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# Editorial: Taking Back Science

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As I am writing this editorial, the U.S. has just elected a new president. In a recent *Newsweek* article, Sharon Begley (2008) discusses how a climate of distrust of science has prevailed under the Bush administration. Global warming, stem cell programs, and even evaluations of sex education programs have all been under attack by an administration seemingly more interested in discrediting science to support its political agendas rather than in presenting more appropriate economic or moral arguments. Begley asserts that the negative attitude toward science and "inconvenient facts" will take a great deal of work to undo. Compounding the problem, the Department of Education has severely limited acceptable program evaluations to those with experimental and quasi-experimental designs, approaches that are often poorly suited to understanding complex social interactions, like teaching and learning science. I am looking forward to an administration that will value scholarship and bring more credibility to science and science education research. I imagine most science education researchers (regardless of partisan affiliations) are feeling the same way.

The work of science education researchers has never been more important, for both the U.S. and the world. Schools in the U.S. must begin to recover from an over-emphasis on high-stakes testing and the resulting reductionist pressure on curriculum. With renewed attention and energy will come renewed opportunities to implement improved instructional practices and professional development. Throughout the world, people face increasingly complex environmental, economic, and political challenges requiring thoughtful action by leaders and societies that understand and value scientific inquiry and data-driven decisions. All of these offer opportunities for science educators to better understand how school science can prepare us for the future.

The articles in this issue represent a range, depth, and quality of science education research needed to take back a respect for science. They all explore ways to help students understand science and scientific inquiry and/or to support science teacher development that promotes the same. The methods fit the questions and contexts and range from case studies to the use of inferential statistics. Eric Pyle explores a model of inquiry for the Earth sciences. This provides an important perspective for teacher educators who are helping teachers see how inquiry fits into the interdisciplinary and observational nature of Earth science. Su Swarat reports on attribute dimensions that help us understand what makes a science topic interesting to middle school students. Jill Marshall investigates electric circuit diagrams and helps the reader to see the importance of explicit discussion of representation issues. Tsung-Hui Tu and Wei-Ying Hsiao document the verbal interactions of teachers and their preschool students providing important data on early science learning and is an excellent starting point for preschool teachers to examine and reflect on their own practice. Randy Yerrick, Rebecca Ambrose, and Jennifer Schiller present a case study that explores the complexity of promoting inquiry-based practices and provides important insight into the role of classroom placements, cooperating teachers, and teacher educators' relationships with those teachers. Molly Weinburgh and Kathy Smith also present a case study and report on the complexity of supporting a teacher's growth to more reflective practice. It points to the fact that a teacher's growth may impact his or her relationships with colleagues. Gwen Nugent, Gina Kunz, Richard Levy, David Harwood, and Deborah Carlson compare a field-based and traditional geoscience course for preservice teachers. The findings support the use of a field-based course resulting in better high-level questioning. Gili Marbach-Ad, Randy McGinnis, and Scott Dantley report on base-line data collected in relation to the implementation of a teacher professional development model at both historically black colleges and universities and predominantly white universities and colleges. The baseline provides some interesting differences in the results from the two types of institutions and will provide important data for comparison after for this project and for other science education researchers. Finally, Octavia Tripp and Charles Eick examine the use of a Myers-Brigg type inventory in assigning secondary science education student teachers with their cooperating teachers. Findings reveal important considerations for science teacher educators, including the values of some dissonance in temperaments to foster pedagogical growth and the importance of the relational dimension for the cooperating teacher.

I believe each of these articles helps us meet the challenge of our times: to take back science as a credible and valued endeavor in our global society. Such thoughtful research is critical to understanding the complexities of helping students value, appreciate, and understand the nature of science.

## References

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# A Model of Inquiry for Teaching Earth Science

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Abstract

Teachers and administrators have heard recent calls for more inquiry-oriented science instruction at roughly the same time more emphasis has been placed on high-stakes testing in science. While these two factors justify an examination on assessment practices, they also justify a refinement in teaching approaches to science inquiry. At their core, models of inquiry-science teaching attempt to engage student in active processes of science knowledge construction, emulating the process of science itself. But each domain in science has unique, if overlapping, histories, traditions, and conventions that have directed inquiry within those sciences. This paper outlines a model of inquiry science teaching that more accurately reflects the nature of the Earth sciences than do generic or physical science-based models do. This model incorporates elements recognizable for any science domain (question posing, methods definition and application, and solution determination), but also provides specific mechanisms within each element that reflect the nature of the Earth sciences, in current, historical, and classroom contexts. These mechanisms include descriptions of materials, space, and time; observations and modeling; and interpretations and historical representations. Possible pathways for short- and long-term instructional planning are also discussed.

Teaching Earth science in the K-12 classroom presents a challenge compared to other sciences in the curriculum. Earth science is an interdisciplinary science, encompassing ideas from physics, chemistry, and biology, but applied through geology, meteorology, oceanography, and in K-12 curricula, space science and astronomy. Earth science is not a narrow set of ideas, but a synthesis of many concepts, traditions, and disciplines in science.

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Geology, by definition, is the study of the Earth, but how does one systematically inquire about the Earth? Fundamentally, the Earth sciences provide information on (a) *materials* (such as rocks, minerals, water, etc.), (b) *space* (i.e., where the materials are found or how they are distributed), and (c) *time* (i.e., how materials and their distributions have changed and evolved). Historically, studies in each of these areas have been both descriptive and interpretive and have included activities such as isolating a map location for a land feature, determining the length of a river, or suggesting the depth of an oil reserve.

Compared with the other sciences, the Earth sciences are relatively young, and as the science of geology has matured, the role of interpretation has become more important. These interpretations include identifying factors that cause Earth events, interpolations between specific locations, and extrapolations of process beyond available data.

Interpretations are common both in a predictive (forward in time) manner and a "retrodictive" (backwards in time) manner.

Many state curricula place a heavy emphasis on geology content as a part of Earth science courses. Because geologic phenomena are so interconnected, the same basic ideas can be extended to other areas of Earth science. At the same time, many states have also included "inquiry" as a part of these same curricula. As defined by the National Science Education Standards (1996), inquiry instruction can be defined as including both "understanding of scientific inquiry" as well as "abilities necessary to do scientific inquiry." Inquiry experiences in the Earth sciences are often vicarious or indirect, because direct experimentation, such as is used in the physical sciences, is typically not possible (National Research Council, 1996). The natural variability of Earth materials, their broad but often interrupted (or missing) distribution, and the extended time spans required for Earth processes to operate often shape Earth inquiries in such a way that it would be difficult to control all of the variables and represent real world conditions in a laboratory. In addition, the evidence derived from Earth inquiries can be ambiguous and lack opportunities for direct, discrete confirmation.

It has been suggested that educational environments can be ill-structured (Nespor, 1987), and as a result of a mismatch between highly structured curricula against a less well structured content domain and classroom environments, considerable pressure is placed on teachers decision-making capacities (Keys & Kang, 2000; Keys & Bryan, 2001). Because of these factors, it can be inferred that teachers may avoid inquiry altogether in Earth science classes without having more specific means of facilitating student completion of content objectives. This work attempts to define understandings of geoscience inquiry, positioned in a manner that suggests decision-making strategies for teachers to enhance their students' abilities with respect to geoscience inquiry. In this work, many of the examples presented are focused on geology, but have at least some connections with other aspects of Earth science.

## Structural Framework

### *Teasing Apart Problems in Geoscience*

An important consideration in Earth inquiries is that students should create "by [their] own effort an independent assemblage of truth," a point made by one of the fathers of American geology, T.C. Chamberlin (1897, p. 848). What becomes apparent early in any Earth inquiry is that the questions are often based on incomplete information about complex, interactive, and (ultimately) uncontrollable events, and thus, these questions defy simple or discrete explanation through any single pathway of inquiry (Ault, 1998; Frodeman, 1995). Getting lost in the details of this complexity is easy, so when teachers fall back on questions that are trivial or limited to confirmation of previous results it is perhaps merely defensive and "safe" in a classroom. Knowledge of how these details are framed in the geosciences is vital in recognizing what are relevant problems in the geosciences, and thus the work below provides a historical and philosophical framework on which teachers might base instructional decisions.

### *An Inquiry Framework for Instruction*

The instructionally defensive strategy is acceptable to a point, but as Chamberlin noted, Earth inquiries should result in an independent construction of the knowledge – the very basis of constructivist learning. Chamberlin's thoughts hold true even if a student is to merely confirm that which is already known. In extending the learning experience beyond confirmation, Monk and Dillon (1995) suggested that classroom inquiries can be broken into three separate components: (a) defining the question, (b) choosing methods, and (c) arriving at solutions. For each of these three stages, one must also determine what the inquiry is about (materials, space, or time?). Given the variability of students' abilities to construct these components, teachers must also control the level of inquiry, deciding the extent to which each of components is pre-defined. Using this basic framework, the instructional sequence can be defined by teachers, sequencing events so as to allow either the introduction (by the teacher) or construction (by the student) of each component. Thus, a large-scale framework of the work described below is based on this basic sequence, incorporating first the nature of geoscience inquiry and subsequently how this nature can be manifested in a classroom setting.

*Levels of Inquiry*

Teachers have a range of options when deciding the level of structure to be provided to students in any inquiry. Bell and his colleagues (2005) described key aspects of inquiry as (a) *confirmational*, in which students are expected to confirm known (at least by the teacher) information, (b) *structured*, in which students respond to a teacher-specified question and method, (c) *guided*, in which students select procedures and justify answers to a question proposed by the teacher, and (d) *open*, in which students select both the question and the method in a general area devised or suggested by the teacher. These levels become important tools to teachers, who often struggle with their beliefs about what is expected of them by content standards versus their students' capacities (Keys & Bryan, 2001). By planning how much pre-defined information is given to students, it is possible for teachers to begin to reconcile these competing beliefs. Thus a third, finer-grained framework for the work below specifies what appropriate levels of information could look like.

In each of the following sections on questions, methods, and solutions below, corresponding examples from the geosciences are defined, sketching the origins and applications of each and providing an understanding of geoscience inquiries. These examples are further framed with respect to possible levels of classroom inquiry appropriate to student abilities, provided in a table form (see tables I, II, and III). To further illustrate classroom applications of an Earth science-specific model of inquiry, each section also begins with a classroom vignette.

*Defining the Question in Geoscience Inquiries*

> Vignette A
>
> An issue Mrs. Spurrier has always struggled with is getting her students to understand the relationship between landforms and the rock structures underneath the land surface. Her students can identify folds and faults on a test without problem, but they cannot seem to see how this has anything to do with mountains, stream drainage patterns, or landslides. During a topographic map reading exercise, one of her students asks her why the river channels on some maps look like the branches in a leaf, while on other maps the pattern looks like steps or ladders. From cross-sections, Mrs. Spurrier decides that she can structure a student investigation around maps on which she can place known faults and ridges of resistant rock (sandstone, etc.). The question she poses to them is this: What do faults and rocks have to do with the course of rivers?

Inquiries in the Earth sciences are not necessarily about making generalizable statements that go beyond a setting. They can, instead, consist of describing an event that represents a setting and then comparing descriptions for different settings (Ault, 1998). The challenge is to frame these questions in terms of material, space, and time, and then facilitate larger and longer-term understandings by promoting a larger significance, extending to other areas or times.

Time, for example, is not intentionally progressive. As a matter of fact, time in geology is often treated as regressive – that is, what has happened in the past. Geology as a science is dependent on time and place (Toulmin, 1990), and Earth inquiries are fundamentally place bound. Only when taken as a group can one integrate inquiries across locations and time (Kitts, 1977). Hillside creep measurements, for example, start by measuring slope positions in different locations and at different times, and only when a body of data on positions, soil types, vegetative cover, etc., is built up over time can one begin to make generalizations about landslide hazards.

*Descriptions of Materials, Space, and Time*

At the simplest level, meaningful questions in Earth science center on descriptions (e.g., a description of what a rock or mineral is made of). These questions lend themselves to responses that confirm what is already known, limited to a defined set of minerals or rocks. Finley (1982) further defined descriptions as (a) *classifications* – a characteristic is present or not, such as cleavage, (b) *comparisons* – more or less of a given property, such as hardness, and (c) *quantitative* – fixing a number to some characteristic, such as density or specific gravity. At a guided inquiry level, new or unique materials can be introduced, and questions could center on comparisons and contrasts between the new materials and what is already known. Questions of space, such as where certain minerals can be found, can be posed in a similar fashion involving classification and comparison with where the same mineral can be found, perhaps determining a map location. Time questions can be structured about a sequence of when minerals found together formed, working backwards in time based on the size and shape of mineral grains in a rock.

On the other hand, student observations about Earth phenomena are necessary if they are to generate or accept more open questions. Chin and Brown (2002) speak to the authenticity of student-generated questions, particularly with respect to their direct personal experiences versus those that are teacher-derived and perhaps outside of students' direct experience. Students must be able to define aspects of their own direct or indirect experiences with Earth events, even if they use their own words and not necessarily scientific terminology. Thus, a student-generated question of why a backyard stream floods is as valid as a broader question of why New Orleans flooded during Hurricane Katrina, so long as the questions consider materials, time, and space.

*Interpolation and Extrapolation*

As one moves from descriptions to interpolations, adding more dimensions adds more complexity to questions, but it also expands the range of questions that can be asked. For example, one could ask how a stream channel changes with respect to time or to changes in water flow. An individual might not be able to observe directly such changes all of the time, but defining a trend from more than one dimension helps to establish a jumping off point from which extrapolations can be drawn. Students may be able to extrapolate what the stream channel might look like during a flood or how those changes differ from lower flow conditions. One could also pose questions of interpolation, in an attempt to describe materials that may have been changed or removed by Earth processes.

Interpolations do not inherently imply the cause of what is changed or how fast it changed. Interpolations and extrapolations, however, become increasingly reliant upon visualizations (Ault, 1994), such as maps, charts, scales, and graphs. Simply drawing the contour lines on a topographic or weather map requires interpolation between three points – the starting point of a line and the two measured points the line is to be drawn between. Verbal descriptions alone cannot adequately convey the necessary patterns that we would have students investigate. Visual representations of the geometry of rock layers, graph patterns of heat flow from the interior of the Earth across various layers, or maps of the ocean floor all provide a taste of the complexity of Earth systems that should frame meaningful questions, especially when projecting across time, space, or material gaps.

A basic idea in Earth science is uniformitarianism, a theory that results in an understanding that Earth processes today allow us to make inferences about similar processes in another place or time. Uniformitarianism relies on pattern recognition, to the extent that Earth processes and the resultant features we observe today can be extrapolated forward or backward in time beyond the information we have at hand. Adding more dimensions enriches questions, such that at least two aspects of a phenomenon must be addressed.

*Interactions*

Earth phenomena, from the dramatic impact of an earthquake to the subtleties of groundwater flow are complex and multivariate and defy simple explanations. To even begin to understand them, descriptions of materials, space, and time must be defined. Alone, however, these descriptions fall short of providing a fuller, causal explanation of Earth phenomena. When inferring beyond data or across gaps in data, various aspects of Earth phenomena are influenced by other factors that are part of the same overall system. Weather forecasts, for example, offer general projections of future weather conditions for an area, but the actual weather in a location can be influenced by small variations in wind, ground cover, or topography. The interactions of these components raise questions that come even closer to defining the Earth phenomenon of interest. For example, defining what climates would be like on Earth for different plate positions over time would connect all three elements – materials, space, and time – and create a question that is three dimensional in nature. Add to this question the relationship of geographic barriers, and a mechanism for different plant or animal speciation becomes available. This is then a four-dimensional question, one that comes closer to reality.

There is utility in using phenomena to explain other phenomena. The more dimensions added to a question, the closer it comes to reality, with the potential benefit of creating more interconnections between questions. Thus, the availability of water (or lack thereof) from local wells can best be investigated by asking about soil characteristics, slope, recharge areas, and the volume of water extraction over time.

Interactions are scaleable, but with an increase in scale comes an increase in ambiguity or questions for which there would not be enough data for students to develop meaningful questions; that is, a scientific question may be valid and legitimate, but there is no way to pursue it in the classroom. With a sufficiently large scale, however, questions can be based within a "sphere": lithosphere (rock), the hydrosphere (water), atmosphere (air), and cryosphere (frozen). Questions are bounded by the materials present, the ways the materials are distributed across an area, and the ways the materials change over time, giving each sphere a sufficiently limited set of material-space-time considerations that students can define questions within them. Where these spheres interact may offer the most interesting questions, such as how ocean water makes plate tectonics possible.

In Vignette A, Mrs. Spurrier has posed a question structured around an interaction between the underlying geologic structure in an area and the stream patterns for that area. In doing so, she based this question on an interaction between how materials are distributed or oriented and what pattern the streams assume over a larger area. To explore the application range of questions for both the nature of geoscience inquiry and student abilities, sample questions are posed in Table I.

Table I

*Sample Earth Science Inquiry Questions*

| | **Confirmation** | **Structured** | **Guided** | **Open** |
|---|---|---|---|---|
| **Description** | What is the estimated ratio of dark minerals to light-colored minerals in a rock sample? | What is the role of grain size in the settling rates of sediment in a column of water? | What metamorphic minerals form at different temperatures and pressures? | What kind of rocks can be found behind the school? |
| **Interpolations & Extrapolations** | From the data provided, construct a graph that shows the negative relationship between grain size and rate of cooling for molten rock | If small grained igneous rocks have a rapid cooling rate and large grained igneous rocks a slow cooling rate, what is the rate of cooling for mixed grains? | What is the lateral extent and thickness of rock unit? | What is the geology of area the town is in? |
| **Interactions** | How are the deposits left by glaciers and alluvial fans different? | In what ways are grain sorting and grain size related to the environment in which a rock forms? | How does latitude and proximity to the ocean affect the physical geography of an area? | How does the elevation of the town affect its climate? |

*Choosing Methods – Observations and Models*

Vignette B

Mrs. Spurrier and her students cannot help but observe that the day after a heavy rainstorm her classroom is filled with the overpowering stench of raw sewage. Yet the stream that flows next to the building is usually barely flowing at all. The odor has only become apparent after the growth of the nearby subdivision. Besides the obvious problem the smell represents, Mrs. Spurrier decides that this is something to have her students investigate.

As a part of setting up the investigation, Mrs. Spurrier has her students list factors they believe have caused or are related to the problem. Her students have identified such factors as the amount of rainfall, the frequency of heavy rainfalls, the size of the stream channel, and the number of houses in the subdivision. One student also asks whether the houses were attached to a public sewer line or used septic tanks.

There are obvious public health hazards to which Mrs. Spurrier does not wish to expose her students, so she structures the inquiry carefully, selecting a time that has been without rain for several days to have students take careful measurements of the size and depth of the channel, what they see in the channel, etc. She also assigns students to research the factors they have previously identified. Using these pieces of information, the class constructs a map showing the school grounds, the stream, and the subdivision. Using rainfall data from the local TV station, they construct a model that suggests that if a rainfall is over ¾ in. then the room will smell awful the next day. All they need is a heavy rain to test their model….

Unlike investigations in physics, Earth science investigations seldom include the direct manipulation of variables (Frodeman, 1995; Toulmin, 1990), except in the context of simulating an Earth process under laboratory conditions. Two geologists who profoundly influenced the nature of research in the Earth sciences were Grove Karl Gilbert and Thomas C. Chamberlin, who formulated basic descriptions of not just specific phenomena in geology, but also refined the methodological approaches through which geologists address questions of interest. For physicists, methods are tied to law and theory. But according to Gilbert (1886) method is related to *hypothesis* and *antecedent*. Antecedents in the context of Earth phenomena are factors that are both logical connected to a phenomenon, causal with respect to the nature of the phenomenon, and also linked to the timing and duration of the event. Hypotheses stand in for a set of antecedent conditions that could explain a given phenomenon (Kitts, 1977). For instance, an especially heavy rainfall after days of rain upstream of a location could be linked to floods downstream. The hypotheses resulting from these antecedents, however, are not necessarily the same testable statements one would find in the physical sciences. They are statements of starting conditions of materials in space with respect to some initial time point. This assumption of hypothesis → antecedent becomes the central basis for retrodiction (Ault, 1998).

Hypotheses in geology are different than those for physics, in that many are historical tools rather than straight predictions from a controlled experiment. One can rarely be assured that any two examples of an Earth phenomenon are exactly the same, whether in time or place (Ault, 1998). Although antecedents are interpretative endpoints that contribute to models, hypotheses are the means by which models are tested. According to Kitts (1977), Gilbert believed that rigid theoretical structures, such as those in chemistry and physics, are a threat to the development of progressive histories – that in seeking or even requiring a directionality in a theory was not necessary when generating descriptions from one phenomenon to another. Directionality, particularly with respect to time, implies an increase in diversity and complexity, one with a definable order. One need not assume that a particular Earth phenomenon was in the past less complex or resulted in a simpler to understand result. For instance, when defining what conditions were like in the past or will be in the future, one does not have to assume that a particular Earth phenomenon was less complex in the past. Stream deposits of 400 million years ago are as complex and recognizable as stream deposits today. Any different assumption would imply that uniformitarianism is not a useful tool for Earth science inquiries.

Chamberlin (1897), in applying the idea of multiple working hypotheses contended that since Earth phenomena rarely result from a single cause, a single hypothesis is inadequate. Because there are multiple contributing causes to a single Earth event, multiple hypotheses need to be articulated, explored, and pitted against each other, with the understanding that the multiple hypotheses need not completely account for the phenomenon. Perhaps the flooding in one location is the result of heavy rain on saturated ground upstream, but the flood could also be caused by a blockage of flow downstream. According to Ault (1998), these multiple hypotheses produce "independent, converging lines of inquiry" (p. 207). Thus, an Earth science classroom that is dedicated to a flexibility of methods, such as through guided inquiry, closely matches how Earth science inquiries have been made in the past, using observations to provide specifics of an Earth event, while using *models* to test causal mechanisms.

*Observations*

Observations in geology are more than just verbal descriptions, although such descriptions provide the "raw material" for the formulation of hypotheses. Were observations limited to measurements of grain size, bed thickness, strike and dip of a rock unit, and geometric relations of folds and faults, they would be largely indistinguishable from measurements of force, voltage, pH, or concentration. What separates geologic observations from chemical observations is the need to consider a range of scales, whether such scales are in the microtextures seen in shocked quartz grains at an impact site, the thickness of the rind on a weathered rock, road cuts with multiple rock layers, or the large-scale map patterns of mountain belts. Such observations are essentially identical, whether the observations are determined by high-tech tools (such as satellite imagery and laser altimetry) or more traditional tools (such as pocket transits and petrographic microscopes). The difference is in the scale of the spatial range and volume of data collected.

The second distinction is made with respect to the terminology used in descriptions. Detailed descriptions of materials include many unusual terms, such as *anticline, subduction zone,* or *hot-spot volcano*. Terms such as these provide not only descriptions of shape or form, but also information on cause, and they provide clues to where other such observations might be made. . These observations are inherently interpretive, rather than experimental (Ault, 1998). Organized into taxonomies, observations are designed to fully represent the Earth phenomena of interest. To the extent that these taxonomies fail to fully account for the events, they lose the level of reproducibility required of scientific inquiries, and therefore lack utility for continued use.

*Models*

Even though normal modes of inquiry in Earth science do not involve the direct manipulation of variables in the same manner as other sciences, there are circumstances in which the question requires changes in how observations are made. Manipulating how observations are made, however, usually requires a model of some sort with variables that can be changed. Models are dependent on the overlap or cumulative effect of different factors, as well as the boundary conditions in which the model is used (Harrison & Treagust, 2000). For instance, describing an eruption of a volcano requires observations of the temperature of the lava, how much of different chemical elements are available, and how much gas is in the lava. Change any of these variables, and a different eruption will result, which frequently happens across eruptions from the same volcano over time.

Models that are of use in explaining Earth-phenomena in this way fall into one of four categories:

1. A *simulation* model, where one tries to duplicate how the materials change when conditions are changed (e.g., when samples of limestone are immersed in different concentrations HCl to duplicate how rocks containing $CaCO_3$ chemically weather).
2. A *functional* model, in which a measurement is used to make interpolations or extrapolations (e.g., deciding how long a sedimentary layer took to accumulate based on how fast different sediments settle).
3. A *cyclical* model, in which connections between specific materials across time and/or space are explored (e.g., the behavior of solid Earth materials over time in the rock cycle.
4. A *global* or *systems* model, in which the end result is an interpretation based on observations of complex phenomena (e.g., the relationship of rock types to plate margins). (Stevens & Collins, 1980)

In an instructional sense, it is important to ensure that students know when one type of model or another is appropriate, what model components are or can be determined in the context of the question of interest, and how various models for an Earth phenomena can be compared and contrasted (Stevens & Collins, 1980). In answering these questions, models can become more or less sophisticated, with students learning through the refinement of the models. Models that allow for the testing of alternative solutions (as is called for through the multiple working hypotheses structure discussed previously) can also support or refute predictions applied to novel situations. Finally, mapping the distinctions between different models can help prevent models from becoming distorted or made too shallow, a source of misconceptions.

In the context of inquiry, however, there is an inherent danger that when models are created, one can make them overly closed ended and thus reduce their use to a direct confirmation of an Earth event, with limited opportunities for discussing the limits of that model (the investigator found exactly what they were looking for; therefore, the job is done). With limited guidance, students are capable of generating questions for which defining all of the necessary parameters is nearly impossible, thus, leading to ambiguous or misleading results.

In Vignette B, Mrs. Spurrier guided her students in an investigation requiring them to make or collect observations and to use them in the context of a functional model. What the students may find in their investigation is that no one model best fits their situation without sufficient observations. The real source of the odor was determined to be the subdivision's compact "package" water treatment plant, which failed due to increased load from additional homes providing influent. A range of methodological approaches for various problems are presented in Table II.

Table II
*Sample Earth Science Inquiry Methods*

| | **Confirmation** | **Structured** | **Guided** | **Open** |
|---|---|---|---|---|
| **Observations** | Counting the numbers of faces on defined crystals | Comparing the angles between the faces of different-sized crystals of the same material | Determining the permeability of different rocks by immersion in water for different amounts of time | Using the bulk density of a soil sample with pH to determine how weathered local soils are. |
| **Models** | Identifying where different rock samples can be found on a diagram of the rock cycle. | Use the percentage of quartz, feldspars, and rock fragments to identify the sedimentary environment in which a rock formed. | Using a stream table with different types of sediment and water flow rates to characterize streams. | Modeling a variety of shoreline forms and slopes to determine tsunami inundation |

Arriving at Solutions – Interpretive and Historical

Vignette C

Many of Mrs. Spurriers' students travel to the beach on school breaks. The most popular route to the beach is right down the nearby state highway. Being a fan of the beach herself, Mrs. Spurrier knows the route well, and she poses a descriptive question to her students: Count how many ridges they pass over or through have white sand in the road cut and have short, scrubby little pine trees on them. When the students return from break, some students tell her they saw two or three such ridges; others saw four or five. She asked them how these ridges compared with the beach, and at first, the students were a little confused. When they discussed the parts of the beach and the areas just behind the beach, the lights went on for some of the students. "Those sandy ridges were where the beach was once, weren't they? " asks one of her students.

Given the wide range questions tied to Earth phenomena and the methods used to define them, the next step is to decide what answers make sense. Solutions to questions in Earth science span the range from narrow, prescribed answers based on classification to a broad set of answers capturing the complex and dynamic nature of Earth systems. Frodeman (1995) contended that meaningful answers in geology are either interpretive, using a "truth-seeking" approach, or are of a historical nature (regarding the sequences of

Earth events). In this light, they become persuasive arguments. It is not an adequate solution to make observations framed from a single point of view to generate reasonable inferences. One can define a process that describes a phenomenon, such as river flooding, but until the mechanisms producing that process are defined (such as the size of the adjacent floodplain, stream peak discharge, and peak flow duration), the solution remains isolated and incomplete. Once a series of interpretations are made available as a narrative description, they become historical and contribute to larger understandings of groups of Earth events.

*Interpretations*

In general terms, interpretations in geology are reflective of the variety of geological conditions and the complexity of interactions among these conditions. Interpretations take the raw material of observations and attempt to reconcile one set of observations to another. Interpretations also allow the testing and possible refutation of models. Such "tests" are framed in the context of the original goals (questions) of an investigation, which result in certain discoveries to the exclusion of others (Frodeman, 1995). A case in point is the history of plate tectonics as a theory in geology. Thomas Kuhn (1970) suggested that exceptions supporting an alternative interpretation either never happen at all or occur all of the time when phenomena are explained. The hypothesis of continental drift, as articulated by Alfred Wegener, was a counter instance to the hypothesis that continents were "fixed" in place. Those that saw continents as fixed in place saw the data of the "drifters" as puzzles to be accounted for without continents moving. Data such as "fits" between continental margins, transoceanic similarities of plant and animal fossils, and matched sequences of sedimentary rocks were explainable by now-submerged land bridges.

The resulting crisis was not over continental drift per se, but over methods and interpretations. Drifters wanted a uniform explanation for all of the patterns they observed, but "fixers" preferred an approach that made continental drift one possible theory. It was only when different geophysical data, such as paleomagnetic stripes, gravity anomalies, and heat flow measurements from the sea floor were observed, that the idea of plate tectonics could be developed. This idea did not build directly on continental drift but used different lines of evidence to refute continental fixity successfully and account for the data puzzles introduced by the Drifters (Oreskes, 1999).

*Historical Representations*

What happened or is found at a particular place and time is a solution that satisfies the need for retrodiction in Earth inquiries. This again is what separates Earth inquiries from that of the other sciences. In the physical sciences, experiments can be set up, controlled, results recorded, and conclusions communicated across the research community for replication in different times and places. Following the described procedures ensures replication of results. In Earth inquiries, one form of solution is a narrative description of the phenomenon or object of inquiry. With detailed descriptions, two main goals can be accomplished: (a) the contribution of a set of ideas to a larger problem of interest, such as the relationship of the porosity and permeability of a limestone layer to how much oil it could contain, and (b) the reconciliation of different descriptions of the same phenomena by different models, such as the description of a lava flow by either the type of rock in the flow or the density of gas bubbles in the flow itself (Frodeman, 1995). Once these narratives are integrated into a larger set of ideas, they have value as a solution to a larger path of investigation. "Expert" groups of students might separately describe the same samples of materials, framed by different models, but collectively their observations would define the Earth phenomenon related to the samples.

Another form of historical solution in Earth inquiries is the analogy. Normally, an analogy in science consists of a target concept and an analogue of the event, object, or phenomenon (Glynn, 1991). For example, glaciers are often described as "rivers" of ice, and can represent several of the same class of phenomena, such as erosion, deposition, etc. The analogy breaks down when one considers the mechanisms of glacial processes, ones that generally do not emerge without a narrative description. These analogies are conceived independent of time and spatial distribution, and often limit themselves to the characteristics and behavior of materials. Analogies applied as historical solutions to Earth inquiries require the consideration of time and space. Uniformitarianism, for example, can be considered in terms of the consistency of physical laws over time, or through the projection of current observations of cause into the past (Gould, 1987). Thus, the narrative allows for any unique phenomenon to be directly and quickly considered by analogy to another similar, well-characterized event. Thus, the Mercalli scale of earthquake intensity can provide a fairly accurate estimate of the energies released in an earthquake event based on the damage caused by the earthquake, even if few seismographs are available where the earthquake occurred.

What should characterize any analogy (and all too often forgotten in the use of analogies) is the definition of the limits of an analogy. There were, for example, conditions on the ancient Earth that do not now currently exist, such as those that produced the Precambrian banded iron formations. Today, there is simply too much oxygen in the atmosphere for exposed iron to exist long in a form other than hematite ($Fe_2O_3$). There are also the limits imposed by the incongruity between geologic time and human time. We can, by analogy, relate *Skolithos* (an extinct burrowing worm known from preserved burrows in clean sandstones) found fossils of Cambrian quartzites to the worm burrows found on today's beaches, but can we reverse the analogy and anticipate what today's burrows will look like on a preserved Myrtle Beach in the distant future (Frodeman, 1995). Mrs. Spurriers' students saw a great deal of sand when they went to the beach, but they needed structured or guided interpretations to see those sandy ridges as past beach terraces. They also needed guidance to see that the ridges are a historical record of sea level changes. Additional solution examples are found in Table III.

Table III
*Sample Earth Science Inquiry Solutions*

| | Confirmation | Structured | Guided | Open |
|---|---|---|---|---|
| **Interpretations** | A determination of the relative movement along a fault plane from map pattern data | Description of a paleoenvironment based on rock and fossil types | An estimate of the past location of a continent, based on rock type, fossils, paleomagnetic information, etc. | Determining the direction of stress for a local area based on mineral orientation and folds/faults, etc. |
| **Historical Representations** | A sequence of events for the formation of rocks and structures, developed from a 3-D block diagram. | A determination of the age or timing of a divergent plate margin from the similarities and differences of fossil and rock types. | A reconstruction of past positions of a continent based on a regional stratigraphic column | A sequence of the tectonic events for an area |

*Discussion of a Complete Model*

Much of the information presented above is centered on one aspect of inquiry as defined science standards (NRC, 1996), the understanding of the traditions and conventions of geoscience inquiry, with some support for instructional design. The model is graphically represented in Figure 1. In considering the above model of Earth science inquiry in an instructional sense, a teacher needs to consider the application both within the context of an individual lesson as well as planning for students' conceptual growth. Within the general model of constructing inquiries, teachers guide students through questions, using specific methods to arrive at desired or expected solutions. To support such transitions, the teacher's work centers on facilitating students' opportunities for each inquiry component, providing sufficient information (and materials) for students to proceed. This involves a determination of how much information is specified to students (questions, methods, solutions) to describe the level of inquiry.

*Connections Between Nodes*

In order to make instructional sense of this model, the transitions between the "nodes," as defined by the structure of geoscience inquiry, can serve to describe specific classroom actions in a manner that informs teachers in commonly used terminology. This terminology should consequently find application in specific lesson plan elements. The 5E Learning Cycle (Center for Science, Mathematics, and Engineering Education, 2000) offers a general framework to which the connections can be overlain. To illustrate this application, there is a school in the Virginia Coastal Plain that has behind it on the school grounds a small stream that cuts through layers of Miocene-age sediments. One of these layers is rich in large shell fossils, including *Chesapecten jeffersonius*, a large scallop that is the state fossil of Virginia. As a result, this fossil is sought after by students (*engagement*). After identifying what fossils are present (usually more than one species) in the layer, the range of individual fossil sizes, layer thickness, and lateral extent can be determined. Reviewing and sorting all of the descriptions helps to frame the observations that characterize the layer (*exploration*). By comparing this layer with other layers that are different, and by researching for other, similar layers, the layer can be interpreted as a shell shoal (*explanation*). Shell shoals are sandy beds that typically form near an active beach, and since this location is approximately 40 miles from the current beach, instructional conditions are ripe for students to engage in a new investigation that uses interpolations to frame further observations to fill in data gaps, or extrapolations of correlation to subsequently test the model that the shelly layer is in fact a shell shoal (*elaboration*). Student knowledge can subsequently be tested by soliciting their supporting evidence for predicting where additional shell shoals might be found (*evaluation*).

*Complexity of Inquiry*

As students' conceptual understanding grows, Earth science inquiry lessons should reflect a consequent growth in complexity and larger understanding. Recall that while the level of inquiry is based on the amount of information supplied to students, not on the complexity of that information. Starting first with relatively constrained, one-dimensional descriptions linked to observations and consequent interpretations, more dimensions can be added to the questions, leading to more complex modeling and historical descriptions. The shift could take place over time between lessons, but also within the context of a lesson. Complexity in this classroom inquiry can be increased by the introduction of additional dimensions, such as fossil density within the shell shoal, morphological differences in the fossils, and variations in the sediments. Observations can be seen as contributing to models being used as tools for framing subsequent observations, particularly in comparing the shell-rich sediments with other, well documented shell shoals, both contemporary and ancient. Finally, the interpretations made by students of the conditions that led to the deposition of the layer in the first place, as well as layers above the shell shoal, can be used to build a history of the local area. This history can then describe changes in sea level in the past (retrodictions) and make predictions for the future. In this manner, students' inquiries can lead to a deeper understanding of the multivariate reality that make up Earth systems. A graphical description of both the Earth science inquiry model as well as the instructional application can be found in Figure 1.

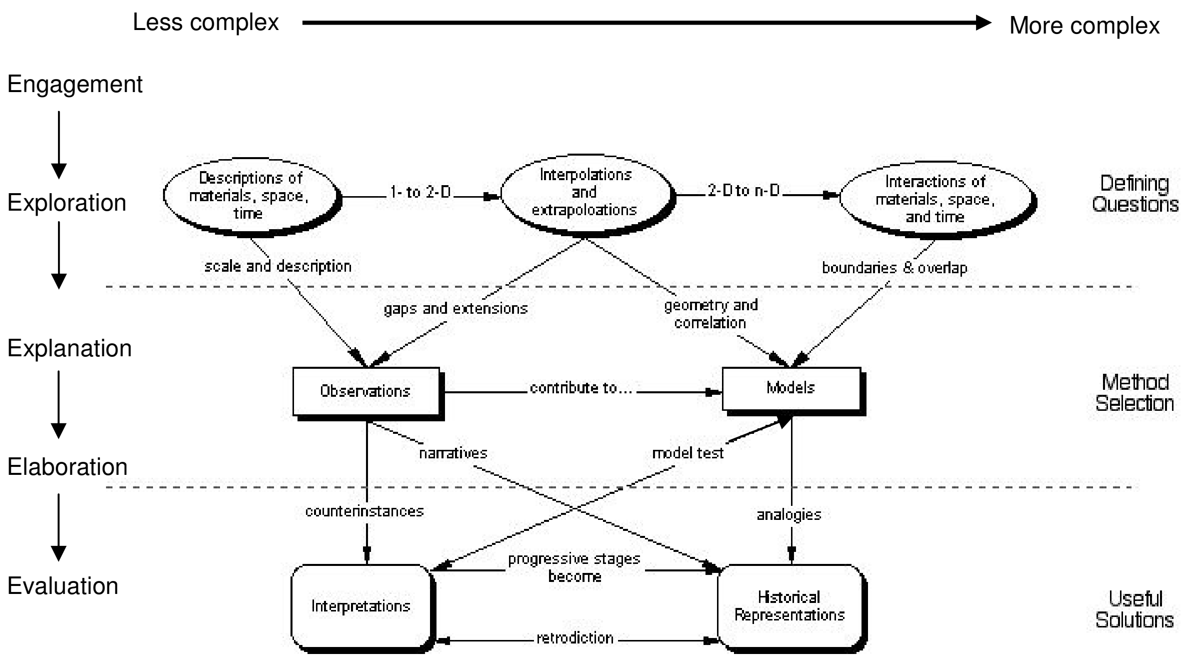


*Figure I.* Summary Representation of an Inquiry Framework for the Earth Sciences

Selecting the level of complexity is a decision-making process involving teacher professional knowledge, depth of content knowledge, and understanding of student capacities and development. Keys and Bryan's (2001) suggest that this decision-making process is a reflection of the need for teachers to reconcile their beliefs of the both the nature of inquiry as well as the abilities of their students. The documentation of these processes, particularly with respect to this model of geoscience inquiry, is a rich vein of investigation in its own right. With a model that captures both the complexity of instructional planning needs and the nature of inquiry in the Earth sciences, teachers and professional development providers have a tool that supports a richer understanding of science inquiry in general.

