

TECHNOLOGY EMBEDDED SCIENTIFIC INQUIRY: A STUDY OF TEACHER KNOWLEDGE AND PRACTICE

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ABSTRACT

This article briefly describes the National Science Foundation funded project (2004-2007), *Translating Information Technology into Classrooms*. It presents the external evaluation results of the teacher preparedness of the information technological skills. Based on these results and the National Science Education Standards pertaining to scientific inquiry, *Technology Embedded Scientific Inquiry* (TESI) model, is constructed for the professional development of TITiC teachers. The article argues that the TESI Model should be used for promoting conceptual understanding of the what, how, and why of science underpinning scientific reasoning. Based on the external evaluation results in the TITiC project, a research agenda is proposed to study teacher knowledge and practice of TESI.

KEYWORDS

Scientific Inquiry, Information Technology, Teacher Knowledge, Teacher Practice, Professional Development

INTRODUCTION

The primary goal of the National Science Foundation—Translating Information Technology into Classrooms (TITiC) Project, a partnership between Wayne State University and Monroe Public Schools, was to educate and train high school science teachers (9-12 grades) to use IT (GIS/GPS, probes/sensors and communication tools) in empirical science. Besides using IT in empirical science teachers were also encouraged to teach science *with* and *through* IT in their classrooms (McFarlane & Sakellariou, 2002). *With* IT means doing simulated investigations. *Through* IT involves access to scientific sources and published analyses that may be shared and discussed with peers. Although the TITiC project primarily focuses on empirical science, many students' projects also displayed simulations and critical science.

Central to empirical science, investigative simulations, and investigative critical science is scientific reasoning. This implies that in science learning students not only be expected to evaluate the content but also the scientific methods: Students should learn scientific theory (content) derived from the experimental results through discourse. They should also learn the (methods) science processes--the gathering, organization, and display of data; the use of evidence, evaluation of evidence to inform theory, application of logic, and construction of an argument for their proposed explanations; revision of methods and explanations; and public presentation of the results with a critical response from peers. Web-based communication tools can be used to expose interpretations of data to critical peer review. This will indeed encourage electronic community of scientific inquirers. With the support of IT, students may experience the way scientific inquiry takes shape in authentic science problem contexts.

How do we develop student conceptual understanding of the what, how, and why of science using IT? TITiC group's fundamental belief is that if we educate and train teachers in using IT to developing

conceptual understanding of the what, how, and why of science, then teachers will be confident to teach their students. Our goal then was to first reach the teachers.

This was accomplished in three phases with each cohort of 15 teachers over 3 years:

- (1) In the first phase, teachers were engaged in a specially designed two-week summer institute. The teachers were taught high-end technologies: Geographic Information Systems (GIS), sensors, and Web-based communication tools in the context of scientific investigations.
- (2) In the second phase, each teacher engaged at least 5 students in long-term projects in the study of the Lake Erie ecosystem using high-end technologies: Geographic Information Systems (GIS), sensors, and Web-based communication tools. At the end of long-term research projects, the first cohort students presented papers at the 2006 Scientific Research Symposium at Wayne RESA to an audience consisting of students and teachers from three schools, the National Advisory Board members, some parents, and significant others. The National Advisory Board members commented students' presentation is the proof of the pudding.
- (3) In the third phase, each teacher integrated information technologies into their regular curriculum.

The first cohort teachers are doing the third phase. The second cohort teachers are doing the second phase. We are now in the process of recruiting the third cohort of teachers for the summer institute. Teacher experience average 14.5 years. The TITiC project serves 9 schools representing urban, suburban, and rural; economically disadvantaged and advantaged; and students population primarily consisting of Anglo-Americans and African-Americans (See Table 1).

