,16).

In the OSTA model participants simultaneously experience discovery *personally* and come to understand the nature of scientific inquiry that makes it possible--from start to finish. This fundamental focus differs from that of programs involving apprenticeships in on-going, often methodologically sophisticated faculty research. In contrast, more traditional RET programs are valuable because they effectively convey the character of the contemporary research enterprise and state of knowledge in a discipline, but the participant becomes temporarily engaged in activities based on questions and procedures that they have no intellectual role in formulating and usually no role in completing.

Comparing the Programs: The two very different RET programs are of similar length (6 weeks), both have been honed through years of previous offerings, and both have shown promise of effectiveness for teachers from grades K-12 in the limited research that has been conducted on them. Yet each is constructed around very different premises. CIRL places engagement in on-going, , authentic scientific research as the central agent of change in teachers. A central question of the research is to investigate the relative effectiveness of both of these programs.

Goals and Projected Outcomes

As indicated above, this project is guided by the questions posed by the NRC: What do teachers need to know and be able to do to use inquiry effectively? What kinds of professional development can help prospective and practicing teachers both develop and use inquiry effectively? (33). Thus, our goals are to generate a deeper, more generalizable knowledge of the necessary features of RET's and their influence on teachers' knowledge and practices, on the personal characteristics that optimize teacher learning from RET's, and to describe how inquiry practices as employed through RET teachers shape student learning. Past research findings suggest that RET's are as influential for elementary- as for secondary-school teachers, so the target population will be K-12 (16). Further, to examine the interaction of the RET experience with teacher career development, our target population will include teachers at the preservice, induction, mid-career, and leadership stages of their careers (44). It is anticipated that findings will be useful for informing RET's about optimal program structure, participant selection, and teacher learning experiences needed to maximize the role of inquiry in classroom teaching.

Research Questions and Hypotheses

To study the areas that both enable and constrain teachers' understanding, application, and consistent use of inquiry-based teaching approaches presented in RET's, this project will study teachers before, during, and after their RET experiences as well as the students in these teachers' classrooms. Using a research-based model of reform (TCSR, see Related Research above) to understand the translation of teachers' experiences in RET's into their teaching practice, this research will have four areas of focus (47).

- First, what are the essential features of RET's? That is, what features (e.g., participation in authentic science research, the pedagogical approach employed to facilitate inquiry, support after the program) best optimize teacher learning about and enactment of inquiry?
- Second, what influence do RET's have on teachers' understandings and their practices? That is, do teachers find research experiences in both models to be intelligible in terms of classroom inquiry (i.e., Do they find it understandable? Can they recognize it?) (e.g., 16,36)? What factors in each model are most important in shaping teachers' understanding of inquiry (e.g., 3,18)? Of these factors, which can be mediated through program instruction? What factors are most important in shaping teachers' consistent enactment of inquiry (i.e., investment in the research question, sustained follow-up, reflective journals, contextual influences)? Of these factors, which can be mediated through program design?
- Third, how do RET's interact with the personal characteristics of participating teachers (20)? Is there a stage of teacher development in which an RET is more (or less) effective (44)? Does participation in either or both models enhance job satisfaction and thus retention of preservice or induction-period teachers? Are teachers with a high degree of pedagogical discontentment and high degree of science teaching efficacy more likely than others to develop an understanding of inquiry teaching (43,37)? Are these same teachers more likely to employ inquiry in their classrooms?
- Fourth, what influence does the mode of inquiry instruction supported by RET's have on student learning [broadly conceived to include both conceptual and affective gains (46)]? Does teaching through inquiry allow for more robust learning of science than traditional approaches? Does inquiry help improve students' interest in science (21)? Are some groups of students more successful in learning through inquiry? [Prior research suggests that students from non-mainstream cultures experience difficulties learning through inquiry (26,27,42).]

The answers to these questions will allow teacher professional developers to make better decisions regarding the necessary structure and follow-up for RET programs, will allow for more informed participant selection, and inform the degree to which contextual factors need to be addressed to support inquiry. Other findings of this research promise to inform science teachers as to the efficacy of using inquiry to support student learning of science. The findings promise to enhance teacher learning experiences, teacher knowledge, and the learning experiences of students in their classrooms.