## Conclusions

It should be readily apparent that even without the same level of control over the conditions of inquiry enjoyed by other sciences, inquiries in Earth science might be structured in a manner that reflects of the nature of the various Earth science disciplines. With the current emphasis placed on inquiry-oriented science instruction, it is important that teachers have a deep understanding inquiry that is reflective of nature and conventions of the discipline. A full instructional explication of the proposed Earth science-specific model of inquiry is beyond the scope of this work, but it should become clear that the central questions, methods, and solutions in Earth science can be defined in instructionally meaningful ways. Furthermore, as recommendations for Earth science curricula embrace an Earth systems approach (Hoffman & Barstow, 2007), it is important to remember that hypothetico-deductive methods of analysis are ill suited to broader descriptions of how the Earth works. Earth science inquiries should be seen as dynamic and are scalable, to meet the demands of individual inquiries while contributing to an overall understanding of Earth systems. With this in mind, it is possible to take Earth science instruction away from simple terminology-based descriptions and build authentic investigations for students to experience.

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# Using the Reflective Teaching Model in a Year-long Professional Development: A Case Study of a Second Year Urban Elementary Teacher

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Abstract

This study examined the change in a third grade teacher (Jennifer) who engaged in a year-long professional development model during her second year of teaching in an urban district. In particular, she embraced the Reflective Teaching Model (RTM) which was unique to this professional development. Jennifer and nine other teachers from her school participated in 120 hours of professional development over a ten month period. In addition to a 2-week summer institute, Jennifer engaged in 14 RTM cycles from September to May, attended five Saturday workshops, and corresponded through many email dialogues. Four themes emerged from field notes, teacher reflections, email communication, observations and interviews. Three were not a surprise as they paralleled the goals of the professional development (growth in content knowledge, increase of pedagogical skills, and value of prolonged professional development, especially the RTM). However, the fourth (alienation by her team) was a surprise and raised questions about the professional development and the culture of schools.

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## Introduction

The early 1990s were filled with calls for changes in the way science was being taught in U.S. schools (AAAS, 1993; NRC, 1996). In response, professional development for science teachers changed to include an emphasis on ways to help teachers develop and implement more inquiry based instruction as well as increase their content knowledge. This emphasis asked teachers to change their behaviors as well as the way many of them thought about teaching and learning. However, educational change and innovation proved to be difficult and slow (Pace, 1992; Tyack & Cuban, 1995). Two reasons cited by teachers for why they had not tried innovative approaches include lack of confidence in their own ability and lack of collegial support (Pugh & Zhao, 2003;

Tyack & Cuban, 1995). Research into models of professional development reported some common aspects among successful professional development. One aspect cited is having a critical mass of teachers from one location (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Rhoton & Bowers, 2001); a second is working with teachers over an extended period (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; Weinburgh, 2005); a third is co-teaching in their classrooms (Hart, Najee-ullah & Schultz, 2004; Weinburgh, 2003); and a fourth is using local issues/concerns to help contextualize the learning (Burroughs, Schwartz & Hendricks-Lee, 2000).

With these four components in mind, we planned a professional development experience for teachers at two high-needs, urban elementary schools. The experience was designed to help increase (1) science content knowledge about water issues, especially concentrating on Texas issues; (2) pedagogical skills, especially inquiry-based teaching; and (3) reflective practice, as encouraged by the Reflective Teaching Model. Twenty teachers (ten from each school) volunteered for the experience knowing that it involved a two-week intensive summer institute, monthly Saturday follow-up workshops, and Reflective Teaching Model (RTM) sessions at least once a month during the academic year. The principal of one school and the instructional lead teacher at the other school were aware of all activities during the academic year and were highly supportive of the program.

## Theoretical/Conceptual Framework

### *Professional Development*

The term professional development encompasses many different types of activities. One of the most familiar is non-degree seeking activities through which teachers up-grade their knowledge and skills. In the mid and late 1990s researchers proposed several models of professional development that build on a conception of knowledge construction derived from the work of Vygotsky (Haney & Lumpe, 1995; Howe & Stubbs, 1997; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Radford, 1998; Rhoton & Bowers, 2001). These models stress that the teachers, like any learners, use new experiences in building (constructing) their own understanding. The models also stress that the teachers become active participants in knowledge generation. They recognize the role of the more knowledgeable other in helping the learner move through the zone of proximal development while stressing the active nature of learning. These contextual topics may then be used to suggest larger, more generalizeable ideas.

Research tells us that teachers' knowledge is local, contextualized, personal, and relational (Burroughs, Schwartz & Hendricks-Lee, 2000). Therefore, many of the models suggest that the providers of the experience tailor it to the population, including specific content that is most relevant to the participants. Using topics and examples that are 'local' to the district, school, and classroom, results in more authentic learning for the teachers and may result in teachers taking ownership of the content.

Time is an important factor for successful professional development, with many of the models suggesting that teachers need to have an extended period of time during which to involve themselves with the new ideas. An approach cited by several researches is having more than 100 hours of contact with each teacher (Haney & Lumpe, 1995; Howe & Stubbs, 1997; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Radford, 1998; Rhoton & Bowers, 2001). Having an intensive summer workshop allowed the teachers to experience new teaching methods, multiple outdoor activities, and new content. Continuing to meet during the academic year encouraged the exchange of ideas between the teachers.

Professional development stops short when it fails to include an implementation component to bring new behaviors and skills from the training program into the classroom (Anderson & Mitchener, 1994; Gibbons, Kimmell & O'Shea, 1997). To nurture real changes in teaching behavior, opportunities to practice and to receive coaching are crucial (Guskey, 1986.) Models such as the RTM give teachers time to practice their new skills and time to reflect on the effectiveness of these skills in their classrooms at that point in time.

*Reflective Teaching Model*

The Reflective Teaching Model (RTM) has been used with mathematics and science teachers to help them implement reform teaching strategies (Hart, 1994; Hart, Najeee-Ullah & Schultz, 2004; Weinburgh, Hart & Carriere, 2007) since the early 1990s. The RTM is grounded in the theories of constructivism and metacognition. It relies heavily on a pair of teachers (or teacher and teacher educator) being able to *model effective practice, share authority*, and *reflect on practice.* The model recommends consistent, on-going sessions of joint planning/teaching/reflecting. Either member of the team may teach the lesson created during shared planning sessions or both may co-teach the lesson. Reflecting on one's practices requires a form of deep thinking in which one poses questions and solves problems. This reflection is encouraged in the planning and the debriefing phases of the RTM.

*Modeling.* Teaching is a very complex activity. Goldsmith and Schifter (1997) suggest that teachers may not have useful images of non-traditional teaching practices. Therefore, they may not be able to enact new ways of teaching without first seeing examples. Having another person model ways of teaching that are different from their own, especially if it is done in their classroom with their students, can give them new images of teaching. These new images in turn provide a foundation on which they may construct new ideas of how classrooms can look and sound.

*Authority.* Weinburgh et al. (2007) suggest that part of the strength of the RTM lies in changing the power structure usually seen in professional development models. This power shift occurs when authority is shared by the classroom teacher and the teacher educator for all parts of the lesson – planning, implementing, and reflecting.

> Sharing authority is critical for the successful interaction of teachers and teacher educators, as well as teachers and students. All participants in the RTM (teachers and teacher educators) are seen as learners and all are seen as teachers. The ability of an inservice teacher or a teacher educator to relinquish intellectual control and allow others to share in the generation of content or pedagogical ideas

> is a subtle but significant shift in roles from the traditional teacher as teller. It builds trust, ownership, and cohesion among those involved. RTM requires that the teachers plan with a partner, teach using a new strategy/pedagogy, and debrief about the lesson" (Weinburgh et al., 2007, p. 24).

*Reflection*. The critical construct of reflection helps teachers in changing their practice. Teachers need to engage in experiences in which they not only try innovations but also are challenged to think deeply about their assumptions of teaching. The discussions during the planning of lessons and after the teaching of the lessons give the teachers time to question the goals, values, and beliefs that guide their work. They are encouraged to articulate their questions and formulate answers. With questioning comes change.

## Purpose of Study/Research Questions

The case study presented here examined the change in a third grade teacher (Jennifer) who embraced the Reflective Teaching Model (RTM) as a professional development model during her second year of teaching in an urban district. In particular, this was an attempt to examine change in content knowledge, pedagogical skills, and reflective practice. A close examination of one teacher in an urban school who utilized the RTM had the potential to shed insight into factors which facilitate or hinder teacher change.

## Context

### *School*

The research was conducted in an elementary school (student population of 500) in a large urban area in the southwestern part of the USA. The school served kindergarten through 5$^{th}$ grade students with three teachers per grade level. Table I shows the comparison of the demographic information for the school and the state. Teacher turnover in Jennifer's school was about 20% per year which was higher than the state average but less than the district. The principal wanted the science scores to improve at Johnson Elementary School (pseudonym) and appeared to support the teachers in their participation in the project offered by a nearby university.

Table I
*Demographics of the school and the state.*

| | % by Ethnicity | | | | % by Subgroups | |
|---|---|---|---|---|---|---|
| | Hispanic | African-American | White | Asian | Economically Disadvantaged | Limited English |
| State | 45 | 14 | 38 | 3 | 55 | 16 |
| School | 65 | 25 | 10 | 0 | 66 | 67 |

*Jennifer*

Jennifer was a 24-year old, white female with a bachelor's degree in elementary education at the time of the study. She was a second year teacher who taught a self-contained third grade class. She was on a team of three teachers, was the youngest of the three in years and in teaching experience, and was the only one with the state endorsement for English Language Learners (ELL). Jennifer, her two third grade team mates, and seven other teachers from her school participated in the project. Although Jennifer was the most active, all of the Johnson Elementary School teachers participated in at least 4 RTM cycles (five other teacher participated in 8 RTM cycles, one participated in 7 RTM cycles, two in 5 RTM cycles, and 1 in 4 RTM cycles).

*RTM for Jennifer*

The RTM cycle used by Jennifer, Erin and Sally was typical of those used throughout Johnson Elementary School. For the first cycle, Molly met with all three and helped plan a lesson that would be taught to each of the 3rd grade classes. The next day she observed each teaching the lesson and debriefed with each of them later in the day. This pattern of planning a grade-level lesson did not continue, instead, for the rest of the RTM cycles each teacher scheduled planning times independently of each other. Because each lesson was co-planned with Molly, the lesson could be taught by either Molly or the teacher alone or co-taught by both. In Jennifer's case, Molly taught two lessons, Jennifer taught seven lessons, and they co-taught five lessons. Jennifer did not observe Erin and Sally teaching nor did they observe her teaching.

## Methods

*Research Paradigm*

A case study is "…an intensive, holistic description and analysis of a single instance, phenomenon, or socials unit" (Merriam, 1998, p. 27). It offers a ways of examining "… complex social units consisting of multiple variables of potential importance in understanding the phenomenon" (Merriam, 1998, p. 41). The case described here occurred in a bounded context – one teacher during a year-long professional development experience. The investigators were the primary instrument for gathering and analyzing data and, therefore, had the ability to respond to each situation by maximizing opportunities for collecting meaningful information (Merriam, 1998).

*Data Collection*

Data were collected during the two-week intensive summer workshop and during the following academic year. To assess the teachers' content knowledge directly related to water issues covered by the project, a 10-item short-answer paper-pencil test (Appendix) was administered on three occasions. The test data were collected on the first and last days (pre- and post-program) of the 2-week summer workshop in July and approximately one year later (follow-up), after the school year ended in June. Teacher products such as graphic organizers, KWLs, lesson plans, and reflections were collected for ten months. Notes made by the primary researcher during RTM planning sessions and lesson observations also added data about content knowledge, especially as related to the specific lesson to be taught.

Each of the teachers had the opportunity to engage in RTM cycles two times a month during the following school year (September, October, November, January, February, March). Participation varied among the teachers. To assess pedagogical skills and reflective practice, data were collected from several sources during the academic year including the primary researcher's field notes, teacher reflections, email communication, and written lesson plans. During observations, the primary researcher looked for and recorded the use of inquiry-based teaching techniques and strategies modeled during the summer workshop and discussed during the planning of the lesson. In February, all of the teachers discussed their experience while being audio taped.

*Data Analysis*

Scoring keys were constructed for the paper-pencil 10-item test such that each item could receive a total of 0 to 3 points, yielding a top possible score of 30. Using this grading rubric, three raters (the first author, second author, and graduate assistant) independently scored each test without knowledge of the test-taker or time of test. Inter-rater agreement was determined by summing the item totals and obtaining correlations (Pearson's $r$) among the raters' total scores. Correlations ranged from .99 to .96, indicating high scoring reliability. The average scores from the three raters for each teacher were then calculated and used for further analyses. The data from the paper-pencil were analyzed by comparing the total pre/post scores.

Data from the teacher paragraphs, researcher field notes, teacher reflections, email communications, Jennifer's discussion of her experience, and lesson plans were analyzed independently by the first and second authors using a constant comparative method (Denzin & Lincoln, 1994; Glaser & Strauss, 1967). Triangulation, using multiple sources of data to confirm the emerging findings, established validity in case studies.

Yin (1994) suggested organizing the large about of data collected in case studies in a case study data base. From this data base categories or themes that capture some recurring pattern are established. Merriam (1998) pointed out that "devising categories is largely an intuitive process, but is also systematic and informed by the study's purpose, the investigator's orientation and knowledge" (p. 179). The data were examined recursively by the first and second author and comparisons were made between the authors. As the data were examined, themes emerged and descriptions were written. Jennifer was asked to read all interpretations of data made by the researchers (member checking).

## Results

The data indicate that Jennifer changed in several ways over the 10 months of this study. Not surprising and consistent with the goals of the project as well as with a previous study (Weinburgh, 2003), three themes emerged from the data: (1) growth in content knowledge about water issues (summer topic) and topics covered in the third grade standards for the state, (2) increase of pedagogical skills, especially engaging students in inquiry, and (3) value of the RTM as a professional development model. However, a new, unexpected, and concerning theme emerged for Jennifer as the year progressed – alienation by her two third grade team mates. The idea of alienation had not emerged in other studies about RTM and did not appear in the literature on science professional development and, therefore, had not been part of the theoretical framework.

### *Summer*

Jennifer's pre-program test resulted in 6 points out of 30 (20%), the post-program test resulted in 27 points out of 30 (90%), and the follow-up test resulted in 28 points out of 30 (93%). She made the lowest pre-program score of all twenty teachers in the project. Immediately after the test, she told the college professors that she really liked science, but that she did not know much science content and did not feel comfortable teaching science. After participating in the summer workshop (field trips included a trip to the water treatment plant, sewage plant, Trinity River, and Eagle Mountain Lake; labs included simulations of lake turn-over, single-point pollution, and a tasting test of bottled water; inquiry-based activities included building the most efficient water tower, determining what grass required the most water, and proposing a xeroscaping plan for their school; lessons included mini-lectures on major water issues), Jennifer wrote the following entries in her journal.

> I have learned so much. I hope I can excite my students the way that you have excited me. [July 29]

> I questioned the value of doing the water tower, especially since there were no directions given, but I learned so much – like head pressure – and became convinced that students can work without all the step-by-step directions that I usually give. [July 29]

Jennifer was already seeing the value for herself and her students of less structured activities in learning science. She found the open debate on how to build the tower stimulating and realized that all the content objectives for the lesson were met as a result of the student-generated [in this case the workshop teachers] data. This entry also indicted that she was reflecting on the summer activities and connecting them to her students and their needs. During the summer, the college professors modeled parts of the

RTM by debriefing their lessons. These debriefings were unrehearsed. Jennifer was skeptical of the RTM at first. After observing the third debriefing session modeled by the professors, she wrote,

> At first I thought the discussion about the lesson was faked but today Ray was pretty harsh with himself and Molly about the lesson. Together they did a 'think aloud' in which they re-thought the lesson and came up with a really good idea for next time. I hope my team can have this kind of frank talk about teaching. [July 27]

From the very beginning, Jennifer made references to her 3rd grade team mates, both of whom were in the professional development program. She was pleased that they could learn together and could then use their new skills and knowledge with their students. She looked forward to a form of collegiality that she saw between the college professors. As she said,

> This is the first professional development that I have attended with my team mates. I am so glad that we are here together. [July 25]
>
> Sally and Erin [pseudonyms for her team mates] know so much more science than I do. I know that I will learn from them. [July 29]
>
> We (her team mates) talked today about ways to use the water-treatment plant with our 3rd graders. This is going to really help me with my ELL students. [August 2]

Jennifer's lack of confidence was evident in her journal entries but so was her willingness to learn. In actual fact, she was the least knowledgeable about science within her grade level. Trained as a generalist, she only had one science course at the college level. Erin, in contrast, had six college science courses and Sally had three courses.

*Academic Year*

Molly met with the ten teachers at Johnson Elementary School in August to establish the first RTM session. Jennifer and her two third grade team mates decided to plan together with Molly during the first week in September as did the seven other Johnson teachers. Molly's notes indicate that she arrived at the school early on the day of the planning session and spoke briefly to three other participating teachers before going to Jennifer's room. Jennifer finished teaching, sent her students to "specials" and began an animated discussion of the beginning of the year and her students as she and Molly waited for Sally and Erin to join them.

The first RTM session was a little slow but resulted in the three teachers admitting that they wanted to help the students compare the sun and moon as a review but were not sure how to do this. Jennifer expressed concern on two levels – her lack of confidence in her own understanding of the sun and moon and her skills in helping her students. As she said,

> I am not sure about the topic myself and I am not sure I know how to help the students. You know, I have most of the ELL students this year. Also, many of them are from the apartments [a low SES housing complex with high crime rate and high mobility]. [September 9]

Together, the three teachers and Molly planned a review lesson. Part of the planning involved Molly helping the teachers articulate what they wanted for the students as a result of the review. She took the time to add a discussion about the moon and the sun thereby helping the teachers with content. When asked if any of them had ever used a VENN diagram, Jennifer responded that she had not and expressed concern about how her students would react to using it. She originally planned to only do a class VENN on the board. After some thought she changed her plan and gave groups of four students a set of hoops and sentence strips to use on the floor. She bought the hoops that night at Wal Mart. Molly watched the lessons of all three teachers the next day. Each teacher debriefed separately due to scheduling issues. Jennifer's schedule allowed her to debrief the lesson immediately afterward. Jennifer was very hard on herself but was pleased with the use of the VENN diagram. During the debriefing, she said,

> I would never have thought of this on my own and was not sure about using it, but it worked. I liked the big ones on the floor. The students, especially the ELLs, liked moving the sentence strips around. I think the students were able to use the strips to express what they know. It gave me a change to ask them to read to me. [September 10]

Jennifer emailed Molly twice before the next RTM session in late September to tell her about a class or to ask a question. She used the VENN once again during that time. One of her main concerns was working with low income, ELL students. She was not sure she could relate to their needs. This concerned her on a personal and professional level. By November, Jennifer had engaged in five RTM sessions. An email on November 13 was characteristic of her communications:

> Molly-Friday the 14th I now have an ARD during the time we were going to meet! Could you still meet with Sally and Erin at that time? Could I meet with you from either 11:35-12:10 or my music time is 12:30-1:10. Do either of those times work? I do not want to miss a planning session with you. [November 12 email]

As it turned out, Jennifer and Molly met, but her team mates did not. This was the beginning of a pattern in which Jennifer found time for RTM sessions, but Sally and Erin found reasons why they could not meet at the agreed upon time and rescheduled without Jennifer or missed a session completely. Molly's notes describe her impressions after being in the school for a RTM session with other teachers in the building saying,

> Although Sally and Erin seem pleased on one level that Jennifer is introducing new ideas into her teaching and sharing them (and her handouts) with them, there appears to be some tension. Neither Sally nor Erin seemed to want to put the effort into teaching that Jennifer is showing. Neither appeared to hold Jennifer's belief that the students they teach can learn and deserve exciting lessons. [November 15]

> Jennifer is using many of the ELL strategies that we have discussed. She is using science as a way to add reading, writing and speaking into the daily lives of her students. Her room is now overflowing (in a good way) with plants, animals, lots of pictures, books, and a growing word wall. Her science content is improving as she is more interested in researching the topic she is introducing to her students. [November 17]

By December, Jennifer was using each RTM to check her content and to try new teaching strategies. She often came to the planning session with questions about how to best engage her students and to clarify a science content concern. Her reflections on what worked and what did not work became more analytical and looked more closely at the children's work and responses rather than at her own reactions and thoughts. However, she was concerned because her team mates were not planning with us as often and because they were commenting that Jennifer's children were much too active. As she observed,

> I wish the team planned together better. [December 2]

> Erin suggested that I wanted to do things with our 3rd graders that urban, ELL students could not do. I could not make her see that the (state standards) actually required this type of activity and depth of content. [December 2]

In a separate RTM with Erin, Molly noted that Erin thought the students should be in their seats with less talking (even though she had a few students who were ELL and needed to speak as often as possible). Erin indicated that her students were always quiet and very well-behaved, unlike Jennifer's class. By this time, Sally was finding it impossible to meet for a planning session - some student "emergency" occurred, pre-empting each scheduled planning session. In addition, she was not using materials that Jennifer gave her to help supplement lessons.

During a RTM session in March, Jennifer planned a lesson on the food web. She had the common misconceptions that she should draw arrows from an organism to what it eats. She did not understand that the web shows energy flow. The planning session helped her understand the concept of a food web more fully.

> Thinking about the whole energy and matter cycle with Molly allowed me to have an understanding of the food web that I had never had. [March 28]

Her first thought was to give all groups the same set of organisms. While Jennifer and Molly discussed what Jennifer wanted the students to learn and how best to do this, Jennifer decided to have different organisms for each group. She wanted the students to see that there could be lots of combinations. After teaching the lesson, she commented,

> The group with the organisms that were almost the same as the book did very well, the other groups had trouble. I realized that they (the children) did not really get the concept but had just memorized the one in the book. I was so glad that the activity was designed in way that would let me know that they did not know. [March 29]

> I was unsure how to answer Pedro's question and it just felt right to look to you for help. I love that you are there for me and can guide my students and model good questioning for me. I could not have done it. [March 29]

> Planning with you and having you here to watch or to intervene as needed has been the BEST. I mean the BEST thing that could happen to me as a teacher. How do others teachers grow if they do not have this type of help?" [March 29]

Her content knowledge and confidence in her own teaching improved with each RTM cycle. In addition, Jennifer had become very reflective, asking questions about teaching and learning that would not have occurred to her prior to participation in the project. Molly reflected about the same plan/teach/reflect session,

> Jennifer was very relaxed today when the students asked the question about the mouse. She handled it well. I was glad to be there to support her. [March 29]

She also wrote about Jennifer's academic growth. Later in the day, Molly added an entry to her journal. She noted,

> Rumor has it that Jennifer is not liked by her team mates. They feel that she is stepping beyond her bounds. They are critical of her trying things that most other teachers in the building are not doing. Becky (first grade teacher) is complimentary of Jennifer, saying she is an excellent teacher. [March 29]

> Jennifer wants to continue the RTM into April even though the project officially ends. [March 29]

> By April, Jennifer wrote,

> I cannot imagine what this year would have been like without Molly. My skills as a teacher and my confidence in myself have sky-rocketed. [April 11]

> Yesterday the students designed their own investigation. The only rule was that I had to approve it prior to their starting and that the materials had to be easy for me to get by today. Today, they conducted their investigation and it was amazing. Without the planning sessions all year with Molly, I would never have done this and my students would have been the ones to suffer from my lack of knowledge and confidence. [April 20]

> From the experience, I know that students can do things that many adults think they cannot. With just a little planning on my part and setting a rich environment, I can see the children increase their knowledge and skills in science and increase their use of English. [April 20]

Jennifer specifically comments about her growth in knowledge and confidence. She attributes this to being in the project. In particular, she comments on being able to help her students move toward their own inquiry as a large step for her as a teacher. She is glad that she participated. Molly's notes from April captured Jennifer's growth and her feeling of despair,

> Jennifer has grown as a teacher. Her science content is much stronger and her teaching shows her confidence. She is reflecting on her teaching in a deep and thoughtful way. Her students are engaged in activities that her team-mates think are too hard for 3rd graders. [April 05]

> Jennifer is looking for another job. My heart breaks for her – she feels that she is deserting her students by leaving this school. [April 05]

Molly visited the school again the next week. She spoke to all the teachers briefly to wish them a good summer. An entry in her journal captures the conflict between Jennifer and Erin.

> I talked with Erin today about Jennifer not returning. She indicated that Jennifer did not really fit with the 3rd grade team, that her students were talkative and often out of their seat. She was not sure why Jennifer's students had good scores on the state tests because she saw the students as undisciplined. [April 11]

*The End of School*

The academic year ended, Erin and Sally signed contracts to stay at Johnson Elementary while Jennifer did not sign her contract. Jennifer told the others that she wanted to work closer to her home, but she told me that she did not feel comfortable working with Erin and Sally. She felt that her values no longer matched theirs. Her new belief in the value of student talk and more open inquiry did not parallel the beliefs of Erin and Sally. She also realized that she would never influence them to change their beliefs. She stated that, in her opinion, both Sally and Erin were better teachers for having been in the project but that neither were "where I am" (Jennifer, April 11). She expressed sadness that there would be more distance between her and Molly which would result in less contact. On a positive note, she was looking forward to her new assignment in a new district.

## Discussion

The purpose of the research was to seek an understanding of the effect of the RTM as a professional development tool for elementary teachers who teach in urban schools. Jennifer, as a 3rd grade teacher in an urban school engaging in multiple iterations of the RTM, helped provide the researchers with rich description and understanding of the RTM process but also of the dilemmas and conflicts that Jennifer encountered. This study left the researchers with many more questions than answers. Jennifer's personal and professional growth was remarkable yet sad. One might ask if the professional development was effective. As we examined each of the themes that emerged, we began to see a complex, confusing, and complicated answer.

*Content*

The significant gain in test scores showed that the intensive summer workshop did improve her recall knowledge about water issues. Also, highly important was the follow-up score a year later, showing that the new content knowledge was retained. As with any assessment instrument of this type, one should note that a paper-pencil test can serve only as a general indicator of what has been learned. The qualitative analysis suggests that Jennifer constructed much richer representations of the information she encountered, beyond the sample of items included on the test. In addition to the knowledge about water, Jennifer continued to learn new content as she engaged in the RTM with Molly. Her content as well as her knowledge-in-action (Ethell, 1997; Korthagen & Kessel, 1999) improved over the academic year. It is possible, but not probable, that her content knowledge would have increased substantially without the RTM sessions. However, Jennifer believes that the professional development greatly affected her content knowledge and her ability to help students.

The RTM sessions also helped contextualize and localize her knowledge as she used it with her students (Burrough et al., 2000). She used her new knowledge to enrich instruction and to engage the students in discussions about science that would have been impossible for her the year before. Her confidence in her ability to help students understand, and even like, science improved. She became more interested in making connections between science and other disciplines.

*Pedagogy*

Jennifer recalled that she was very structured in her approach to teaching during her first year and that working with Molly allowed her to try teaching innovation with her students. She began to use strategies, such as word walls, sentence strips, open-ended questions, think-pair-share, and manipulatives, that were modeled in the summer and discussed during the planning sessions of the RTM. She also moved from guided inquiry to much more open inquiry. As suggested by Guskey (1986), Jennifer found that having the opportunity to try new skills while having a more experienced person in the room in case she needed help was invaluable. She was able to perfect her new skills before she used them "solo". The transfer of skills from the summer workshop to the classroom was facilitated through the RTM sessions. The most significant advancement was an inquiry activity in which the students asked their own science questions, developed a method to answer their questions and supported their conclusions with evidence.

In addition, Jennifer used skills with her students that she learned about and saw modeled during the summer and reviewed during the RTM sessions. She could not take the students on a field trip to the Trinity River but did take them three blocks from the school to investigate a creek. She incorporated more pairing of students and talking in small groups into her lessons and asked students to support their statements with data.

Jennifer's concern that she could not help her ELL students diminished as she sought ways to include them in a more active way. She used strategies specific to ELL students that she learned during the summer or that she and Molly discussed during the RTM sessions. Her students, both native speakers and ELL, found multiple ways of expressing their science ideas.

*Reflective Teaching Model*

Field notes provided evidence that the project fostered new awareness and attitudes about the learning and teaching of science, beyond the study of water. This research is consistent with other research (Hart et al., 2004; Weinburgh, 2003, 2005; Weinburgh et al., 2007) concerning the use of the RTM. Teachers who engage in reflective planning and analysis of their teaching do appear to gain in positive ways not seen in other professional development models.

Jennifer enjoyed the two-week summer workshop but found that her greatest content and pedagogy gains were during the academic year when she taught her own students. She took advantage of the RTM from the beginning, embracing it as a way to engage in one-on-one coaching and mentoring. She quickly felt a sense of shared authority as seen in her enthusiasm for learning from Molly as well as teaching Molly. She also began to trust herself and Molly as they co-taught her 3rd grade students. Of particular note was her unwavering belief that the ELL students in her class could learn if she provided them with rich, engaging environments.

This model of professional development stressed the importance of thinking about teaching. By October Jennifer was engaging in discussions about her teaching as she began thinking about why she made decisions about teaching and how those decisions affected her students. At first her questions were directed to Molly with the expectation that an answer would be quickly found. Over time, her questions were more introspective and less answer-bound.

*Alienation*

Jennifer gained from the experience but she also lost. An unexpected outcome of the professional development experience for Jennifer was the growing alienation from her team mates. She began the summer as a member in good standing with her two 3rd grade teachers but by December they were seeing her as being deviant. Her belief in the ability of her students and her efforts to improve her teaching appeared to threaten Erin and Sally. Rather than embracing her attempts to share materials and ideas with them, they began to work in subtle ways to discredit her. By January they were dropping hints that her 'rich' parents were buying her supplies and letting her use the color printer for her handouts. They did not add that she also made copies of the color handouts for them. In addition, they suggested that her students were out of control, citing behaviors that Molly did not find to be inappropriate. Pace (1992) reported a similar conflict with teachers who were trying to implement literacy instruction.

While her relationship with her team diminished, her love of teaching, her understanding of her students, and her ability to teach science increased. When other teachers in the building were asked to describe Jennifer, all but her team mates praised her enthusiasm and hard work. Although the principal supported the professional development and thought that Jennifer was a good teacher, she did not take any steps to understand why Jennifer was considering leaving the school and did leave. This treatment was most painful for Molly as she watched a good teacher being pushed away from an urban school in which she could have had a great influence on minority students and especially ELL students.

Conclusions

In designing professional development, we sought to get a critical mass from one school because we held the assumption that the teachers would provide support for one another as they tried new teaching strategies. In this case, conflicts developed between Jennifer and her 3rd grade team mates. Pace (1992) and Tyack and Cuban (1995) concluded from their studies that this may be more common that we generally acknowledge, certainly more so than most of the literature on science professional development indicates (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003; Radford, 1998; Rhoton & Bowers, 2001).

Although there are several definitions of alienation dating from Seeman's 1959 essay, "On the Meaning of Alienation", most include the three constructs of isolation, normlessness, and powerlessness (Brooks, Hughes & Brooks, 2008; Shoho & Katis, 1998). Isolation can be a physical or sociological condition. In the social sense, "isolation has to do with the degree to which an individual feels an affinity to their community's values, beliefs, and norms of behavior" (Brooks, Hughes & Brooks, 2008, p. 48). Jennifer's isolation from her 3rd grade team mates was based in her change in beliefs about teaching and learning and the value she placed on them. During her first year of teaching, she fell into a pattern of following the lead of Sally and Erin. This changed as she embraced ideas from the project more completely than either of them.

Normlessness is similar to isolation in that it is associated with teachers who do not feel as if they are a part of the norms within the school. In this case, the teacher's difference is often seen as negative rather than as positive. The norms of Johnson Elementary were changing as a results of the project but Jennifer's two team mates were the most resistant to change. Because Jennifer identified with the 3rd grade, she felt the normlessness associated with her grade level more than the normness of the school.

Powerlessness "represents an inability to influence one's choices in a given environment. Teachers who feel powerless believe they can not affect the decisions of others" (Shoho & Katis, 1998, p. 52). During September, October and November, Jennifer tried several ways of affecting the decisions made by Sally and Erin. She first found passive-resistance and later more open opposition to her ideas.

Jennifer appeared to exhibit all three of these toward the end of her tenure at Johnson Elementary. Pugh and Zhao (2003) suggest that two main sources of alienation may result from the type of professional development offered in the project. The first is a disruption of the existing culture within the school. Schools cultures strongly embrace the idea of equity. When it is perceived that a teacher is getting an unusual amount of the resources, the results may be alienation (Kerchner, 1992). Jennifer got concrete resources for her classroom and one-on-one mentoring – both of which may have upset the egalitarian culture found in many schools (Pugh & Zhao, 2003).

Another source of teacher alienation, according to Pugh and Zhao (2003), is an escalation of existing conflicts between peers and/or administration. Although Jennifer did not appear to have pre-existing conflicts, she already had a reputation for spending a lot of time at school and providing her students with 'extras'. For example, she did not think it was unusual to buy hula-hoops for her students to use in making VENN diagrams to show their understanding of the moon and sun.

Emerging from this research is the reminder that the complex social structure of schools can have an impact on professional development. Jennifer's team mates did not grow professionally at the same rate as Jennifer, which resulted in an uncomfortable situation for them and for Jennifer. Jennifer was personally hurt by the reaction of her team mates.

This case study adds to the body of literature on professional development by describing the positive and negative implications for professional development. Our assumption that a critical mass of teachers in a building would lead to more substantial change needs to be rethought. Schools are complex social structures with many un-written rules. This research highlights the need to more fully understand schools and the power structures within them as we provide professional development for teachers.

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# Appendix

## Water Project
## Pre/Post Test
(scored on a 3 point scale)

Name:________________________________________ Date:__________________

Please answer the following questions as fully as possible. You will be asked to answer them again in August. This will help us determine how well we presented the materials.

1. Where does scientific knowledge reside? How does it get there?

2. What evidence is there that there may be a water crisis?

3. Why can you buy laundry detergent that does not contain phosphate?

4. Pesticides appear to be very beneficial. What are the harmful effects of pesticides such as DDT?

5. What made lakes in Canada and the Eastern US become devoid of fish and what has been done about it?

6. How have river systems been altered by human beings and what has this done to fish such as the salmon?

7. How does the water treatment plant work?

8. How does the sewage treatment plant work?

9. List some benefits and some hazards of wetlands and marshes.

10. What is the "learning cycle"?

# Match-Making to Enhance the Mentoring Relationship in Student Teaching: Learning from a Simple Personality Instrument

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Abstract

Four student teachers in secondary science education were matched with cooperating teachers based on four personality constructs identified from a simple Myers-Brigg type inventory. Placement decisions were based on compatibility of primary or secondary temperaments informing pedagogical approach in the classroom and particular skills needed for mentorship. Teaching dyads were most fruitful where primary or secondary temperaments were in common, but not both. Some level of dissonance in temperaments fostered pedagogical growth in one student teacher. All temperaments studied supported learning to teach science with unique strengths. One construct called "relational" appeared necessary in mentor teachers for fostering relationships with ample support and communication.

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## Introduction

The most valued experience in teacher education programs is the student teaching practicum or internship (McIntyre, Byrd, & Foxx, 1996). Student teachers (interns) enter their cooperating teachers' classrooms with enthusiasm and high expectations that they will be able to implement their preferred approach to planning and teaching, receive adequate guidance and support, and learn from an otherwise experienced authority (Munby & Russell, 1994). Most of them enter internship after reflective field experiences that have helped them better understand their values and beliefs as well as pedagogical skills as beginning teachers (McLean, 1999). They hope to be placed with a cooperating teacher who will support their preferred approach to teaching and needs in learning to teach, and not clash with them. Their positive attitude and overall experience in the internship depends on meeting this expectation (McIntyre, Byrd, & Foxx, 1996).

Though past research has highlighted the socializing influence of the cooperating teacher on the intern (Su, 1992), this influence can greatly vary depending upon the nature of classroom contexts and teacher practice (Copeland, 1980). The influence of the cooperating teacher in shaping intern practice depends upon multiple factors. Some of these factors include congruence of teacher practice with university program, quality of ongoing mentorship, university-school collaboration, and proper mentor matching (Potthoff & Alley, 1996). Exemplary practitioners alone do not shape intern practice as much as individuals who provide explicit and quality feedback (Borko & Mayfield, 1995). Even so, interns are more willingly influenced in practice by cooperating teachers whose views about teaching and learning are closely aligned to their own initial beliefs (Bunting, 1988; Graham, 1997). In such cases, the fruitfulness of the match from a constructivist perspective is in the scaffolded learning and advancement of skill that occurs, and not in the compliance and tact needed to complete the experience (Lacey, 1977).

Programs in teacher education emphasize the quality of classroom instruction and the mentoring role of cooperating teachers in internship. However, little attention has been paid to matching the personality qualities of interns with a suitable cooperating teacher. Mentor matching has existed as a consideration for field placements for some time now (Leslie, 1971; Mahlios, 1982). Yet, few large university programs, if any, systematically consider mentor-matching as an important consideration in placing interns (McIntyre, Byrd, & Foxx, 1996). Internships were shown to be more productive when matches were made where interns felt suited to their teacher (Potthoff & Alley, 1996). Practical considerations from the perspective of practitioners allude to the importance of proper matching, considering such personality qualities as temperament, degree of flexibility, and structure (Croker, 1999). For example, interns needing more guidance and structure for their experience should be placed with cooperating teachers who are suited to provide it.

Recent research that has reconsidered the relationship between interns and cooperating teachers has brought up supportive qualities including emotional support, peer relationship, collaboration, flexibility, and feedback (Beck & Kosnik, 2002; Sudzina, Giebelhaus, & Coolican, 1997; Zeichner, 2002). Beck and Kosnik (2002) conclude that the elements most valued by interns had to do with their relationship with their cooperating teacher. Conflict with the cooperating teacher is often cited as one of the major reasons given for failing internships (Harwood, Collins, & Sudzina, 2000). Successful matches would be characterized by greater rapport, more communication, and a more trusting and harmonious relationship (Koerner & Rust, 2002; Knudson & Turley, 2000; Stanulis & Russell, 1999). Information that can help to foster better relationships between cooperating teachers and interns would likely support the success rate of internships and learning from it.