Table 1. The Percentage of Ethnic/Racial and Student Disabilities Composition

Demographics %	CSD	DCSD	GPPS	MPS	RCS	SCSD
Black	4	91	8	9	55	5
White	91	3	89	87	43	87
Hispanic	2	6	<1	3	.2	6
Asian Am	2	<1	2	<1	<1	1
AM. Indian	<1	<1	<1	<1	. <1	1
Multiracial						1
Hawaiian			<1	<1		1
Students with Disabilities	10.5	14.2	4		48	23

Note: In 2006, Grade 12 Science MEAP state average is 57% and student economic level (sel) state average is 36%. Corresponding figures for TITiC schools are as follows: CSD: Crestwood School District--MEAP 59%, sel 30%; DCSD: Detroit City School District--4 schools MEAP 22%; sel 72%; GPS: Grosse Pointe Public Schools MEAP 80%; sel 4%; MPS: Monroe Public Schools—MEAP 50%; sel 34%; RCS: Romulus Community Schools—MEAP 40%; sel 48%; SCSD: Southgate Community School District—MEAP 41%; sel 23%.

THE NEED FOR PROPOSED RESEARCH STUDY

At the end of the summer institutes in both years our external evaluation team led by Dr. Mark Jenness, Western Michigan University (SAMPI) asked the TITiC teachers (15/year) to rate their

preparation to use specific technologies on a scale of 1 (not well prepared) to 4 (well prepared). Except for GIS related technologies, which require a high learning curve, all other technologies, key to science learning and teaching received high ratings. The ratings for 2005 and 2006 are presented in Table 2 (SAMPI Report to NSF 2005, 2006).

Table 2. Teacher Preparedness Rating of Technologies

Technologies	2005 Results	2006 Results
Logger Pro Software	3.14	3.50
Vernier Probe-computer/calculator interfacing	3.14	3.83
GPS	3.43	3.29
Water Test Kits	3.14	3.50
Spectrophotometer	3.36	3.37
GIS	2.29	2.79 (2.79 for Arc View, 2.86 Arc Map, 3.00 for Google Earth in 2006)
TITiC Portal	2.36	2.79

Based on the external evaluation results we can claim that the TITiC teachers are prepared to use IT in science education and learning. However, we cannot claim that science teachers are IT adept in scientific inquiry? Based on what our teachers are able to do and based on the National Standards of Scientific Inquiry, we have now developed the Technology Embedded Scientific Inquiry Model (TESI), which weds IT and SI. This union will promote conceptual understanding of the what, how, and the why of science (scientific reasoning), using IT. The development of the TESI model is the major outcome of the TITiC project.

TECHNOLOGY EMBEDDED SCIENTIFIC INQUIRY (TESI) MODEL

If teachers are expected to provide their students with necessary knowledge, skills, and tools to be able to do scientific inquiry, then the teachers need to become TESI adept. To consider a science teacher TESI adept, the TITiC project envisions that the teacher should enable students to embed technology in at least 3 key characteristics of scientific inquiry outlined by National Science Education Standards (American Association for the Advancement of Science, 2001; Grandy & Duschl, 2005; Krajcik, Blumenfeld, Marx, & Soloway, 2000; NRC, 1996, 2000). Thus we propose the TESI Model for professional development of teachers (See Figure 1). The cognitive and behavioral indicators that teachers should display are the following three characteristics of scientific inquiry: scientific conceptualization, scientific investigation, and scientific communication. Research evidence indicates that all these three areas of scientific inquiry may be enhanced with information technologies. Thus we need to embed IT in scientific inquiry.

The three TESI characteristics fit into “teacher subject matter content knowledge and pedagogical content knowledge” that provide the foundation needed for effective classroom performance (Schulman, 1986; 1987). The 3 TESI-characteristics also reflect a complex process that is mastered through a long socialization process of becoming a scientist. Teacher development and proficiency in these three characteristics of scientific inquiry, in turn, will improve their understanding of the *nature of science* (NOS) characterized by Lederman et al. (2002), which will serve as a predictor of both teacher understanding of scientific inquiry and their classroom performance.