Work Plan and Research Design

The project will recruit and study five cohorts of at least 24 teachers as they participate in one of two RET models, OSTA or CIRL. (Although separate funding will be sought to support an increase in the size of the teacher cohorts through the affected discipline directorates at the NSF, the number selected [24] for support herein was seen as the minimum necessary to complete the project.) Teacher participants will be sought via advertisements on the NSTA website and in NSTA Reports, through promotion at regional and national teacher meetings, conferences, and workshops, and notices sent to state science supervisors in all states. Preservice teachers will be from the Arts and Sciences Masters in Science Teaching program and will meet their science research requirement through this program. (Note: No NSF funds will be expended for support of these students.) Educational research on these programs will be conducted under the direction of the Science Education Program faculty and carried out through graduate students and postdoctoral researchers in that program. OSTA with its clerical and professional staff will manage any general administrative details for the program.

Details of the Research Design. The research (to be conducted by the Science Education faculty) will employ a mixed methodology, emphasizing quantitative measures for the description of teachers' backgrounds and personal characteristics, contextual features of schools, and student learning and qualitative methods for program descriptions and descriptions of teachers' enactment of inquiry. The research design is summarized in Table 1. (Unless otherwised noted, all research instruments and data sources are described in the referenced literature.)

Timetable Summary (for each of five cohorts)

January: Recruit teacher participants, participant assignment into a program
February-May: Collect pre-program data from teachers and their classrooms
June-July: Conduct RET science research and pedagogy experiences for teachers
August-May: Collect post-program data from teachers and their classrooms.

Follow-up sessions for teachers in follow-up cohort of the experimental design. Engage in data analysis. (Begin new cohort cycle overlapping this work in January.)

Table 1. Overview of the Constructs to be Studied, Instrumentation and Data Analysis

Research Focus	Time Period	Construct to be Measured	Instrument/Data Source	Analysis Technique
1	pre summer program	Features of RET program	Artifact analysis; interviews with developers	Thematic analysis (Patton, 2002)
1	during summer program	Features of RET program	Participant observation in 6 week sessions.	Thematic analysis (Patton, 2002)

1, 2, 3	pre and post summer program, yearly post program	Teachers' conceptions of and practices of inquiry	Teacher submission of inquiry based lesson plan and video of enactment (Blanchard, 2005; Dutrow, 2005)	*STIR* Science Teacher Inquiry Rubric *(*Beerer & Bodzin, 2003)
1, 2, 3	end of summer program	Teachers' conceptions of inquiry	Teacher constructed *Inquiry Templates* (Dutrow, 2005)	Quantitative comparison to template drawn from practicing scientist (Dutrow, 2005)
1, 2, 3	post summer program and year post program	Teachers' long term practices of inquiry	Interview and artifact analysis of unit plans	Thematic analysis (Patton, 2002)
2	pre and yearly post program	Contextual support for an barriers to enactment of inquiry	*Surveys of Enacted Curriculum* (K-8 and Highschool) (Wisconsin Center for Education Research (2003)	Quantitative comparison of responses
2	pre and yearly post program	Contextual support for an barriers to enactment of inquiry	Interviews about barriers to inquiry (Gess-Newsome et al., 2003)	Analysis directed by *Teacher Centered Systemic Reform model*(Woodbury & Gess-Newsome, 20020
3	pre and yearly post program	Pedagogical discontentment	*Pedagogical Discontenment Measure* (Sowell et al, in review)	Quantitative comparison of responses
3	pre and yearly post program	Science teaching self-efficacy	*Science Teaching Efficacy Belief Instrument (*Riggs & Enochs, 1990	Quantitative comparison of responses
3	yearly post program	Teacher retention	Science teacher retention data from appropriate school districts	Quantitative comparison of retention of RET participants and their colleagues

4	post program years 4 & 5 only, during unit of instruction	Degree of inquiry employed in teaching unit	Participant observations during experimental unit	*STIR* Science Teacher Inquiry Rubric *(*Beerer & Bodzin, 2003)
4	post program years 4 & 5 only, pre and post unit of instruction	Degree of student learning	Valid and reliable content measure appropriate to target science content. 4 measures for each of the different units	Quantitative comparison of student learning across inquiry and traditional classrooms