In this research we studied the working relationship between four cooperating teachers and their interns through the framework of a four-quadrant personality instrument that is based on the Myers-Briggs type indicator (Bryce, 2002). We wanted to learn if the information from this instrument on temperament styles would be fruitful in our thinking on intern placement through strengthening relational qualities based on personality traits. Specifically, we wanted to know if the personality constructs of the instrument were congruent with the predominant philosophical (teaching and learning) and mentoring concerns of secondary science interns and their cooperating teachers. Sharing similar philosophical and mentoring concerns would likely strengthen the relationship between cooperating teacher and intern, leading to a more productive internship. Applying these and similar constructs in practice could support placement coordinators in having additional information for making stronger individual field placements with higher rates of satisfaction and success in learning to teach.

## A Complex View of Mentoring in Internship

Proper mentoring in preservice teacher education depends upon the mentor's support of interns as they make the transition to classroom teacher (McNally, Cope, Inglis, & Stronach, 1997). This support includes modeling effective practice as well as a generous dose of supportive feedback on intern performance. Properly trained and effective mentors can make a difference in the learning experience of interns when both parties are committed to mutually shared goals of teaching and learning (Sudzina et al., 1997). Mutually shared goals can range from more global perspectives, such as a common philosophy of education, to more specific ones, such as how to manage and discipline students in the classroom. Lack of mutually shared goals is indicative of a mismatch between teaching philosophies, styles, or needs of the intern in learning to teach. Even with strong mentors, internships can be difficult if there is a mismatch in teaching styles that can lead to personality conflicts between parties (Agee, 1996; Graham, 1997; Sudzina et al., 1997). For example, placing an intern who has a traditional view of teaching with a more progressive cooperating teacher can lead to built-in conflicts over planning and teaching that cannot be resolved (Graham, 1997). Agee (1996) documented through case studies of cooperating teacher-intern relationships that compatible teaching philosophies supported rapport and learning in internships. These examples support a constructivist view of learning in internship where dialogue on mutually understood and embraced teaching goals is an important part of learning and growth in internship (Moll, 1990). It also shows that successful mentoring relationships depend as much on interns and their predispositions as they do on cooperating teachers and their mentorship skills.

A broader framework for viewing the mentoring role of cooperating teachers must study the dyadic relationship between the cooperating teacher and intern. This framework does not negate the trainable attributes of good mentors, but does not take the technical-rational view that well trained mentors alone will always foster strong internships. In viewing mentoring as complex, one must take the constructivist perspective that looks at prior personalities, values, and understandings of participating parties as well as particular needs of interns (Martin, 1996).

> Mentoring is complex, not least because although the novice teacher's professional development is the central focus, this is influenced by the individual personalities of the subject mentor and the novice teacher, the novice's individual needs (their starting point and the 'baggage' they bring with them), and the mentor-novice relationship, which will itself change over the course of the programme. (p. 43)

Through this framework mentoring is viewed as a shared enterprise between cooperating teacher and intern with success depending upon both individuals (Sudzina et al., 1997). Interns are not blank slates but bring their own expectations and ideas to internship of what they expect and need from their cooperating teachers. Interns must be placed with cooperating teachers who can meet these unique expectations and needs through shared philosophies, needed strengths, and compatible personalities that foster strong rapport that drives the desire to learn and grow professionally (Sudzina et al., 1997).

A complex approach to mentoring also considers cooperating teachers' varied styles of mentoring that may or may not be compatible to interns' learning needs (Graham, 1993). Again, in this dyadic relationship the role of teaching philosophies and preferred styles of practice play an influential role. Beliefs and teaching styles of cooperating teachers have a parallel influence on mentoring styles, showing strong similarity in practice (Hawkey, 1998; Martin, 1997). A cooperating teacher who provides a highly structured environment and curriculum for her students is likely to provide similar structure for her intern, rather than allowing the intern immediate independence in practice. An intern may not need or want *mentoring through structure* if she is already highly organized and has a preferred approach to planning and teaching. On the other hand, the dissonance created by such a cooperating teacher for a less organized intern can lead to important growth and development in this area (Croker, 1999; Hawkey, 1998). Compatibility pairing of cooperating teachers and interns on mentoring styles and learning needs may work best through knowing what each participant provides and needs from the dyad. A reduction of dissonance to learning levels, while maintaining a high level of compatibility between pairs, would be the goal of this matching. Such pairing may be promising in supporting relationships based on preferred teaching approaches while also targeting the learning needs of interns.

## Four Colors Personality Inventory

Personality theorists, Donald Lowry and Nathan Bryce, simplified the complicated labels of the Myers Briggs Inventory into four colors to represent predominant temperaments: Blue, green, gold, and orange (See Table I).

Table I
*Comparison of personality type categories of Myers-Briggs and Lowry-Bryce.*

| | | | | |
|---|---|---|---|---|
| Myers/Briggs | ENFJ INFJ<br>ENFP INFP | ENTJ INTJ<br>ENTP INTP | ESTJ INTJ<br>ESFJ ISFJ | ESFP ISFP<br>ESTP ISTP |
| Lowry/Bryce | Blue | Green | Gold | Orange |

These temperaments form the basis of personality inventories and have application in parenting, workplace relationships, education, and counseling (Lowry, 1990). Based on the four-color temperament classification, each person can be described best by one color that fits his or her personality more than any other (Bryce, 2002). This is the individual's primary color or temperament. In addition to one's primary color, the secondary color provides additional personality description and usually supports the primary color. The fourth color is the least developed temperament because an individual is not often described by its characteristics. By understanding an individual's primary color, one can better understand an individual's predominant personality traits. The utility of the four temperaments is in better understanding how people react to situations and each other. Temperaments direct people emotionally through everyday life, whether a person is easily depressed, casual, formal, careful, or carefree (Hartman, 1987). Teacher knowledge of one's predominant temperament can enable conscious change in behavioral interactions with others, personal professional development, and understanding of the predominant behavior of others (Pankratius, 1997; Rosenfeld & Rosenfeld, 2006).

The Insight Learning Inventory© was chosen for this study because it presented the four colors in ten different categories, many of which related to teaching and interacting in the classroom (See Appendix). These categories focus on values, communication, motivation, work, supervision, recreation, childhood, youth, education, and love. Once categorical statements were read, each statement was given a rating. The rating for each category ranged from 1-4 with 4 meaning this statement is always like me and 1 meaning the statement is seldom like me (Bryce, 2002). Answers are tallied from each response keyed to a specific color to reveal the sum score for the four temperaments: gold, orange, green and blue. An individual's color spectrum is determined by the total numeric score for each color with the highest number or brightest color as primary with subsequent color scores below it (Bryce, 2002).

The color spectrum allows the individual to see a visual image of one emerging. The image shows traits that temper actions, preferences, likes, and dislikes. The combination of these four colors (color spectrum) characterizes the person (Hayward, 2001). Color traits have been used to shed light on teachers' and students' interactional styles in the classroom; how the teacher teaches and how individual students learn best (Bryce, 2002). In this study, color traits were applied to interactional styles between cooperating teachers and interns in planning, teaching, and mentoring in the classroom. Qualities or characteristics of each predominant color type composed the theoretical framework for thinking in this study. A synopsis of the general temperament or personality characteristics for each color in the educational setting is described in Table II.

Table II
*Comparison descriptions of personality type characteristics of Lowry and Echols (2000).*

| | |
|---|---|
| Blue | Compassionate, supportive, caring, cooperative, communicative, relationship-driven, encouraging, flexible, harmonious |
| Green | Problem-solving, expert, investigative, intellectual, competent, logical, autonomous, questioning, intolerant, curiousity-driven |
| Gold | Ordered, traditional, dependable, duty-driven, accountable, responsible, loyal, routine-driven, controlling, organized, authoritarian |
| Orange | Change-driven, free-spirited, spontaneous, risk-taking, experiential, expressive, hands-on, informal, entertaining, relevancy-driven |

## Context and Methods

At the end of their program in our rural southeastern university in the United States, secondary science education interns are individually placed with cooperating teachers for their 15-week student teaching (internship) experience. As program faculty who also teach and supervise these interns, we wanted to strengthen our approach in making placement decisions so that more interns would view their cooperating teachers as meeting their mentoring preferences as well as needs in becoming more proficient in the classroom. In the spring of 2004 we used the results of the Insights Learning Inventory© taken by our cooperating teachers and interns prior to placement to inform our discussions and placement decisions. Our goal was to better meet interns' mentoring wants and needs through placement with a compatible cooperating teacher. We also wanted to further develop the mentor-protégé relational qualities that we knew supported a successful internship.

Four interns and their cooperating teachers agreed to participate in our study of compatibility and mentor-protégé relationship in the internship. Each of these cooperating teachers had a minimum of ten years of science teaching experience and was known as a leader in their respective schools – all were department heads or chairs. Past collaboration with these teachers showed that they varied in predominant teaching approach and style but were considered effective teachers in practice. All of them regularly used the laboratory in science teaching. The Insights Inventory results informed our placement discussions through a deeper consideration of predominant and secondary temperament styles as characterized by color (blue, gold, green, orange) in the Inventory. Based on the literature and our past experience we viewed these styles or colors as a human construct that could potentially help in our understanding of preferred teaching and mentoring styles. In this way, we did not view the Inventory from a positivistic stance as it was intended but from a constructivist one, emphasizing its usefulness for us (Von Glasersfeld, 1989). We also viewed the Inventory's numerical results as a beginning point of thinking about each participant, feeling more strongly about the usefulness of the constructs themselves than the fidelity of the numerical scores.

Placements decisions began with science subject area major. Then, we sought compatibility by placing interns and cooperating teachers together who shared one or more of their highest scoring colors (predominant or secondary temperament) while also considering the mentoring needs of interns based on anecdotal evidence from lived experience with them in our classrooms and prior field placements (Van Manen, 1990). The goal of placement was to meet interns' mentoring needs as we saw them along with meeting their preferred styles of teaching as informed by the Insights Inventory. Table III shows intern-cooperating teacher pairing, inventory results, and school level and course taught in internship. Pseudonyms are used in this study.

Table III
*Intern and cooperating teacher pairings informed by inventory results.*

| Intern | Inventory Score: Blue, Gold, Green, Orange | Cooperating Teacher | Inventory Score: Blue, Gold, Green, Orange | School Level and Course |
|---|---|---|---|---|
| Mary | 36, 26, 17, 16 | Forrest | 20, 28, 25, 24 | High School: Environmental Science and Biology |
| Rose | 24, 21, 23, 27 | Michael | 20, 17, 33, 31 | Middle School: Integrated Science |
| Nate | 22, 22, 30, 29 | Tamara | 19, 20, 26, 15 | High School: Chemistry and Physics |
| Bonnie | 29, 32, 30, 20 | Leslie | 26, 33, 32, 20 | High School: Chemistry and Physical Science |

The two co-researchers of this study had previously taught and later each supervised two of the four interns in this study. We felt that we had a unique perspective and understanding of these participants and their experience as students in our program. Along with this understanding, we had placed, studied, and supervised interns for five or more years each. This experience informed our understanding of the internship process and difficulties experienced by interns. Thus, we were well poised to take a phenomenological perspective to this study, where participants and co-researchers together brought insight to this lived experience and a powerful combined understanding for a deeper interpretation of it (Van Manen, 1990).

During intern supervision, each co-researcher took copious field notes of observed teaching practice, areas needing professional development, and advice shared between teachers and supervisor. These notes informed researchers' understanding of each intern's teaching experiences, strengths and weaknesses, and brought deeper interpretations to the results of this study. Each university supervisor as co-researcher interviewed the participants (intern and cooperating teacher) individually in their two cases during the middle and end of the internship. The first semi-structured interviews focused on the *gathering of* general data on cooperating teacher-intern working relationship and concrete experiences from which perceptions of compatibility were based. The second semi-structured interviews *reflected on* initial data in light of the personality constructs of the Insights Inventory and how these constructs supported different facets of teacher practice and style in the mentoring process (Van Manen, 1990). Participants also commented on the general idea of using like-temperaments in placement decisions.

## Data Analysis

The interview data generated from each of the four cases were analyzed descriptively to make sense of each particular case and the fruitfulness of the mentoring process, including teaching temperaments and relationship perceived by participants (Merriam, 1998). Field data were used to triangulate responses to questions on intern practice and the cooperating teachers' views of intern practice. Descriptive coding of interview data on issues of temperament characteristics, compatibility, teaching style, and support preceded the development of thematic statements that captured significant aspects of participants' responses and experience (Van Manen, 1990). Examples of thematic statements include, "She needs more help in organization and putting her own ideas into practice," or "Both have a shared passion for science, demonstrations, and relating it to the real world." These thematic statements were later placed into the color category or categories whose characteristics best informed or related to the emergent theme. For example, "She needs more help in <u>organization</u> (gold) and putting her own ideas into practice" was categorized as a gold issue; "Both have a shared <u>passion for science</u> (green), demonstrations, and <u>relating it to the real world</u> (orange)" was categorized as both a green and an orange issue. This approach to categorizing the data by color was an iterative process between re-searching thematic words and phrases from the literature and looking for them in our data (Van Manen, 1990). Co-researchers also worked collaboratively in seeking agreement on the placement of each theme in the appropriate color category. These data were then compared to the Inventory results, checking the usefulness of the four color constructs, and fidelity of the Inventory's temperament scores and ranking in each case.

Lastly, each researcher drafted anecdotal narratives of their two cases that described the mentor-protégé relationship of dyads through story that included essential features of each relationship grounded in lived experience (Van Manen, 1990). Each anecdotal narrative raised the emergent themes specific to each case including the color construct associated with the theme from data analysis. The co-researchers chose anecdotal narrative in telling the story of each intern's experience because of its power to involve the reader personally in the lived experience of each intern, using less abstractive language and technical forms of writing to describe what has been learned in each case. The intent of this approach was to couch our *general* learning from the framework of personality constructs analysis within the *particular* stories of each case.

> What is often not seen is that anecdotal narrative as story form is an effective way of dealing with certain kinds of knowledge. 'Narrative, to narrate,' derives from

> the Latin *gnoscere, noscere* 'to know.' To narrate is to tell something in narrative or story form. The paradoxical thing about anecdotal narrative is that it tells something *particular* while really addressing the *general* or the *universal*. And vice-versa, at the hand of anecdote fundamental insights or truths are tested for their value in the contingent world of everyday experience. (Van Manen, 1990, p. 120)

Each story included vivid descriptions of the mentor-protégé relationship, what worked well between them, and the differences and similarities that were points of tension and support between them. Each narrative describes both the strengths and limitations of each mentoring relationship based on the personality traits of the dyads – identified by color construct – and the ongoing professed needs of each intern. The discussion that follows the narratives examines the usefulness of our approach, and the Insights Inventory, in creating successful matches in each case. Also, we will further theorize on our work based on what has been learned across cases for possible ideas for further study.

## Results

### Mary's Story
*A blue-gold intern with a gold-green-orange cooperating teacher*

Mary was a self-sufficient student throughout her program. She felt comfortable in planning and teaching students. She was adept at using technology in her day-to-day teaching, especially PowerPoint presentations in her lectures, as well as lab-based activities related to her subject matter. This comfort was likely due to her past experience in teaching lab classes in biology at the university before her internship. She also felt very comfortable with interacting with her high school students. This was evident in her frequent use of one-on-one assistance during class. Also, she typically interacted with her students in the classroom before and after class time through instigating discussions on their interests and what they did outside of class. She took a genuine interest in getting to know them personally, and ultimately developed a strong rapport with them – a particularly blue trait.

Mary was known for pulling her work, and lesson plans, together at the last minute. Even so, these lessons were well organized and executed in her classroom – a particularly gold trait. This last minute approach initially worried her cooperating teacher, Forrest, who was concerned about Mary being prepared to teach well in advance of each day – a particularly gold trait. However, once he saw that Mary could pull together and teach a strong lesson, even at the last minute, he worried less about this issue. He initially stressed with Mary how to structure her lessons with appropriate event changes to teach during the lengthier (96-minute) block period, including a hands-on component.

Forrest viewed his role as a mentor in supporting the needs of his interns. This support often took the form of sharing resources and ideas for teaching through a collegial relationship where interns approached him to discuss planning issues and other concerns. Forrest was very humble and approachable. He shared frequently that he was always impressed by the scientific knowledge of the interns placed with him. He valued their understanding of science and intellectual prowess more than their novice abilities – a particularly green trait. His collegial and supportive role for intern autonomy characterized Forrest's relationship with Mary – another particularly green trait.

One of Mary's limitations in teaching was her ability to relate her subject matter to students' lives and interests. Although she took a unique interest in their lives, she seemed to divorce this interest from her lesson's content. Her teaching approach, though well executed, still emphasized core content and principles of science. Forrest raised this concern with Mary and tried to help her to consider how she could better relate her content to students' lives and their personal interests – a particularly orange trait.

Mary continued to develop her relationship with her students throughout her internship – her strong blue trait. She spent time with students that were not successful for her cooperating teacher. Forrest even mentioned that he was also impressed with Mary's desire to spend time trying to reach the students that he could not, reaching them on a personal level. However, his own strong but gentle and collegial working rapport with Mary, as well as past interns, displayed a concerned and supportive ethic that typifies a good mentor – a particularly blue trait not apparent in his inventory results.

Mary was so thankful that she had Forrest for her cooperating teacher. She had heard from so many other interns of the differences that they had with their cooperating teachers, even in overall good placements. She had no qualms at all about Forrest. He, in turn, was once again impressed by the quality of interns that the university sent him. He often said that he could work with anyone.

Rose's Story
*An orange-blue-green intern with a green-orange cooperating teacher*

Rose was more mature in attitude and age than most students in our program. She recently returned to school after working in the agricultural sector, utilizing her undergraduate and master's degree in agronomy and soils. As a methods student she was placed with Michael, a somewhat disorganized middle school teacher who thrived on learning new science and letting his students do science – a particularly green trait. Michael often spontaneously changed his plans for teaching in order to pursue an area of student interest or tie his teaching to an event in the news – a particularly orange trait. He even retained laboratory activities from year to year that students really liked because they were 'fun' or 'cool.' The downside of this approach is that his lesson plans over time were often characterized as 'jumpy' or inconsistent. Rose greatly appreciated this approach to teaching science, and wanted to become more proficient at it – indicative of green and orange traits. She and Michael individually petitioned us to let Rose come back to his classroom as an intern.

Rose appeared to be organized in her studies, planning, and teaching – a particularly gold trait not apparent in her inventory results. She was an excellent student in the traditional sense, and consistently planned lessons that were strong in inquiry and process. Rose particularly liked the inquiry methods and approach to teaching science that she learned in her program – a particularly green trait. However, like most of our program students, she did not see how she could blur the line between lecture and lab, process and content. Though time in lecture was infrequent, she often delivered too much content at one time, and in a way that often was too complex for students to understand.

Rose appreciated the autonomy that Michael gave her in planning her lessons and teaching as she liked. He treated her as a colleague, and as such, spent time with her discussing science and inquiry approaches to lessons that she proposed – a particular green trait. For example, Michael was especially interested in how Rose would integrate plant science into her plans in a way that would be interesting to students. She did so through a plant growth inquiry project and also interested Michael in the topic – even when he thought plants would not interest him. However, most of their professional conversations were initiated by Rose who often felt that Michael did not reach out to her to see if she needed help, or to frequently let her know that she was doing a good job or support her when a lesson seemed to fail.

Rose saw herself as caring for her students' learning more than Michael did, and taking time with the ones that seemed to have difficulty – particularly blue traits. Michael felt strongly about not 'babying his students' or being concerned about the personal dynamics and interactions among them. Even in his interactions with Rose, he was direct in his assessment of her performance when asked, even while sharing with us that she was an excellent intern. Rose shared that she did not mind this aspect of Michael's personality because of her own maturity. However, she shared that another younger intern would not get the moral support and teacher initiated feedback needed from Michael.

Like Michael, Rose was very flexible and willing to change her plans in pursuit of a last minute 'better approach' or to integrate a new tie that would help student interest and learning – a particularly orange trait. However, she brought structure to Michael's classroom through her prior planning and preparation of strong lessons, and her institution of new routines and procedures in handling classroom management – a particularly gold trait. She often shared with us that she brought enough structure, organization, and personal maturity to have a successful internship with Michael. Another intern may not fair as well.

Bonnie's Story
*A gold-green-blue intern with a gold-green cooperating teacher*

Bonnie was a serious student who was knowledgeable of her content area. She believed in having control of her class – a particularly gold trait. She did not like for her students to miss class for reasons that she felt were not important, such as leaving class for prom preparation. Unlike her teacher Leslie who felt that the students could make up the work because prom was part of the high school experience. Bonnie did not like the thought of having to provide makeup work for students.

Bonnie had very high expectations for her students and wanted them to get all they could from her creative lessons and motivating activities. She would provide activities that supplemented and enhanced many concepts that she taught. In doing this, Bonnie felt that students would benefit and learn more because she was going the extra mile to reach many students who had voiced that they had a chance of seeing the lesson in a different way. Bonnie felt that she was developing more of a relationship with the students – a particularly blue trait – caring that each student was learning in different ways other than the more traditional way of her teacher, Leslie. Leslie viewed her own style of teaching as more traditional, not being creative because her training was basic and did not incorporate inquiry approaches. Leslie did implement laboratory exercises as part of her teaching routine of lecture and problem-solving. Leslie believed Bonnie's style reflected inquiry because this had been Bonnie's training in her methods classes.

Bonnie and Leslie agreed on some of the same lessons for instruction but Bonnie felt that her students would learn better through more hands-on lessons, while Leslie felt that students should have more structured and traditional instruction – a gold trait. Bonnie and Leslie both commented that they were somewhat procrastinators but in the end they both realized in their own way they must be organized in working with their students. However, Bonnie was an independent thinker and resented being constantly reminded of teaching tasks that she was capable of doing – a particularly green trait. For example, Leslie had given Bonnie several assignments for the students and kept reminding Bonnie of what she expected. Bonnie felt that Leslie's reminders were a way of exerting control over what she asked Bonnie to do – a gold trait.

Bonnie several times mentioned that Leslie grew more supportive of her preferred approach and competence as an intern – a green trait. Towards the end of internship, Leslie did let her try new activities. Bonnie came up with her own ideas and was encouraged by Leslie not to be scared to try them in the classroom. Bonnie felt as though Leslie trusted her more in the end.

Several times Bonnie and Leslie clashed in their thinking but Bonnie started seeing that she and Leslie were much alike. They like having control and being in control. Bonnie's control was for the sake of the students, where the students could have an outlet for expression – supporting blue trait. Leslie's control was for the students but in the way of making it safe and structured for them. Bonnie realized that if they did clash it was because they were very much alike in their primary and secondary temperaments. Leslie admitted that she was controlling and did not share much about the touchy-feely aspects of the blue temperament. She also shared that she was more rigid whereas Bonnie was more flexible in the classroom with the students. Leslie thought that she and Bonnie complimented each other in that Bonnie brought the more caring element to their fairly similar style of running the classroom.

In the end, Bonnie was glad that she had the opportunity to work with Leslie because in so many ways they were alike. She could not see herself working with a teacher who was not very organized. Both cooperating teacher and intern had to learn to trust each other's judgments and abilities in order to garner respect in their relationship.

Nate's Story

*A green-orange intern with a green-gold cooperating teacher*

Nate was a fun loving and rather laid back guy. He believed in getting to know the students and building a trusting relationship with them. He liked using demonstrations and hands-on activities. He was very comfortable in an uncontrolled and non-traditional classroom – typical of the orange trait. Nate's teacher Tamara was more structured and did not like a chaotic environment – very typical of the gold trait. She believed in structure with clearly defined rules and directions. Both teacher and intern felt that inquiry was an important part of teaching science – a particularly green trait – but Tamara thought that inquiry and related activities must be planned and organized. Nate on the other hand saw hands-on approaches as being more spontaneous, fun and engaging – a particular orange trait. However, both teacher and intern emphasized the facts, practical information, and concrete skills.

Nate found his cooperating teacher to be too regimented in her teaching. She did not like interruptions while she was speaking, especially student questions while she was lecturing – a gold trait. Nate answered student questions no matter when they came up. In planning lessons, Nate tended to procrastinate and preferred a sketchy plan so that if issues came up in the class he could address them, rather than having to come back after following a strict lesson plan – a particularly orange trait. Nate valued the spontaneity of the class and wanted some freedom in the class so the students would enjoy learning and doing – orange traits also. He believed that if any assignment or lesson was not fun, the students will not want to do it.

Nate believed in scientific knowledge and was very competent in his content area. He taught using presentations that were somewhat logical and interesting. His activities used in teaching typically explored a critical thinking base, utilizing models, charts, and thought-provoking objects that elicited curiosity in the classroom – particularly green traits.

Nate adjusted to meet many of his teacher's expectations in organization and structure, and genuinely felt that he benefited from it. What they had in common was a desire to teach through inquiry, utilizing demonstration and activities as a predominant approach in teaching. Tamara was impressed and pleased to see this desire in Nate – her green trait. Nate and Tamara both explored and experimented, working with gadgets and toys in teaching physical science. Tamara provided many activities and resources to Nate who used them to engage the students, motivate the students, and encourage the students. Nate shared that Tamara was always there for him if he needed her – a blue trait.

Tamara and Nate were highly collegial in their relationship – green trait – even though Tamara saw herself more in a parental role with Nate as the older son. They ultimately enjoyed working together because even though they differed in structural approaches to teaching, they were similar in their desire to teach through inquiry means. Because of their similarities, Nate believed that they could support each other in their differences. They also both learned from each other in that Nate saw the importance of structure and Tamara saw a need for more flexibility.

## Discussion

The fidelity of the Insights Learning Inventory© scores to our observation and interview data on what we learned about personalities in each of these cases revealed mixed results. The difference between numbers in most cases supported the relative spectrum of each individual triangulated from the other data. The exceptions in this study were Forrest whose blue temperament did not show strongly in his inventory (last of all colors) and Rose whose gold temperament also showed last in her inventory. The temperament framework (colors) itself was fruitful in informing our thinking about placements and the importance of the interplay between dyads' different personalities, abilities, and philosophies of teaching in the mentoring relationship (Von Glasersfeld, 1989).

In our complex view of mentoring, each experienced cooperating teacher in this study provided unique mentoring skills for their interns (Martin, 1996; Sudzina et al., 1997). Leslie provided strong organization and structure, Forrest provided daily support and nurturing, Michael modeled and supported student-interest forms of science teaching, and Tamara provided structure and guidance for inquiry forms of teaching. Without special mentor training, each teacher's strengths in mentoring typically followed their temperament constructs and how they also interacted with students in the classroom (Hawkey, 1998; Martin, 1997; Rosenfeld & Rosenfeld, 2006). A cooperating teacher's pedagogical approach could also be the template for interns to model in learning to teach, whether self-imposed (Rose) or teacher-imposed (Bonnie). This result is not surprising considering that interns are novices in learning to teach, and modeling in authentic practice is a large part of this process (Author, 2005). However, only one intern, Mary, was completely satisfied with her cooperating teacher. Two interns, Rose and Nate, shared minor differences between personalities that impacted their ongoing relationship with their teacher but did not interfere with their ability to teach as they preferred. Bonnie was the exception who required our intervention, "[struggling] under the tyranny of [a] "good" teacher[s] who believed that there was only one way to do things…" (Sudzina et al., 1997, p. 32). In a perfect world, each cooperating teacher would equally express the spectrum of temperaments needed to mentor an intern in the science classroom (Bryce, 2002; Hayward, 2001; Kalil, 1998). In our study many such personality traits emerged that in-and-of themselves were beneficial for supporting a science intern (See Table IV). Only the blue color trait stands out as necessary for all actively supportive cooperating teachers.

Table IV
*Beneficial character traits by color expressed in cooperating teachers.*

| *Temperament Color* | *Beneficial Traits for Science Mentoring* |
|---|---|
| Gold | Organization, structure, preparation |
| Blue | Active mentor, supporter, relationship |
| Green | Autonomy, collegiality, science knowledge, inquiry |
| **Orange** | Spontaneity, Real world issues, activities, fun |

## Blue Temperament for Mentoring

The blue trait in our study acted as the glue of moral support, active coaching, and daily supportive feedback (i.e., communication) that most interns require in this stage of their early development as teachers (Abell et al., 1995; Koerner & Rust, 2002; Knudson & Turley, 2000; Stanulis & Russell, 1999). Without a strong enough blue temperament, cooperating teachers in our study often remained aloof to the everyday support and encouragement needed by interns as they experienced the difficulties and turmoil of learning to teach and manage students. Interns who especially need this moral support will feel isolated and alone in their placements, even feeling despondent about the many failures that they will experience in the learning process. Rose shared how she was older, more mature and so did not need Michael's everyday support, encouragement, and understanding, but that another intern may suffer without it. Bonnie also suffered from a teacher who was often oblivious to her personal difficulties and struggles. Both these cooperating teachers claimed to not be 'touchy-feely' people and also remained aloof with their students. They were hired to teach science and concern over individual student difficulties was not part of their job description.

## Gold Temperament for Organized Instruction

In learning to teach, some modicum of gold temperament must also be present in the cooperating teacher, the intern, or both. Successfully teaching for targeted achievement gains in students requires some sense of sequential and organized instruction. Structure as evidenced through procedures and routines for managing the classroom is also important for beginning teachers to observe and practice. 'Winging it' may work for the experienced teacher whose plans and directions are implicit and based on experience, but this approach does not work for the novice. However, we have learned that this structure can be provided in part or whole by either party in the dyadic relationship. In a Vygotskyan sense, if needed, the skills and abilities in structure and organization must be brought to the internship in a dissonant arrangement to spur intern learning; not a disparate arrangement (Elliot, 1995; Graham, 1993). Some interns may need to be stretched to learn some of these skills from their teacher (Croker, 1999; Hawkey, 1998). However, if two individuals are too disparate in this area, conflict and not learning may result.

Before this study framed our thinking, we anecdotally considered this aspect of temperament in making intern placements. We readily knew our students who needed a stronger hand in oversight in student teaching because they were not as independently organized and structured as we felt they needed to be to successfully plan, teach, and manage students every day. Nate in particular needed this organization and structure for success; a teacher who would model organization and gently work with him to achieve it. Of all the temperament styles that we studied, gold was the most critical for a successful learning experience for novice interns but was also most difficult to match properly. Some modicum of gold in each dyad was important in cultivating a respectful relationship where interns readily and willingly learned from their cooperating teacher (Abell et al., 1995). Too much imposed structure and control or too little structure and control by the cooperating teacher could both lead to an intern's lack of respect for a cooperating teacher. Bonnie claimed that she preferred someone just like her as a cooperating teacher, but Leslie likely provided too much control and organization to an intern who did not need it (McNally et al., 1997). Rose provided her own structure in planning what she wanted to do without any strong organization or structure to model from Michael. Nate received just the right amount of structure from Tamara, but not without complaint along the way. This dissonance in his relationship with Tamara stretched him to grow in structure and organization, what he needed (Croker, 1999; Hawkey, 1998). What would have been the outcome of this internship if Tamara was too structured and controlling? Certainly more study is needed in the area of autonomy and control, structure and support in student teaching. The proper amount of scaffolding needed for each intern's practice is variable and a crucially important foundation for learning in student teaching.

### Green Temperament for Inquiry

In learning to teach science as inquiry and motivating students to learn, these case studies have taught us that we cannot underestimate the need for green and orange temperaments in science teachers. Mentoring may require the underlying scaffolding of organization, structure, and moral support in successfully learning to plan, teach, and manage in the classroom. But to teach science as inquiry and carry out inspirational, novel, and motivational methods and projects to learn it is vital if science teachers are to meet the goals of national standards in practice (National Research Council, 1996). Michael and Tamara as cooperating teachers were constantly modeling inquiry forms of teaching, dialoguing on science and inquiry practice with their interns, challenging their own students' thinking in science, and seeing concrete experiences with science as an integral part of their classrooms. Also, these cooperating teachers almost immediately interacted with their interns professionally as colleagues, not apprentices; a desirable and competent position to obtain by the end of most internships (McNally et al., 1997). These particular traits were what endeared Rose and Nate to their cooperating teachers, despite their teachers' other shortcomings. A compatible philosophy or pedagogical orientation to teaching science formed the basis for establishing a strong respectful relationship within these dyads (Agee, 1996; Graham, 1997; Sudzina et al., 1997). If the goal for new science teachers is to teach science through inquiry, then all cooperating teachers in a science education program need to have some modicum of love of science learning and an inquiry orientation; what we have found as particularly green traits.

### Orange Temperament for Spontaneity and Relevance

If the green temperament supports a love of science learning, knowledge, and support for teaching science as inquiry, then the orange temperament provides the innovation for implementing it in exciting and motivational ways. Inquiry is student-centered, phenomenon engaging (hands-on), focusing on student questions and interests in exploring and learning science. It can also be spontaneous in seizing the teachable moment, science in the news and in students' lives. Inquiry at its best can go off-script from a teacher's detailed lesson plan, following student leads and interest. All of these descriptions are typical of the fun, spontaneity, and risk-taking of the orange temperament (Bryce, 2002). Few science teachers in our program exhibit this temperament. Michael was the only cooperating teacher in this study who typified this description, and his intern thrived on this freedom and fun-loving attitude toward teaching science through inquiry. However, Rose was able to structure it for herself. Some modicum of these traits are desirable in science teachers if they are to move away from more traditional practices in the classroom to greater innovation that can spur student motivation and learning. However, if too strong, as in Michael's case, this temperament may be too confusing for most interns who look for predictability and some sense of routine in their internship classroom. How a predominant orange personality type copes and stretches to become more organized and structured in their teaching would be an interesting further study. School systems often favor personality traits and characteristics in science teachers found in the other three personality colors, lessening diversity and opportunity for many students who are not motivated to learn through traditional approaches.

Implications for Intern Placements

The construct of personality temperaments and its impact on pedagogical preferences and mentoring during student teaching will continue to inform our thinking and practice in intern placements. Before this study we typically placed interns based on the availability of experienced cooperating teachers who were somewhat exemplary role models for intern practice. But we intuitively knew that this approach was not always successful for our interns who in the past could clash with a cooperating teacher with whom a previous intern thrived – In many of these cases almost leading to a failed internship (Harwood, Collins, & Sudzina, 2000). Our only consideration of temperaments was in providing structure for interns who needed it.

In addition, we have been re-sensitized to the literature on inquiry and pedagogical orientations based on prior experience (Crawford, 1999), and now, teaching and learning orientations that are correlated with temperament and learning styles (Pankratius, 1997; Rosenfeld & Rosenfeld, 2006). Being sensitized to the presence of green and orange temperaments will enable us to better value and cultivate those teachers in the crucial role of modeling science as inquiry with innovative ways of connecting science to students (NRC, 1996). Further research is needed in studying science teachers with inquiry and innovative orientations, how these orientations developed, and using this knowledge to potentially develop such orientations in future and current science teachers.

More importantly, for all of our cooperating teachers who do not express strong relational traits (blue), we need to provide professional development on mentoring so these teachers can begin to stretch into a temperament area in which they need to grow. Relational qualities such as communication, trust, and feedback will continue to remain vital components in any supportive internship experience (Stanulus & Russell, 2000).

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## Appendix

## Insight Personality Instrument©

Below are 10 questions and 4 answers for each question. Using the scale below, give a point value to each answer. Record that number on your answer sheet to reveal your color spectrum.

| | | |
|---|---|---|
| 4 points | Always like me | (100% of the time) |
| 3 points | Usually like me | (75% of the time) |
| 2 points | Sometimes like me | (50% of the time) |
| 1 point | Seldom like me | (25% of the time) |
| 0 points | Never like me | (0% of the time) |

1. Values
*What words describe you?*

A. I am a kind, truthful, friendly, caring, artistic, peace-loving person. Feelings and relationships are very important to me.

B. I am a trustworthy, obedient, polite, helpful, loyal, organized, goal-setting person. I respect rules, routines and traditions.

C. I am a curious, scientific, logical, clever, calm, problem-solving person. I like to study and discover new things on my own.

D. I am a friendly, energetic, playful, skillful, upbeat, risk-taking person. I need to be free to get up and go when I feel like it.

2. Motivation
*Why do you do the things you do?*

A. I like to do thoughtful and kind things for other people. I try to make the world a nicer place to live in.

B. I want to do things that are good and decent. I want to show that I am responsible. I want to be productive and successful.

C. I think a lot. I like to experiment with my ideas and try to make them better. I want to prove that they are important.

D. I like action and adventure. I like challenge and competition. I want to experience what life has to offer. I want to be the best.

3. Communication
*How do you like to talk to other people?*

A. I like to talk and visit with my friends and family. I am a good listener. I show my feelings but do not like to argue or fight.

B. I try to use correct and proper language when talking or writing. I sometimes sound bossy and old-fashioned to others.

C. I like to talk about things that are important to me. I ask lots of questions to get to the important facts. I am fair and impartial.

D. I am bold and like to say what is on my mind. I talk with energy and power. I am fun to talk with and like to joke around.

4. Work
*What kind of work would you enjoy?*

A. I want a job where I can work with living things, like people, plants and animals. I also -like to do things that are creative, musical or artistic.

B. I want a steady job where I can work hard and earn what I deserve. I always get the job done - even if l have to work overtime.

C. I want a job where I can think of new and improved ways to do things. I can work 24 hours a day if the work is really stimulating.

D. I want a job where I can show my talents and skills. I do not want to be tied down. I want immediate rewards for my hard work.

5. Supervision

*What kind of leader are you?*

A. I am a true friend to the people I lead. I like to work side by side with them. I try to make sure they are happy and enjoy their jobs.

B. I like to be in charge and help make the rules. I expect people to do their duty and work as hard as I do.

C. I prefer to lead talented people who can work on their own. I welcome change and improvement. I keep my eye on the future.

D. I am a go-getter leader who makes things happen. I do not like planning meetings and silly rules. I work best under pressure.

6. Recreation

*What do you do when you want to have fun?*

A. When I want to have fun and relax, I like to do things with other people, particularly my family and close friends.

B. When I finish my work and want to relax, I like to participate in structured and well-planned activities or sports.

C. I like to keep my mind working even when I am supposed to relax. I have the most fun when I can learn or do new things.

D. I love to play. I love to perform. I love to party. I enjoy physical contests, daring activities and challenging sports.

7. Childhood

*What were you like as a child?*

A. I liked to pretend and had a good imagination. My pets were very important to me. If I won a contest, I always felt bad for the losers.

B. I was an obedient child. I looked to my parents and teachers for direction. I was more grown-up than other kids. I did not like change.

C. I asked lots of questions and liked to experiment and-figure things out for myself. I enjoyed reading, inventing and investigating.

D. I was a noisy and fun-loving child. I was always on the go and full of life. I did not like rules and often got into trouble.