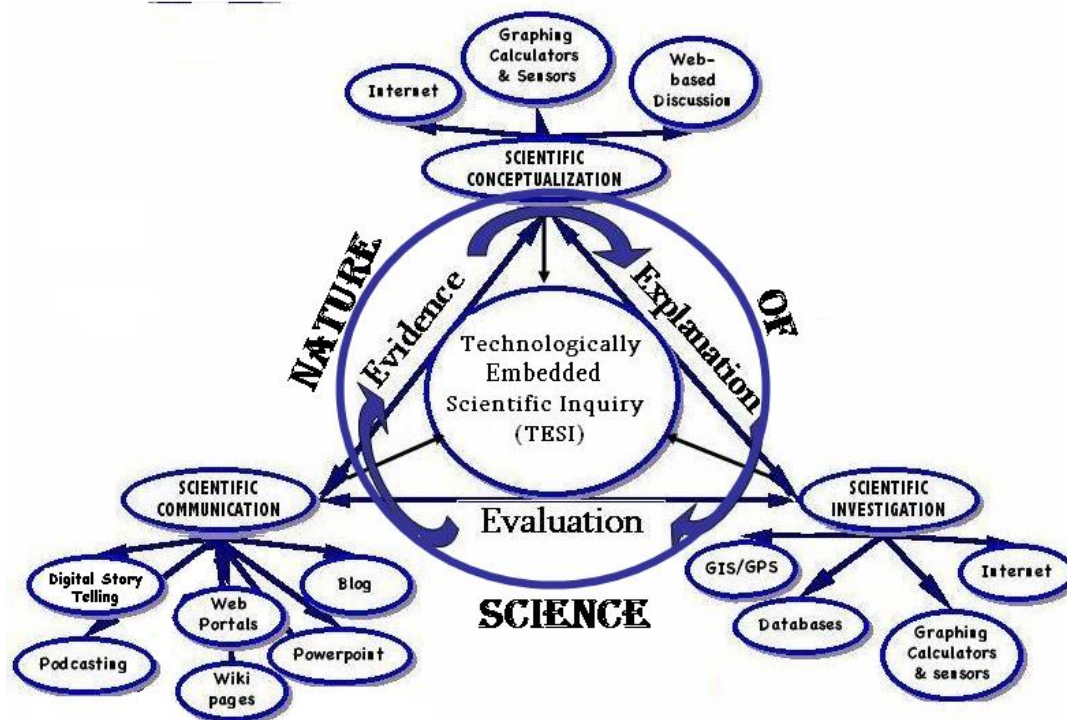


Figure 1. TESI Model for Professional Development

Technology Embedded Scientific conceptualization

Technological embedded scientific conceptualization involves (a) understanding subject matter knowledge underpinning a problem of inquiry will shape the way learners engage in scientific investigations, and (b) testing and clarifying conceptual ideas will lead to deeper understanding of the subject matter knowledge. Based on these beliefs, teachers should know and practice how to establish an adequate prior knowledge base. For example, students' understanding of the theoretical concept of dissolving is important for the investigation of water quality. For testing and clarifying conceptual idea of "dissolving" students may be asked to elicit their prior understanding with salt/water system, idea sketching, carrying out small-group discussion, and writing. Using students' conceptions as a baseline, teachers should know and practice how to help students construct, evaluate, and reflect-on the need to know science knowledge that supports scientific investigation. Some ways to construct, evaluate, and reflect are to:

- negotiate scientific meanings from historical knowledge development of dissolution
- develop scientific meanings through active involvement, continued exposure, and growing skill and understanding
- acquire and assess students' developing explanations through small-group discussions, labelled drawings, writings, and concept mapping.