Sampling. All of the participants in both RET programs will be invited to participate in the study. The sample will include at least 24 teachers/year, for a total of at least app. 120 teachers, distributed between preservice/induction period/mid-career/leadership stage teachers (44). Half of each of these groups will have little follow-up contact with program except that required to collect post-program data; the other half of each group will have follow-up with program staff, with bi-monthly visits to classes and meetings of the program group spread through the following year. Given prior research from both programs that points to their effectiveness for elementary-school teachers (14,16), the sample will include teachers K-12. Given the practical rigors of both programs (6-week, summer commitment), it must be recognized that teachers that choose to participate may have a commitment to enhancing their teaching, thus biasing the sample. Nevertheless, this self-selection is a feature common to all RET programs. To strengthen the comparison of the two RET's, participant selection will target a closely paired sample across the two programs to maximize similarity between groups of teachers in each (e.g., grade level taught, years of experience, content expertise, personal demographics).

In order to investigate the role of post program support, half of the teachers from each RET group will experience little follow-up contact except that required to collect post-program data. The other half of each group will have follow-up support by program staff, with bi-monthly visits to classes and three real-time virtual meetings with the entire follow-up group spread throughout the following year.

Details of the Research Questions.

Research Focus 1, Essential Features of Effective RET's. For this research focus it will be necessary to understand and faithfully describe both RET's and to document their relative effectiveness. Based on related science education literature and historical knowledge developed in each program, it is relatively easy to describe what those essential features *might* be:

1 CIRL RET—participation in authentic, on-going, research that is conceptually and technologically rigorous, emphasis on developing content knowledge, a more limited

emphasis on teaching strategies.

2 OSTA RET—participation in research pursuing one's own questions supported through staff scientists, rigorous reflective analysis of pedagogical approach employed in the RET, personal generation of essential features of an inquiry lesson. And, as is also suggested by research conducted in the OSTA RET (6):

3 Post-program support.

It is important to systematically describe and document the activities associated with these programs, necessitating participant observation and artifact analysis. Too, these descriptions must be partnered with a comparison of the relative influence of both RET's in shaping teachers' understandings of classroom inquiry and their ability to enact classroom inquiry. The data that will be collected to address research focus 1 are detailed in Table 1. The characterizations from this "thick description" of each program will be paired with a broad assessment of the relative impact of each, looking across teachers' abilities to find the essential features of inquiry as intelligible, their abilities to plan lessons employing these features, and their abilities to enact these features in classrooms (16,36). Thus, the degree to which teachers in each RET understand and enact inquiry will be documented in this portion of the research through largely quantitative comparisons of scores on the inquiry template rubrics and scores on the STIR protocol in examining instances of their inquiry lesson plans. This combination of program descriptions with analyses of their relative effectiveness in catalyzing teacher understanding of inquiry will generate understandings of the essential features of RET's.

Research Focus 2, Influence of RET's on Teachers' Conceptions and Enactment of Inquiry. The goal of this focus is to generate a fine-grained understanding of change in teachers' conceptions of classroom inquiry, their abilities to enact classroom inquiry, and their inclinations to do so. For such a description, many of the same data sources will be employed as employed in the first aspect of the research; but a more detailed description of change in each teachers' conceptions and practices will be undertaken, more akin to that found in teacher education and conceptual change literatures (41,40). Data from each individual will be analyzed and compared with RET experiences, follow-up (or lack thereof), and teaching context. The questions for this focus are:

•Do teachers find research experiences in both models to be intelligible (36) in terms of inquiry-based pedagogy in the classroom? We hypothesize that they will to a limited degree after the initial program, but that this will increase for some over time with classroom enactment. For this question we will analyze data from individuals on their inquiry templates and inquiry lesson plans to document degree to which their intelligibility varies

•What *factors* are most important in shaping the degree to which teachers find the research experiences intelligible in terms of classroom inquiry (i.e., investment in the research question, sustained follow-up, reflective journals)? Given the breadth of this question, this aspect of the investigation must be more exploratory. Briefly, we hypothesize that teachers experiencing more structured reflection and focus on the pedagogical features of inquiry, both during and post program, and teachers who were personally invested in the research question will experience greater increases in intelligibility. For this question we will analyze teachers' responses to an inquiry template completed during the program and associated scoring system developed by Dutrow (16) and compare these results to their interview comments and document analyses.