8. Youth

*What were you like as a teenager?*

A. My friends were very important to me. I tried to include others in my group and tried very hard to get along. I was often the peacemaker.

B. I enjoyed belonging to clubs and sports teams, being part of student government and working on school projects.

C. I was very independent. I did hot need friends to be happy. I set my own rules and standards. I focused on my hobbies and interests.

D. I did a lot of wild and crazy things with my friends. I stayed close to the action. l pushed the limits and had a lot of fun.

9. Education

*What subjects do you like to learn about?*

A. I prefer learning about subjects that focus on people: drama, creative writing, literature, music, languages, social studies and the arts.

B. I prefer learning about traditional subjects: reading, writing, arithmetic, business, law, government, history and home economics.

C. I prefer learning about subjects that focus on ideas: science, computers, engineering, drafting, mathematics and architecture.

D. I prefer learning about subjects that focus on action: athletics, art, drama, dance, music, carpentry, ceramics and vocational skills.

10. Love

*What do you expect from your relationships?*

A. I want to live happily ever after with someone who is loving, romantic and devoted. I give my heart and soul to my relationships.

B. I want a traditional home life with a dedicated and dependable spouse. I show my love by doing my part and keeping my promises.

C. My head rules my heart. I express feelings only - when necessary. I do not form relationships-unless it makes sense and fits into my lifestyle.

D. I want a lover who enjoys my favorite activities and likes to explore new and exciting things together. I like lots of physical contact.

Answer Sheet

Use this form to record your answers. Using the scale below, give a point value to each answer. Record those numbers below. When you are finished, total up each vertical column.

| | | |
|---|---|---|
| 4 points | Always like me | (100% of the |
| 3 points | Usually like me | (75% of the time) |
| 2 points | Sometimes like me | (50% of the time) |
| 1 point | Seldom like me | (25% of the time) |
| 0 points | Never like me | (0% of the time) |

| | | | | |
|---|---|---|---|---|
| 1. Values | A.____ | B.____ | C.____ | D.____ |
| 2. Motivation | A.____ | B.____ | C.____ | D.____ |
| 3. Communication | A.____ | B.____ | C.____ | D.____ |
| 4. Work | A.____ | B.____ | C.____ | D.____ |
| 5. Supervision | A.____ | B.____ | C.____ | D.____ |
| 6. Recreation | A.____ | B.____ | C.____ | D.____ |
| 7. Childhood | A.____ | B.____ | C.____ | D.____ |
| 8. Youth | A.____ | B.____ | C.____ | D.____ |
| 9. Education | A.____ | B.____ | C.____ | D.____ |
| 10. Love | A.____ | B.____ | C.____ | D.____ |
| TOTALS | A. | B. | C. | D. |

# What Makes a Topic Interesting? A Conceptual and Methodological Exploration of the Underlying Dimensions of Topic Interest

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Abstract

Interest has long been recognized as an important motivator of learning. Recent research, however, has reported a trend of declining interest in science among young students, which suggested that school science has not been effectively fostering student interest. In order to help students develop an enduring interest in the topics taught at school, the first, and perhaps the fundamental step is to understand what it is about a topic that makes it interesting (or uninteresting). As a preliminary effort to address this question, a mixed-method study combining quantitative data from paired-comparison preference judgments and qualitative data from semi-structured interviews was undertaken with the goal of determining the underlying topic attributes that influence middle school students' perceived interestingness of school-related topics. The results suggest a set of possible attribute dimensions – a topic's activeness, importance, familiarity, coolness, and challengingness. Implications of the findings in the context of related research and future research directions are discussed.

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## Introduction

*The Importance of Interest in Science Education*

Commonly conceptualized as a relatively stable motivational orientation or personal predisposition that develops over time towards a particular stimulus or domain (Renninger, Hidi & Krapp, 1992), interest has long been recognized as playing a significant role in education. In *Interest and Effort in Education* (1913), Dewey argued that interest is the ultimate driving force behind self-initiated learning behaviors. According to Dewey, when a person is genuinely interested in something, he or she will automatically be motivated to engage in activities that allow him or her to learn more about it. That is, if people are interested in what they are learning, then the issue of lack of motivation that so many educators and researchers are battling against may be solved.

Given the intimate relationship between interest and motivation (Hidi & Harackiewicz, 2000), it is not surprising that the positive impact of interest on learning has been documented in a wide range of learning situations. Positive correlations have been observed between interest and a variety of standard learning outcomes such as test scores, grades, and GPAs (Krapp, Hidi & Renninger, 1992). A meta-analysis (Schiefele, Krapp & Winteler, 1992) showed that interest on average accounts for about 10% of the observed achievement variance across subject areas, types of schools, and age groups. Particularly relevant in this study is the finding that the average interest-achievement correlation for natural science subject areas is among the highest (r = 0.34) – a quite large effect considering the complicated nature of education. Furthermore, interest has also been shown to positively impact learners' cognitive skill development, such as facilitating deep (as opposed to superficial) information representation (Schiefele, 1996) and promoting the use of metacognitive strategies (Pintrich, Marx, & Boyle, 1993), both of which are learning outcomes desired in science education.

Recognizing the important role interest plays in promoting learning, educators would be encouraged if students showed interest in the materials taught at school. However, students' academic interest seems to be declining over time (Anderman & Maehr, 1994). This trend is particularly obvious among secondary-school students, and with respect to subject domains such as science (Eccles & Wigfield, 1992, Martin, Mullis, Gonzalez, & Chrostowski 2004; Schmidt et al., 2001; Yager & Yager, 1985). Faced with this reality, researchers have suggested that one way to improve student interest is to provide materials that cater to students' interest, which students presumably are more likely to be motivated to learn (Edelson & Joseph, 2004; Garner, Brown, Sanders, & Menke, 1992; Wade, 2001). However, in order to do so, we need to first develop a firm understanding of what students are interested in.

*Previous Research on Understanding Interest-influencing Factors*

One approach to understand student interest is to identify the science topics that students consider interesting. For instance, Dawson (2000) asked seventh-grade students in Australia to indicate the interestingness of 77 science topics (e.g. 'earthquakes') representing a broad range of scientific domains, and identified a set of topics that are most popular for these students. A similar approach was also taken with a group of 14- and 15-year-old students in England as part of a large-scale study on student attitudes toward science (Jenkins & Nelson, 2005). Baram-Tsabari and Yarden (2005) examined the (primarily science) questions Israeli children sent to a popular children's TV show that provides answers to these questions (e.g. 'if you go on a diet, where does the fat go?'), and found that topics of biology, technology and astrophysics were of high interest to the nine to twelve year-old children.

A considerable amount of work has also been done in examining the interest-influencing properties of two types of object of interest – perceptual stimuli and text. Berlyne (1960, 1971) is perhaps the most prominent researcher who studied the relationship between characteristics of simple perceptual stimuli and their perceived interestingness. Using simple visual (e.g. polygons) or auditory (e.g. tones) stimuli, Berlyne and colleagues (Day, Berlyne, & Hunt, 1971) varied selected aspects of the stimuli (e.g. the number of sides of a polygon) and examined how such variation affected people's interestingness judgments. The findings from these studies led Berlyne to propose a set of stimuli characteristics – which he called *collative_variables* – that contributed to the perceived interestingness of such stimuli: novelty, complexity, unexpectedness, ambiguity and variability.

In the field of text comprehension, consistent with Berlyne's views concerning collative variables, texts with unexpected, suspenseful or conflicting content tend to elicit more interest than texts lacking such features (Hidi & Baird, 1986; Hidi, 2001; Iran-

Nejad, 1987). Other features of texts have also been shown to influence interestingness judgments. For example, texts that include characters or life-themes that an individual can identify with (Hidi, 1990, 2001; Krapp, Hidi & Renninger, 1992), and texts that deal with personally relevant issues (Garner, et al., 1992; Schraw, Flowerday & Lehman, 2001; Wade, 1992) are more likely to be deemed interesting. In addition, other content-bound text characteristics such as text coherence (Schraw, Bruning & Svoboda, 1995; Schraw & Lehman, 2001), intensity (Hidi, 1990, 2001), vividness (Schraw, Bruning & Svoboda, 1995), and activity level (Garner et al., 1992; Wade, 1992) have all been shown to be sources of interest in texts.

There is no doubt that these research findings provide valuable information. For example, knowing what topics are of high interest to students can help teachers in choosing (when possible) what topics to teach, and what we know about interest in text can help textbook writers and publishers create reading materials that are more attractive to students. However, it is unlikely that we could build a science curriculum solely based on the topics in which students expressed interest, or make a boring topic interesting simply by teaching it via exciting texts. That is, the information gathered in previous research is far from sufficient to guide our practice in enhancing student interest.

## Purpose of Study

In this paper, I propose an alternative way of understanding student interest that combines the foci of the above-mentioned studies. That is, I am exploring what *about* the objects of interest – in this case, the various content topics students are required to learn at school – makes them interesting (or uninteresting). Specifically, I propose the approach of examining the topics students currently encounter at school, identifying those that are deemed interesting (or uninteresting), and investigating the attributes that make them more interesting (or uninteresting) to the students than others. For the purpose of this paper, I focus primarily on science topics.

## Methods

### *Study Design Considerations*

In contrast to previous research that manipulated stimulus properties to examine how they affect 'on-the-spot' judgments of interestingness, this study examined what characteristics are associated with students' enduring interest of school-type topics – often referred to as *topic interest* (Schiefele, 1996) – by engaging students in a simple task of judging which one of a pair of topics is more interesting. This task of *paired-comparison preference judgment* was chosen in this study mainly because of its potential, when coupled with the *multidimensional scaling (MDS)* analysis technique (Kruskal & Wish, 1978), to discover the 'hidden structures' of data that are otherwise difficult to capture (Carroll & Arabie, 1980) – in this case the underlying dimensions of topic interest. That is, instead of asking young students to describe the characteristics of a topic that makes it interesting (or uninteresting), which is a very difficult task, I tried to extract such information from their responses to a series of simple preference judgments.

Follow-up interviews with individual students were also conducted as an alternative means of data collection, with the goal of verifying and further exploring the findings that emerged from the paired-comparison preference judgment data.

*Participants*

Participants were 16 students in a sixth-grade science classroom of a suburban middle school near a major Midwest city in the USA. The participants consisted of an equal number of boys and girls; their diverse ethnic background (5 Caucasian, 9 African-American, 1 Asian, and 1 Hispanic) reflected the school and the district they belong to. Participants also varied in terms of academic performance level (5 high, 7 medium, and 4 low) and perceived science interest level (7 high, 5 medium, and 4 low), both of which were subjectively judged by their teacher by comparing them with fellow students of the same class.

*Materials and Procedures*

Data were collected using two questionnaires and a series of interviews over a period of 4 weeks. Two questionnaires were administered at an interval of 3 weeks, with the second questionnaire designed to confirm and elucidate the results of the first. All participants completed both questionnaires. The interviews were conducted one week after the administration of Questionnaire 2. Half of the participants (eight students) were interviewed.

*Questionnaires.* Questionnaire 1 (Appendix 1) was aimed at soliciting from participants their interest-based topic preferences. Sixteen topics (Table I) were included in the paired-comparison preference judgment task. In order to facilitate the discovery of any possible underlying dimensions of topic interest, I selected a wide variety of topics -- fourteen science topics from different science content areas, three math topics and two extracurricular topics. I limited the selection to 16 topics to ensure that students had sufficient time to complete the task within the allocated time (one 40-minute class period).

Table I
*Topics Used for Interestingness Judgment*

| Topic | Code | Content Area(s) Represented |
|---|---|---|
| How cells work | HC | Science - Biology |
| How animals survive in the wild | HA | Science - Biology |
| Sexual reproduction in animals | SR | Science - Biology |
| How pollution harms the environment | HP | Science - Environmental |
| Forces and gravity | FG | Science - Physics |

| | | |
|---|---|---|
| Stars and planets | SP | Science - Astronomy |
| Earthquakes and volcanoes | EV | Science - Geography |
| How our bodies turn food into energy | OB | Physical Education & Health / Science - Biology |
| Why junk food is bad for us | JF | Physical Education & Health |
| The US government | US | Science - Social |
| Different cultures and countries | DC | Science - Social |
| Math puzzles | MP | Mathematics |
| Charts and graphs | CG | Mathematics |
| Fractions and proportions | FP | Mathematics |
| Basketball | BB | Extracurricular |
| Video games | VG | Extracurricular |

In Questionnaire 1, participants received a booklet including all possible (120) pairs of the 16 topics. For each pair, participants were asked to answer the question: 'If you had to listen to someone talking about the topics A and B (*referring to the two topics in the pair),* which do you think you'd find more interesting?' Participants were asked to indicate their answer for each pair by using a highlighter (provided with the booklet) to mark the one they found more interesting. In addition, as a validity check for the pair-wise comparison data, a separate set of questions asking participants to rate how interesting they found each topic on a 4-point Likert scale was included on the last page of the booklet.

It should be pointed out that the typical pair-wise comparison tasks used with the MDS analysis technique (Kruskal & Wish, 1978) ask participants to judge the similarity (or dissimilarity) between two objects (e.g. How similar are car A and car B). However, considering the developmental stage of the participants and their limited availability to complete the questionnaire (one class period), I chose to use the simpler task of judging 'which of the two is more interesting' (as opposed to 'how similar topic A and B are in terms of their interestingness') to ensure that the task is not too difficult or time-consuming for the participants. In comparison to the typical judgment tasks, this simpler version does not quantitatively capture the actual perceptual distances (in terms of interestingness) between the topics. However, for the purpose of this study, only a qualitative characterization of such distances is needed, which can be easily derived from the data collected through the simpler judgment task. Therefore, the choice of the simpler judgment task is more appropriate for the participants, and at the same time, provides sufficient information to accomplish the goal of this study.

Questionnaire 2 (Appendix 2) was designed based on the data derived from Questionnaire 1 (see the 'Results and Discussion' section for details). Specifically, participants were asked to rate each of the 16 topics on the following attribute dimensions on a 5-point Likert scale: *active, cool, mysterious, important, familiar,* and *typical of school* (e.g. 1 = not active at all, 5 = very active). These attributes were reviewed and approved by the science teacher for their intelligibility for the participants, and a brief description of the attributes was provided to ensure that participants understood their meaning.

*Follow-up Interviews.* Semi-structured interviews (Miller & Crabtree, 1999) were conducted after the administration of the second questionnaire to gain further understanding of why the participants found some topics interesting but not others. Eight out of 16 participants were chosen for interviews. The interviewees were first randomly selected, and then minor adjustments were made to meet two criteria: 1) Their demographic and academic characteristics were approximately the same as the entire participant group; 2) They were recommended by their science teacher for their 'consistently good and respectful behavior', an attempt to ensure the success of the interviews and the quality of the interview data.

To avoid restricting interviewees' answers to the attribute dimensions identified from the paired-comparison preference judgment data (i.e. the dimensions included in Questionnaire 2), no reference to these dimensions or Questionnaire 2 was made. Instead, interviewees were presented with the top five most and least interesting topics he or she had reported in Questionnaire 1, and asked to explain what it was about these topics that led to such judgments. Each student was interviewed individually for 10-15 minutes during regular class periods. All interviews were tape recorded and transcribed verbatim.

## Results and Discussion

### *Perceived Topic Interestingness*

Participants' ratings of how interesting each topic is (in Questionnaire 1) were averaged to see how topics vary in terms of their perceived interestingness. The results showed that across participants the extracurricular topics ('video games', 'basketball') were rated as the most interesting ones, while the math topics ('charts and graphs', 'fractions and proportions', 'math puzzles') were rated as least interesting. Most of the science topics received middling values, with the exception of 'stars and planets' (highly interesting), 'sexual reproduction in animals' (uninteresting), and 'why junk food is bad for us' (uninteresting).

### *Multidimensional Scaling (MDS) Analysis*

Multidimensional Scaling (MDS) was used in this study to analyze the paired-comparison judgment data. Originated in psychometrics, MDS has been used in various fields to help researchers understand people's judgments of the relationship between members of a set of stimuli (Young, 1985). In essence, MDS constructs a spatial representation of stimuli in which the distance between any two stimuli corresponds to the perceived proximity of the stimuli. By doing so, MDS summarizes a large number of relations among stimuli in a perceptual space that can be easily visualized, which often makes it much easier to comprehend the data (Kruskal & Wish, 1978). This unique feature of MDS lends it the power to reveal the underlying structure of data, and thus makes it an appropriate analysis tool for this study.

*Configuration of Topic Interest.* The particular MDS model used in this study was Tucker's *Vector Preference Model* (Tucker & Messick, 1963), because this model was better suited to analyze the type of simple preferential choice data available in the study. In this model, each individual's pair-wise comparison data are compiled to form a matrix representing the topic preferences (in terms of topic interestingness) of the particular individual. The rows and columns of this matrix are the 16 topics, and the value in each cell represents the individual's preference choice between the row topic and the column topic. The values were coded as 1s and 0s, where 1 means that the column topic is preferred over the row topic and 0 otherwise. The sum of each column was calculated to give a 'ranking' of the corresponding topic, with the sum showing how many times this particular topic was preferred over the other topics. The 'topic rankings' of all participants were then combined to form a new matrix, with the rows representing the participants and the columns the topics. Each row shows the particular participant's 'preference rankings' of the topics.

This new matrix was then used as input in the non-metric MDS program available in SPSS – the ALSCAL program (Young, 1985). The values in the matrix were treated as ordinal data, and Euclidian distances between the topics were generated by the program to obtain a configuration of the topics in a space of interestingness. As the rough 'rule of thumb' states that the number of stimuli (in this case, 16) minus one should be at least four times as great as the configuration dimensionality (Kruskal and Wish, 1978), MDS solutions with more than three dimensions were considered inappropriate for this data set. Therefore, solutions with 1-3 dimensions were generated (Table II). Comparison of the goodness-of-fit for these solutions showed that the increase of dimensionality reduced S-Stress ('badness-of-fit' indicator) substantially, and correspondingly increased R-square values. Therefore, the 3D solution (the best-fitting solution) was chosen as the most appropriate representation of data. The details of the 3D configuration are shown in Table III and Figure 1.

Table II
*Summary of Multidimensional Scaling (MDS) Solutions with 1-3 Dimensions*

| Solution Dimensionality | Young's S-Stress (‘Badness-of-fit' indicator) | Percent of S-Stress reduction by adding 1 dimension | R-square (‘Goodness-of-fit' indicator) | Percent of R-square increase by adding 1 dimension |
|---|---|---|---|---|
| 1D | 0.23 | --- | 0.85 | --- |
| 2D | 0.14 | 39.1 | 0.91 | 7.1 |
| 3D | 0.07 | 50.0 | 0.96 | 5.5 |

Table III
*Coordinates Representing the Location of the Topics in the 3D MDS Configuration*

| Topic Code | Coordinates | | |
|---|---|---|---|
| | Dimension 1 | Dimension 2 | Dimension 3 |
| HC | 0.32 | 1.00 | -0.86 |
| HA | -1.06 | -0.56 | 0.39 |
| FG | -0.44 | 0.88 | -0.67 |
| EV | -0.86 | 0.26 | 0.43 |
| SR | 1.77 | -0.44 | -1.22 |
| US | 1.01 | 1.49 | 0.22 |
| HP | -0.02 | 0.89 | 0.17 |
| FP | 1.93 | -0.18 | 0.87 |
| OB | 0.20 | 0.69 | -0.61 |
| JF | 1.34 | -0.78 | -0.31 |
| DC | -0.65 | 0.54 | 1.29 |
| MP | 1.17 | -1.15 | 0.53 |
| CG | 1.43 | -0.73 | 0.39 |
| VG | -2.47 | -0.79 | -1.01 |
| BB | -2.32 | -1.47 | 0.11 |
| SP | -1.33 | 0.34 | 0.28 |

Because the dimensions produced by the computer programs may not be meaningful or not susceptible to direct interpretation (Kruskal & Wish, 1978), MDS configurations require subjective interpretations. In order to uncover the dimensions that could explain the positioning of the stimuli (in this case, the topics) in the configuration, the 3D MDS configuration was first visually examined to 'look for lines in the space…such that the stimuli projecting at opposite extremes of a line differ from each other in some easily describable way' (Kruskal & Wish, 1978, p.31). Six such lines that appeared to represent various topic *attribute dimensions*[1] were detected – *active* (dynamic, fast-changing in nature), *cool* (popular or fashionable), *important* (bearing personal significance), *mysterious* (puzzling; very little is known), *familiar* (commonplace or usual), and *typical of school* (associated with school).

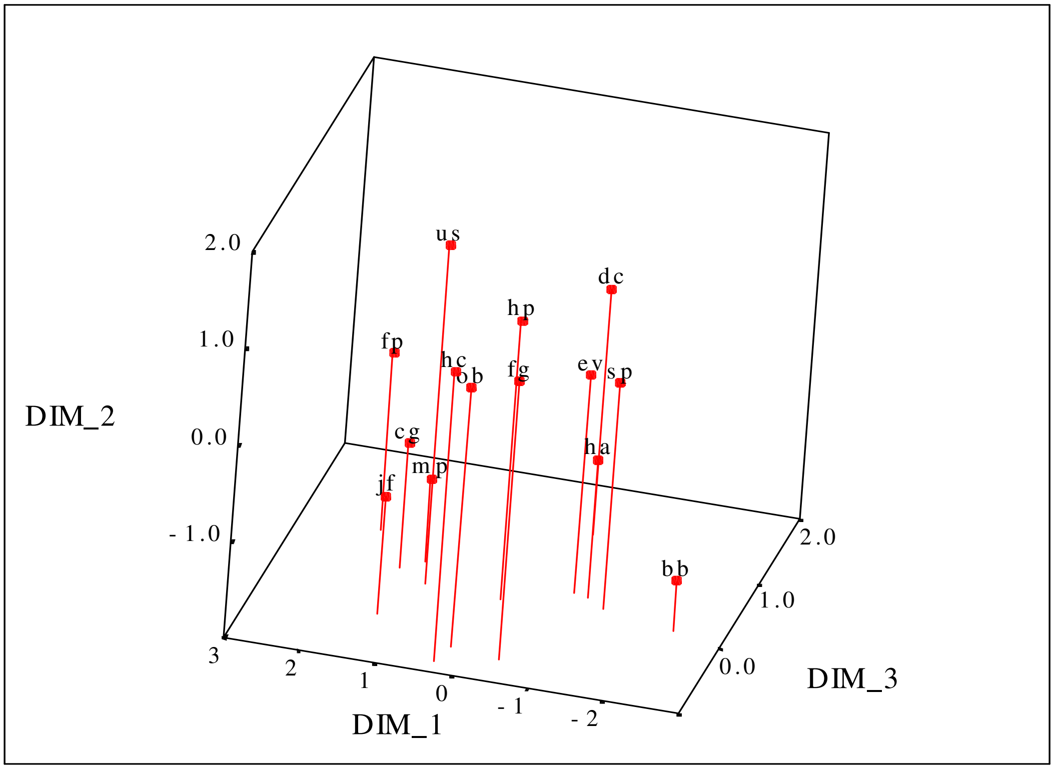


*Figure 1.* 3D MDS Configuration of Topic Interestingness based on Paired-Comparison Preference Judgment Data

To test these interpretations, Questionnaire 2 was administered to obtain participants' perception of the topics on these attribute dimensions. For each attribute dimension, individual participants' ratings were averaged to obtain a score for every topic (Table IV). The correlations of the average scores on these attribute dimensions (Table V) showed that the *active* and *cool* attribute dimensions are highly correlated (r = 0.946), suggesting that participants may have the tendency of viewing active things as cool, which possibly could be explained by the participants' age and developmental stage.

Table IV
*Average Participants' Ratings on Speculated Attributed Dimensions on 5-point Likert Scale*

| Topic Code | Attribute Dimensions | | | | | |
|---|---|---|---|---|---|---|
| | Active | Cool | Important | Mysterious | Familiar | Typical of School |
| HC | 3.31 | 3.19 | 4.56 | 2.69 | 2.75 | 4.50 |
| HA | 3.06 | 3.25 | 4.06 | 2.88 | 3.19 | 3.88 |
| FG | 3.93 | 3.47 | 4.31 | 3.00 | 3.13 | 4.50 |
| EV | 3.75 | 3.19 | 4.13 | 2.69 | 3.87 | 4.56 |
| SR | 2.75 | 2.75 | 3.19 | 2.81 | 2.63 | 3.44 |
| US | 2.94 | 2.56 | 4.00 | 2.50 | 3.33 | 4.69 |
| HP | 3.00 | 2.75 | 3.81 | 2.56 | 3.25 | 3.31 |
| FP | 2.50 | 2.44 | 3.63 | 2.56 | 3.81 | 4.63 |
| OB | 3.38 | 2.81 | 3.50 | 3.06 | 3.06 | 3.69 |
| JF | 2.50 | 2.13 | 3.31 | 2.81 | 3.13 | 3.40 |
| DC | 3.94 | 3.69 | 4.06 | 2.94 | 3.87 | 4.44 |
| MP | 2.88 | 2.44 | 3.00 | 2.44 | 3.56 | 4.63 |
| CG | 2.53 | 2.56 | 3.19 | 2.50 | 3.50 | 4.25 |
| VG | 4.44 | 4.50 | 2.88 | 2.19 | 4.63 | 1.88 |
| BB | 4.75 | 4.69 | 3.13 | 2.19 | 4.44 | 2.88 |
| SP | 4.13 | 4.31 | 4.44 | 3.88 | 4.50 | 4.44 |

Table V
*Correlations of Average Participants' Ratings of Topics on Speculated Attribute Dimensions*

| | Active | Cool | Important | Mysterious | Familiar | Typical of School |
|---|---|---|---|---|---|---|
| Active | --- | --- | --- | --- | --- | --- |
| Cool | 0.946* | --- | --- | --- | --- | --- |
| Important | 0.130 | 0.100 | --- | --- | --- | --- |
| Mysterious | 0.063 | 0.087 | 0.596* | --- | --- | --- |
| Familiar | 0.657* | 0.701* | -0.182 | -0.074 | --- | --- |
| Typical of School | -0.349 | -0.416 | 0.603* | 0.384 | -0.275 | --- |

* $p<0.05$

If, as I speculated, these attribute dimensions have a systematic relationship to the positioning of the topics in the configuration, then the configuration (i.e., the location of the topics in the 3D space) should be able to explain these average ratings on the attribute dimensions (i.e. the loadings of the topics on the attribute dimensions). To test this, a multiple regression was performed using the average rating on each of the attribute dimensions as the dependent variable and the coordinates for the 3D configuration as the independent variables. This procedure was not conducted with the attribute dimension *typical of school* because it did not follow a normal distribution as revealed by a Q-Q plot normality check. For the rest of the attribute dimensions, the regression analysis (Table VI) revealed a significant relationship for all attribute dimensions except for *mysterious*. Therefore, only the attribute dimensions *active, cool, important,* and *familiar* were confirmed as having systematic relationships with the coordinates. These results suggest that topic interest is influenced by, though not limited to, how active, cool, important, and familiar the topics are perceived to be (Figure 2).

Table VI

*Multiple Regression of Average Attribute Dimension Rating on the Coordinates for the 3D MDS Configuration of Topic Interestingness*

| Attribute Dimension (Dependent Variable) | Regression Coefficients | | | | | | Multiple R | R-square |
|---|---|---|---|---|---|---|---|---|
| | Dimension 1 Coordinates | | Dimension 2 Coordinates | | Dimension 3 Coordinates | | | |
| | B (SE) | β | B (SE) | β | B (SE) | β | | |
| Active | -0.472* (0.059) | -0.919 | 0.053 (0.094) | 0.065 | -0.057 (0.115) | -0.056 | 0.919* | 0.844 |
| Cool | -0.508* (0.065) | -0.905 | -0.045 (0.104) | -0.051 | -0.062 (0.128) | -0.056 | 0.916* | 0.839 |
| Important | -0.086 (0.067) | -0.219 | 0.486* (0.107) | 0.783 | 0.153 (0.131) | 0.199 | 0.806* | 0.650 |
| Familiar | -0.278* (0.075) | -0.640 | -0.183 (0.119) | -0.266 | 0.326* (0.147) | 0.381 | 0.805* | 0.647 |
| Mysterious | -0.019 (0.077) | -0.067 | 0.178 (0.122) | 0.389 | 0.031 (0.151) | 0.055 | 0.389 | 0.152 |

* $p < 0.05$

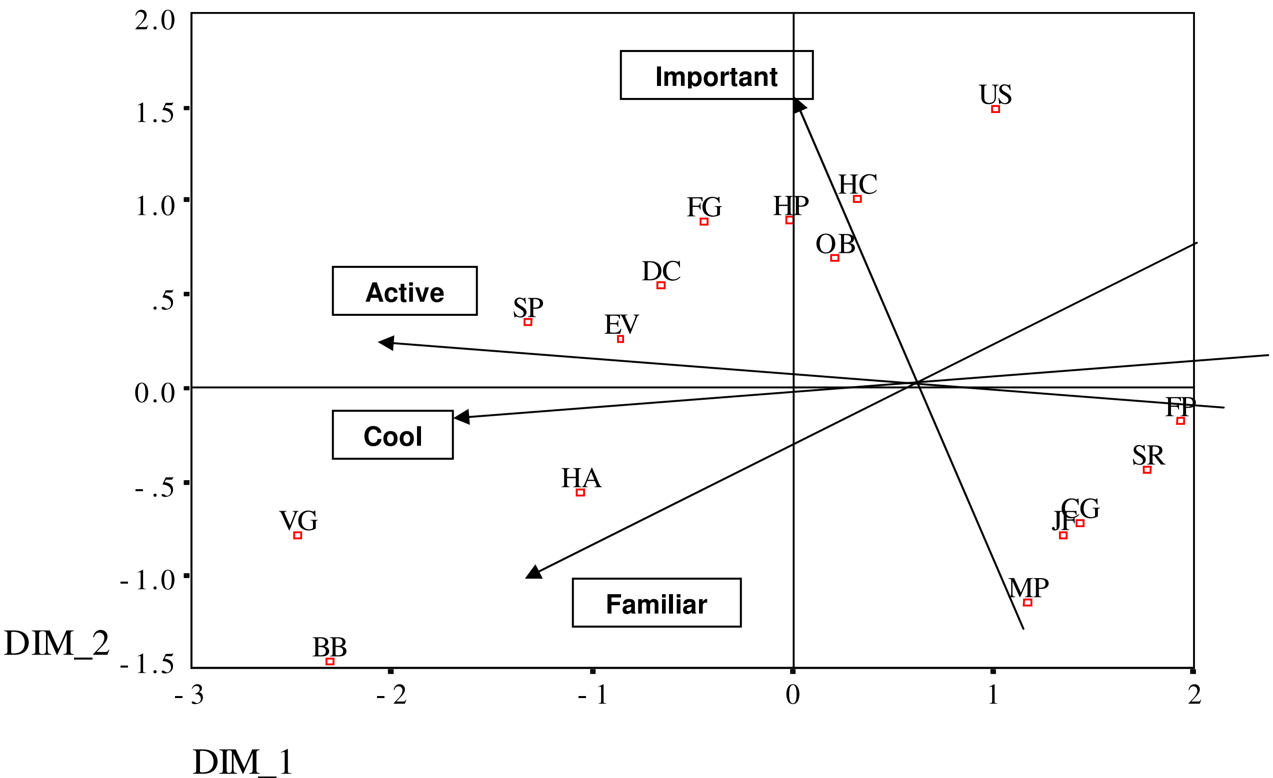


*Figure 2.* 3D MDS Configuration of Topic Interestingness with Topic Attribute Dimension (showing the plane of Dimension 1 and 2)

While it is quite likely that these attribute dimensions do not have a linear relationship with topic interestingness, a hierarchical linear regression was performed using the participants' ratings of topic interestingness as dependent variable and their ratings of topics on the *active, cool, important,* and *familiar* attribute dimensions as independent variables to gain a general sense of the relative strength of these four attribute dimensions (Table VII). The results showed that, while all of these four attribute dimensions influence participants' topic interest, *active* and *cool* seem to be the particularly strong ones.

Table VII
Hierarchical Regression of Topic Interestingness Ratings on Ratings of Topics on Attribute Dimensions

| | Attribute Dimensions (Independent Variables) | Regression Coefficients | | R-square | R-Square Change |
|---|---|---|---|---|---|
| | | B (SE) | β | | |
| Step 1 | Important | 0.186 (0.047) | 0.244* | 0.059 | 0.059* |
| Step 2 | Important | 0.104 (0.046) | 0.137* | 0.185 | 0.125* |
| | Familiar | 0.271 (0.044) | 0.370* | | |
| Step 3 | Important | 6.361E-03 (0.040) | 0.008 | 0.428 | 0.243* |
| | Familiar | 0.154 (0.039) | 0.210* | | |
| | Active | 0.406 (0.040) | 0.545* | | |
| Step 4 | Important | -1.820E-02 (0.038) | -0.024 | 0.496 | 0.068* |
| | Familiar | 7.070E-02 (0.039) | 0.096 | | |
| | Active | 0.238 (0.048) | 0.320* | | |
| | Cool | 0.275 (0.048) | 0.398* | | |

*p<0.05

*Interview Data Analysis*

One of the reasons for using a procedure such as paired-comparison preference judgments in an attempt to discover some of the determinants of topic interest was the belief that people (especially children and adolescents) might not have these determinants available for introspection, and/or would have difficulty articulating them. This belief was supported by the work of Nisbett and Wilson (1977), which raised serious concerns of people's ability to accurately introspect and report on their cognitive processes. It was further confirmed by my observation that, for the interviewees, verbalizing reasons why they found something interesting (or uninteresting) seemed to be quite difficult. Most interviewees, for one or more topics, could not give explicit reasons for finding them interesting or boring, even when they expressed strong opinions about the topics' interestingness. For example, when asked about the topic 'charts and graphs', Kevin[2] stated his opinion definitively and quickly: 'Oh, I don't like those at all'! But when I asked him to explain his opinion, he said: 'Just don't like looking at boring stuff'. When further probed, his only response was: 'Yeah, but they're just lines and shapes. Doesn't seem fun to me'. Kevin was not alone in this regard; similar responses such as 'I don't know', 'They're just fun to play', or simply long periods of silence were common among the interviewees. Clearly much of the participants' knowledge about their own interest development was tacit, which made it difficult for them to explain why they found some things interesting and others not.

*Coding Process. The coding process of the interview transcripts loosely followed the procedures recommended by Emerson, Fretz and Shaw (1995). The interview transcripts were first informally reviewed to get a general sense of any themes they might contain. Individual interview transcripts were then coded line-by-line to identify all the factors that interviewees claimed to influence their judgments of how interesting (or uninteresting) a topic was. Codes emerging from individual transcripts were compared, and codes that represented similar factors were combined. The resulting codes were applied to all transcripts, and definitions of codes were further specified to enhance their fit to the data. The final list of codes is listed in Table VIII. The coding results were summarized, analyzed, and compared with the findings from the MDS analysis.*

Table VIII
*Codes used to analyze interview data*

| Code Domain | Code | Definition | Number of interviewees who mentioned this factor |
|---|---|---|---|
| Familiar | Familiar | Things personally experienced in either learning or informal situations | 4 |

| | | | |
|---|---|---|---|
| | Novel | Things that differ from daily practice or appear novel | 4 |
| | Overexposure | Things that have been encountered too often | 2 |
| Important | Important | Things that affect human lives in general, affect own lives or future, or are otherwise deemed important | 6 |
| Active | Active | Things that have a fast-moving or constantly changing nature | 5 |
| Challenging | Challenging | Things that are 'not too easy' and pose intellectual or physical challenge | 4 |
| | Too hard | Things that are deemed too difficult | 2 |
| Cool | Cool | Things that are deemed popular among friends or peers | 2 |
| Non-school | Non-school | Things that are not typically associated with school | 2 |
| Mysterious | Mysterious | Things that little is known of, cannot be controlled, or present uncertainties in how they happen | 2 |
| Top-down | Top-down | Things whose interest is inherited from a superordinate category | 4 |
| Teaching method | Teaching method | Things whose interest depends on the way they are taught | 4 |

*Major Topic Attribute Dimensions.* With the exception of coolness, all of the topic attribute dimensions confirmed in the MDS analysis emerged as major factors that influence topic interest. In addition, interviewees also suggested a new attribute dimension – the challengingness of a topic.

Judging by the frequency of occurrence[3] (n=12), the most salient factor that influenced participants' topic interest was pertinent to their *familiarity* with the topic. Topics that participants had personal connection to or experience with seemed to be deemed interesting. For instance, Lauren expressed high interest in the topic 'earthquakes and volcanoes' because her mother almost lost her life in an earthquake. Similarly, Paul rated 'stars and planets' as interesting because he had done a project on this topic in a science fair. The finding of a familiarity dimension is consistent with the results identified in the MDS analysis; but beyond that, the interview data suggest that an important determinant of familiarity may be personal connection or involvement, rather than merely exposure in everyday life.

While familiar topics were deemed interesting by several interviewees, the interview data also revealed that the relationship between topic *familiarity* and topic interest is not linear. A couple of interviewees suggested that *novel* topics – those that differ from their daily lives – seemed to be interesting as well. Both Sam and Kelly found 'different cultures and countries' interesting because they found it interesting to see the difference between their own and other cultures. Paul found basketball interesting partly because 'at my old school, we didn't play basketball that much'. On the other hand, topics that participants were too familiar with or to which they were *overexposed* were considered boring. This pattern was particularly obvious for the topic 'why junk food is bad for us': 'Because that's all they talk about. Like in gym, we had to watch movies about why junk food is bad for us, and I KNOW junk food is bad for us, I don't want to learn about that any more… At this age, they don't need to drive it into us as much' (Interview-Paul).

Consistent with the MDS analysis results, interviewees also reported topic *importance* as a factor that influences topic interest. However, the interview data suggested that topic importance was interpreted in at least two different ways by the participants: 1) Topics pertaining to things that affect human lives in general were deemed important – Sam claimed to be interested in 'how pollution harms the environment' because 'it (the pollution) kills things…it smells bad…it makes our world really nasty' and he wanted to 'know more about it…help prevent it'; 2) Topics pertaining to things that affect participants' own lives were deemed important. For example, several interviewees expressed the belief that math topics had no use in their lives or future: 'Oh man! Those (fractions and proportions) are so boring…You're sitting there in a hot room, writing, doing tons of worksheets, wondering how it's going to help you in the future' (Interview-Adam).

Similar to the *active* attribute dimension identified in the MDS analysis, topics that have to do with things of a dynamic or fast-changing nature seemed to be considered interesting. For example, 'video games' were considered interesting partly because of its 'constant action' (Interview-Adam), and 'basketball' was found interesting because it was 'more active, more fun to do…You run around instead of sitting at a place studying' (Interview-Kelly). Interestingly, two students expressed opposite opinions about 'the US government' based on their different perceptions of its activeness -- Sam thought the topic was boring because 'it's like sitting around and stuff', while Adam saw it as interesting because 'it's always changing. It's different changing patterns'.