Building student scientific knowledge has been successful with computer-based probe laboratories (Mokros & Tinker, 1987; Sokoloff & Thornton, 1998); knowledge scaffolding and integration (Davis & Linn, 2000), and computer visualization, modeling, and simulation (Ebenezer, 2001; Edelson & Gordin, 1998; Feurzig & Roberts, 1999; Hsu & Thomas, 2002; Huppert, Lomask, & Lazarowitz, 2002; McFarlane & Sakellariou, 2002). For example, ThinkerTools (White & Frederiksen, 2000) is

an inquiry-based curriculum in the physics of motion that enables students to explore and test their conceptions of motion through an in-depth understanding of the processes of scientific inquiry. They also used a reflective assessment tool that assessed the quality of scientific inquiry of theirs and others. When the computer-based probe laboratories required students to make pre-lab predictions for their lab questions and compare with the real time data outcomes displayed during the experiment, students were significantly successful at confronting their preconceptions about how science works and make plausible conceptions than students who were not required to make pre-lab predictions (Sokoloff & Thornton, 1998). The mental operation of “comparing” is the main core operation for learning and developing understanding (Marzano et al., 2001) and this operation is true for learning how to do science.

Technology Embedded Scientific Investigation

Teachers should know and practice how to scaffold students in developing critical abilities to study issues that have personal meaning; formulate researchable questions or testable hypotheses; demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment; and design and conduct scientific investigations. In all of these areas teachers need to develop skills to use a variety of technologies, such as measuring instruments, and calculators, electronic devices and computers to test and clarify ideas that guide scientific investigation and to collect, analyze, and display data; use measurement for posing questions, formulas for developing explanations, and charts and graphs for communicating results; recognize how the investigation itself may also require clarification of research questions, methods, controls, and variables; organize and display data; and revise methods and explanations; use evidence, apply logic, and construct an argument for proposed explanations; formulate and revise scientific explanations and models (physical, conceptual, and mathematical) using logic and evidence; discuss and argue based on scientific knowledge, the use of logic, and evidence from their investigation that result in the revision of explanations; and analyze an argument by reviewing current scientific understanding, weighing the evidence using scientific criteria to find the preferred explanations and models, and examining the logic so as to decide which explanations and models are best.

For gathering data and selecting evidence, computers provide students with tools to manipulate and understand the interactions of their environment (Bransford, Brown, & Cocking, 2000; Cognition and Technology Group at Vanderbilt, 1990; Ebenezer, 2001; Ebenezer et al., 2003; Kozma, 2000; Lapp & Cyrus, 2000; Linn, 2003; Schultz, 2003; TITiC Project, 2004-2007; White & Frederiksen, 1998). In the probe lab experience, students gather real time data in less time and spend more time analyzing graphical representations of the data, questioning results, restructuring ideas, questioning the implications of their own findings, and exploring new questions to investigation, probably based on a newly introduced variable into the experiment (Lapp & Cyrus, 2000; Schultz, 2003).

Technology Embedded Scientific Communication

Technological embedded scientific communication involves communicating research process, research results, and knowledge claims via classroom discourse and public presentation with a critical response from peers and experts. Augmenting the probe and other science data collecting technologies for selecting evidence are the Information Communication Technology tools that incorporate computer-based scaffolds to either support or refute competing theories by constructing valid yet opposing arguments from multiple perspectives in response to scientific and socio-scientific issues. This new emphasis on scientific inquiry represents a fundamental shift in teaching science as “exploration and experiment” to science as “argument and explanation” (NRC, 1996, p. 113). Therefore, TESI adept science teachers should enable students to participate in *dialogic discourse* (Duschl & Osborne, 2002) with IT. Furthermore, *Michigan Curriculum Framework and Science Benchmarks* (2000) states in order to construct “new scientific knowledge” (p. 1), high school students need to “communicate findings of investigations, using appropriate technology” (p. 4).