- What factors are most important in shaping teachers' consistent enactment of inquiry (i.e., to what degree do they find *classroom* inquiry intelligible? To what degree are they familiar with national reforms and learning theory? What are the salient contextual variables: class size? administrative support? number of colleagues using inquiry? degree of expertise in content? influence of standardized assessments?)? Given the breadth of this question, this aspect will be more exploratory. Teacher enactment data focusing on classroom inquiry practices (observations analyzed with *STIR*) will be meshed with themes arising from teacher enactment interviews and *Surveys of Enacted Curriculum (10).* These data will be analyzed using the TCSR model (47).

Research Focus 3, Interaction of RET's with Personal Characteristics of Teachers. The goal of this focus is to generate a fine-grained understanding of the interaction between the RET experience and the personal characteristics of the teacher, recognizing that these characteristics will influence what is learned from the RET and the RET experience itself may shape some of those same characteristics. The questions for this focus are:

- Is there a stage of teacher development in which an RET is more effective? We hypothesize that there will be more change seen in those teachers who are in their maturationand leadership stages (44) and less change for teachers who are novices or in their induction periods. For this question, we will group teachers into stages of professional development and compare the intelligibility and enactment data across them.
- Does participation in either or both models enhance job satisfaction and thus retention of preservice or induction-period teachers? We hypothesize that job satisfaction and retention rate will be greater for teachers who both find inquiry intelligible and are successful in consistently enacting it in their classrooms than in similar groups who either were not in the RET experience, fail to find it intelligible, or fail to consistently enact it in their classrooms. For this will we compare job satisfaction of three groups of teachers: those from the RET's who find inquiry intelligible and consistently enact it, those from the RET's who do not find inquiry intelligible and do not consistently enact it, and those from a matched group of non-RET teachers.
- Are teachers with a high degree of pedagogical discontentment and high degree of science teaching efficacy more likely than others to develop an understanding of inquiry teaching (37,43)? Are these individuals more likely to employ such practices in their classrooms? We hypothesize that teachers with a high degree of science teaching self-efficacy and a high degree of pedagogical discontentment will be more successful in finding inquiry intelligible and successfully enacting it in their classrooms. For this we will compare the degree to which inquiry is found to be intelligible across 4 groups of RET teachers: high pedagogical discontentment/high teaching self-efficacy, high pedagogical discontentment/low teaching self-efficacy, low pedagogical discontentment/high teaching self-efficacy, low pedagogical discontentment/low teaching self-efficacy.

Research Focus 4: Student Learning Through Inquiry. Beginning in year 4, the research will broaden to include a focus on generating an understanding of the influence of inquiry on student learning. Studies on inquiry-based learning that focus on student achievement have been few. Leonard (28) and Marx et al. (29) show that inquiry instruction in the classroom can be an effective vehicle for supporting student learning. Although these studies are important, the Leonard study was conducted in a university setting and the Marx et al. study, while quite comprehensive, encompassed only the middle grades. Clearly, further research documenting the relative effectiveness of inquiry instruction in comparison to more traditional, didactic approaches to student learning is required. Thus, research questions for this focus are:

- Is inquiry versus traditional instruction more effective in supporting student learning? Our hypothesis is that students experiencing an inquiry unit will have stronger, long terms conceptual gains in the content than students in traditional classrooms.
- Is inquiry versus traditional instruction more effective in fostering positive student opinions of science? Our hypothesis is that students experiencing inquiry instruction will have more positive opinions of science than students in traditional classrooms.
- Does the difference between inquiry and traditional instruction differ by grade levels? The literature is less clear here, but we hypothesize that inquiry may be found to be more effective in supporting the learning of students in the lower grade levels.
- Does learning following inquiry and traditional instruction differ across student demographics (including both SES and ethnicity)? Based on Lee's work (26,27), we hypothesize that inquiry will be less effective in supporting student learning for low SES students and non-mainstream students.