A new attribute dimension emerging from the interview data was how *challenging* a topic was perceived by the participants. Not surprisingly, topics that were appropriately challenging were deemed interesting. For instance, when asked why 'fractions and proportions' was uninteresting, Lauren said: 'They're really easy… sometimes I'd really like to have a challenge. And fractions and proportions, I understood immediately' (Interview-Lauren). Similar views were expressed by other participants on various topics.

*Minor Topic Attribute Dimensions.* Interestingly, the cool attribute dimension did not emerge from the interview data as a significant influencing factor of topic interest. Only two interviewees, when commenting on the topics 'video games' and 'basketball', hinted at the popularity of them among friends. This pattern was inconsistent with the MDS analysis results in which the cool dimension was shown as a significant influencing factor. One possible reason is that the interview questions asked the interviewees to focus on the characteristics of the topics themselves, which might have discouraged them from thinking about how the topics were perceived among peers. It is also possible that interviewees may be (consciously or not) unwilling to embrace peer influence as an explanation for their interest.

Similar to what the MDS analysis suggested, the interview data provided little support to the speculated *typical of school* and *mysterious* attribute dimensions. The *typical of school* attribute dimension was only brought up by two interviewees when discussing the topic 'video games' – 'It's fun, unlike some things we do at school' (Interview - Lauren). No direct reference to the *mysterious* attribute dimension was made by the interviewees, although two of them suggested that things with uncertainty, either uncontrollable or having various possibilities were more interesting – For instance, Adam found 'how cells work' interesting because '…they just work by themselves, that humans don't really control', and Paul expressed an interest in 'fractions and proportions' because 'it's like a mystery kinda. There are different ways of doing it'.

*Non-Topic-Attribute Factors.* Though not the focus of this study, the interview data also suggested factors other than topic attributes that might play a role in topic interest development. The most salient one is participants' interest in the broader domain to which the topic belongs – that is, their interest in the domain determines whether they found the topic interesting. This pattern was particularly obvious for the math topics and the topic 'how animals survive in the wild'. For example, when asked about specific math topics, Linda said: 'I hate math. I hate anything that's included with math…It's so boring. Anything related to math is boring'. Similarly, when asked to explain why 'how animals survive in the wild' is interesting, Lauren responded: 'I don't know. I've always been interested in animals'.

Among the science topics, 'why junk food is bad for us' seemed to be an exception both in terms of its interestingness rating and its location in the MDS configuration. The interview data suggested a unique factor that could explain such 'odd behavior.' Three interviewees categorized this topic as uninteresting for a similar reason – 'I love junk food, so I don't want to know it's bad for us' (Interview-Linda). It seems that in this case, a clear implication of the topic conflicted with participants' personal preference, which elicited a negative feeling toward it, and thus low interest in learning more about it.

Lastly, consistent with previous research findings (Bergin, 1999; Mitchell, 1993), half of the interviewees mentioned that the way in which a topic is taught also affects how interesting it is perceived. Two particular teaching methods were reported to enhance a topic's interestingness – using visual representation such as movies or demonstrations, and embedding the topic in individual or group projects.

## General Discussion

By analyzing the paired-comparison preference judgment data, I identified four topic attribute dimensions – *active, cool, important* and *familiar* – that influence participants' perception of how interesting a topic is. Among these attribute dimensions, the *active* and the *cool* dimensions seem to be the most important ones (see Table VI and Table VII), which suggests that topics that are considered dynamic in nature or popular among peers are more likely to be perceived as interesting. Interestingly, however, while the interview data confirmed the positive relationship between a topic's activeness and interestingness, interviewees did not place an emphasis on how cool a topic is or how popular it is among peers as an influencing factor of topic interest. These seemingly contradictory results bring up the possibility that the perceived *coolness* of a topic could very well be the result of its interestingness – that is, a topic may become popular because it is interesting, rather than the other way around. In this regard, the *active* attribute dimension seems to be a more robust factor that influences topic interest development, since it is unlikely that participants' view of how active a topic changes as a result of their interest in it.

Extending previous studies that identified content topics students are interested in (Dawson, 2000; Jekins &Nelson, 2005), this finding suggests that instead of generating a list of topics alone, it might be more useful to examine why students perceive certain topics as more active than others. For the data presented here, it is easier to understand why 'video games' and 'basketball' were perceived as active in nature, but the reasons are not so clear for 'stars and planets'. Thus, if we could understand what kind of experiences shape students' perception of a topic's activeness, we would be in a better position to provide students with such experiences in order to help them view the topic as active, and hence interesting.

Though not as strong as the dimensions *active* and *cool,* both the MDS analysis and the interview data suggested that how *important* a topic is may influence how interesting it is thought to be. More precisely, topics dealing with materials relevant to participants' lives – either about their own lives, the physical environment they live in, or the society to which they belong – are considered more important, and thus more interesting. This observation echoes previous studies that suggested positive impact of personal relevance on interest (Schank, 1979; Schraw, Flowerday & Lehman, 2001), and on similar constructs such as motivation (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Eccles & Wigfield, 1992). What is rather surprising, however, is that the participants seemed to view math topics as irrelevant to their lives, a rather alarming message that was revealed by both the questionnaire and the interview data. This observation is also reflected in the relationship between how *familiar* and interesting the topics are perceived to be. Figure 2 suggests the general trend that things participants personally experience or encounter more often in their daily lives are high on the familiarity dimension, and math topics once again were not high on the list. Part of this disconnection could be due to the design of traditional math curricula, as they have been often criticized for portraying math as irrelevant to students' lives (Mitchell, 1993;

Popkewitz, 1988; Wu, 1996). But the finding also points out the need to give students more out-of-school opportunities to engage in activities involving mathematics. Such exposure conceivably would help students perceive math as more familiar and relevant, and thus more interesting.

It should be pointed out that these four attribute dimensions are unlikely to be the only, and possibly not even the most significant dimensions that influence students' topic interest. The *challenging* attribute dimension that emerged from the interview data provides a good example of other possibilities. As the appropriate level of challenge has been suggested to influence short-term interest elicitation (Hidi & Baird, 1986) and to enhance motivation (Csikszentmihalyi, 1990), it is conceivable that a topic's *challengingness* may also play a role in topic interest development. This possibility, together with other unidentified factors, need to be further explored in follow-up studies.

The methodological approach used in this study, particularly the coupling of paired-comparison preference judgment task with MDS analysis, has proved to be successful. By moving beyond the previous strategy of identifying content topics students are interested (or uninterested) in, this approach allowed us to begin to understand *why* students find certain topics more interesting than others. As Jenkins and Nelson (2005) pointed out, the topics individual students express interest in often appear idiosyncratic in nature, which makes them less useful in guiding curriculum development. However, if we could understand the common features that underlie the topics of high (or low) interest, we might not need to worry as much *what* topics we teach that interest students; instead, we could focus more on creating environment, context, or means in which a particular topic is taught so that it is perceived as more active, familiar or important, and thus more interesting.

## Limitations and Future Directions

In this study, I was able to identify a set of topic attributes – *activeness, coolness, importance, familiarity,* and possibly *challengingness* – that influence middle-school students' topic interest. In addition, the data also suggested non-topic-attribute factors that possibly affect how interesting a topic is perceived to be. While identifying these factors is an encouraging step toward answering the question 'what makes a topic interesting', the present study also raised several issues that need to be addressed in future studies.

First, it is unclear how the term "interest" was understood by the participants. The interview transcripts suggested that students often equated "interesting" with "fun", "liking", or simply "willing to do", which possibly represented different constructs. While this lack of clarity is understandable given the flexible use of the word "interest" in everyday language (Valsiner, 1992), it nonetheless points out the need to define "interest" more precisely in follow-up studies.

Similarly, the 'purity' of the topic attribute dimensions identified in this study is unclear. That is, it is uncertain whether the participants interpreted the attribute dimensions in the same manner. Despite the fact that brief definitions of the attribute dimensions were provided at the time of questionnaire administration, it is quite likely that participants interpreted the dimensions differently from the definitions, and different students assigned slightly different meanings to the same dimension. In fact, the interview data suggested that such divergence from the provided explanations, as well as sub-dimensions within each attribute dimension, indeed exist. Therefore, follow-up studies need to separate out these sub-dimensions, and examine their individual impact on topic interest.

Due to practical reasons, the sample size of this study is quite small. While the study design, particularly the use of the MDS analysis technique, allowed us to extract valid information with only a small number of participants (Kruskal & Wish, 1978), it should be kept in mind that, to the extent that the results are generalizable, they might well only hold for similar populations. It is likely that different attribute dimensions would emerge with different populations. For instance, as peer influence has been suggested to be the strongest during early adolescence (Berndt, 1979; Steinberg & Silverberg, 1986), it is quite likely that the *cool* dimension identified in this study might not be a significant factor for students of other age groups. Replicating this study with different populations would be an important next step.

Related to the constraint that I only had limited access to a small group of students, the validity and reliability of the instruments used were not established prior to their administration. While detailed instructions regarding how to complete the questionnaires were given to the participants, it is likely that students interpreted the items or even the rating scale differently from the original design. Administrating the instruments to a group of students that are comparable to the participants in this study and examine closely how they interpret and complete the questionnaire items would greatly strengthen the findings.

Lastly, I am uncertain whether students' perception of a topic's interestingness as assessed in this study is the same as that when they are actually engaged in learning about the particular topic. Given the ultimate goal of this research is to inform teaching practice, this distinction is quite important. The interview data implied that even for a topic that is high on all of the identified interest-influencing attribute dimensions, the teaching method through which it is taught could easily make it uninteresting. Therefore, in future work, I plan to explore the influence of different teaching methods on topic interest, as well as their interaction with the identified topic attributes in guiding topic interest development.

## Notes

1. In order to differentiate from the configuration dimensions (i.e. the coordinates), the term 'attribute dimensions' is used to refer to the attributes of the topics that may explain their perceived interestingness, represented as additional lines in the configuration (see Figure 2).

2. All student names in this paper are pseudonyms.

3. The frequency of occurrence refers to the number of times a factor was mentioned by the interviewees. Please note that a factor could be mentioned multiple times by the same individual, as the individual could refer to the same factor when discussing different topics.

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## Appendix 1: Example items of Questionnaire 1

**If you had to listen to someone talking about the topics A and B, which one do you think you'd find <u>more interesting</u>? Highlight it!**

| | | | | |
|---|---|---|---|---|
| 1 | A) | Why junk food is bad for us | B) | Earthquakes and volcanoes |
| 2 | A) | Charts and graphs | B) | Stars and planets |
| 3 | A) | Different cultures and countries | B) | Why junk food is bad for us |
| 4 | A) | Stars and planets | B) | Basketball |
| 5 | A) | Forces and gravity | B) | Earthquakes and volcanoes |
| …. | | | | |

**Rate <u>HOW interesting</u> you think each of the following things is using this A-D scale:**

| A | B | C | D |
|---|---|---|---|
| Very **<u>Un</u>**interesting | Somewhat **<u>Un</u>**interesting | Somewhat Interesting | Very Interesting |

For each question, highlight the letter that best describes your opinion. Make sure that you highlight **<u>one</u>, <u>and only one</u>**, letter.

| | | | | | |
|---|---|---|---|---|---|
| 121 | How cells work | A | B | C | D |
| 122 | How animals survive in the wild | A | B | C | D |
| 123 | Forces and gravity | A | B | C | D |
| 124 | Earthquakes and volcanoes | A | B | C | D |
| …. | | | | | |

## Appendix 2: Example items of Questionnaire 2

Some things are more active, and others are more passive. Active things often have lots of energy, involve many activities, or change a lot.

**How <u>ACTIVE</u> do you think the topic is?**[1]

Circle the number that best describes your opinion. Please circle one and only one number.

| | Not Active at all → | | | | Very Active |
|---|---|---|---|---|---|
| How cells work | 1 | 2 | 3 | 4 | 5 |
| How animals survive in the wild | 1 | 2 | 3 | 4 | 5 |
| Forces and gravity | 1 | 2 | 3 | 4 | 5 |
| Earthquakes and volcanoes | 1 | 2 | 3 | 4 | 5 |
| Sexual reproduction in animals | 1 | 2 | 3 | 4 | 5 |
| The US government | 1 | 2 | 3 | 4 | 5 |
| How pollution harms the environment | 1 | 2 | 3 | 4 | 5 |
| Fractions and proportions | 1 | 2 | 3 | 4 | 5 |
| …. | | | | | |

[1] The same questionnaire format was used for the other five attribute dimensions.

# The Impact of a Field-Based, Inquiry-Focused Model of Instruction on Preservice Teachers' Science Learning and Attitudes

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## Abstract

The purpose of this study was to determine the effects of a field-based, inquiry-focused geoscience course designed to provide preservice teachers with opportunities for active, hands-on scientific investigation and for gaining skills in inquiry pedagogy. Impact on student learning and attitudes was measured through (a) dependent t-tests comparing pre- and post-measures for students enrolled in the new field course (n = 12) and (b) analysis of covariance comparisons between field course students and education students in the traditional, classroom-based course (n = 12). Results showed that students in the field course scored significantly higher than students in the traditional course on measures of inquiry, confidence for teaching science courses, knowledge building, and cooperative learning. There was no significant difference between the two instructional groups on geoscience content knowledge, indicating that students in the two courses gained an equivalent amount of knowledge. Additionally, although there was no difference in students' use of low-level questions, the field class scored significantly higher in high-level questioning. Results provide evidence of the promise of this approach in helping preservice teachers develop the needed skills and content knowledge to create effective and engaging science courses for their students.

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## Introduction

Many education majors in our nation's colleges and universities experience undergraduate science courses in a large introductory lecture and lab format. While these courses are rich in content, they often do not engage students in active, authentic scientific investigation, nor do they adequately address the problem-solving processes and inquiry skills required to teach science to others. It is difficult for our future teachers to create effective and engaging science courses for their students without exposure to such experiences. The National Research Council Report on Teacher Education (2000a) recommends that university and college science, mathematics, and engineering departments should: (a) assume greater responsibility for offering courses that provide teachers with strong exposure to appropriate content and that model the kinds of pedagogical approaches appropriate for teaching that content, and (b) reexamine and redesign introductory courses to better accommodate the needs of practicing and future teachers. This paper discusses the impact of a new field-based, inquiry focused geoscience course designed to achieve these National Research Council recommendations.

The development of student inquiry skills and scientific literacy are emphasized in a variety of reports, standards and reform movements (American Association for the Advancement of Science, 1993; National Research Council, l996, 2000b; U.S. Department of Labor, 2000). However, the research base on how to most effectively teach these skills remains limited (Anderson & Mitchener, l994; Bybee & Fuchs, 2006; Smith & Wenk, 2006). Indeed, much of the research in science education has been conducted in physics and has focused on differences in how experts and novices approach and solve scientific problems (Bruning, Schraw, Norby, & Ronning, 2004). The lack of research is particularly acute within the discipline of geoscience, where a limited research base on effective pedagogy (Anderson & Mitchner, l994) is compounded by the scarcity of research on how students develop an understanding of Earth sciences (Dodick & Orion, 2003).

One approach which offers promise to help preservice teachers develop the needed skills is direct field experience with opportunities for active, authentic scientific investigation and for gaining skills in inquiry pedagogy. Geoscience educators have maintained that field work is "critical to the development of spatial reasoning, to the ability to create integrated mental visualizations of Earth processes, and to developing facility with analyzing the quality and certainty of observational data supporting geoscience theories" (Manduca, Mogk, & Stillings, 2002, p. 21).

This research focused on investigating and documenting the effects of a new field-based, inquiry-focused geoscience college course. Specific objectives were to: (a) determine the effectiveness of a field-based, inquiry-focused course in impacting preservice teachers' geoscience achievement, attitudes, and inquiry skills; and (b) assess the influence of field activities, as compared to classroom-contained activities, on preservice teachers' geoscience achievement, attitudes, and inquiry skills.

## Conceptual Framework

The past decade has been marked by fundamental changes in the way science should be taught, based on an emerging view of learning as an active process of sense making and mental construction (Bransford, Brown, & Cocking, 1999; Donovan, Bransford, & Pellegrino, l999). Scientific expertise is not simply accumulating information but "a principled and coherent way of thinking and representing problems" (Shepard, 2000, pp. 6-7). Research on the development of scientific expertise confirms the importance of helping students understand major scientific concepts and related factual information, and develop a variety of inquiry abilities (National Research Council, 2000b).

*Scientific Inquiry*

To enhance scientific literacy, educators are challenged to teach not only factual knowledge generated by science but also to teach the process of obtaining this information, scientific inquiry. Scientific inquiry is a complex human endeavor through which practitioners systematically investigate natural phenomena on Earth and in space. Scientific inquiry is not easy to define and perceptions can vary greatly depending on whom you ask. Much effort has gone into defining scientific inquiry in an attempt to provide a basis for science education purposes (e.g. National Research Council, 1996, American Association for the Advancement of Science, 1993).

Bybee (2002) describes the key elements of scientific inquiry as observation, hypothesis, inference, test, and feedback. However, scientific inquiry not only comprises these key practical components, it also requires recognition that scientific knowledge may change in response to new evidence (National Research Council, 2000). Furthermore, even though the basic process remains similar, scientists take many different paths in their quest to answer questions, and this search is fueled by curiosity, creativity and hard work. The creative process involved in developing hypotheses and theories to explain how the world works and then figuring out how they can be put to the test of reality is "as creative as writing poetry, composing music, or designing skyscrapers" (American Association for the Advancement of Science, 1990, n.p.).

The foundation for building students' science literacy is outlined in the *National Science Education Standards* (National Research Council, 1996) and the companion book *Inquiry and the National Science Education Standards* (National Research Council, 2000b). These documents outline inquiry science as a three-legged stool (see also Vasquez, 2008, p. 12). The first leg of the stool is students' ability to do science, i.e. the process of conducting an investigation. The second is students' understanding of scientific inquiry or their knowledge of the nature of science. The third requires teachers to use inquiry as a set of teaching methods.

Too often science is taught as a collection of irrefutable, disconnected facts, with scientific investigations embodied in facts and principles offered by the textbook (National Science Foundation, 1997). This approach has many problems, not the least that it misses the opportunity to teach critical skills such as problem solving, communication, and critical thinking. Indeed, teaching science as strictly a body of information results in conveying only the abstractions and reduces the process of acquiring scientific knowledge into an artificially polished and overly simplified "how to" manual. As a consequence, this approach provides students with sanitized concepts that have few connections and little personal relevance. The result is rote memorization and limited comprehension of scientific information and almost complete ignorance of the process used to generate that information (Chiappetta & Koballa, 2002). In order to learn the process of scientific inquiry students need opportunities to ask questions, seek answers, analyze data, discuss ideas, and apply scientific concepts in a variety of contexts to describe and explain phenomena (Ericsson, Krampe, & Tesche-Romer, 1993; National Research Council, 1996). The student must play an active role in formulating and testing hypotheses through data collection, rationalizing any conflicts in original beliefs and evidence, inventing a new conception that better explains the observed data, and communicating and sharing results.

Teaching teachers to successfully implement inquiry-based practices is a goal of teacher education and is a central component of the National Science Education Standards. While research has shown that teachers can develop the skills necessary for an inquiry-based classroom (Crawford, 2000; Wallace & Kang, 2004), preservice teachers face unique challenges in creating and successfully implementing inquiry lessons (Windschitl, 2002, 2004). To implement inquiry in the classroom, preservice teachers must be knowledgeable of, and comfortable using, the teaching techniques associated with inquiry-based education, including the processes of observation, question development, critical thinking, cooperative learning, general problem solving, and communicating and sharing results. Research has also documented the importance of preservice teachers' underlying beliefs and attitudes about teaching and science, which impact their teaching practices (Crawford, l999; Pajares, l992).

*Field Experience*

The experience of observing real geological structures in their natural environment and learning about the types of evidence that contribute to scientific understanding has been demonstrated to be of value in promoting inquiry and processing teaching behaviors. Results from learning research support the cognitive and affective value of incorporating a field experience into geoscience curricula. A comprehensive review of research studies dealing with the impact of fieldwork (Rickinson et al., 2004) concluded that well planned and delivered fieldwork provides experiences that cannot be duplicated in the classroom; it also positively impacts attitudes, leading to reinforcement between affective and cognitive domains of learning and higher level learning. Other research has shown that field experiences not only permit but actually encourage perception of the integrated whole, not just the individual parts (Kern & Carpenter, l986).

The opportunity for direct hands-on experience provided by a field trip can be useful for transition from a concrete to abstract level of cognition as described by Piaget (1990). It can lead to conceptual change and refinement of student pre-conceptions (Tal, 2004). Furthermore, McKenzie, Utgard, and Lisowski (1986) showed that students who participated in a geological field trip for education majors exhibited significant gains in evaluation items that involved inquiry and investigative skills and that required active involvement. Field work has also been shown to be a key factor for improving students' understanding of geological time (Dodick & Orion, 2003).

The type of experience afforded by the field experience is a critical variable. Mackenzie and White (1982) compared the value of learning programs with *processing* field excursions versus learning programs plus *traditional* field excursions. The processing excursions emphasized students (a) becoming an active part of the experience rather than mere observers, (b) generating information rather than receiving it, and (c) constructing their own records of the scene rather than accepting the teacher's version. Results documented the superior effectiveness of the processing excursions, particularly in fostering student retention.

"Authentic science," a central strategy of science teaching, occurs through fieldwork. It requires that students assume active, investigative roles, thinking like a scientist and "doing" real science. Key to the success is not just providing students with a science immersion experience, but also helping them conceptualize science as a creative process and way of thinking rather than a defined body of content (National Research Council, 2007).

The need to integrate more authentic science experiences is prevalent in all K-12, undergraduate science, and teacher education courses. The traditional geology laboratory experience provided to undergraduates, although a valuable addition to the traditional lecture, can never be a substitute for evidence gathered directly from the field. It cannot replace the experience of observing real geological structures in their natural environment and learning about the types of evidence that contribute to scientific understanding, as well as extraneous evidence that can obscure (Manduca, Mogk, & Stillings, 2002). The goal of the new course described in this article was to teach geoscience concepts and inquiry methods by actively engaging students in fieldwork and invoking their use of complex reasoning and experimental inquiry skills.

## Method

### *Instructional Treatments/Class Descriptions*

This study involved a comparison between learning outcomes for students enrolled in the field-based inquiry-focused geoscience course and students in the on-campus, traditional classroom-based geoscience course. The field course was first offered at a large public Midwestern university during the 3-week summer session in 2004. The course provided students with the opportunity to study a variety of locations in Nebraska and Wyoming. It covered the traditional geology content offered in the classroom-based course, Geology 101, but also provided students with active, hands-on field-based opportunities to observe, compare, and investigate geological structures in their natural environment. Instructors focused on exposing students to the Earth systems concepts and content outlined in national science education standards. Class was conducted among a variety of rock exposures, on top of glacial deposits, in river valleys, and on mountainsides, literally bringing textbook concepts alive through real-life experiences in the field.

At the beginning of the course the instructors provided students with key questions to consider at each predetermined stop: (a) what makes the sediment and rocks there unique, (b) how were the rocks deposited or formed, and (c) what has occurred since their formation to lead to their current appearance. Students classified the world around them based on careful observation, comparison, and their growing geoscience understandings, using field books, the instructors, and fellow students as resources. A mobile library, comprising a range of K-12 Earth science curricular materials and activities, was provided for students to utilize, examine, and critique. There was a clear focus on providing students with a solid background in geology, recognizing that a basic understanding of geologic principles was necessary before students could approach geology from an inquiry perspective.

The course provided an immersion in scientific inquiry, focusing on developing a new set of mental skills in the students. Students were provided many opportunities to utilize science process skills including observation, documentation, classification, questioning, formulation of hypotheses and models, and interpretation and debate. Opportunities were provided during the course to integrate the learning of geology with teaching practices. Instructors used the experiences in the field, the drive time in the vans, and the time spent at the daily campsites to introduce and discuss teaching curricula and strategies. Students were given sample boxes so that they could collect, label and classify samples of Earth materials to build a personal set of geoscience materials to use when they teach. Digital cameras were used to record images of natural phenomena. Each student received a DVD of the images to use in their future classroom activities. Near the end of the course students were asked to generate a series of lesson plans to teach plate tectonics.

A key strategy was modeling of the inquiry approach by the course instructors. At each of the stops along their route through Nebraska and Wyoming students were asked to come up with their own questions and try to answer the question with the resources provided. Students used their senses (i.e. how does a rock feel, taste, look) and other means to observe and gather information. They carefully explored each site, recorded their findings in their field books, and drew conclusions. Where possible, these conclusions were shared with the entire group, with the instructors facilitating the discussion through probing questions and offering alternative explanations or interpretations as appropriate. In keeping with the tradition of discussion and debate among scientists and scientific research teams, the two instructors sometimes engaged in a debate about possible interpretations.

As the trip progressed instructors encouraged students to compare and contrast concepts at the different sites and speculate underlying reasons for noted differences. A sample of topics and activities for day two of the trip is found in Table I.

Table I
*Topics and Geoscience Principles Covered in Day 2 of Field Course*

| Location | Topics [Principles and Concepts] | Activity |
|---|---|---|
| Platte River | Sedimentology/Modern environments1 – fluvial systems 1 [actualism] | Examine the Platte River System at a variety of locations along the route; measure stream velocity, collect sediment samples and examine grain size, shape, and composition; examine sedimentary structures |
| Lake McConaughy | Sedimentology/Modern environments 2 - lacustrine and eolian systems [actualism] | Collect sediment samples from sand dunes; compare and contrast with river sand |
| Medicine Bow | Soils 1 | Dig soil pits in a variety of locations and record observations |

A key component of the course was students' use of field books, which provided a log of their observations and explanations. These books became the students' documentation of the experience and were rich in illustrations of rock and soil deposits.

The traditional, classroom-based course was a general education lecture/lab course, Geology 101. Meeting three times per week for one hour each, it was also accompanied by a once-a-week 2.5 hour lab. This course focused primarily on classroom contained activities utilizing a structured approach. The lab allowed opportunities for students to interact with Earth materials, but within a classroom environment supplemented by limited, local field trips. A summary comparison of key differences between the field and traditional courses is presented in Table II.

Table II
*Comparison of Field and Traditional Courses*

| Location | Traditional Classroom | Field |
|---|---|---|
| Learning goals | Geology concepts and principles | Geology concepts and principals<br><br>Inquiry-focused pedagogy |
| Lab approach | Observing rock and sediment samples provided by teacher | Collecting own rock and sediment samples |
| Field trips | Local field trip | Total field immersion |
| Setting | Large lecture class with structured lab | Small group, learning community |
| Teaching approach | Instructor-centered | Student-centered; guided inquiry approach |

The decision to use Geology 101 as a comparison group was made despite the fact that the goals of the two classes are not identical. The two courses shared a common purpose of increasing student knowledge of geoscience. The field class, however, had the additional goal of enhancing pedagogical understanding and increasing student understanding of the inquiry process. Thus, the classroom-based course served as a comparison group for measuring student geoscience knowledge and a control group for measuring the pedagogically-oriented outcomes of inquiry skills and attitudes and confidence for teaching science. Differences in contact hours for the two courses should also be noted. The on-campus course carried 4 hours of credit; the field course carried 3. However, the nature of the field class meant that students had virtually unlimited access to instructors with opportunities for interaction beyond the typical instructional time period. The amount of instructor-student contact depended on student initiative; some students took advantage of the opportunity and others did not.

*Participants and Data Collection*

Since students in the field-based course were all education majors, only education majors enrolled in the traditional classroom-based course for Physical Geology were invited to participate in this research project. Research participants included the 12 students enrolled in the field-based course (Summer Session, 2004 and 2005) and 12 education students enrolled in the classroom-based course (Fall 2004 and Spring 2005).

The small numbers were due to the limited subject pool; however, we were able to achieve a balanced design of 12 subjects per condition, which is important in meeting the ANCOVA assumption of equality of variances. Based on previous studies showing significant effects for various attitudinal and cognitive measures for students participating in field experiences, our sample size was deemed sensitive enough to achieve the desired effects. In particular, Kern and Carpenter (l984) found highly significant effects ($p < .10$, Cohen's d [effect size] = 1.24 to 1.60 [Cohen, 1988]) for the impact of a field experience on undergraduate students ratings of value, interest and attitude towards geoscience and geoscience course topics. McKenzie et al. (1986) also showed significant gains ($p < .05$) for inquiry and investigative skills for preservice teachers involved in a field course.

There was no deliberate matching of students in the two groups; however, the two groups were surprisingly similar on several key demographics, including gender, classification, number of previous science courses taken, and major. Table III provides a breakdown of student characteristics.

Table III
*Comparison of student demographics in field and traditional class*

| | Field | Classroom |
|---|---|---|
| Gender | | |
| Males | 2 | 2 |
| Females | 10 | 10 |
| Classification | | |
| Freshman | 1 | 1 |
| Sophomore | 4 | 4 |
| Junior | 4 | 4 |
| Senior | 3 | 3 |
| Previous Science Courses | Mean = 1 | Mean = 1 |
| Major | | |
| Elem. Ed. | 5 | 5 |
| Middle School | 1 | 1 |
| Secondary Ed. | 0 | 5 |
| Special Ed. | 1 | 0 |
| Science | 3 | 0 |
| Music | 1 | 0 |
| English | 1 | 0 |
| General Studies | 0 | 1 |

All participating students completed a packet of questionnaires at the beginning of the course and again at the end of the course.

***Measures***

A variety of instruments were used to assess the impact of a field-based geoscience course on preservice teachers' cognitive and attitudinal perceptions, behaviors, and skills. With one exception (the multiple choice content test), all instruments were previously published and validated. Internal reliability estimates (Cronbach Alpha) for each of the instruments and/or scales, calculated from our research data, ranged from .78 to .98. Following is a description of the measures and their instrumentation.

*Inquiry skills and attitudes.* Key elements of inquiry are careful observation, the development of questioning skills, the use of cooperative learning, and the differentiation between scientific observation and inference. Two instruments were used to measure these elements: (a) *Student Perceptions of Classroom Knowledge-Building (SPOCK)* (Resta et al., n.d.) and (b) an observation/inference instrument using a picture prompt format recommended by Molitar and George (1976). *SPOCK* has several scales to measure students' knowledge building and classroom perceptions. Students are asked to indicate how frequently they think the activities described in the items occurred in previous (pre) and the current (post) science class. Items are on a 5-point-Likert format (1 = almost never, occurred on a very rare occasion or not at all; to 5 = almost always, usually or always occurred). The two *SPOCK* scales used to measure questioning skills were (a) question asking - low level and (b) question asking - high level. Low-level questions focused on learning the answers for the test and what the instructor wanted students to learn. High-level questions examined students' use of high-level questions to more fully understand the content, satisfy their curiosity, and help them learn the material.

Cooperative learning was measured through a *SPOCK* scale focusing on the degree to which students worked cooperatively on assignments and actively shared ideas. A sample question was "My classmates and I worked together to help each other understand the material."

A final inquiry skill assessed was the differentiation between scientific observation and inference. This outcome variable was included in the research design because of the importance of this skill within the geoscience field. Evidence in the geosciences is largely observational, and a significant portion of geoscientists' work involves observing natural phenomena and inferring events in the past or processes beyond human perception (Manduca, Mogk, & Stillings, 2002). This skill was measured by an observation/inferences instrument consisting of 6 picture items depicting an easily recognized event, i.e. a broken window with a baseball lying on the floor. Students were asked to make both observations and inferences about the event. A total average score for the scale was derived with 100 total possible points.

*Knowledge.* Two knowledge measures were used in this research. Geoscience content knowledge was measured by a 30-item multiple-choice assessment prepared by the course instructors based on questions that had been developed for the traditional, on-campus class.

Another knowledge measure, focusing on deep learning, was drawn from the knowledge building subscale from *SPOCK*. This scale examined the extent to which students related new class knowledge to prior knowledge, went beyond the class material and developed new understandings and deeper learning.

*Confidence for teaching science.* Students' confidence for teaching science-related courses was measured through a 15-item scale that asked students to think about themselves as future teachers and rate how confident they were in achieving various classroom tasks (i.e., teach concepts that students are expected to understand, write lesson plans that interest students, etc.). Ratings range between 0 (no chance in achieving the tasks) and 100 (completely certain that they could achieve the tasks). A total average score for the scale was calculated. This scale was derived from Bandura's (l977) theory of self-efficacy which is based on one's belief in their ability to cope with a task. Research has shown that teacher efficacy is related to positive teaching behavior and student outcomes (Enochs, Scharmann, & Riggs, l995; Woolfolk & Hoy, l990).

*Data Analysis*

Two sets of statistical analyses were conducted. The first was a dependent t-test between pre- and post-measures for students in the field class. This test was intended to determine any significant increases or decreases in the cognitive and attitudinal measures as a result of taking the field course. The primary analysis was a one-way analysis of covariance (ANCOVA) examining differences in post-measures between the field and traditional classes. The ANCOVA used the pre-measures as covariates to adjust for initial differences between the two class groups. Despite the small sample size, all significant ANCOVA analyses met the homogeneity-of-slopes assumption. There were no significant interactions between the covariate and group (field, traditional class); group differences on the dependent variable among groups did not vary as a function of the covariate.

## Results

Results are summarized in Table IV, which shows the average score per measure, the t- and F- statistics, effect sizes, and the level of significance. It is important to note that, despite the small number of subjects, all of the hypothesized effects were significant and the effects sizes for the significant results were all large (Cohen's $d > .8$ and $\eta^2 > .14$ [Cohen, 1988]).

Table IV
*Summary of t-test and ANCOVA analyses*

| Measure | | Field-Class Means (n=12) | | | Cohen's D Effect | | Regular Class Post | | $Eta^2$ Effect | |
|---|---|---|---|---|---|---|---|---|---|---|
| Inquiry Skills and Attitudes | | | | | | | | | | |
| Question Asking Low Level (*SPOCK* subscale with 20 possible points) | .86 | 14.08 | 12.42 | 1.04 | .30 | .32 | 10.92 | .14 | .01 | .71 |
| Question Asking High Level (*SPOCK* subscale with 25 possible points) | .96 | 19.5 | 22.0 | 2 .09 | .60 | .06 | 12.92 | 13.43 | .39 | .001*** |
| Cooperative Learning (*SPOCK* subscale with 25 possible points) | .91 | 16.08 | 22.33 | 3.95 | 1.14 | .002** | 18.58 | 4.69 | .18 | .04* |
| Observations and Inferences | .78 | 57% | 77% | 5.07 | 1.46 | .000*** | 64% | 10.99 | .36 | .003** |
| Knowledge | | | | | | | | | | |
| Content Knowledge | .81 | 38% | 51% | 3.99 | 1.15 | .002** | 49% | .15 | .01 | .70 |
| Knowledge Building (SPOCK subscale with 50 possible points) | .91 | 33.0 | 40.17 | 3.08 | .89 | .01** | 29.58 | 17.6 | .46 | .000*** |
| Confidence Teaching Science Related Courses (100 point scale) | .98 | 58.48 | 80.13 | 3.73 | 1.08 | .003** | 78.51 | 6.0 | .22 | .02* |

$*p < .05$, $**p < .01$, $***p < .001$

Results show that the field course significantly increased student use of cooperative learning strategies, differentiation between observations and inferences, deep learning (knowledge building), and confidence in teaching science. The field course was also superior to the traditional, classroom-based course in fostering student use of high-level questions, cooperative learning, differentiation between observation and inferences, deep learning, and confidence in teaching science.

## Discussion

### *Inquiry Skills and Attitudes*

A particularly enlightening result was that the field course promoted students' high-level questioning, but had no impact on low-level questioning. Students were more likely to increase their use of high-level questions that allowed them to more fully understand the content, satisfy their curiosity, and help them learn the material. They did not increase low-level questions that focused on learning the answers for a test. Results show that students in the field class were intent on gaining understanding. It is interesting that the high-level questioning scores for the field class increased from pre to post, while the scores for the traditional classroom actually decreased. The field work and the instructor modeling of the scientific inquiry process contributed to student development of higher-order questioning skills, while traditional classroom settings and strategies had no positive impact.

Both the t-test and ANCOVA were significant for the cooperative learning measure, indicating that the field experience increased students' use of cooperative learning strategies. Again, the modeling of instructional strategies to enhance cooperative learning and sharing of ideas and explanations was important to the field course success and provided students with a model of how cooperative learning strategies could be implemented in a K-12 classroom.

The t-test and ANCOVA for the observation and inference measure were both significant, indicating that the field experience directly contributed to student differentiation of observation and inferences, which is a critical inquiry skill for prospective K-12 science teachers. It is especially encouraging that the field students scored higher on the observation portion of the assessment since careful observation is a critical skill in geoscience.

Adjusting to an inquiry-based teaching approach was not always easy for students. Comments from students and reflections in their field books documented students' initial frustration with the student-centered approach, and particularly the instructors' penchant for encouraging students to answer their own questions and not rely on the instructor for quick answers. As one student reflected in his field book mid-way through the course, "When a students' main (all) experiences are lecture-based, it can be difficult for a student to shift gears into inquiry. I suspect myself and my classmates are experiencing difficulty shifting gears." By the end of the course students felt more comfortable with the inquiry approach and developed a sense of self-confidence in their own abilities to carry out an investigation, develop a hypothesis, and share results with fellow students and instructors to refine conclusions.

*Knowledge Measures*

T-test results for the content knowledge multiple choice assessment and the *SPOCK* knowledge building scale were both significant, indicating that the field experience significantly increased students' knowledge in both these areas. In addition, the ANCOVA was significant for the knowledge building (deep learning) measure, but not the content knowledge measure. These results confirm that field course students gained an equivalent amount of content knowledge as students in the traditional class but increased in their perceptions of their abilities to expand, extend, and transfer their knowledge. Findings are consistent with hypothesis that the field pedagogy would promote deeper, contextual learning through the opportunity to experience "real" Earth science through fieldwork. These results support previous research (Kern & Carpenter, 1986) documenting the effectiveness of field experience in allowing students to develop a holistic view of geoscience content.

*Confidence in Teaching Science*

The t-test and ANCOVA statistical tests for this measure were both significant, indicating that the field experience positively impacted preservice teachers' confidence in teaching science. This is consistent with our hypothesis that the field experience, which modeled effective science pedagogy and provided basic geoscience content knowledge, would result in increased student confidence in their ability to teach science.