Transformative communication as a cultural tool for guiding inquiry science (Polman & Pea, 2001), teaching science through on-line peer discussions (Hoadley & Linn, 2000) and computer-mediated

reasoned argumentation have been successful in creating communities of enquirers (Bell & Linn, 2000, de Vries *et al.*, 2002; Duschl *et al.*, 1999; Ebenezer & Puvirajah, 2005). Ebenezer and Puvirajah (2005) carried out middle school students' argumentation on the particle theory of matter using WebCT Discussion Boards.

PROPOSED RESEARCH QUESTIONS AND METHODS

Effective classroom use of technologies by students for clarifying their ideas, gathering data, selecting evidence, and carrying out scientific discourse depends upon teacher competence and confidence (Collis, et al., 1996) along with the teacher's skill with and access to technology tools (Knezek & Christensen, 2002). As teachers progress from simple applications toward full integration of technology in the classroom in support of higher cognitive functions, research findings are less conclusive and need to be further explored (Knezek & Christensen, 2002). Thus I have formulated several research questions to measure teacher knowledge and practice.

Data Collection and Analysis: Teacher Knowledge and Practice of TESI

A. Quantitative Assessment of Teacher Knowledge of TESI

1. Does the TESI science teachers' **knowledge** significantly improve the teaching of (a) scientific conceptualization, (b) scientific investigation, and (c) scientific communication starting from the summer institute at the end of year 1 to the end of year 4? (pre/post tests with cognitive tasks—See below and Appendix A)

a. Declarative or Propositional Knowledge of Scientific Inquiry, Schematization.

One important element of practicing scientific inquiry is understanding the history of scientific inquiry. As part of our assessment, teachers will read a description of a case study of scientific exploration and discovery. Later we will ask them to recall the case history as completely as possible. We will rely upon a panel of active, productive scientists to review our materials and to rate the elements of the story in terms of their typicality and importance. We expect individuals with well-developed schema to recall more of the story content and to recall it in ways that reflect the organizational features of the schema. Our expectation is that before TESI summer institute training, most teachers will have very little schematization of scientific inquiry, but that with time and experience, it will improve.

b. Procedural Knowledge of Scientific Inquiry.

i. Abstraction. Our inclusion of abstraction derives from the work of Ohlsson and Regan (2001). Their model is that conceptual creation cannot be explained strictly in terms of pre-existing knowledge. For example, Darwin could have been an expert in evolutionary theory because the field did not exist before he proposed it. They make this point by noting that, in general, innovators who are working at the boundary of knowledge cannot be experts in what lies beyond that boundary (pp. 246). They define abstraction in terms of representing relationships between elements. They clearly distinguish abstraction from the concepts of generalizing and abstracting which have been related to abstraction in other theories. In the task, the individual is presented with a set of small objects which can be fit together into the same configuration as the double helix, although in a 2-dimensional rather than 3-dimensional array. They measured the time to reach each insight as well as total time to solve the problem (approximately 30 minutes). There were considerable individual differences among subjects in time to identify the insights and total problem solution. The important thing for our purposes is that these differences indicate that the capacity to use the principles of scientific inquiry can be assessed independently of science content knowledge. **ii. Data Interpretation.** The second procedural task is derived from a series of studies conducted by Dunbar and colleagues on the interpretation of data, including work on the confirmation bias present in the interpretation of scientific data (Dunbar, 1995; Dunbar & Fugelsang, 2005; Fugelsang, Stein, Green, & Dunbar, 2004). The area is of interest because data interpretation is a critical element involved in the transition from fact-based instruction to inquiry-based instruction. The task is a laboratory created to duplicate the activities observed in the laboratories of scientists (Fugelsang et al., 2004). Participants are

sequentially presented with plausible, implausible, and neutral theories linking two variables. Following each theory, participants view data concerning the two variables, and periodically they make judgments about the causal link between variables. Although their work was experimental and not designed to study individual differences, the task does allow us to index the willingness of participants to respond to inconsistent data based on the covariation between the data and causality judgments. Clearly we need to conduct additional research to establish the best task structure to obtain meaningful data on patterns of data interpretation.