The research proposed here draws heavily in structure from a similar project currently underway in the FSU Science Education program (7). Teachers involved in either of the RET's in years 1-3 who have been found to be effective in enacting classroom inquiry will be selected for participation in this portion of the research. Ideally, learning outcomes should not be assessed until at least 1 year after the teacher has gained experience employing inquiry in the classroom (24). It is hoped that a minimum of 16 such teachers will be identified through the first 3 years of research. Those teachers will be paired with non-RET teachers at their school sites, so that each pair of teachers (RET and non-RET) teaches similar class content and serves similar student demographics. Within these 16 pairs of teachers, the RET teachers will be asked to teach a unit that employs classroom inquiry as a central teaching strategy and the non-RET teachers will be asked to teach a similar unit that employs more deductive, didactic teaching strategies. Given that our teacher sample will be drawn from teachers who work in grades K-12, it will be necessary to design 4 different sets of units including one for K-3, 4-6, 7-9, and 10-12.

The independent variable for this research is the method of instruction. In the experimental group (inquiry-based), the form of inquiry to be employed in the unit is Schwab's level 3 (open-ended inquiry) and level 2 (guided inquiry), or as close to these levels as is allowed by the skills and sophistication of the students (38). The control group will experience a traditional, prescriptive, laboratory-based unit in which students are given an investigation with background material, a pre-set question, a set of directions, and the materials for the lab. The inquiry-based and traditional units will be the similar in terms of the content covered, the amount of time spent on the unit, the standards met, the materials used, and that laboratory investigations are employed. The only difference will be the pedagogy employed.

A first dependent variable will be content knowledge of the students. Pre/post tests appropriate for each of the four grade groupings will be developed and field tested prior to the teaching of the units by teachers. Content validity for questions related to each of the constructs will be assured via review by a panel of experts and by drawing from extant instruments in the literature. Field-test groups will participate in one of the units, including pre and post tests. Based on the results of the pilot administration, items will be evaluated and revised. An exploration of split-half reliability and measures of internal consistency among test items will be part of this revision. At this stage, length of the test will also be addressed in terms of instrument reliability (30).

Classroom inquiry is thought to foster meaningful learning, and such learning should retained by the student long after instruction. Therefore, both short- and long-term retention of the learning will be measured by administering the post test both immediately following the unit and much later after a set period of time.

A second dependent variable of learning through inquiry will be attitudinal. It has been suggested that middle-school students' science interests are enhanced after a long-term exposure to inquiry instruction (21). Thus, attitudes of students toward science will be compared across groups of students from traditional classrooms and groups of students in classrooms whose teachers (from both RET programs) have who have been found to consistently enact classroom inquiry. Student science opinions will be measured using the *Science Opinion Survey* (34). Like the content measures, the opinion survey will be administered pre, post and delayed-post instruction.

Data from Focus 4 will be analyzed using a hierarchical model such as HLM (8), with the teaching approach (traditional versus inquiry-based) as the key variable. Other independent variables (e.g., teacher, class, school, grade level, and school district) also will be included.

Important Milestones

The research to be conducted has as its primary goal to inform the wider educational community. That said, if the data are unequivocal about some aspects of the findings, the research ideally should be employed to inform the redesign of the programs. This decision must be carefully considered by the leadership team, recognizing that such changes limit the sample of the broader study, but could also contribute significantly to it. Milestones include:

Years	
2	Presentations at NARST and/or ASTE
3	Presentations at NARST and/or ASTE; Project review to determine if subsequent RET years should be restructured
4	*JRST*/*Science Ed* submissions; Presentations at NSTA and/or AERA
5	*JRST/Science Ed* submissions; Presentations at NSTA, NARST, ASTE, and/or AERA.

Key Personnel

FSU is uniquely positioned for such a project through its sustained experience supporting K-12 science through OSTA (College of Arts and Sciences), through CIRL (NHMFL), and the Science Education program (College of Education).