## Summary

The field-based, inquiry-focused course model developed for delivery of an undergraduate geology course significantly impacted key skills and attitudes of preservice teachers. This research demonstrated that students participating in the field class scored significantly higher than their counterparts in the traditional classroom-based course on inquiry skills and attitudes, deep learning, and confidence for teaching science-related courses. It is important to note that the field class scored equally well on the multiple choice content test as students in the traditional course. They gained an equivalent amount of geoscience knowledge while concurrently gaining confidence in their science teaching abilities and increasing their perceived use of high-level questions and cooperative learning strategies. These results provide evidence that this instructional model can be effective in promoting attitudes, knowledge and skills necessary for teaching K-12 science. Future research will refine the course model by incorporating a pedagogical component, providing preservice teachers an opportunity to use their field experiences as the basis for developing and teaching a sample geoscience unit to middle school students. We believe this strategy will help students make the transition from practicing inquiry as a student to implementing inquiry as a teacher. Observational measures to evaluate preservice teachers' pedagogical skills in actual teaching situations will also be added to reinforce the self-report data reported in this study.

While these results provide evidence of the promise and success of this approach, the long-term impacts are equally important. How effective are the field students in implementing inquiry strategies in their classroom? The research team is maintaining contact with students who have completed the course and taken teaching positions, with the hope of documenting their implementation of inquiry-based approaches in their own classroom. Ultimately, the long-term goal of this research is to develop an optimal model by which preservice educators are provided with the necessary content knowledge and pedagogical skills to feel empowered, capable, and prepared to create effective and engaging science courses for their students.

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# Students' Creation and Interpretation of Circuit Diagrams

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Abstract

I report results of a study of representations of electric circuits and interpretation of circuit diagrams by students in a class for pre-service teachers and graduate students in science education. Students' representations of circuits prior to instruction on the conventions of circuit diagrams were collected and catalogued according to representative characteristics and classified as either figural/iconic or abstract/symbolic or a mixture. As might be expected, prior experience with circuits was related to the level of abstraction in the ways students chose to represent circuits before standard circuit diagrams had been introduced in the course. Students' native competence was also evident, however, as one student without prior experience developed her own abstract scheme for encoding information in circuit diagrams and continued to use it after conventional diagrams were introduced. Students were also interviewed as they interpreted non-standard and conventional circuit diagrams. The interviews revealed that previous experience with formal circuit diagrams, and the unstated but accepted conventions therein, led to difficulties in treating an existing circuit diagram as a completely abstract representation in one case, in contrast with expectations that experienced students would recognize circuit diagrams as complete abstractions. These results imply that students may be disadvantaged when conventional diagrams are simply presented as the norm, without explicit discussion of representation issues.

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## Introduction

It is quite common for students to experience difficulties in developing a robust understanding of even the simplest electric circuits, despite instruction on the topic (Fredette & Lochhead, 1980; McDermott & Shaffer, 1992). An international comparison (Shipstone et al., 1988) found that these difficulties are essentially the same across countries, suggesting 'an almost 'natural' coherence to the learning difficulties within the cognitive structure' (p.315). In the same study, however, some problems had apparently been overcome by intense treatment of a given topic within a particular curriculum, showing that these difficulties are not insurmountable. Physics education researchers have demonstrated that carefully designed curriculum can address identified difficulties, allowing students to construct a more robust understanding (Shaffer & McDermott, 1992).

A key element of understanding electric circuits is the creation and interpretation of electric circuit diagrams. Johsua and Dupin (1985) argued that the 'privileged role played by the diagram' in electronics makes it critical to understand the relationship between students' cognitive representations of circuits and their encoding, reading, and use of circuit diagrams (p.129). These skills are prerequisite to solving many problems on standard assessments of circuit knowledge. To solve standard paper and pencil circuit problems, students must recognize the symbols used for electrical components, avoid attributing unintended meaning to conventions such as the use of straight, perpendicular lines, and extract information from the diagram about the completeness of the circuits, any elements bypassed by shorts, and series and parallel components. Although these perceptual skills might be considered primitive, successful interpretation/creation of circuit diagrams mirrors understanding of circuit behavior and is linked to developing a successful problem representation (Caillot, 1985).

In a European study at the secondary and university levels, students interpreted diagrams figuratively, focusing on surface perceptual features rather then the abstract indications of connectivity, and thus made incorrect predictions about the represented circuits (Johsua, 1984). In another European study, university students not currently enrolled in a circuits course used topological features of the circuit drawings (such as the fact that symbols representing resistors were parallel to each other or collinear with each other) to determine electrical features of the represented circuit, i.e., which resistors were electrically in series or parallel with each other (Caillot, 1985). Even after traditional instruction at the college level, students often have difficulty in interpreting standard circuit diagrams as abstract representations of the electrical connections between elements in a circuit as opposed to literal representations of the physical layout of an actual circuit (McDermott & Shaffer, 1992).

Still, most studies in the literature have primarily focused on students' ability to create and interpret standard circuit diagrams, without addressing what diSessa and colleagues have labeled 'metarepresentational competence,' that is, students' native capacities for representation and their responsiveness to instruction, in addition to the value of teaching about representation explicitly. This limited view 'overlooks not only a stunning pool of understudied native competence, but also a greatly undervalued target for instruction' (diSessa, 2004, p.294) Understanding how students might represent electric circuits in the absence of instruction, and the reasons for their choices, might not only enfranchise students whose views might have been excluded in the development of the sanctioned representations, but also provide clues about how best to develop students' abilities to evaluate standard diagrams in comparison to their own.

Thus, there is need for further investigation into the ways students, especially students who lack previous experience with electric circuits, would elect to represent circuits on paper, what these representations might indicate about student conceptualization of circuits, and how these native tendencies might influence students' interpretation of standard circuit diagrams. Such differences might ultimately help in explaining differences in success on assessments of circuit understanding (which often rely on successful interpretation of standard diagrams) and, by extension, in secondary and post-secondary coursework in this area. With this study, I sought to identify students' preferred ways of representing electric circuits prior to formal instruction in circuit diagram conventions, and the ways in which novice students interpreted conventional diagrams, both toward the ultimate end of designing curriculum that would address the needs of all students in understanding circuit diagrams more effectively. Specifically, the research questions for the study were:

(1) Are there differences in the way students represent electric circuits when not constrained by the conventions of standard circuit diagrams?
(2) Do students employ differing schema in interpreting standard circuit diagrams?
(3) Do these differences have implications for instruction?

## Methodology

*Setting*

The study took place in a physical science course designed for pre-service teachers and graduate students in science education, for which I was the instructor. The class met three hours per week and the unit on electric circuits comprised seven weeks of the course. Students worked in small groups to explore topics in physical science hands on using the *Physics by Inquiry* curriculum (McDermott, 1996). As part of the curriculum, students were asked to sketch representations of circuits they had created before being giving formal instructions about how such circuits are commonly represented in circuit diagrams. After formal circuit diagram conventions were introduced, students were asked to match non-standard diagrams of circuits to their standard counterparts.

*Sample*

The sample consisted of 15 students in the physical science course. Five of the participants were graduate students in physics or science and mathematics education (three with previous teaching experience in science and two seeking secondary science teaching certification), three were chemistry majors seeking certification as composite secondary science teachers, four were education majors and three were undergraduate students fulfilling a general science requirement.

One of the education majors had previous experience with circuit diagrams in a high school physics class, and all of the science majors and graduate students had exposure to formal circuit diagrams in at least one college course. In addition, one of the chemistry majors, John, had extensive experience with electric circuits prior to entering the teacher preparation program (six years as an electronics technician and six years as a field service engineer for two electronics companies), and one of the graduate students had taught high school level physics briefly. The remaining five students reported no previous experience with formal circuit diagrams. In this report, all students are identified by pseudonyms.

*Data Collection and Analysis*

One source of data comprised work samples collected from all 15 students; these included diagrams from lab notebooks, homework, and exams. All students in the course gave informed consent for the study, indicating willingness to submit their work for analysis, which occurred subsequent to the end of the course and did not influence grades in any way. To get at students’ native thinking, it was necessary to focus on representations created by students early in the curriculum, before formal circuit diagram conventions were introduced. In early tasks in the *Physics by Inquiry* curriculum, students are asked to sketch configurations of a battery, bulb and wire that cause the bulb to light (or not light) and to make representations illustrating arrangements of other simple circuit experiments. It was my expectation that these early tasks, calling as they did for illustrations of a physical set up rather than circuit diagrams specifically, might reveal how students, even those with previous experience with formal circuit diagrams, would naturally choose to illustrate the relationship between elements in a circuit. These representations, as well as those created later in the course, were examined and categorized according to their features following the typology of Karmiloff-Smith (1979).

I characterized as figural circuit diagrams in which students had made a clear effort to create an accurate, visual representation of the physical circuit, including details that were not necessary to convey the electrical characteristics or the topology of the circuit arrangement. Diagrams in which students had made some features abstract, but which still reflected the physical appearance or characteristics of the circuit in some way, I classified as abstract-analogic. I classified diagrams as abstract-nonanalogic when students used abstract symbols and indicated connectivity of the circuit in ways that were clearly not analogic to any aspect of the physical referent. These categories were not considered to be mutually exclusive; a single representation might have any combination of figural and abstract features.

Interviews comprised a second data source. The interview task was modeled after a typical *Physics by Inquiry* task (McDermott, 1996). After introducing standard circuit diagrams, and noting their conventions explicitly, this curriculum asks students to match a series of unusual diagrams to their conventional counterparts in order to challenge students’ recognition that the circuit diagram is an abstraction, representing electrical connections only and not physical configuration. Repeated practice in analyzing such diagrams helps students to develop metarepresentational competence and overcome their tendencies to assume a direct correspondence between the appearance of a diagram and the appearance of the circuit it represents (Shaffer & McDermott, 1992).

In the interviews, students were asked to match the non-standard diagram on the left in Figure 1 to its standard counterpart shown on the right, selecting from a set of four standard diagrams. The problem was part of the midterm examination and students had the option of working it on paper and providing a written explanation, or working it as part of a clinical interview. Nine of the 15 students volunteered for clinical interviews. They used a ‘talk aloud’ protocol while they worked the problem shown in Figure 1. I conducted the interviews and they were audio recorded and transcribed. Subsequent to the end of the course, I examined the transcripts and accompanying artifacts for evidence of the interviewees' approaches to decoding circuits and clues as to the features they found to encode meaning.

## Results

### *Representations of Circuits: Results from Student Work Samples*

In response to the task of sketching the arrangements of a single battery, single bulb, and single wire for which the bulb did and did not light, no student in this small sample used a formal circuit diagram to represent the physical situation, despite the fact that the majority of them had some previous exposure to the accepted conventions. On the other hand, only one student, Greg (again, a pseudonym), produced completely figural representations of the circuit configurations he was documenting. Greg was a history major with no previous experience with circuit diagrams. As shown in Figure 2, Greg's sketches were very realistic, including features of a strictly aesthetic nature, such as the name Energizer on the battery.

The majority of the students produced drawings that included figural characteristics, sometimes in combination with abstractions. For example, five students, in addition to Greg, represented the battery in the circuit as a three-dimensional object, even though this aspect was unnecessary to convey the topological configuration of the battery-bulb-wire arrangement. Likewise, some students depicted the light bulb filament in a realistic way, even though this was not necessary in illustrating how the components were arranged. The majority of the students included the protrusion on the positive terminal of the battery in their drawings.

The majority of the female students joined Greg in producing naturalistic depictions of wires that exhibited an organic, as opposed to geometric, character. Two of the female students, Shaniqua, who had studied circuit diagrams in high school, and Inas, who had recently completed a university physics course including instruction in circuits, portrayed wires in a less naturalistic manner; their wires were symmetric and exhibited smooth curvature. They did not, however, employ regular geometric figures to represent the wires.

In contrast, the male students other than Greg all depicted wires using regular geometrical shapes early in the course. Mark and Daniel, both of whom had taught physics at the secondary level, used the straight, perpendicular lines expected in standard circuit diagrams. John, who had used circuit diagrams in the course of work as a technician and engineer, eschewed the straight, perpendicular line convention in favor of a non-standard, but geometrical, representation of wires as circles (see Figure 3).

John's very first representations of circuits did include some abstract elements. For example, from the start he used the formal symbol for a battery, two unequal parallel lines with the longer line representing the positive terminal of the battery (see Figure 3). This symbol does have an analogic aspect in that it represents the parallel metal plates that were used in the first batteries constructed, but it corresponds in no way to the outward physical appearance of the D-cells that he was using at this point. The way John draws the filament in the bulb is also highly suggestive of the filament representation in the symbol generally used in circuit diagrams to represent light bulbs, but he augmented the standard symbol by showing the threaded base of the bulb.

The representations of one student, Jessica, with no previous circuit experience, were particularly interesting. Jessica’s earliest diagrams, illustrating configurations for which the bulb would light, are figural. They show wires naturalistically as simple curves. One of the goals of this first activity was to establish that in order for the bulb to light something must flow in a complete loop of conducting material that includes both terminals of the battery as well as both ends of the light bulb filament. The class established this idea by consensus in a group discussion reporting the results of the ‘light the bulb’ activity, and agreed to refer to this flow as ‘current’.

From then on, Jessica represented wires in her circuit drawings using a distinctive curvature, indicating a native capacity for inventing representations. Figure 4a shows an example from the activity immediately after lighting the bulb. Here the wire exhibits a distinctive curvature entering and leaving circuit elements. Note the seemingly gratuitous curvature as the wire enters the base of the light bulb. Figure 4b shows an example from the next activity in the sequence, in which a switch element was introduced. Note that in this case the curvature seems to indicate that the current departs from and returns to the switch. Finally, Figure 4c shows remnants of this trend from a diagram that Jessica produced after formal circuit diagram conventions had been introduced. The consistency in this pattern indicates that although Jessica’s wires appear to be strictly figural, they actually have a non-analogic character in that they encode information about the current flow. Her rule for representation is indeed systematic. One might have been tempted to dismiss the distinctive curvature in Jessica’s wires as gratuitous embellishment without having heard her describe the current coming out and going in to the specific circuit elements (i.e., the bulb, switch and battery in Figures 4a, 4b, and 4c, respectively). The curvature did not mirror the way the wires actually looked, but rather indicated the way she believed the current was flowing.

In summary, students created representations that varied from highly figural to abstract non-analogic. There were differences in the way students in this small sample represented circuits, but these could be due to differences in the experience these students had with formal circuit diagrams. The three most abstract diagrams (Mark and Daniel’s using straight, perpendicular lines and John’s using a standard battery symbol and a near-standard representation of a light bulb) parallel the symbolism of standard circuit diagrams, and all three of these students had experience with such diagrams. On the other hand, the encoding scheme used by Jessica to represent current flow abstractly in her diagrams, although more subtle, is original to her, rather than a reproduction of something she had been taught.

*Interpretation of Circuits: Results from Interviews*

The nine students who volunteered were recorded as they talked through their solution to the problem shown in Figure 1, which was part of the midterm exam. The exam came after students had considerable practice with such tasks, and only two students had any difficulty in matching the two circuits correctly. To equate the diagrams, students must recognize that the configuration of lines in the drawing does not represent the physical configuration of real wires; their length, and in fact their shape, is arbitrary (although convention dictates the use of straight, perpendicular lines). Students must also realize that lines that simply cross (as in the center of the diagram on the left) do not indicate an electrical connection unless they are marked with a small circle. Both these conventions had been introduced and discussed.

Coding of the transcribed interviews for indications of how students were interpreting the diagrams yielded two major themes: (1) tracing the circuit with respect to current flow and (2) orientation with respect to voltage.

All of the students used the process of tracing the current flow at some point in interpreting the circuit, most of them referring to current explicitly as they did so. Lauren described it in this way:

Lauren: Okay. Okay. Well, there are two ends to the battery. And the way I usually figure it out is by tracing where the current could go, like, where it has to go or it has an option to go.

Using this procedure, students had little trouble identifying the salient features of the circuit. Emily's thinking is typical in this regard.

Emily: So when you follow that wire, you have to come through what I've labeled as Bulb A. and so after I did that, I immediately got rid of choices 2 and 3, because anyway you go, it's multiple bulbs, instead of just one single bulb that all the current has to go through. Then from Bulb A, [I] just picked this wire. And when you follow… Actually, I'll do the other one first. Go from here to where I had B. It [the current] has to go through this one bulb. Then it has to go through what I have as Bulb C. So those two are in series. Come to this connection and eventually back to the negative terminal.

The issue of orientation with respect to voltage, by contrast, arose only for more experienced students, most noticeably for John, who had worked for many years as an electronics technician and engineer. Although he was able match the circuit correctly by tracing the current flow, John indicated that the task was extremely disconcerting to him, describing the circuit as 'the worst one I have ever seen.' When pressed, John had difficulty describing exactly what about the circuit was troubling, as shown in the following transcript.

JM: Worst in what regard?

John: Oh, just…it's…confusing in the way it's drawn. Just because the lines all cross each other so many times. Alright..[Pause] 2 and 3's to the negative side… Around this way this way.. you go through….one...that has its own path directly back. The other one has its own path directly back. So those two are gonna be in parallel with each other and in parallel with these two which are in series with each other. Which tells me it's going to be that one.

JM: OK. You said this was the worst you've ever seen just because lines cross each other?

John: Um… It's got a little more 'spaghetti' look to it than some of them do. I mean, I've seen some where it's drawn intentionally messed up but that one, that one is a little tougher than most, just because the lines curl and twist around. Have to keep track of where they all go so…

JM: In a normal circuit diagram, how do you keep track of how they all go?

John: (silence)

JM: Is it just that none of the lines cross and that's the only difference?

John: Um. Let me think. Well sometimes they cross. I mean that's entirely possible. On a complicated circuit diagram you run out of real estate and you have to cross things a lot. So… but normally the lines are straight and they, you know, they've tried to clear off a little space for… Usually, a discrete circuit group will kind of get its own little chunk of real estate on the paper so that's how I'm used to seeing them. But same basic idea, just following along from one side or the other.

John acknowledged after some thought that it was not the fact that the lines crossed each other so many times that bothered him. In fact, he was quite used to seeing lines cross each other on the complicated circuit diagrams he had encountered in the course of his work with electronic circuits. This is so common that the convention of using the dot to indicate where wires actually connect electrically, as opposed to just crossing on the diagram, was developed to address it. John does indicate that he is used to seeing straight lines, but his final statement gives an indication of what about this drawing actually disturbed him: He is used to diagrams that are organized based on voltage. He typically can 'follow along' from the positive (high voltage) side of the circuit to the ground (zero voltage difference with respect to the Earth, accepted as the standard voltage reference).

Although he does not state it (and probably does not think about it explicitly), the fact that this is easy to do in standard diagrams is the result of *unacknowledged* convention that circuit diagrams will be organized according to voltage in an analogical way, that is, moving down (or across) the diagram corresponds to moving down in voltage. Circuit boards are typically constructed with a high voltage rail (line of electrical connectivity) on one side and a ground rail (zero voltage) on the other. With the high voltage line oriented at the top of the diagram, moving down the page corresponds to moving down in voltage.

In the diagram on the left in Figure 1, the bulb that appears at the *top* of the diagram is actually electrically connected to the negative (*lower* voltage) side of the battery. This placement, above the rightmost bulb which is electrically connected to a higher voltage, violated John's tacit expectation that the diagram will display a figural organization with regard to voltage.

Liz, a graduate student in science education, also made references in her interview that might have been indicative of a vertical organization scheme. In independently creating a standard diagram to represent the convoluted one, she commented that she would draw lines representing connections to elements at the same voltage ‘down to the same level.’ Daniel, who had taught physical science, also referred to the higher voltage end of the battery as the ‘top.’

Inas, a chemistry major, also exhibited a clear preference for diagrams organized by voltage, but in her case the organization was horizontal rather than vertical. She deliberately redrew every circuit diagram placing the highest voltage connections immediately to the right of battery and progressed through lower and lower voltages moving further and further to the right before finally connecting back to the negative end of the battery, as with a typewriter return. Figure 5 shows one of her drawings. She did this even for standard circuit diagrams arranged vertically in order to make sense of them for herself. The textbook used in the second-semester physics course Inas had taken (Haliday, Resnick & Krane, 2001) follows a convention of organizing circuit diagrams by voltage throughout much of its presentation of simple circuits, most often using a horizontal scheme, so it is possible that she absorbed this convention from her previous coursework.

In summary, more novice students were generally able to treat the circuit diagram in this task as a completely abstract representation of electrical connectivity, bearing no figural relationship to the signified circuit. John, on the other, with the most formal experience with circuit diagrams, was disturbed by the lack of an analogic relationship to voltage.

## Discussion

With regard to the first research question, there are indeed differences in the way students represent electric circuits when not constrained by the conventions of standard diagrams. The fact that no student in this sample produced a standard diagram, despite the fact that most had experience with such diagrams, some extensive, may indicate that they interpreted the command to make a sketch as a call for a more pictographic representation, and felt free to use naturalistic representations. This parallels work indicating that even students who are competent with standard representations do not necessarily consider them to be the most appropriate way of ‘conveying story-like information [e.g., how they assembled the battery, wire, and bulb, and what happened] to others’ (diSessa, 2004, p.309).

Greg, the one student who produced a purely figural representation did so in a very realistic manner, but it should be noted that even he distorts perspective in order allow the viewer to see clearly how the connections were made to the battery, indicating that he does indeed recognize the critical features of the story he is telling with his picture (Fig.2). Figural elements employed by other students, such as the protrusion on the position end of the battery depicted by many students and John’s illustration of the threaded base of the light bulb, might also have been considered necessary to provide enough detail of the physical configuration of the bulb, battery and wire to show how the connections were actually being made. Indeed, a fundamental characteristic of circuit diagrams is that they show *that* electrical connections exist but not *how* they are made physically, so the standard symbol was not sufficient. The task at hand required the class to show different ways that connections could be made physically to achieve the same result; all of these could have been represented by one circuit diagram. As diSessa (2004) points out, it is critical that we recalibrate our judgment about representations that deviate from the abstract scientific norm in light of the likelihood that students will employ the norms of more familiar contexts, such as story-telling and realistic depiction, in generating them.

Another indication of metarepresentational competence can be found in the nonanalogic way of representing current flow that Jessica, with no previous circuit experience, quickly invented on her own. To the extent that her representation might indicate a conception that current originates from a particular circuit element, as opposed to traveling in a continuous loop, it may be problematic. Even so, such thinking would never have been revealed had she been required to produce only standard circuit diagrams. Jessica's diagrams add curvature to the extensive catalog of visual attributes used by students to represent intangible properties of systems, including length, width, color, and slant of line segments as documented by Sherin (2000). Jessica's representation is limited in that it seems to indicate only the direction, as opposed to the magnitude, of the current, but it could serve as a building block toward representations that might preserve metric relations with the magnitude of the current.

In regard to the second research question, all students in this small sample resorted to tracing the path of the current to interpret the circuits in the interview task, despite the fact that the voltage construct had been established prior to the time of the midterm and had been the subject of their most recent exercises and homework. John typically referred to electrical connections rather than current flow, but he did use the term path and earlier in the interview referred to 'start[ing] off from one side of the battery and just start moving along.' Once again, however, there appeared to be differences related to formal experience with circuits. Here, in contrast to the earlier task, more experienced students, particularly John, had difficulty treating circuits in a completely abstract manner. Although John expressed no expectation that circuit diagrams should correspond in appearance to physical circuits, he did appear to expect them to be analogic in the sense that elements at higher voltages should appear higher on the diagram. This expectation may have been the result of an unacknowledged convention for circuit diagrams that he had subconsciously subsumed into his decoding schema.

An analogic correspondence to voltage may be also at the heart of some of the difficulties experienced by European students in interpreting diagrams (Caillot, 1985). The diagrams that yielded the fewest correct answers were those in which elements violated the expectation of a relationship between voltage status and position on the diagram. In all but the simplest cases, the diagrams with the highest success rate maintained this convention. Students were confounded when components of circuits were drawn at the same level in diagrams, but were not at the same voltage. Dupin and Joshua (1987) also found that students had a higher success rate, particularly in lower grades, on a series of questions (their Table VI) that referred to a diagram in which the same vertical position corresponded to the same voltage in two circuits students were asked to compare, versus another one (their Table V) in which there was no analogous correspondence.

Cohen, Eylon and Ganiel (1983) come close to acknowledging the importance of an analogic correspondence to voltage in their study when they report the results of a question on their questionnaire that used a diagram with the elements again arranged analogically with respect to voltage, this time horizontally rather than vertically. Only a quarter of the students and 40% of the teachers responding to the questionnaire were able to answer the question correctly; 1/3 of the students did not respond at all. The authors argue that the problem 'could be solved almost *by inspection*, provided the concepts of pd [potential difference], emf [electromotive force], and current are correctly understood' (p.411, emphasis added). Solving this problem by simple inspection of the diagram without further analysis, however, requires that the diagram be organized according to voltage.

Finally, these differences in the way that students represented and interpreted diagrams could indeed have implications for instruction, assuming they are found to hold in larger populations.

First, insofar as they have demonstrated students' native competence at creating representations, these findings point toward the importance of providing students with opportunities to display this competence and to acknowledge its validity. Students who are able to employ representational skills developed in other areas may become more engaged in school science. DiSessa (2004) posits that differences between the standard school science practice of simply presenting a sanctioned representation and enforcing its use and allowing students to develop metarepresentational competence based on their native capacities may be 'particularly important in engaging students from segments of the population who have been systematically underrepresented in scientific careers' (p.300).

Next, the issue of organizing circuit diagrams analogically by voltage may mask difficulties in circuit understanding, to the extent that they allow some students a short-cut to analyzing circuits that does not require a complete understanding. If students have been *told* that the arrangement of lines in the circuit drawing is completely arbitrary, other than to show connections, but, in fact, the arrangement always conveys information about the voltage levels of circuit elements, they are likely to have trouble when this tacit convention is violated. Instructors might make the voltage convention explicit and provide students with opportunities to discuss whether it held true in certain diagrams, and whether diagrams that violated this convention were indeed more difficult for them. Scientists have an obligation to articulate the principles of representation they employ, as well as their interpretive strategies (diSessa, 2004). Perhaps more importantly, science educators also have an obligation to articulate these principles and strategies explicitly to students.

Use of the implicit voltage convention may also affect the outcome of assessments that invoke it. In addition to those described earlier, the assessments of circuit understanding used others in large-scale studies typically maintain the convention of an analogic correspondence with voltage (either vertically or horizontally) except on problems explicitly designed to test interpretation of the circuit diagrams themselves, such as problem 4 on the DIRECT (see, for example, Engelhardt & Beichner, 2004, p.108-114). One can only speculate about the effect on their results of including more items that violated the analogic expectation. The reported advantage for students with practical experience in circuits (see, for example, Sencar and Eryilmaz, 2004) might be diminished.

Further, some reported gender differences in circuit understanding may in fact be traceable to the diagrams used to represent the problem situations. In one study that investigated the issue of gender difference in understanding circuit diagrams, female students had slightly higher overall error rates than male students on a multiple choice quiz assessing understanding of electric circuits (Meltzer, 2005). Nonetheless, the only statistically significant gender difference, favoring males, was on a question that used a circuit diagram (as opposed to a verbal description) to convey information about the configuration of a circuit. (There were, however, also differences in the way that the responses to the questions on the quiz were represented, confounding the issue of the influence of the circuit diagram, as opposed to a strictly verbal description, in the question itself.)

Finally, alternative representations such as the one created by Jessica may comprise one of the missed opportunities for instruction described by diSessa (2004). Failing to critique the sanctioned representations, and to evaluate other possibilities, may limit some students' opportunities to make sense of circuits. Many authors have argued the priority of either current or voltage as the appropriate organizational construct for analyzing circuits (e.g., Cohen, Eylon &Ganiel, 1983), but ultimately students are better served by being able to address circuits in both ways, evaluating the affordances and limitations of each. Explicit comparison of circuits like Jessica's with those of other students, as well as standard circuit diagrams, might provide the first step in developing the metarepresentational competence that would scaffold this enhanced understanding. In additional to providing more equitable opportunities for learning, including representations from female students like Jessica, and other students from groups who were largely excluded from the original codification of the constructs governing electric circuits, could enrich the existing ways of representing and analyzing electric circuits as established in school science. This is not to imply that such students necessarily think about circuits in a different way from those who originally developed the established canon. Rather, representations such as those produced by Jessica, might constitute 'a larger canon, rather than a different one, a richer, perhaps even multifaceted representation of reality, but not a separate reality' (Keller, 1987, p.46).

## Conclusions, Limitations and Implications for Further Work

The ways that students in this study chose to represent electric circuits were varied, in some cases in alignment with standard conventions, likely based on previous experience with circuits, and in some cases completely original to the students. It is of interest that, in contrast to expectations, previous experience actually limited a student's ability to treat circuit diagrams as abstractions in one case reported here. This points to the fact that the ability to decode standard circuit diagrams may not reflect the ability to think abstractly about circuits so much as a familiarity with, or inclination toward, one particular way of organizing circuits.

On the other hand, there are indications here that some students may indeed treat circuit diagrams as abstract objects, but use non-standard rules for encoding/decoding information from them. As long as the 'accepted' conventions remain tacit, such students, in addition to others who have simply not absorbed the standard rules on their own, may be at a disadvantage. Further, the results offer the possibility that such alternative coding schemes might form the basis for representations that many students, particularly students who are less likely to have internalized the formalisms of standard circuit diagrams prior to instruction, might find useful. Such alternative representations might be profitably incorporated into the introductory instruction on electric circuits, if instructors were willing to deviate from circuit diagram conventions. Curriculum thus modified would have the potential to benefit all novice learners, but would be of particular benefit for future teachers who will be called upon to interpret the variety of representations that their own students will produce. At a minimum, instruction should make students explicitly aware of accepted but unstated conventions in formal circuit diagrams.

The results here are of limited generalizability due to the small sample size. A larger sample of students would permit a clearer test of how students are most likely to represent circuits given freedom to do it in any way they choose. A larger sample might also reveal additional students who, like Jessica, use curvature, or possibly other mechanisms not seen in this sample, to encode information in circuit drawings. These results are also limited by the descriptive methodology. Repeated tests with more students and a variety of coders would indicate whether the coding schema employed here is robust.

Although it did examine students' representations and interpretations of representations over a longer period (several weeks) than most described in the literature, this study also was not designed to investigate the trajectories of students as they developed metarepresentational competence with regard to electric circuits or the co-evolution of circuit concepts and circuit representations. A detailed study of changes in students' thinking over time will be required in order to maximize the potential of these initial findings to inform the curriculum. Finally, it remains to be seen whether the development of metarepresentational competence, in particular including the perspective of alternative representations, enhances students' understanding of circuits, as well as their ability to interpret the standard diagrams they are likely to encounter in further course work and in dealing with electric circuits outside of the classroom setting.

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## Figure Captions

*Figure 1.* Diagram matching task (after McDermott, 1995). Students were asked to match the unusual circuit drawing on the left with the standard drawing on the right.

*Figure 2.* Greg's representation of a circuit configuration for which the bulb did not light.

*Figure 3.* John's earliest circuit representations, including the conventional double parallel line symbol for the battery and a geometrical representation of the wire.

*Figure 4a.* Jessica's initial diagram encoding information about current flow.

*Figure 4b.* A second example of Jessica's diagrams.

*Figure 4c.* A representation that Jessica created after the introduction of formal circuit diagram conventions.

*Figure 5*. Inas' representation of a circuit using a horizontal voltage information encoding scheme.

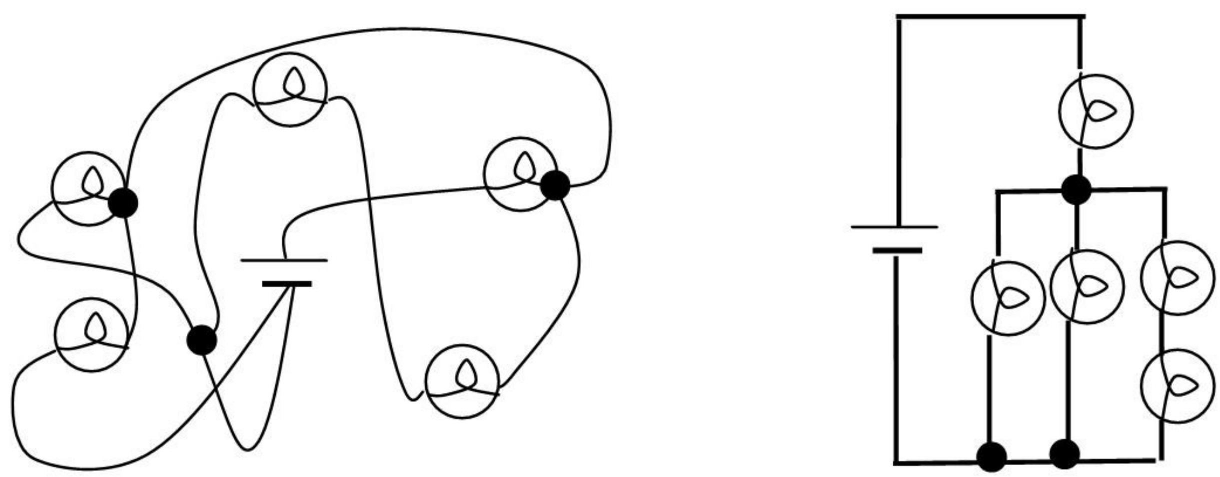

Figure 1

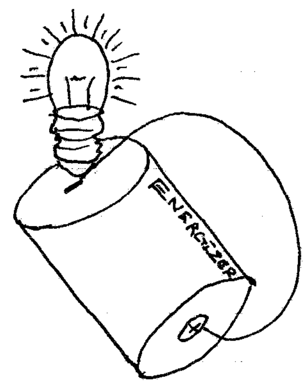

Figure 2

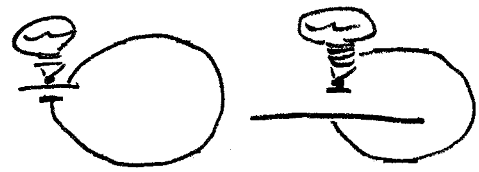

Figure 3


Figure 4a

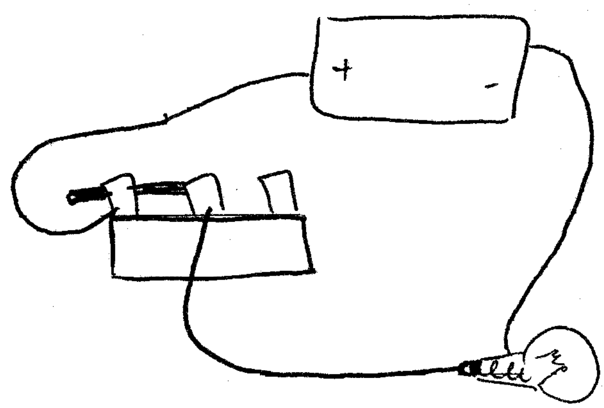

Figure 4b

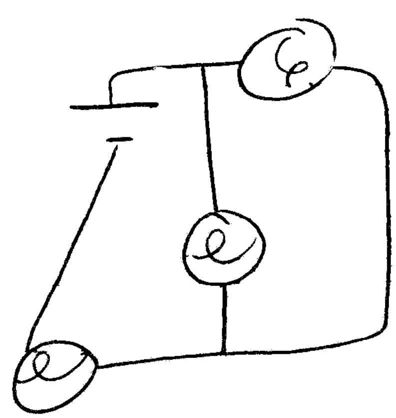

Figure 4c

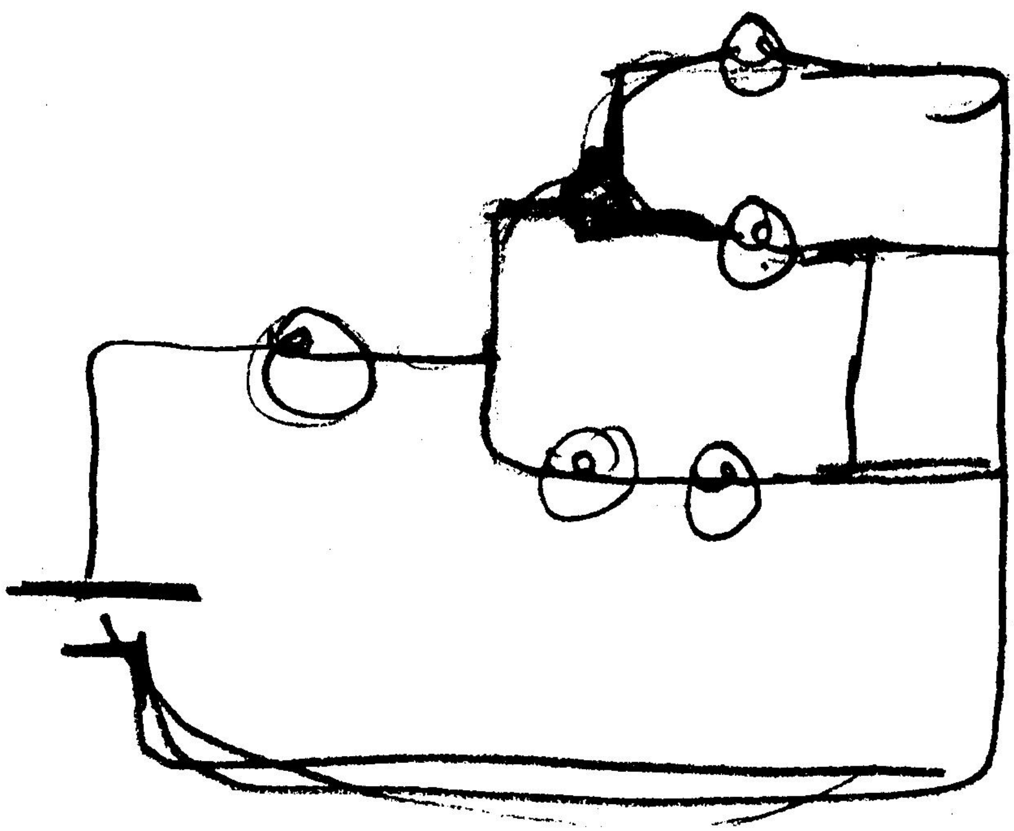

Figure 5

# Ascribing Legitimacy: Pre-service Teachers Construction of Science Teaching Expertise in Multiple Communities

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Abstract

This paper is a case study describing contextual influences on elementary pre-service science teachers' views of expertise and community membership as they came into the fold of public schools. It documents through the framework of Lave and Wenger's Situated Cognition Theory how the joint enterprises, shared repertoires, and mutual engagement in the learning of science and math teaching were affected by the novice teachers' views of expertise and mastery. Specifically it describes how efforts to promote inquiry-based practices through participation in a Community of Practice with expert elementary teachers were diminished by pre-service teachers' experiences in other classrooms where science instruction was not a focus. Implications are discussed for making changes in novice teachers' beliefs and practices through improved programs, mentoring, and collaborative partnerships.