B. Qualitative Assessment of Teacher Development and Interpretations of TESI Practices

2. How do the classroom **practices** of participating TESI teachers change with respect to the teaching of (a) scientific conceptualization, (b) scientific investigation, and (c) scientific communication from years 2 to the end of year 4? (verbatim transcripts of appropriate portions of video-recordings and narrative accounts) How do teachers interpret their experiences in becoming ITESI adept? (individual interviews and case-studies)

Qualitative observations via video recordings and narrative accounts capturing classroom events during the TESI units will occur in all three years in all the classrooms. At the end of the second year of data collection (or at the end of third year of the project), based on the TESI-COP measures, we will select 5 teachers with excellent, 5 teachers with average, and 5 teachers with poor ratings for individual interviews for interpretation of their experiences in becoming TESI adept. With qualitative data transcripts from the interviews, we will first use a content analysis method (Miles & Huberman, 1994). We will code and generate categories of meaning from the data. In the third year of data collection (or the fourth year of the project), we will select representative samples of teachers for in-depth observation based on the developing categories of meaning (conceptual framework). For each of the representative sample of teachers taking part in in-depth case studies, a data profile will be composed to observe development on TESI. We will use the Constant Comparative Method (Glaser & Strauss, 1967) to analyze the data obtained from our theoretical sampled teachers to develop a more completely grounded theory of TESI.

Some Quantitative Measures.

The validity on teacher practice for each of the 3 characteristics of ITESI draws on reform documents (AAAS, 2001; NRC, 1996, 2000) and Information Technology educational research (Knezek & Christensen, 2002; Linn; 2000; Linn, 2003; Linn et al., 2004). Based on these reform documents and research studies, we have already developed TESI-COP consisting of individual Likert items for each of the 3 characteristics of the TESI. These survey items use a 0 to 5 Likert scale for response categories, namely, (0=None, 1=Little, 2=Some, 3=Good, 4=Excellent). To establish reliability and validity of the TESI-COP in year 1, two graduate research assistants will conduct classroom observations (video recordings and narrative accounts) of at least 35 science teachers who are not in the TESI project. To achieve the inter-rater reliability of classroom observations, these research assistants will independently arrive at inductive themes based on videos and narratives and then convert these into quantitative measures using the TESI-COP. Thus the TESI-COP descriptors are possible indicators, not a required “check-off” list as opposed to many other classroom observation protocols that are used in teacher education. **Data analysis.** Estimates of inter-rater reliability for the TESI-COP measures will be obtained by computing intra-class correlation coefficients and kappa statistics. Because we have the same teachers over 3 years of data collection based on three dependent variables (a) scientific conceptualization, (b) scientific investigation, and (c) scientific communication, to examine the changes in teacher practice longitudinally a multivariate analysis of covariance (MANCOVA) will be used. A multivariate design will use a combination of univariate repeated measures and multivariate analysis techniques (Tabachnick & Fidell, 2001).

C. Comparing Knowledge and Practice of TESI by TESI and Non-TESI Teachers

3. Does the TESI science teachers’ **knowledge** and **practice** compared with the non-TESI show a significant difference in the teaching of (a) scientific conceptualization, (b) scientific

investigation, and (c) scientific communication starting from year 2 to 3, and year 3 to 4, as well as longitudinally?

Data Collection and Analysis: For the **knowledge** part, methods for Question 1 will be followed concurrently with TESI and Non-TESI teachers and results will be compared for significant differences. We will use the MANCOVA layout to quantitatively analyze the data collected from year 2-3, and year 3-4. Analysis for year 2 through year 4 is a repeated measures MANCOVA. Based on this design, assumption of at least a moderate effect size (Cohen's $f = .25$), and the harmonic mean of the proposed sample size, the estimated statistical power is .86. For the **practice** part, methods (qualitative and quantitative) for Question 2 will be followed.