Since its inception in 1983, OSTA has served as a catalyst and provided support for science outreach partnerships between the university and K-12 students and teachers (22). Intellectual and financial support of the office not only has been maintained but has grown steadily over the 22 years since then. Currently OSTA has full, *permanent* support for six faculty members and 1.5 office staff members, eight programs for K-12 students, four professional-development programs for K-12 teachers, one program for undergraduate students, and one for graduate students, as well as grant support for several additional programs. Their work includes years of reform-based teacher professional development.

The CIRL was established in 1998 at the NHMFL at FSU, formalizing the educational outreach of the laboratory. CIRL has administered the NHMFL Research Experiences for Undergraduates program and has a robust educational outreach program with ties to teachers throughout Florida. CIRL has conducted teacher workshops in 7 states for dissemination of curriculum products created at the NHMFL (now in use in over 20 states). Most notably for the current proposal, in 1999, CIRL received funding from the NSF to conduct a Research Experiences for Teachers (RET) program, now in its eighth year.

The Science Education Program is in the College of Education, Department of Middle and Secondary Instruction. The program offers bachelors, masters, specialists, and doctoral degrees in science education, and has over 20 active doctoral students. It is currently the site of funded research into the role of pedagogical discontentment in shaping teachers' responses to reform, in the role of inquiry in shaping student learning, and a series of studies devoted to investigating the conceptual development of teachers involved in RET's.

These well-established Florida State programs bring a wealth of expertise and experience to the proposed research project providing quality professional development for its teacher participants and research into the RET professional development process. Dr. Ellen Granger, Director of OSTA, Dr. Patricia Dixon, Director of CIRL, and Dr. Sherry Southerland of the Science Education Program will form the leadership of the grant. Dr. William Herrnkind, a renowned scientist and co-PI and lead scientist from the OSTA project, will join them on the project leadership team. The final members of the leadership team will be two master teachers: one will be recruited and hired as the full-time project coordinator, and the other will be hired to work full-time during the summer experiences, but will continue employment in the public school system during the academic year.

Dr. Southerland, who is co-editing an upcoming text focusing on classroom inquiry, is an Associate Professor in the Science Education Program. She will take the lead on directing and conducting the research on the RET programs. Although one of her students was involved in assessing the impact of these programs in the past, she was not directly involved in developing or delivering either of these RET programs. Dr. Southerland has published over 23 research articles and chapters, co-edited a special issue of *Journal of Research in Science Teaching*, and has been involved in 9 local and national grants to sponsor science education research and professional development experiences for teachers. Currently, Dr. Southerland is the doctoral coordinator for the Science Education Program.

Dr. Granger will be the lead administrator of the grant and will lead the OSTA RET program. She is the Director of the OSTA and is an Associate in Biological Science. She has over 15 publications devoted to biological science or science education research. Dr. Granger has held over 25 state and national grants focusing on science teaching and learning, the projects from many of which have won state or national recognition. For over 14 years, she has developed and led many science teaching and learning experiences for K-20 students and professional development activities for K-12 teachers. Dr. Granger also directs a bachelor's and a master's degree program in science teaching for the College of Arts and Sciences at FSU.

Dr. Dixon will lead the NHMFL RET program. She is the Director of the CIRL for the NHMFL, conducting educational programs for students, teachers, and the general public. She has secured funding for the RET program since 1999 and has participated in national conferences on RETs working with other program managers to determine best practices for diverse RET sites. Dr. Dixon is also an adjunct instructor at Flagler College, developing and teaching their Science Methods for Elementary Teachers course. She has secured over $3 million in grants for curriculum development and workshops for its dissemination.

Dr. Herrnkind will be the senior scientist for the project. He is a Professor in the Biological Science Department and holds the Godfrey Chair of Biological Science at FSU. He has maintained an active, funded research program since 1968 and has an international reputation for his marine ecology research. Dr. Herrnkind has directed 16 Ph.D. and 24 M.S. projects in Biological Science and served on the committees of over 8 M.S. and Ph.D. recipients in Science Education. In 1985, he developed the award-winning *Saturday-at-the-Sea* program for middle-school students as a means of encouraging their interest in the nature and pursuit of science; it has served over 15,000 students to date.