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## Introduction

### *Scientific and Mathematical Literacy in Pre-service Teacher Preparation*

That providing students with opportunities to construct knowledge using explicit, tacit, cognitive, social and authentic evidence, especially in collaborative circumstances creates meaningful instruction is emphasized in reform documents (NRC, 1996). Such instruction immerses students in the learning process; allowing them to become active members in the scientific community. How students interpret and process knowledge construction is an integral part of the educational and psychological underpinnings of current reform-based recommendations. From these perspectives we aim to help pre-service elementary science teachers appreciate the tenets of inquiry learning (vonGlasersfeld, 1989; Driver, Asoko, Leach, Mortimer, & Scott, 1994) and the importance of collaborative contexts (Ball, 1988; Roth, 1995, 1996, & 1997; Richmond & Striley, 1995; Eichinger, Anderson, Palincsar, & David, 1991). Appreciation of inquiry based learning and its application in the classroom are essential for pre-service elementary science teachers. This case study explores tensions inherent in helping pre-service teachers develop an inquiry approach to science teaching. Tensions that came not only from their beliefs surrounding learning and teaching formulated prior to and during their enrollment in university teacher education courses (Brickhouse & Bodner, 1992; Duschl & Wright, 1989, Hodson 1993; Lantz & Kass, 1987; Lederman, 1992, 1999; Lortie, 1975) but also from their participation in several different communities of practice (Wenger, 1998).

Professors in science education with inquiry based philosophies and constructivist backgrounds use these premises when creating learning environments for pre-service elementary science teachers. Specifically these expert professors use three important components shared by the perspectives of the National Science Education Standards (NSES) 1) recognize norms of classroom discourse which run contrary to constructivist notions, 2) engage pre-service science teachers in authentic problem settings and engage them in reflecting upon their actions as teachers (Schon, 1983), and 3) interpret reform recommendations (AAAS, 1989; NRC, 1996) to guide future teacher learning, evaluation and research.

Few studies in science teacher education document how complex and arduous it is to create substantive change in pre-service elementary science teachers' beliefs and practices or to impart constructivist philosophies in less than congruent settings. While we are supportive of inquiry and believe that teachers should teach this way, we are skeptical of reports that large numbers of teachers are entering the workforce prepared to teach according to the NSES.

*Challenging Pre-service Teachers Beliefs and Experiences*

The approaches advocated in the NSES contrast with the landscape of observed practices pre-service teachers are exposed to during their preparation (Carlsen, 1991 & 1993; Cazden, 1988; McDiarmid & Kelly, 1997; Feinman-Nemser, McDiarmid, Melnick, & Parker, 1989). Pre-service science teachers perceive traditional approaches such as disseminating factual information, concentrating their teaching efforts on skill or algorithmic practice, and retrieval of information as "normal" for two reasons. First, these practices are commonplace in many public education field experiences. This fieldwork is often the first time pre-service teachers formally observe authentic classroom behavior. Secondly, and perhaps more importantly, these traditional experiences are aligned with their own prior science education (Florio-Ruane & Walsh, 1980; Borko, 1991; Rodriguez, 1998).

For many pre-service elementary science teacher candidates, engaging in inquiry lessons is foreign and uncomfortable. It not only requires understanding of the content in deep and complex ways but it also requires challenging their learners to think and act in new ways in the classroom (Gee & Gabel, 1996; Lampert, 1990). Gee (1989) argues that learning a new discourse of this kind is analogous to putting on an entirely new costume complete with instructions for how to respond differently in specific social settings. Because the creation of a new science discourse community implies the reconfiguring of participation, rewards, and authority; many accepted norms are no longer functional (e.g.

grades, correct answers). Consequently, novice teachers must not only learn to function within the expectations of a discourse community they must also "unlearn" much of what they have already come to expect as ordinary (Ball, 1988).

One of the first steps toward assisting pre-service elementary science teachers in teaching for reform standards is to challenge their' pre-existing beliefs about the adequacy of their knowledge base for teaching science; including both overconfidence and insecurity (Abell, Bryan, Anderson, 1998; Appleton, 1992; Ball, 1988; Jeans & Farnsworth, 1992; McDiarmid, 1990). Those who have been successful science learners often underestimate their preparedness to teach the subject, especially in a manner that contrasts with their traditional learning experiences. At the other end of the spectrum, many pre-service elementary teachers shy away from trying any new experiences because of their self-perceived weak science background. Their current scientific abilities are gauged upon past, failed, traditional experiences (Appleton, 1992, Jeans & Farnsworth, 1992).

Unfortunately, research has shown that simply challenging pre-service elementary science teachers' beliefs is insufficient for making dramatic change (Adams & Krockover, 1999; Cook-Freeman & Smith, 1997; Author, 1999). Not surprisingly, these findings echo prior psychological studies arguing that accommodation of contrasting beliefs requires the believer to develop dissatisfaction with previously held conceptions, understanding and appreciation of a contrasting conception, practice using the new conception, and application of the new concept in a future endeavor (Posner, Strike, Hewson, & Gerzog, 1986). In other words, pre-service elementary science teachers will need opportunities to test out new teaching practices in order to begin to have faith in them. We investigated the degree to which this was possible in a multi-faceted elementary teacher education program.

*Communities of Practice Impacting Teacher Education*

The inability for teacher education institutions to regularly produce excellent elementary science teachers can be explained in part by considering the multiple communities influencing teacher education programs. Beyond geographical and logistical differences, there is an implicit boundary that exists between university faculty and public school practitioners. University faculty are often the advisors for pre-service teachers and are largely dependent upon public schools to offer relevant teaching experience. University professors consistently strive to gain legitimacy and collaboration with public school practitioners to establish mutual goals for pre-service elementary science teachers. If university faculty are unsuccessful in real collaboration, there is little support for challenging overly simplistic or misdirected views of teaching science. Ad hoc solutions and teaching advice, overt directives, and pragmatic solutions offered by public school practitioners to complex educational issues will resonate with our novice teachers. As Lave and Wenger (1991) argue, "directive teaching in the form of prescriptions about proper practice generates one circumscribed form of participation [in school]…the goal of complying with the requirements specified by teaching engenders a practice different from that intended" (p. 96-97).

Pre-service teachers often operate amidst competing ideologies as teachers often suggest views about teaching that compete with those offered by university faculty. Whether on an individual basis or some collective socio-political agreement to oppose constructivist approaches, resistance has been shown to restrict the effectiveness of teacher education initiatives towards reform. This is partly why some argue (Ball, 1988; McDiarmid, 1990) teacher novices must also be able to observe experienced teachers modeling different strategies that map well onto constructivist notions of teaching. Granting pre-service teachers time and incentives to prepare lessons, receiving feedback from individuals they perceive as experts, and protecting them from the accountability pressures that potentially restrict their choices are all aspects of constructing a meaningful context geared toward changing teachers' practices.

Conflicting ideology arises in the form of well-organized resistance to reform recommendations from the school (Claus, 1999). It may also come in the form of pre-service teachers negotiating terms of engagement in their university experience (Adams & Krockover, 1999). University students themselves operate within an accepted set of beliefs and values harboring separate agendas. Some of these agendas are reminiscent of public school students (e.g., negotiation of minimum standards) which have been well documented (Jackson, 1986; Goodlad, 1984; Cusick, 1983; Lemke, 1990) but have not been well studied in university settings. This kind of resistance to constructivist teaching among pre-service teachers can be more tacit. For example pre-service teachers may profess student-centered beliefs but behave in teacher-centered ways. While pre-service teachers may think they have changed their beliefs, researchers argue that they can still operate in contrast to professed beliefs without deviating from the ways that they were socialized to perform in classroom contexts (Simmons, Emory, Carter, Coker, Finnegan, Crockett, et al., 1999).

Given the teacher education program's limitations, contact hours and the uncertain context in which they are placed, pre-service science teachers may also focus upon minimalist strategies of surviving the credential experience. Regardless of its origin or manifestation, resistance to inquiry teaching stemming from pre-existing negative student attitudes is larger than the literature on teaching reform initiatives indicates (Cook-Freeman & Smith, 1997). Teacher educators must routinely balance the interests of multiple communities while promoting new kinds of lenses to old school problems. Their arduous task is to offer pre-service teachers the opportunity to strengthen their learning and provide support for changing and expanding teachers' knowledge both in the content area as well as that of the pedagogical choices associated with inquiry teaching.

Framing our work within the context of communities of practice (Wenger, 1999) was central in the orchestration of our methods course as well as the analysis of teacher learning we examined. We assumed that pre-service teachers must themselves engage in scientific inquiry as learners before they could fully embrace reform recommendations. According to Lave and Wenger (1991) learning to teach (like other apprenticeship ventures) is influenced by factors other than the dissemination of expert knowledge or skills. Rather than defining it as the acquisition of propositional knowledge, Lave and Wenger (1991), situate learning

> "in certain forms of social co-participation. Rather than asking what kinds of cognitive processes and conceptual structures are involved…[they inquire] what kinds of social engagements provide the proper context for learning to take place" (Lave and Wenger, 1991, p. 14).

Situated learning draws attention to participants' engagement in and interpretation of social environments. Co-construction and co-participation in learning endeavors as members of a community transcends the considerations of individual shifts in knowledge. Learning to be an expert contributor in this community and how to speak about the relations between newcomers and old-timers is described by Lave and Wenger (1991) as the processes of legitimate peripheral participation (LPP). Learners enter the process of becoming a full participant in a social community by developing identities, engaging with artifacts and apprenticing with experts. *Identity*, in particular, is a central construct of LPP as Lave and Wenger (1991) argue that, "learning and a sense of identity are inseparable: they are aspects of the same phenomenon." (p. 115). Identities are carved out individually and collectively in relation to members' sense of shared repertoire and established means of mutual engagement (Wenger, 1999). Further, communities are productive to the degree that they operate toward an agreed joint enterprise which shapes the collective identity of the community. The Communities of Practice perspective offers a framework for considering the multidimensional social worlds which pre-service teachers negotiate. Each of these communities has a distinct form of engagement, joint enterprise and repertoire (Wenger, 1998). In teacher education endeavors, individuals can clearly develop idiosyncratic ways of managing in cohort situations in which a group of students progresses through a credential program together, the cohort can evolve its own community of practice where resources are distributed, knowledge is shared by the group rather than being the purview of individuals, and each member contributes expertise of some aspect of practice.

Each community has its own norms of behavior and ways of negotiating with the institutions in which they reside. These are not always aligned and pre-service teachers have to manage these various norms in personally meaningful ways. The more aligned the communities are, the less stressful the management effort will be. Situated learning perspectives highlight the importance of attending to communities of practice in order to understand issues of transfer. Cobb and Bowers (1999) noted that students need to view practices in different contexts as commensurable in order for the transfer of skills and ways of thinking to transfer from one context to the other to occur.

We used the framework of Communities of Practice to better understand why our efforts to cultivate inquiry orientations in our pre-service elementary science teachers often fail. We studied the effectiveness of our efforts as we examined our students' reflections and practices (Schon, 1983). To report on our progress in cultivating tenets of inquiry learning and teaching among our pre-service elementary science teachers, we address the following questions.

1. How do pre-service elementary science teachers interpret their immersion into a community of practice in which constructivist science pedagogies are promoted?
2. What factors of their pre-service experience affect their appropriation of new teaching approaches into their own repertoires?

## Method

### *Instructional Context*

The situated learning perspective shaped our work in two ways. First, it directed our attention to the various communities to which the pre-service elementary science teachers belonged, particularly the norms of behavior in those communities, the pre-service teachers' level of participation along the apprentice/expert continuum, and the goals and purposes of each community. Second, the situated learning perspective reminded us to attend to ourselves as members of various communities. In this case, we were both new faculty members at a large institution with ten different elementary certification programs. We acknowledged that each had a specific and unique community that we would have to negotiate.

The first author taught elementary science methods in two of the seven different field based cohorts in the College of Education. For one of those cohorts he identified a group of local elementary teachers from the community who taught elementary science classes using constructivist methods to collaborate with his elementary pre-service teachers. The pre-service teachers worked with these local teachers during specific assignments in the science methods course. He felt that engaging pre-service teachers in observing, planning, teaching, and reflecting with the collaborating teachers would promote selected values and practices and would provide the pre-service teachers with an apprenticeship experience. Consequently, our study became a case study defined by the experiences of a single cohort among several made available to pre-service teachers at our university. Lave and Wenger's model for interpreting the experiences of emerging knowledge and cognition is particularly apt for describing this context as,

> Apprentices gradually assembl[ing] a general idea of what constitutes the practice of the community. This uneven sketch of the enterprise (available if there is legitimate access) might include who is involved; what they do; what everyday life is like; how masters talk, walk and work, and generally conduct their lives; how people who are not part of the community of practice interact with it; what other learners are doing; and what learners need to learn to become full practitioners. (Lave and Wenger, 1991, p. 95)

We hoped that the learning done at the University would transfer to teaching in the public school through this apprenticeship experience. In this particular program the pre-service elementary science teachers also had a concurrent placement for other university course assignments at various schools in the same single district.

TRIBE School was the pseudonym for the chosen site for this experience because the teachers there had expressed interest in inquiry science and had established classroom communities where children were used to engaging in the open-ended activities associated with inquiry based science instruction. Much of the work of creating a community of practice had been done by the classroom teachers because they had developed a common view of science teaching supported by various activities with the first author. The first author assumed it would be easier for the pre-service teachers to complete inquiry science with children at TRIBE School because the children were used to engaging in inquiry. He assumed the pre-service teachers' concurrent placement would create obstacles because the existing communities of practice at the other schools in the district were typically oriented toward traditional instruction and not constructivist science teaching practices. 12 of the PSTs were located at TRIBE for their concurrent placement. The rest were at various other schools.

The content of the methods course included pre-service teachers' reflecting upon their own experience as learners as well as different notions of what it means to teach from vicarious engagement in detailed classroom cases (See Appendix). In several assignments students were asked to observe and interview children engaging in inquiry activities without direct teacher instruction. Pre-service teachers were asked to read from a variety of genres supporting reform positions in science education. Most importantly all pre-service teachers were required to teach three inquiry based lessons at TRIBE school and to write about these experiences. This multi-faceted approach to teaching methods was meant to reach students from a practical, experiential, and theoretical perspective—encouraging them to reflect upon what kind of beliefs they held, understanding what actions are key indicators of their beliefs, and reflecting upon the complexity of crafting teaching for oneself.

*Key Participants*

Not far into the data collection process we learned that we, as new faculty members in the College of Education, were newcomers in a context where the communities of academics, practitioners, and novices (university students) were already well defined. It wasn't necessarily the case that we were inexperienced since between us we had already more than 10 years' experience teaching elementary methods courses at other universities. Rather, the culture of our new university had developed its own unique culture esoteric to the outside observer. We did not have the luxury of limited peripheral participation as we entered these new communities. We were expected to take up full participation immediately. We felt that a focus on the similarities and differences between these contexts would allow us to participate more effectively. Next, we solicited the aid of an exemplary pre-service teacher in a role similar to that of Tobias' student researcher (Tobias, 1990). It was imperative that this student was revered by peers and could bridge the gap between us and the pre-service teacher community. Her role in the research team was as documenter, informer, and ethnographer after the conclusion of the methods course. Once the student was invited into the study we did not attempt to conceal her identity as a researcher. The results reported in this study were heavily influenced by a representative student "voice" as a result of her direct involvement in data collection and data analysis. Our study hence became an effort to better understand our students and the communities to which they belonged as well as an effort to situate ourselves to the new contexts in which we would be working.

The selection of this student researcher was influenced by her demonstrated knowledge and alignment with promoted teaching ideologies associated with current science reform. She was also a respected student leader and was nominated by her peers to an internal steering committee to assist the professor in interpreting student concerns.

*Data Collection and Analysis*

This section describes the sources and methods used for collection and analysis of data as well as provides a rationale for the kinds of questions which guided our investigation. Primary data sources included notes from class meetings, student journals, researcher journals, field notes, and follow-up interviews, and student focus groups. This rich variety of data sources was necessary because we sought to develop a defensible argument that described pre-service elementary science teachers' views of teaching "expertise" in this situated cognition context from artifacts of planning, teaching and reflecting (Baum-Brunner, 1993; Evertson & Green, 1986).

Focus groups were conducted on a biweekly basis to bridge the two communities. Not only did this focus group clearly identify leaders of the group right away, the group also recognized pre-service teachers who would struggle in the course and those who would likely succeed. Once chosen this panel met biweekly with the instructors to discuss the goals and assignments of the course.

A list of general, open-ended, explicit and implicit questions regarding students' participation in planning and teaching guided our initial inquiry. To develop a deeper understanding of students' professed beliefs, students were observed in their classroom setting and asked to explain the differences in their plans for using inquiry and their perceptions of success. In short, we were interested in understanding what sense the group members were making of the activities and what prior knowledge influenced their thinking. To encourage reflection on their experiences and to provide us with critical insight into how students were making sense of their learning, students were asked to maintain a weekly journal which served as a log and record of their learning. In summary, the research catalog consisted of the copies of student journal, field notes from the instructor entries, our own research notes and comments, transcripts from group and individual interviews, and references to the supporting materials artifacts (e.g. email communication).

Our data analysis methods were an amalgam of participant observation, ethnographic interpretations, and deconstructing teaching issues, because we did not trust the self-reported beliefs of interviews with pre-service teachers, nor our own emotionally laden observations driving our inquiry of the context (Cochran-Smith & Lytle, 1990; Clark & Peterson, 1986). These methods allowed us to triangulate and member check observations and artifacts. Data sources were gathered and organized into research catalogs. Student journals and field notes were chronologically correlated to each entry and event. These correlations served not only as sequential markers but as important sources for comparative analysis of field-based and university experiences. Events, transcriptions, and artifacts were coded with the input of the participant/researcher/student to guide the analysis and subsequent history written about these artifacts. Codes were subsequently re-examined for their verifiability and prioritized according to their ability to describe a wide array of events where conflicts or congruence were found.

## Results

### *Explicating the Community of Practice Shared by University Pre-Service Teachers*

> "My big problem is that I really don't know enough about the subject to create a decent lesson."
>
> (Tony's Journal September, 1999)

Pre-service elementary science teachers in this study maintained a tightly knit cohort group throughout the course of this study. The science methods course was offered in the second semester of an intense two-semester credential program. Strong relationships and roles were formed within the group which encouraged pre-service teachers to reinforce beliefs about learning and teaching, commiserate around perceived obstacles and negotiate the expectations of the program. This group constituted what might be best termed a "quasi-community". Following Lave and Wenger's (1991) model it could not be considered a community of practice due to a lack of intergenerational relationships. There were no experts handing down practices over time.

The pre-service elementary science teachers shared many conservative beliefs concerning expert teaching and, since they had only brief contact with public schools in their new roles as pre-service teachers, these beliefs were heavily influenced by their science experiences as learners. The pre-service teachers' community of practice represented their participation as members in public schools for most of their lives, understanding their membership through an apprenticeship of observation (Lortie, 1975) and socialization.

*Joint Enterprise.* The university pre-service elementary science teacher cohort group had three competing enterprises or goals, some of which were imposed by the university and others that were taken on as a matter of self-preservation. These included 1) completion of course assignments, 2) interpretation and application of theoretical constructs presented in the course, and 3) the maintenance of one's identity and experience as a teacher.

The first enterprise, completing the requirements of the course and program was the most pragmatic and potentially the most costly if it was not attended to. One of the most frequently mentioned concerns for students was their lack of time to complete required assignments. Students regularly and openly discussed strategies to reduce commuting time, complete assignments, and please their assigned master teachers. One precipitant of this enterprise was consistent complaints among many pre-service teachers as they recorded in journals feeling "overloaded" and wary of "long reading assignments" of more than 5 pages.

First day impressions - OVERLOAD! The course objectives and work-load look daunting. I hope the reading assignments are not too long or technical, it looks like a lot of reading…we have varying schedules, for work, teaching, and families.

The second enterprise of the community was imposed by the university course instructors--to engage with the ideas presented by the University faculty. Students were expected to read and think about inquiry science, consider the complexity and advantages of teaching in this way. The requirements of the class asked that inquiry based science methods be incorporated in journal entries, interviewing children, writing and revising lesson plans and teaching inquiry science lessons. It was explicitly stated in the syllabus that failure to at least address this enterprise would also risk failure in the course and subsequent delays in receiving accreditation.

The third enterprise of the community was to establish and maintain the members' identities as knowledgeable people who had already developed a solid understanding of teaching through their experiences as students in school. This enterprise involved boundary maintenance (Wenger, 1998); separating practical experience from the theoretical world of the university. It also represented one of the central tensions of the course—to honor students' beliefs about teaching while engaging in activities and discussions that attempted to change those beliefs that did not align with constructivist theory. This tension is described as a "conflict between continuity and displacement" (Lave and Wenger, 1991, p. 114) as newcomers were required to engage in practice and understand it though it was still foreign to their experience in other communities. Students' personal goals, ranging from egocentric quests to gathering knowledge, tools and practical resources showed how disjunctive and individualized the cohort was on this enterprise.

Matt: I feel I pretty much know what I need. I would like to learn practical things more than anything else. There is a difference between what should be taught and what, in most cases, is realistic in the modern classroom. …I am hoping we get some practical examples and advice. I will be going on the internet in hopes of finding a suitable lesson I can adapt.

*Shared Repertoire.* The repertoire of the group in relation to science methods grew out of their shared histories (primarily based on previous failures or fears) as science students. While none of the students went to elementary school together, their memories of science were very similar as were their feelings about these memories. This collective history is similar to that found in other studies (Bryan & Abell, 1999; Abell & Bryan, 1997). Students reported their discomfort with their own scientific knowledge and anxiety about teaching students in a content area they felt inadequately equipped to teach. Journal entries exposed this group's need for increased "content area knowledge" and their fears of "not knowing enough to create a decent lesson plan".

Erin: What I want from Science Methods class is to be comfortable [teaching science]. Science had always been a hard subject for me and I have difficulty in learning it. It is important for an instructor to provide lessons that are engaging, interesting, and challenging.

Janice: I have never been good at science. Science for me was always, "Open your book to this page, copy these definitions, and answer the questions at the end of the chapter.

Kent: I need this class to help me gain CONTENT AREA KNOWLEDGE. Science is one of my weaknesses primarily because I have never learned to enjoy science and therefore have retained very little information. [emphasis his]

Students would routinely describe histories of difficulty in science, referring mainly to negative experiences in science in high school. Only two students reported having a positive experience in science at any level, and most students were unable to recall even one positive science learning experience. It is important to note that part of this discomfort and perceived lack of preparedness may be attributed to the imbalance of attention to reading and literacy in their teacher education program. In part this had to do with major literacy movements happening locally in this urban setting and part by the accountability movement inspired by No Child Left Behind.

*Mutual Engagement.* Some university courses never evolve into a community of practice. Although class members may have the joint enterprises and shared history described above, members never engage mutually in their enterprise or recognize the similarities in their own learning experiences. Wenger (1998) includes community maintenance, relationships, and shared ways of doing things as aspects of mutual engagement.

Students' understanding of their mutual engagement in the community was evident early on and far exceeded the first author's understanding. Roles for students in the community appeared pre-determined and self-selected. When the instructor first announced there would be substantial collaboration and group work required for unit plan development, students unanimously rejected the possibility of the instructor selecting the groups. Within a matter of minutes all students had divided themselves into triads for unit planning and collaboration. Though the students were asked directly why they chose to work with one another, they were generally inarticulate and responded with "We've just always worked together in the program… We've got group projects going on in all our classes and we have to keep a lot straight."

Upon further analysis we found a striking pattern for the roles students reportedly took on within their groups while completing assignments. 4 of the 5 triads verified in debriefing that 3 roles were used that mimicked the joint enterprises model above. The focus of these 3 roles were: 1) the big ideas represented in the course (Joint enterprise #1), 2) the tasks and timelines for completing assignments (Joint enterprise #2), and 3) the obstacles to teaching for understanding (Joint enterprise #3) (See figure 1). Members described that there was a specific individual who would connect the group tasks with the larger set of ideas represented by the readings, feedback from instructor, and goals of the program. Similarly, there was an individual in each group who did the bulk of the complaining and raised issues and obstacles during group work. Finally, there was a third and separate individual identified in each group as the taskmaster who always found a way to move the group forward in the assignment.

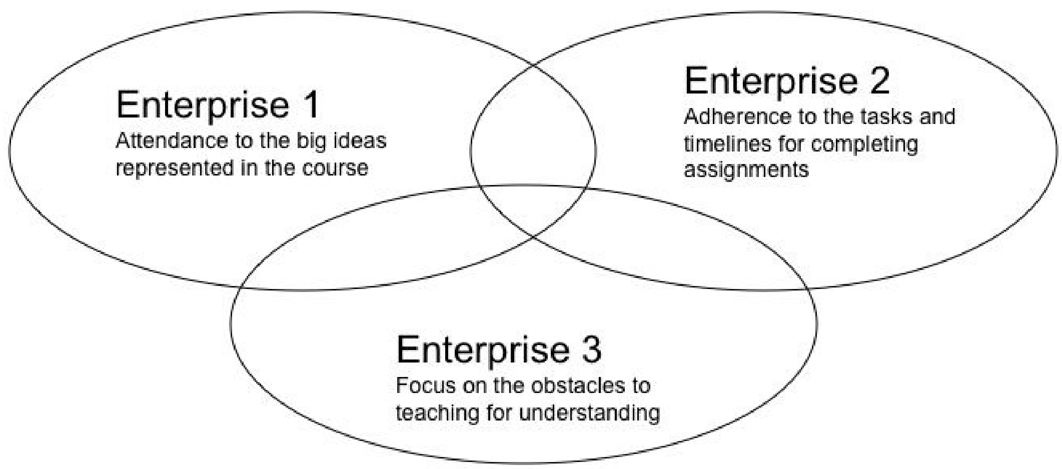


Figure 1: The emergent joint enterprises of small group work within the class

*Explicating the Intended Community of Practicing Science Teachers*

*Joint Enterprise.* The TRIBE Elementary teaching staff maintained at least three pertinent joint enterprises in their collaborations with the university, including: 1) attending to the learning of their students, 2) maintaining independence from district imposed literacy reform, and 3) socializing pre-service teachers into regular classroom practices which accentuated their pre-established learning contexts and routines. The first enterprise was one of the reasons the university worked so closely with TRIBE Elementary. Both faculty and administration had a shared vision and a good relationship that linked their joint commitments to student learning. It was a school that scored among the highest level of their district literacy measurements despite their independent strategies for SES grouping with other schools in their immediate vicinity. Other schools had succumbed to the pressures of the large urban district to operate a pull-out model that TRIBE faculty deemed inequitable. However, because of their high scores, teachers were allowed to teach in ways they believed were ethical amidst growing pressures to conform.

The university had a strong literacy and reading faculty and their relationship with TRIBE was symbiotic in that the university needed to place teachers and TRIBE continued to recruit pre-service teachers for their expertise. One teacher commented, "We love to have students [from this university]. We get approached all the time from [other] institutions. They just don't invest the time and contact with teachers to prepare them for REAL teaching." Clearly TRIBE teachers appreciated the institution's commitment to strong science teaching. Though pre-service elementary science teachers also saw these differences they were often interpreted differently as burdensome or onerous. However, to be a good teacher and part of the accepted staff at TRIBE, pre-service teachers needed to demonstrate a clear interest in children's learning and a willingness to go along with established routines. Like the pre-service teacher cohort, the joint enterprise involved boundary maintenance (Wenger, 1998) separating the insiders from others through shared or espoused beliefs about teaching while engaging in activities and discussions attempting to change them.

Shared Repertoire. The shared repertoire of the TRIBE teachers included both professional and personal commitments. Not only were teaching events and artifacts like morning announcements, class schedules for literacy development and science time practiced routinely, other more reflective professional teaching repertoires were also practiced and expected of one another. These included time after school to coordinate instruction and share resources, planned development time for extending instruction, reporting back on projects and committees, and also for formulating a literacy vision and plan of instruction to counter district decisions. As the principal described,"[to ignore the district pullout model] that they will leave us alone if our scores stay up, but I've been told that they will pull funding if we don't comply."

Teachers also maintained a shared repertoire of a more personal sort as well. There were baby showers, birthday lunches, and other social repertoires that distinguished them from the cohort of pre-service teachers. Even though some pre-service teachers were placed at TRIBE for up to a year, there was not a report of any pre-service teacher receiving recognition on a birthday lunch or other special event. There were even regular dinners on specific weekends at which wine and music were enjoyed but it was in the words of one teacher, "for the old seasoned ones" to get together. While this community had a shared repertoire, it was not inclusive of the pre-service teachers.

Mutual Engagement. While some faculty never evolve into a close community of practice, this could not be said of TRIBE. Teachers shared the joint enterprises, history, repertoires, vision, and the understanding of one another's classrooms to be mutually engaged in moving in the same direction as a faculty. Wenger (1998) specifies avenues of community maintenance, relationships, and shared ways of doing things as aspects of mutual engagement. The mutual engagement at TRIBE had only been strengthened by recent bouts with the district administration. With threats that funding would be pulled for non-compliance with a district mandate, teachers petitioned the principal who fully backed his teachers to have a parent night explaining the dilemma and the teachers' solution to the problem. Every teacher was in attendance that evening along with more than 200 parents in a filled multi-purpose room to hear how the teachers were meeting the needs of the children and ask the parents to begin fundraising in preparation for the nearly $40,000 that could be lost with a district power play. The first author attended the town hall meeting, observing the support from parents, commitment of teachers to one another and the course they were taking, and unanimity shared among community members, teachers and principal. As one teacher said,

> We're all in this together. We know we're doing a good job, the parents know, and the scores show it as well. Look at them. No one is complaining, they're all agreeing with us. They're asking what they can do to help. We have our ducks in a row and we're doing great…I don't know why the district would insist on something that doesn't make any sense to any of us.

While each teacher had a different kind of role in the parent night; some were speakers, some handed out fliers, some collected signatures on a petition; they were all mutually engaged in the joint enterprise involving a professional commitment to one another and the children they taught every day. It was within this community of practice that we sought to assist pre-service elementary science teachers in legitimate peripheral participation, aiming to model reflective practice and planning toward specific learning outcomes through collaboration. It was within this community that the first author taught example lessons in classrooms with children and assisted teachers in the development of their own lessons while the pre-service teachers observed, and as pre-service teachers observed, facilitated interviews between pre-service teachers and children, and supported pre-service teachers to plan lessons of their own for eventual use.

*Explicating the Successful Transfer into the New Community of Practice*

As discussed earlier, TRIBE Elementary School was an exceptional community of practice that contrasted with traditional descriptions of elementary science teaching. The school boasted exceptional leadership in the areas of teacher professional development, parental involvement, student equity issues, and a strong history of university collaboration. Several teachers had chosen to focus upon students' conceptual learning and the promotion of inquiry teaching strategies.

Some pre-service teachers in our study were able to transfer their knowledge and transform their practice in the methods course, describing their own experience as not only successful but transformative. These were students who internalized the premise of their methods course, excelled in all assignments, synthesized readings and applied theoretical frameworks to their own experience teaching. When we inquired about their growth as a teacher, pre-service elementary science teachers described attributes and insights they had acquired beyond simply learning techniques, skills or strategies to present science better to students.

Solumai, like several other pre-service teachers modeled a critical perspective regarding her experiences as a student and teacher. However, there was a limit to the number of pre-service teachers TRIBE Elementary could support. Of the more than two dozen pre-service teachers in the cohort, less than one fourth were placed for the year at TRIBE. Her immersion in this community of practice was more intense than pre-service teachers who spent their mornings at another school placement prior to the afternoon methods course at TRIBE. Solumai described the difference she observed between pre-service teachers early on in the methods course. "Most students wanted one question answered in this course, and one question only, "How do I teach science?"… I [quickly] realized that the course [dealt with]…a great deal of information and reflection beyond science methods instruction." Lave and Wenger (1991) argued that the perception of who holds "expertise" will shape an individual's participation and practice. It was clear from many of the pre-service teachers who experienced minimal transfer that they were placing their notion of expertise in mentors outside TRIBE, in more traditional and didactic settings.

The pre-service teachers who were successful in their transfer into this new community of practice recognized the complexity of teaching and the demands of teaching science for deeper understanding among children. Their journals reflected a strong commitment to examining children's thinking, not only after their assigned interviews and teaching but throughout the course. Moreover, successful pre-service science teachers were prone to recognize the limitations of their own attempts to address the pre-conceptions and problem solving strategies of children. Following their attempts to teach the units they developed, successful pre-service science teachers used course readings to reconstruct their struggles and reformulate their plans for teaching.

Solumai: I feel that I tried to be very open-minded about the course, and although I embraced the methodology, my implementation was poor. But of course, that's where the reflective teaching part comes in.

Despite such successes with some pre-service teachers, we endeavored to explore the kinds of interpretations our less successful students constructed of their methods course experience and the reasons for their minimal transfer. Our purpose was to explicate several aspects of the arduous task of making change, particularly in our formative years at a new university. In the remaining sections of our results we will use pre-service teachers' journals, teaching observations, completed assignments, and follow up interviews to outline the challenges we faced with pre-service elementary science teachers whose experience was less than transformative, regardless of the positive collaboration and constructivist approach to elementary science instruction advocated by both the University and TRIBE Elementary.

*Challenges of Transference for Newcomers*

*Challenge #1: Redefining expertise in science teaching requires shifts in pre-service teachers' identities.* The first challenge in methods course instructors was making closely held beliefs about science teaching and learning more explicit for our pre-service teachers (Ball, 1988, McDiarmid, 1990). Pre-service teachers' socialization as learners in a conservative public school community of practice significantly shaped their notions about what constituted "good teaching". The pre-service teachers' perceived joint enterprise contrasted with that of the TRIBE school/university methods course collaboration and were manifest in many ways including the pre-service teachers' self-assessment, critique of TRIBE teachers, and interpretations of the class readings.

Throughout the course the majority of students maintained a deficit model for learning science which carried over into their teaching.

Nancy: As a young girl I hated science and always had a deathly fear of snakes. I would dream of falling into a pit with snakes biting me and I couldn't escape. I never saw snakes as a girl… and it wasn't until I recently found my 2nd grade reading basal that I realized that my dreams were based upon a picture I had seen in my [2nd grade basal] book. If someone would have told me that the picture of the coral snake's nest in the book was not local to my area or at least said something besides, "Read this and answer the questions," maybe I wouldn't be so scared of snakes [or teaching science] today. (Nancy's Journal, October, 1999)

With the understanding that many pre-service teachers' experiences were void of any positive engagement in science, the first author routinely engaged students in science inquiry lessons. After each lesson, the pre-service teachers were asked to reflect upon their learning. Many recognized that the lessons were dramatically different from the science they had experienced as children and in their non-TRIBE placements. Pre-service teachers wrote journal entries describing the lessons and reflecting upon how they wanted and planned to teach science. In addition, the readings pre-service teachers were given also helped them to understand the new community of practice from a more theoretical perspective.

After observing teaching and reflecting upon articles and anecdotes of teachers trying to enact constructivist teaching methods, pre-service teachers were asked to discuss their interpretations of teachers' efforts. Several pre-service teachers appeared to make connections between what they were being asked to do in methods class with some of the teaching case evidence they were presented with. Both Sally and Tony expressed interest and excitement when they saw examples of the constructivist model they were reading about. Tony emphasized "Finally, we have a usable reading! A concrete way to apply the constructivist model of teaching…" Learning to participate as a member of a new community is seldom as straightforward as watching and then performing. While pre-service teachers noted differences in teachers' roles and depth of childrens understanding, many pre-service teachers did not abandon their views of teacher expertise. As Lave and Wenger (1991) argued, learning is never simply a matter of the 'transmission' of knowledge or the 'acquisition' of skill…knowers come in a range of types…[and are never unproblematic]" ( p. 116).

The majority of pre-service teachers were highly critical of teachers' efforts to let children discuss their own solutions to problems. In support of research conducted by Bryan and Abell (1999) pre-service teaches were unable to objectively observe teachers attempting to try inquiry teaching without offering many critical comments and suggestions. Despite their diverse readings, videos, example lessons, live observations, and even engagement in science lessons modeling the constructivist approach, pre-service teachers mutually engaged in the practice of criticizing teachers' efforts and explaining why the teaching they observed was inappropriate or misguided. The joint enterprise pre-service teachers were engaging in was the maintenance of their own identity as learners and perceptions of themselves as teachers. Because of their uncomfortable experiences in science and their frustration with not having sufficient guidance, students found fault with teachers letting students debate incorrect answers. As Erin surmised regarding an example of teaching children that sweaters do not produce heat (Watson & Konicek, 1990),

Erin: I think Deb O'Brien [In Watson & Konicek's article] waited entirely too long to give students the answer. Why didn't she just tell them? Doesn't she know that these kids were uncomfortable? I think a teacher ought to learn more about this kind of teaching before they set out to try it and fail. I mean, what about her students? I would be discouraged if I were in her class.

We labored as methods course instructors to confront pre-service teachers' insertion of quick fixes, over-simplistic assessments of teaching, and their pressures to make us tell them what to do in a prescriptive fashion. Despite our efforts to offer contrasting models for teaching and alternative interpretations for children's success and failure in science, pre-service teachers largely referred to the conservative interpretations of their public school experiences to guide their pedagogical choices.

Pre-service teachers who embraced conservative, traditional, and didactic approaches to teaching science were identified early by their cohort peers. Those pre-service teachers who seemed to authentically explore alternatives to teaching were empathetic yet critical of their peers describing them as "shallow" and "resistant." Solumai explained,

Solumai: I can understand clinging to a narrow focus. "Let me learn about teaching science, that's it. No more, no less." For example: Deb O'Brien. We hated that article because we did not want to admit that there were problems/tensions in the classroom that were beyond our control as teachers. As a class, we were hampered by a limited interpretation that we could not move past regardless of prompting by the instructor. Most of us already knew about how we wanted to teach science even though we said, "We don't know anything."

These pre-service teachers who demonstrated the predisposition to explore and be reflective had a difficult time engaging with the majority of pre-service teachers who were gauging effective teaching based upon their own k-12 experiences. Efforts to talk more broadly about children's thinking, lesson planning, and reform issues often degenerated into a negotiation of a shared repertoire embodied in course assignments and deadlines. For example, students with poorer science experiences openly challenged the course expectation to create a lesson to promote deeper content understanding. Pre-service teachers claimed they were unprepared to teach in these ways and unable to learn science because of their prior experiences. Many of these biases were rooted in the premise that "teaching is telling." Ironically, those pre-service teachers who professed the least amount of science teaching knowledge spoke the most authoritatively and critically regarding constructivist teaching methods.