D. Assessment of Teacher Knowledge of NOS

4. Does the TESI teacher **knowledge** of scientific inquiry significantly improve teacher understanding of NOS starting from the summer institute at the end of year 1 to the end of year 4? (pre/post tests using modified version of VNOS C—Lederman et al., 2002)

Declarative Knowledge of the Nature of Science. The nature of science has become a topic of considerable research activity over the past decade (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). There is clear diversity of opinion about what the term means and how it is to be defined, as witnessed by a recent international symposium (Abd-El-Khalick, et al., 2004). Our goal is to obtain a measure of teacher's declarative knowledge about science in general and scientific inquiry as practiced by scientists in the 21st century the Lederman et al (2002) report on the development of an instrument, the VNOS C, has been shown to be a valid indicator of knowledge about the nature of science. Their evidence for validity consisted of comparing college faculty familiar with science to faculty in the arts and humanities. Interestingly, they did not use actual practicing scientists. The instrument uses qualitative analysis of responses to open ended questions. Their validation study involved comparing the frequencies of various themes in the protocols of their two different groups. Further evidence for the validity of the VNOS C comes from a study of grade school science teachers (Ackerson & Hanuscin, 2004). They report that a detailed qualitative analysis of interviews with three teachers showed dramatic change over a 3-year professional development program designed to increase and improve scientific inquiry. The themes that they saw increasing were similar to the themes identified by Lederman et al. (2002). We would like to **expand our understanding** of the perceptions of the nature of science in practicing scientists and use themes identified in studies of that population as a standard of comparison for the TESI science teachers in our study. Starting from the end of year 1 to the end of year 4, we will administer the VNOS C (**now a modified version**). We will quantify responses to the VNOS C by adapting a scoring scheme developed by Ruba et al., (1996) and modified by Vazques-Alans and Manassero-Mas (1999). The definitions and related scores of each category are as follows;

Appropriate (3.5 points). The teacher's response expresses and appropriate view.

Plausible (1 point) Although not completely appropriate, the teacher's response expresses some plausible points.

Naïve (0 points). The teacher's response expresses a view that is inappropriate or not plausible.

E. Qualitative Assessment of Teacher Development and Interpretations of NOS Practices

5. How do the classroom **practices** of participating TESI teachers change with respect to NOS from years 2 to 4? (Video-recordings and narrative accounts) How do teachers interpret their experiences in classroom practice of NOS? (individual interviews and case-studies)

Data Collection. See qualitative methods for Questions 2. The only difference is that we will use the NOS-COP measures instead of TESI-COP for the conversion of the same video-recordings and narrative accounts to quantitative measures.

F. Comparing Knowledge and Practice of NOS by TESI and Non-TESI Teachers

6. Does the TESI science teachers' **knowledge** and **practice** of scientific inquiry, compared to the non-TESI, show significant differences in the understanding and practice of NOS?

Data Collection and Analysis. Methods for Questions 4 and 5 will be followed concurrently with TESI and Non-TESI teachers and results will be compared for significant differences. For the **knowledge** part, methods for Question 4 will be followed concurrently with TESI and Non-TESI teachers and results will be compared for significant differences. We will use the MANCOVA layout to quantitatively analyze the data collected from year 2-3, and year 3-4. Analysis for 2 through 4 is a repeated measures MANCOVA. For the **practice** part, methods (qualitative and quantitative) for Question 2 will be followed. Multiple regressions will be used to examine how well the TESI science teachers' knowledge and practice of NOS predict their knowledge and practice of scientific inquiry. This quasi-experimental pre-post-test design is represented as follows (Campbell & Stanley, 1963).

$$\begin{array}{ccccccc} O_1 & & - & & X & & - & & O_2 \\ O_3 & & & & - & & & & O_4 \end{array}$$

where O = Observation, and X = Treatment (i.e., TESI). Based on the design, assumption of at least a moderate effect size (Cohen's $f = .25$), and the harmonic mean of the proposed sample size, the estimated statistical power is .86.