The Program Coordinator (PC) will be a master teacher and will be responsible for all of the day-to-day details of the project's management (advertisement, recruiting of teachers, scheduling, interfacing between RET teams and educational research teams, organizing travel for data collection, interfacing with school districts, establishing virtual conference schedules, etc.). During the summer portion of the project, the PC will work directly with the teachers during the pedagogy sections of the RET experiences. The PC will help write a detailed administrative manual (including task timelines) for each RET program so that similar programs can be implemented easily by other groups. Along with the Program Teacher Specialist (below), the PC will represent the teacher stakeholder perspective in the project leadership group.

The Program Teacher Specialist will be a master teacher who is hired to work full-time with teachers during the pedagogy sections of the summer portion of the program and will maintain their public school position during the academic year. They will be a member of the project leadership team participating in all year-round meetings. They will bring to the table "on-the-spot" knowledge of the changing trends and challenges in K-12 teaching as they arise.

Essential Features and Characteristics

The research proposed herein will investigate two RET program models spanning both field research in pursuit of teachers' *own* questions (conducted at the FSU Marine Laboratory) and laboratory research in which teachers participate in on-going, authentic science research (conducted at the NHMFL and science departments on main campus). Both of these very different RET experiences have, in preliminary studies, been proven successful for engendering understandings of inquiry (6,14,15,16). Given that the pedagogical design of these RET programs is well established, they are ripe for systematic, rigorous educational research. Furthermore, their different designs have the potential to engender understanding about the features of RET programs that support the full development of the pedagogical content knowledge for reform-based teaching of inquiry. There is a history of research into these programs at FSU, and the proposed research plan would bring together and extend this work, making it more generalizable for teacher professional developers and researchers throughout the country. The existence of two separate units (OSTA and NHMFL) engaged in rigorous design, administration, and evaluation of two different RET models and of a third unit (Science Education Program) with the research expertise necessary to study their effects all at one institution is a particular strength of this proposal.

Dissemination Plan

Yearly presentations will be conducted at a range of organizations: National Association for Research in Science Teaching, American Educational Research Association, and the Association of Science Teacher Education. Publications of the research findings will be written for *Journal of Research in Science Teaching*, *Science Education*, *Journal of Science Teacher Education*, *College Science Teaching*, as well as submitted to the National Science Digital Library (NSDL http://www.nsdl.org). To better access the practitioner audience, team presentations involving RET staff, research staff, and participating teachers will make presentations at the National Science Teachers' Association and submit manuscripts to teacher journals such as *the Science Teacher*, *The Biology Teacher, and The Physics teacher.* To network with others involved in designing RET's throughout the nation, symposia at national meetings will be proposed for years 3, 4, and 5 of the program in which our work will be presented with that of other similar projects. Likewise, a website will be begun year 1 to regularly share the structure of our research and its programs as well as to share our findings.

Results of Prior NSF Support (past 5 years)

Dr. Granger was PI for a Teacher Enhancement Project (ESI-9819431) that resulted in the development of the OSTA RET model to be examined herein. This project resulted in one master's thesis and one Ph.D. thesis from which articles for publication will be forthcoming. She is also co-PI and lead administrator for a GK-12 project (DGE-0139299) and that effort resulted in one Ph.D. thesis (from which an article for publication will be forthcoming) and one edited, published monograph. Dr. Southerland was Co-PI for a Course and Curriculum Development Project (EEC-9872555)that lead to the redesign of a senior engineering course. Her associated research resulted in one master's thesis and two published articles in the *Journal of Research in Science Teaching.* She was also an outside evaluator for a Course, Curriculum, and Laboratory Improvement Grant (DUE-9950624), and that effort resulted in one article published in the *Journal of Science Teacher Education*. Dr. Dixon is PI for the RET program supplement to the core NHMFL grant (DMR-0084173). Two research studies have resulted from this program, a paper from the first has been submitted for publication to the *Journal of Research in Science Teaching* and the second is still in progress.

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