G. Validating the TESI Model

7. Does the aggregate data from 1-6 above, in addition to the confirmatory factor analysis evidence lead to a rigorous, defined TESI model?

A confirmatory factor analysis will be conducted using the measurements at all posttest outcomes for the TESI teachers. This will validate the path arrows and provide path weights to the illustration in Figure 1 above. This will be accomplished using Amos version 7 software. This will also contribute construct validity evidence to the quantitative instruments.

Internal and External Validity

Quantitative. Internal reliability of all quantitative instruments will be assessed using Cronbach Alpha (and Spearman-Brown **prophecy** adjustments for subscales) at the pretest stage. Revisions, including deletion of items and addition of items, will take place at this time. Test-retest reliability, or stability over time, will be assessed by a Pearson correlation administered to the comparison group at the pretest and posttest stages. Standard errors will be derived based on the data (e.g., standard error of measurement, standard error of predictions, and standard error of the difference between the treatment and comparison groups). Internal validity pertains to the determination that the study outcomes are due to the intervention. The TESI teachers have participated for 3 years in the TITiC project and they will have training in TESI during the 2008 summer institute, and pertinent professional development during the year. Internal validity is also evidenced by our research design considerations. Our sample size is 70 (25 experimental teachers and 45 comparison group teachers). Twenty-five teachers from the 45 TITiC group will be randomly selected with a Fortran computer program using IMSL's (1994) RNSRI subroutine, which is based on the Ahrens and Dieter (1985) algorithm. Because we have chosen 25 of the 45 TITiC teachers to participate, and will try to match those 45 with participants from some other source who will receive the instruments but not the intervention, we do have a bit more "random selection", at least as far as the comparison group is concerned. This will give us somewhat more generalizability. For the experimental group, we have included demographics such as similar teaching experiences, a balance of gender, and the participation of both African Americans and Anglo-Saxon teachers who teach a diverse population of students as indicated in Table 1. The schools are located in Detroit (urban), suburbs (Dearborn Heights, GrossePointe, Romulus, Southgate), and rural areas (Monroe). The student population that the teachers teach come from the most affluent society (GrossePointe) to the poorest community (Detroit). We will also establish the reliability and validity of the instruments by adapting the existing instruments or developing new ones. External validity pertains to the generalizability of the results. It is evidenced by the sampling plan for the experimental and comparison groups.

Qualitative. Internal validity pertains to the accuracy of video recordings and narrative accounts of classroom observations that will be established by independent observers. The criteria of trustworthiness, credibility, and corroboration of data (Lincoln & Guba, 1985) depends on the match between verbatim transcripts and video-recordings as well as individual interviews. Triangulation

depends on the intersection of data from video-recordings, narrative accounts, and in-depth interviews. The same lead and sub-questions will be asked of each teacher in a conversational style to pursue a line of inquiry so that teachers will feel comfortable. The nature of teacher participation will be monitored and trajectories will be created for quality of TESI practice. Because we will choose theoretically-based samples of teachers for our qualitative/case study, external validity pertaining to transferability, comprehensiveness, and holistic coverage (Lincoln & Guba, 1985) will be fully addressed. The multiple qualitative data sources used for triangulation will provide confirming and disconfirming evidence for supporting quantitative measures.

SIGNIFICANCE OF THE STUDY

The answers to the above research questions will contribute much to theory and practice of the TESI and nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). We believe a validated set of indicators for identifying TESI adept high school science teachers in the domains of (a) scientific conceptualization, (b) scientific investigation, and (c) scientific communication that lead to deeper understanding of NOS would be useful to both researchers and to those who plan and implement professional development activities. Our work is unique in that it looks at these issues within the context of an intervention designed to educate and train teachers in technologically embedded scientific inquiry. The findings of this study will contribute to the much needed national model building of TESI at the high school level.

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