In summary, most pre-service teachers had shared didactic and sterile learning experiences in science. Few had even described a single positive teaching role model that had helped them to understand science content in deeper ways. Most pre-service teachers with a concurrent placement outside of TRIBE described that science instruction was absent or over-simplistic. Despite their enjoyment of example lessons that the first author used to engage pre-service teachers as learners, they continued to offer pedagogical suggestions consistent with their traditional past experiences. Criticisms of videos and exemplary teacher case studies focused around providing children more “structure” and not letting children wander intellectually “too long without providing them with the correct answer.”

*Challenge #2: Competing notions of legitimate peripheral participation leave newcomers' identities intact.* The goal of the methods course was to introduce the pre-service teachers into a new community of teaching--complete with new kinds of participation which would contrast traditional teaching approaches with current reform visions Unfortunately, the majority of pre-service teachers focused their efforts on a “what works best for me” perspective. Pre-service teachers of this study were kept in a tight knit cohort group throughout. The science methods course was one of the last courses offered in the program and strong relationships and roles were formed within the group which encouraged pre-service teachers to negotiate the expectations of the program.

The first author was unaware of the strength of pre-service teachers' commitment to existing shared repertoires but he was keenly aware of his newness to the university faculty and desired to understand the learning context. From pre-service teacher focus groups and from notes of our pre-service teacher informant we found the pre-service teachers' joint enterprise #1 of completing course assignments involved negotiating with the professor (a perceived outsider to the community) to lessen the expectations on the group as a whole. The cohort nature of the teacher preparation block had allowed pre-service teachers to establish roles and strategies for influencing course expectations. They negotiated tasks in ways similar to that described by Doyle in pubic school settings (Doyle, 1988). Part of the negotiation that grew out of these roles was an agreed alliance among all students. Typically students who encountered difficulty completing one or more of the tasks would contact another group through email and an established web listserv to commiserate prior to the next class session. Groups agreed that together they could lobby for a change in the assignment, deadline, or expectation of completed assignments. Uniformity was a central tactic presented to new methods instructors. Kent’s reference to the way others in the class felt about course expectations was voiced in his journal.

Kent: I feel our frustration level with the class is increasing… Never in my educational career has one class required this much work in a one week period . . . I must be critical of the instructor, I feel it was extremely unfair to give us an assignment of this size and magnitude. Talking with others in our class, I believe, I am not the only one who feels this way.

The pre-service teachers also launched a well-articulated, timed, and coordinated effort lodging complaints. These complaints were not random or spontaneous by nature. Instead, groups of students met to formulate the best plan of attack. Email correspondence, formal letters, phone calls, and seminar discussions were coordinated by more than a third of the class so as to maximize the impact. The underlying message stated by one student was paraphrased as, "It was active lobbying for group effort. There was enormous social and peer pressure with underlying implication of, 'If you don't call or join in the resistance, you're not part of the group."

While the majority of pre-service teachers did present a seamless front, those who were disheartened with their peers remained silent. A small minority of the cohort's pre-service teachers did gather separately and discuss the depreciating expectations and concessions made in the course. These pre-service teachers also recognized patterns of behavior in their peers who, in their estimation, were less than serious about their professional preparation. Solumai expressed her frustration with her peers

Solumai: What frustrates me is the minimalist approach my classmates have toward science . . . I have felt that lately, they are less interested in acquiring methodology and more interested in skating by without having to try anything new or face challenges.

One older pre-service teacher of the course echoed Solumai's frustrations with peers asking "Haven't these people ever taken a real college course? You just don't try to avoid course work like that." Still, the pursuit of negotiations between the pre-service teachers and their methods instructor was led by socially influential pre-service teachers in the cohort. Other challenges to rigor was more subtle but consistent with this kind of resistance. For example negotiating with the professor to lessen the expectations on the group as a whole was promoted by one of the peer nominated panel members. Though the instructor had hoped to corrall support for high standards through a shared sense of community, students like Arnold who volunteered for the advisory panel lobbied for the position based upon certain savvy, persuasive, charismatic qualities not necessarily those representing the interests of teaching children successfully. When Arnold's was nominated for the advisory panel, we became concerned for his ability and knowledge of being able to execute expertly the cohort's joint, resulting in an agenda of enabling pre-service teachers to perform the least work for the most reward. As an example, when Arnold was aware that all members would receive equal grades for group work, Arnold conveniently allowed his group to complete his work without penalty, offering only excuses of weddings, trips out of town, and dates for comprehensive standard achievement tests common to all candidates.

Pre-service teachers' views of mastery in teaching were also influenced by the "expert" teachers they were viewing weekly in their concurrent school site where they would soon teach. While those pre-service teachers placed with TRIBE elementary mentors (like Solumai, Sam, and Madeline) expressed public gratitude and immediate application of new pedagogy and theory, negotiations with professors reached their peek just prior to the pre-service teachers' beginning to actively teach in the secondary school site (not TRIBE). A formal meeting was called by the University faculty member leading the block who had led the collaboration with TRIBE Elementary for years (but had not met with this cohort of pre-service teachers before due to sabbatical). Concessions in the methods course were encouraged, to squelch the discontent of the majority of pre-service teachers. Several, such as Kent, commented directly in their journal, explaining that the reduced workload "released tension" reinforcing the cohort's message 'less is more'.

Kent: I would like to praise the professor for realizing the anxiety of the class with regard to the work load. Today, he reduced what was due in the remainder of our classes. This definitely released tension and anxiety in our class.

Since the strategy complaining to the University cohort leader in a week long coordinated attack had apparently resulted in success, the pre-service elementary science teachers' public resistance became more emboldened.

Like findings of other studies (Adams & Krockover, 1999; Freeman & Smith, 1997), many of the pre-service teachers focused their efforts on practical and immediate agendas like completing assignments and constructing survival tactics for teaching rather than focus on more thoughtful intents of the readings, observations, and debriefing exercises that centered on constructivist strategies. Teachers' self-oriented focus during the course of their teacher preparation often took them on the path of greatest convenience for themselves rather than thinking deeply about course objectives. Though resistance to creative teaching and learning approaches is often attributed to external forces associated with public education (Clauss, 1999), this orchestrated negotiation was largely fueled internally. It confirmed Freeman & Smith's (1997) claim that pre-existing negative student attitudes are more resistant to change than the literature on teaching reform initiatives indicate.

Because of the competing communities of practice to which pre-service teachers belonged the first author was less successful in establishing new shared repertoires and sustained mutual engagement around joint enterprises. We perceived that the joint enterprise of the group of pre-service teachers was to negotiate with their instructors to lower the standards and means of meeting them. This kind of participation was illegitimate from our perspective. Conversely, the first author promoted a joint enterprise of questioning past educational experiences and notions of teaching that pre-service teachers perceived as illegitimate. Our findings give weight to Lave and Wenger's (1991) claim that conferring legitimacy in roles and mutual engagement is central to newcomers' indoctrination, It should be clear that, in shaping the relation of masters to apprentices, "the issue of conferring legitimacy is more important than the issue of providing teaching" ( p. 92). The pre-service teachers did not grant the first author legitimacy and instead interpreted his actions as out of touch with their reality.

In summary, as an experienced professor new to the setting, the first author set out to present an alternative representation of teaching science but the pre-service teacher cohort had pre-determined roles comprised of contrasting beliefs about teaching that were played out in a negotiation with the instructor to change the face of the methods course. Instead of focusing on ways to raise the bar, pre-service teachers used their knowledge of the political hierarchy and unified presence to pass blame on to the outsider to the community—namely the methods instructor demanding high standards. Pre-service teachers were unable to differentiate between what assignments were useful or which approaches were thoughtful ways to engage children in thinking about science.

*Challenge #3: Logistic constraints contributed to the resistance to changing beliefs about teaching.* Several teacher educators have argued that partnership relationships between schools and universities are a key factor in determining the kind of influence teacher preparation has on pre-service teachers (Cuban, 1993; Ball, 1988; Abell et al, 1998; Lieberman & Miller, 1999; Lortie, 1975). We were unable to place all of our students within the TRIBE school for their concurrent placement though we were able to engage all of our students 6 hours weekly in TRIBE classrooms, observing science lessons, planning and teaching their own inquiry lessons, and reflecting with TRIBE teachers, peers and methods instructor. Pre-service teachers who were not placed at TRIBE School for their concurrent placement (an additional 20 hours weekly) did not consider the practices of TRIBE teachers, methods instructors, and student teachers to be legitimate but rather turned to the conservative approaches of their Master Teachers in other school placements. In this way students attended to their joint enterprise #3 of maintaining their identities--embracing repertoires similar to their own public school experience to and citing factors in their school placement as the primary influences over their pedagogical choices.

It was clear from our conversations with teachers in non-TRIBE schools that science would not be incorporated into their curriculum or their expectations of pre-service teachers under their direction—at least during the time of their university placements.

Tony: I have never been asked to teach science and we never get to see science taught in the classroom we are assigned. We only rarely see mathematics taught and when we do it's just worksheets.

Kent: The fact [is that] none of us have taught science, or [have even] seen it being taught in a classroom. [This makes the unit planning] entirely difficult to implement.

The school context for most students was not conducive to reinforcing inquiry teaching for science. In fact, it was rare for students to be able to observe science taught at all in the schools. Once in a while students observed worksheets being completed by children but that was the extent of science instruction. A "literacy" policy was invoked requiring teachers in every school to teach decoding, guided reading, text interpretation, and other specific reading domain skills for the period of 8am-11am daily. Many students reported that their teachers were afraid to teach any other topic during this time as they had been threatened by their local administrator to stay within the guidelines. The symbiotic construct that students were ill-equipped to teach science (Challenge #1) and the implication that they were unable to influence the local curriculum and administration mandates, reinforced pre-service teachers identity of "I need to be told what to do" as a way of managing their joint enterprise #1. While some students pointed to their inexperience as the excuse for their lack of initiative in trying new ways of teaching, others were more explicit about their expectations from methods course instructors.

Despite the openness to other strategies for teaching science and opportunities to watch and participate in teaching inquiry lessons and receive support and feedback during their planning and teaching, pre-service teachers used the conservative and more deficit model of teaching to guide the interpretations of their experiences. Clearly, pre-service teachers immersion and partial practice in another community was not sufficient for shifting their identities. Lave and Wenger (1991) argued this is likely because, "activities, tasks, functions, and understandings do not exist in isolation; they are part of a broader systems of relations in which they have meaning…thus identity, knowing, and social membership entail one another… Legitimate peripheral participation refers both to the development of knowledgeable skilled identities in practice and to the reproduction and transformation of communities of practice. It concerns the latter insofar as communities of practice consist of and depend on a membership, including its characteristic biographies/trajectories, relationships, and practices. Continued practice in another more conservative community resulted was a rejection of the TRIBE context as inauthentic and illegitimate. Many pre-service teachers described the TRIBE school as unrealistic and an isolated case that would fail to function in other "more realistic" environments. Such pre-service teachers largely reverted back to the notion of teaching as carrying out instructions and following guidelines that are provided from above.

Perhaps the most positive aspect of the methods course for these pre-service teachers was the opportunity to try out their planned units and the related methods of teaching at their afternoon school site. Each pre-service teacher had the opportunity to teach six lessons after extensive planning to address students' alternative science conceptions. Though most pre-service teachers found this experience valuable, they interpreted their success from conservative and traditional perspectives. Most students focused on children's affect (e.g.: children smiling, raising hands, and offering correct answers) while paying little attention to the sense making and cognitive processes of the children. The goal of making science fun took precedence over children's' understanding of the concept.

Chris: …We took the students outside and launched a water rocket... This was a fun way to conclude our lessons…The strength of my lesson was that is was hands on for the students. The weakness of my lesson was that the students may not have understood the main idea of the lesson…Next time… I will give precise directions for what the students should be observing [before handing out parachutes].

Pre-service teachers largely began building a system for devaluing science inquiry in school. In their minds, if the district mandated their time in a way that excluded science from the curriculum, then there was no recourse. Most often, pre-service elementary science teachers would plead ignorance about how to revise their lesson plans in accordance to the syllabus expectations. Pre-service teachers would respond with "I don't know what I would do. Please tell me because I never was good at science. How am I supposed to do this?" However, if the advice of the professor was outside the domain of teaching as telling, students would offer a plethora of reasons why it could not be done. "My teacher doesn't teach science", "I hardly know these students." "It takes too long and we have to stay with the curriculum at our school". Arnold was confused about the accuracy in his preparation and implementation of his lessons. Arnold's insecurities branched from not having clear critiques of his use of newly learned reform theory.

Arnold: We don't understand if the corrections we made [on our lesson plans] are right or wrong. I don't know if the lessons we are teaching [in classes currently] are right or wrong…The problem is that there is such a focus on literacy that science teaching gets bumped.

Kent: The fact [is that] none of us have taught science, or [have even] seen it being taught in a classroom. [This makes the] project entirely difficult to implement.

In essence, pre-service teachers claimed they did not know how to teach science until confronted with their beliefs and then proposed a variety of "informed" reasons inquiry teaching was flawed or inappropriate for their concurrent placement.. Below, Janice explains what she perceives the role of a science methods instructor to be:

Janice: I think that's [good science teaching exposure] what the methods course teacher is supposed to tell me.. [how can I] teach well if I've never had any good models and no one is telling me what I need to do?"

Clearly this response lies outside of the realm of total ignorance or lack of opinion towards good teaching. This student represented the strong opinions of many classmates who saw the role of the methods instructor as one of prescribing straightforward advice and small adjustments to their preconceived notions of science teaching. Many pre-service teachers used language of received knowing (Hogan & Clandinin, 1993) and forfeited the responsibility of learning to teach in other ways. Despite the lessons demonstrated in methods class geared specifically to their topic, support in exploring their students' alternative conceptions of the scientific topic, feedback on their planning and student interviews, pre-service teachers continued to demand to be told specifically what to do during their teaching at their concurrent school site.

Despite having been taught to promote student-centered instruction, only a few students left the course professing to value teaching for deeper conceptual understanding. The science instruction pre-service teachers had received and enjoyed during the methods course, did not necessarily apply to their experiences teaching children. Naturally, this dichotomy between philosophy and practice eventually surfaced as a tension that pre-service teachers struggled with, though they did not necessarily recognize what they struggled against. Some pre-service teachers, however, did take on some of the shared repertoires of science inquiry teaching and engaged mutually in reflecting upon the difficulty of unlearning old repertoires and enterprises. As Tony described, "it wasn't until I experienced [through observation and application] it [inquiry based instruction] that it became concrete and vital to my teaching style."

Solumai accepted a position teaching science, just weeks after her completion of the methods course. We were able to keep in contact with her and many of her peers who were successful in science methods at TRIBE. In her reflection on her changed philosophy statement Solumai continued to journal, internalizing the readings and class discussions from her methods course.

Solumai: …I feel that I achieved a measure of success in the course mainly because I am still in the process of taking the course in some way. As I continue working on

> the implementation and the refining of my ideas about teaching philosophy, I realize that there are many ideas from the course that I have not yet tapped into. In fact, I occasionally think about articles we read as I reflect on the issues I face in my classroom and my sense-making …I think about the articles…[In my] reflect[tions] of how I teach and what the students understand.

In the end, pre-service teachers who were successful in their instruction and synthesis were noticeably bothered with their peers' choices to avoid making principled, thoughtful decisions about curricular and pedagogical choices. Madeline blamed choices made by her peers on the difficulty of authentic conceptual change. Solumai cited that collaborating teachers and minimalistic mentality are reasons for a lack of conceptual change in her peers.

Solumai: Madeline and I struggled with the rest of the class as a whole; we felt that their resistance was the product of the minimalist mentality rather than resistance based on any foundation, whether theoretical or practical. [My peers] found Kohl to be highly motivating, yet turned around and said, 'But I can't teach science that way, that's not how it's done in city schools right now. I have no say whatsoever.' I understood the sense that [my peers] were under the pressure of their collaborating teachers, and maybe teaching at [the second school] did not change that context for them.

Madeline: Conceptual change is as difficult a process for adults as it is for young science students. I see our own class as evidence to support this both in their scientific thinking and their beliefs about teaching in general.

## Discussion

While we as teacher researchers do not ascribe to the artificially imposed dichotomies of practice and theory, we must recognize that our attempts to change the practices of pre-service teachers who spent only part of days in a rich collaborative context were heavily influenced by the advice of traditional teacher/mentors and socialization forces of classrooms where they spent the rest of their days. We designed the methods course so pre-service elementary science teachers could engage in Legitimate Peripheral Participation in a Community of Practice where master teachers exhibited inquiry-based practices and reflected with pre-service teachers about what they were doing. However, limits in the ability to place all pre-service teachers in concurrent teaching positions within TRIBE school where methods, observations, and other coursework were facilitated impacted the uptake of inquiry science teaching repertoires and their views of who held "teaching expertise". The majority of the pre-service teachers maintained their original interpretations of successful teaching even after practicing reform methods in a supportive environment. As a result, the LPP that was intended to foster a constructivist learning orientation in the cohort created a wide variety of interpretations and applications of reform teaching with diverse outcomes.

Moreover, the inability to place all students at TRIBE Elementary to work full-time with inquiry-oriented mentor teachers impacted the process of facilitating changes in beliefs and practices. Instead of contrasting pedagogies being embraced and practiced by pre-service teachers, only those who were placed with mentor teachers who took time to teach science in the elementary school in spite of the major push for literacy were able to put into practice constructivist methods with children. Ideally, in identifying mentor teachers for the concurrent placement, care would be taken to insure that they were modeling the practices being taught in the methods courses. Logistically this could not be accomplished during the study given the number and availability of schools and teachers willing to support our pre-service teacher's in field-based settings. When pre-service teachers perceive traditional teachers as "masters" because of predispositions from conservative, didactic learning experiences, in-roads into changing teachers' beliefs and practices are difficult at best.

What was clearly evident and troubling to us was the freedom some pre-service teachers felt to limit and influence their apprenticeship which affected the entire cohort. Lortie (1975) described such socialization forces which shape accepted beliefs and practices and warns of the resulting effects on the quality of teaching. Rodriguez (1998) argued that necessarily these need to be addressed directly and explicitly if inroads are to be made in science classrooms. Otherwise not only do pre-service teachers choose not to adopt or even consider seriously alternative strategies presented in methods course, such pre-dispositions heavily influenced the kind of legitimate peripheral participation experienced by their colleagues at schools like TRIBE.

## Implications

Few would deny that current reform calls for teachers to rethink and fundamentally change some of their approaches to teaching science. A potential problem can develop however, when teachers themselves have not had learning experiences upon which to model new instructional strategies. From our participation in field-based methods courses we perceived the need to engage novice science teachers in a variety of supportive learning situations that challenge traditional conceptions of what it means to teach and learn science.

This says much about the abilities for new teachers to be change agents in schools. The role of socialization and context is powerful. This is of great concern because we largely believe that schools need to change, in the words of the Glenn Report "Before it's too late" (US Dept. of Education, 2000), but preparing large numbers of elementary teachers with example practices separate from authentic contexts will not result in large scale change. Though we have come a long way in recent decades to recognize the complexity of knowledge required by expert teachers and we are carving out ways in which to impart that knowledge to future teachers, we must acknowledge that this takes more resources, time, and expertise than literature suggests is currently available in schools. As Ball, Lampert, and Rosenberg (1991) have argued, "learning to teach entails developing ways of looking and listening, ways of interpreting and reasoning, as well as ways of being and doing (p. 269)." If we want to cultivate reform, we need to develop contexts where pre-service teachers are immersed in inquiry-based environments rather than depending on the piecemeal approach experienced by the pre-service teachers described in this study.

Alongside these revelations, we must recognize the strong socialization processes that attract the membership of future teachers as well as guide them in the field as our surrogates. Novice science teachers have arguably limited ways of viewing teaching from the perspectives of pedagogical choices, student knowledge, or the nature of science. In order to understand and appreciate the complexity and difficulty of teaching for understanding, novice teachers need to experience teaching in authentic contexts. In addition, novice teachers need to be supported to recognize how their own experience in education can be reframed and transformed through critical reflection. University teacher educators cannot function alone in their preparation of future science teachers.

For this vision to come to pass, coordination must occur amongst teacher preparation institutions and public schools. A more systemic approach for the continuous and significant improvement is needed for the preparation, induction, and professional development of teachers. This process needs to empower all members and foster the development of exceptional schools. The reality that teacher educators work within often contrasts with these visions. We must operate in contexts we do not understand or know how to support. We must work with a limited number of teachers we truly trust as expert--fostering communities of practice in which new-comers can observe and partake in common ways of thinking, speaking, acting, and reflecting. We need to create a "culture of practice" that embraces observation, participation and ways of engaging with reform teaching and learning. New comers' legitimate peripheraility provides them with more than an "observational" lookout post: It crucially involves participation as a way of learning--of both absorbing and being absorbed in --the 'culture of practice.' Lave and Wenger, 1991 p. 95).

These and other special considerations of preparing future teachers should be the subject of future studies. Smith (1999) and others (Simmons, et al., 1999) have warned us about the need to carefully consider the kinds of experiences our pre-service teachers bring to the profession. Not only do they bring inadequate scientific knowledge to teach children, but they also bring a variety of beliefs which drive the profession toward conservative models of instruction. Likewise, we cannot assume that because pre-service teachers are learning science in our classrooms that placing them in public school classrooms will result in successful implementation of our methods.

This study expresses the need for extensive dialogue among teacher educators regarding the context into which we insert new science teaching professionals. When professors bring with them to teacher education programs a rich environment for meaningful discourse, it creates a design of quality university programming. Beyond these programs, support needs to follow in the form of available expert teachers in the field. Regular discussions and re-evaluation of the university experiences and partnerships with expert teachers are crucial to linking theory and practice. If faculty are unable to work together within colleges of education and maintain similar roles and relationships with the community public schools, the integrity and effectiveness of the teacher education program weakens.

Collaboration, however, does not simply mean providing a classroom venue and a warm body as a Master Teacher. Collaboration within universities and schools translates into actual practices and sustained support for intended change. Collaboration of professors better supports a symmetrical experience for all candidates while different professors are required to teach similar courses. We believe that improvement within the ranks of teachers begins with their pre-service experience and we feel it is essential to limit the number of “escape routes” for minimalist students. Further, one of the purposes of a teacher education institution should be to shape teachers’ beliefs about teaching and learning and mold their interpretations about their role in their own professional development.

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Appendix

Brief Description of Elementary Science Methods Readings and Activities

**Tentative Course Schedule**

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**Week #1** **(January 24th)**

**What is our experience as learners?**

**Readings Due:**

- Syllabus
- Watson, B. & Konicek, R. (1990). Teaching for conceptual change: Confronting children's experience. **(In class)**

**Assignments Due:**

- Quickwrite #1 "What is Deb's problem?" **(In class)**
- Outline of pedagogical autobiography **(In class)**
- Selection of topic for clinical interview and lesson **(In class)**

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**Week #2** **(January 31st)**

**What does it mean to *know* a scientific concept?**

**Readings Due:**

- Roth, K. (1987). Learning to be comfortable in the neighborhood of science.
- Howe, A. (2001). *Engaging Children in Science, Chapter 1 & 2* Science as a Human Activity, and Children's Thinking and Learning.

**Assignments Due:**

- Quickwrite #2 **(In class)**
- Five Questions to ask children in your clinical interview **(Homework)**
- Draft pedagogical autobiography **(Homework)**
- Student interview protocol and engaging event **(In class)**
- Service Topic **(In class)**

**To assist your pedagogical autobiography**

Related questions:

How comfortable are you in the neighborhood of science? What neighborhood are you comfortable in? Do you dance, write, cook, compete athletically, paint, or something else which requires a wealth of other kinds of knowledge? Once you have considered how well you do or don't know science, explain how knowing something deeply differs from your knowledge of science learned in school or your past science experiences.

What kinds of teacher preparation and teacher growth issues are related to knowing in this kind of way? How do you go about learning science in the same way you know something deeply? Is it important to know science deeply in order to teach it to children?

Where do teachers acquire this kind of knowledge?

(Unacceptable answers include: "I just need teaching experience. I'll learn it from my mentor teacher. It just comes from working in the classroom.") What is it that you need to do to improve you knowledge? What specific items might be included on a plan for your long-term professional development?

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**Week #3** **(February 7th)**

**What do children know?**

**Readings Due:**

- Anderson & Smith (1987) *Teaching Science*.
- Howe, A. (2001). *Engaging Children in Science, Chapter 3.* Integrating Science Content and Process.

**Assignments Due:**

- Final pedagogical autobiography **(Homework)**
- Three example activities on teaching topic **(Homework)**
- Activity critiques (3) **(Homework)**
- Practice interview with peers or children **(Homework)**
- Final interview protocol and engaging event **(In class)**
- Practice student interview report **(In class)**
- Quickwrite #3 **(In class)**
- Draft concept map of science topic **(In class)**

- Topic and venue for interviewing complete **(Homework)**

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**Week #4** **(February 14th)**

**What to teach?**

**What's available?**

**What's appropriate?**

**Readings Due:**

Howe, A. (2001). *Engaging Children in Science, Chapter 4 & 5* Teaching Basic Science Skills.

and Teaching Science as Inquiry.

**Assignments Due:**

- Revised lesson on topic **(Homework)**
- Permission letter **(Homework)**
- Revised concept map of science topic **(Homework)**
- We b resources 5 on and 5 off topic with brief explanations **(Homework)**
- Quickwrite #4 **(In class)**
- Revision #1 of coordinated lessons **(In class)**
- Interview 3 or more college students **(In class)**
- Practice interview results **(In class)**

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**Week #5** **(February 21st)**

**How do I know students understand?: Objectives and student task engagement**

**Readings Due:**

- Howe, A. (2001). *Engaging Children in Science, Chapter* 6 . Teaching Science to Promote Independent Learning.

**Assignments Due:**

- Interview 3 or more children **(Homework)**

- Interview analysis writeup first draft **(Homework)**
- Final concept map **(Homework)**
- Quickwrite #5 **(In class)**
- Second revision of lessons **(In class)**

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**Week #6** **(February 28th)**

**What do I need to know?**

**Readings Due:**

- Kohl, H (1984). *On Growing Minds* Chapters 1-5
- Howe, A. (2001). *Engaging Children in Science, Chapter 7 & 8* Enhancing Instruction through Assessment and Planning for Achieving Goals.

**Assignments Due:**

- Final interview analysis writeup **(Homework)**
- Concept for Learning Center **(Homework)**)
- Presentation of Interview Results (In class)
- Quickwrite #6 **(In class)**

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**Week #7** **(March 7th)**

**My preparation: How prepared am I and where am I going to learn the rest?**

**Readings Due:**

- Howe, A. (2001). *Engaging Children in Science, Chapter 9 & 10* Shaping the Classroom Learning Environment and Including All Children in Science.
- Kohl, H (1984). *On Growing Minds* Chapters 6-10

**Assignments Due:**

- Articles Found (2) **(Homework)**
- Article discussion **(In class)**
- Learning Center Materials **(Homework)**)
- Draft Learning Center **(In class)**
- Midterm Exam **(In class)**
- Quickwrite #7 **(In class)**

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**Week #8** **(March 14th)**

**How do I gauge my performance?**
**Readings Due:**

- Howe, A. (2001). *Engaging Children in Science, Chapter 11 & 12* Integrating Science with Other Subjects. and Taking Science beyond the Classroom.
- Kohl, H (1984). *On Growing Minds* Chapters 11-16

**Assignments Due:**

- Quick write #8 **(In class)**
- Article critiques (2) **(Homework)**
- Social, cultural, historical background of your topic **(Homework)**
- Second revision of lessons **(In class)**

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**Week #9** **(March 21st)**

**What is important to reflect upon?**

**Readings Due:**

- Howe, A. (2001). *Engaging Children in Science, Chapter 13* . Learning Science with Computers.
- Kohl, H (1984). *On Growing Minds* Chapters 17-22

**Assignments Due:**

- Quick write #9 **(In class)**
- Diversity component draft in lessons **(In class)**
- Final revisions of lessons including diversity component **(Homework)**
- Practice peer critique of lesson **(In class)**

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**Week #10** **(March 28th)**

**What are my values teaching science?**

**How does my cultural knowledge and experience affect my teaching?**

**Readings Due:**

- Kohl, H (1984). *On Growing Minds* Finished
- Ball, D. & McDiarmid, G. W. (1991). Why staying one chapter ahead doesn't work.

**Assignments Due:**

- Teach science lessons 1 and 2 in classrooms (**Homework**)
- Videotape and watch science lessons 1 and 2 in classrooms (**Homework**)
- **Journal Entry "How did you do?" "How do you know?"**
  - *Quick write #10* ***(In class)***

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**Week #11** **(April 4th)**

**How are my efforts to manage classrooms sensitive to all students?**

**Factors mitigating success for all**

**Readings Due:**

- Jackson, P. (1992). The practice of teaching.
- Ayers, W. (1993). *To Teach* Chapters 1-3

**Assignments Due:**

- Teach science lessons 3 and 4 in classrooms (**Homework**)
- Videotape and watch science lessons 3 and 4 in classrooms (**Homework**)
  - *Quick write #11* ***(In class)***
  - *Peer feedback for lessons 1 - 4* ***(In class)***

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**Week #12** **(April 11th)**

**Competing agendas in school: Where do I turn my attention?**

**Readings Due:**

– Michaels, S. & O'Connor, M.C. (1989). Literacy as multiple discourse.
– Ayers, W. (1993). *To Teach* Chapters 4, 5

**Assignments Due:**

- *Quick write #12* ***(In class)***
- Teach science lessons 5 and 6 in classrooms (**Homework)**
- Videotape and watch science lessons 5 and 6 in classrooms (**Homework)**
- Peer critique for each member **(In class)**

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**Week #13** **(April 18th)**

**The role of the university in learning to teach.**

**Readings Due:**

- Lampert, M. (1985). How teachers manage to teach.
- Driver, R. et al (1994). Constructing scientific knowledge in classrooms.

**Assignments Due:**

- *Quick write #13* ***(In class)***
- *Revised lesson plans*
- *Self assessment/Response to peer feedback (Homework)*

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**Week #14** **(April 25th)**

**Looking Beyond: What's next?**

**Readings Due:**

- Aikenhead, G. (1996). Border crossing into the culture of science. *Journal of Research in Science Teaching*
- Ballenger, C. (1995). Because you like us: the language of control. *Harvard Educational Review, 62*, 199-208.

**Assignments Due:**

- *Quick write #12* ***(In class)***
- ***Assessment of children's learning***

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**Week #15** **(April 30th)**

**Assignments Due (In electronic format *.doc ):**

- Final Lesson Plans (3) With Diversity Component
- Interview analysis with transcript
- Correlation of interviews/pre-post assessment/lessons

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# Beliefs and Reported Science Teaching Practices of Elementary and Middle School Teacher Education Majors from A Historically Black College/University and a Predominately White College/University

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## Abstract

Project Nexus, an undergraduate science teacher preparation program, was designed to develop and test a science teacher professional development model that prepares, supports, and sustains upper elementary and middle level specialist science teachers. Of particular interest was the recruitment of a diverse teaching force, particularly African American. We implemented our model at two types of universities: a Historically Black College/University [HBCU], and a Predominately White University/College [PWUC]. Of focus in this year 1 study of the program was the need to collect and analyzing baseline data of all the previous year's graduates of the two institution's undergraduate elementary/middle school teacher preparation programs. Determining the baseline data would provide an essential measure from which to compare impact of the program after five years of implementation. We administered an established instrument, "New Teachers' Beliefs and Practices of Science." We compared our sample's responses (closed and open-items) by institution and with a sample of national teachers' responses. Findings indicated that along all statements the 2005 graduates reported that they are more likely to use practices, which are recommended by national latest reform documents (AAAS, 1993, National Academies, 2006, NRC, 1996) than the national teachers' group, with higher percentages in the PWUC than in the HBCU. Interesting, however, on the open-ended item we found that more HBCU graduates thought it was very important to be taught in a culturally responsive manner than did the PWUC graduates. Implications for teacher preparation were discussed.

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## Introduction

This study reports baseline data as a way to document treatment effect in a teacher preparation innovation project (Project Nexus [PN], the Maryland Science Teacher Professional Continuum for Upper Elementary/Middle Level Grades). The purpose for this study was to collect information on the number and characteristics of graduates of two types of teacher preparation programs, Historically Black College/University [HBCU] and a Predominately White College/University [PWCU]. We compared the results between institutions and with a larger national sample.

A primary measure of success for our study will consist of documenting in Project Nexus how many interns are recruited, prepared, and then teach *Standards*-based science to upper level elementary students. The total impact of the innovation in Project Nexus (PN) will be obtained by comparing current baseline data with data collected at the end of five years of project activities. Of interest to determine to what extent the elementary education teacher programs at the HBCU and the PWCU are able to recruit and prepare new teachers who take upper elementary/middle level science teaching positions, and teach in a standards-based manner, particularly those from currently underrepresented groups.

Since our aim is to make empirically supported recommendations for science teacher education, we will base our arguments of the impact of the project's activities on the comparison of the baseline data with the final data. The two areas measured are the new graduate's beliefs (a) of science and science teaching and (b) of the role of their ethnicity/race in their career decision to become teachers.

We report on our baseline data that was gathered through application of survey methodology. The instrument used was "New Teachers' Beliefs and Practices of Science" (McGinnis & Parker, 2001).

## Rationale for the Innovation

A current need in science education is to increase the number of qualified upper elementary/middle school science teachers, particularly those from typically underrepresented groups. To do so, major goals for teacher preparation is to: (a) increase the number of elementary teacher education majors who concentrate in science; (b). recruit students from diverse backgrounds, particularly African Americans; (c). focus on how to teach all populations, commonly referred to as "teaching for all" (Fensham, 1985).

Bransford, Brown, and Cocking (2000) use the term "learner centered" to refer to environments that pay careful attention to the knowledge, skills, attitudes, and beliefs that learners bring to the education setting. The term includes teaching practices that have been called "culturally responsive," "culturally appropriate," "culturally compatible" and "culturally relevant". (p. 134). Teaching for all strategies includes the acknowledgment that learners have developed preferences on how to engage with content: some students prefer audio input; some prefer video input, others prefer seeing the material in writing, writing down the material or when they verbalize the material aloud in their own words (Suinn, 1999).

PN is designed to focus on "teaching for all" strategies that are used broadly in the science and the method courses (see context of the study). In addition, PN focuses on improving the science content background of elementary education majors and preparing them to see relationships between science and mathematics. The focus on interdisciplinary teaching that stress the importance of connections between science and mathematics aligns with the recent call by the National Academies (2006) in *Rising Above The Gathering Storm: Energizing And Employing America For A Brighter Economic Future*" to recruit, educate, and retain excellent K-12 teachers who fundamentally understand biology, chemistry, physics, engineering and mathematics" (p. 5-2). The participants in Project Nexus are from diverse populations, including elementary teacher education majors, with a special interest on those from traditionally underrepresented groups such as African Americans, practicing public school mentor teachers, and informal science education adult leaders.

## Context of the Study

PN is designed to develop and test a science teacher professional development model that prepares, supports and sustains upper elementary and middle level specialist science teachers. PN is a 5-year project supported by the National Science Foundation Teacher Professional Continuum program. The experienced project leadership includes experts in science content, science methods, and informal science education.

Since a significant focus in PN (in regards to recruitment, preparation, and support) is on the ethnicity/race of the prospective teachers, we implement our model at two types of universities. The types of universities consist of a Historically Black College/University [HBCU] and a Predominately White College/University [PWCU] that is a Research University, Very High (Carnegie Rankings System). The representative HBCU University in the first year of the project was Bowie State University [BSU] (2005 elementary education graduates: 63% African-American; 32% White); however, due to an opportunity in the second year of the project to increase the samples size by switching to a larger HBCU institution, we replaced it with a different HBCU university, Florida A&M University [FAMU]. The representative PWCU is the University of Maryland, College Park [UMD] (2005 elementary education graduates: 81% White; 6% African-American).

Markedly, the percentages of African American elementary teacher education majors were lower than those of the general undergraduate African American populations of both institutions (e.g., UMD's African American population was 12%).

### *Innovations in Project Nexus*

PN is a comprehensive research study that will examine four components (detailed below) in a step-by-step fashion as our interns experience them. [For additional information on the project, please visit the project's web site, www.projectnexus.umd.edu].

1. The transformed science content course includes both lecture and lab. It is taught in the College of Chemical and Life Sciences. The lecture part of the course is designed to enable students to develop life long learning skills, an appreciation and understanding of science, and the ability to explain science to

others. The course uses a variety of teaching strategies applicable to both science and non-science courses from the elementary through college level. It is based on a 12-part video series *Unseen Life on Earth.* The videos are used in the course in an interactive manner, after each section of the video there are small group and whole class discussions. The instructor asks questions and encourages student questions. An important goal of the course is to model teaching for all (for different students with different backgrounds and differing preferences on how to engage with science content) with the hope that students who pursue teaching as a career will learn how to teach effectively all learners. In the laboratory section, students design experiments, conduct research, discuss how science is used to solve problems, and get hands-on experience with the world of microbiology through the lens of their own personal interests.

2. The representative informal science entity is Hands On Science Education, Inc., [HOSO] a non-profit organization that offers informal afterschool science education classes for elementary students throughout the US and in several other countries. HOSO was established in 1980 to provide a regular informal science option for pre-school and elementary aged learners. Its activities are consistent with the *National Science Education Standards* (National Research Council, 1996). The informal science education entity is a community-based program that offers afterschool science education courses (1 hour each for 8 sessions). A trained adult leader (usually a parent) leads sessions of up to 11 students in small group activities that are engaging and hands-on/minds-on. Adult leaders receive a full day of training that consists of an orientation to the HOSO curricular materials, including pedagogical guidance, and to an informal science philosophy of teaching and learning science.

3. The transformative science methods course is performance-based. It is taught in the College of Education. Its goals and outcomes align with the standards-based recommendations found in the *National Science Education Standards* (1996) and endorsed by the program's sponsored accreditation association (ACEI/NCATE). The instructor interweaves technology and mathematics throughout the student-centered course. Data management and analysis are emphasized. A commitment is made to represent high quality science instruction as inquiry-based and for all. As such, lecture is diminished and culturally responsive strategies are demonstrated and taught. The instructor uses the Socratic method in both small group and whole class discussions. Interns engage regularly in small cooperative learning groups to answer and pose problems in science that take into account children's thinking. The goal is to utilize such knowledge in instructional design and practice. Interns design both short term (daily) and long term (extended science investigations) learning experiences that are conducted with young learners in an accompanying field experience (Professional Development Schools (PDS) network). Peer coaching is utilized throughout, and ongoing reflection by the interns is required. Linkages to informal science education are encouraged.

4. Field experience in the teacher preparation program is situated in a Professional Development School (PDS) context. Interns in the final year of their program are placed during the fall semester in a participating PDS elementary school. During the fall semester, the interns spend two full days a week in their PDS placement. In addition, they also spend three full weeks (Monday to Friday) in their placements, in August before the young students begin the school year, in mid-October, and in mid-December. The purpose being to obtain a more comprehensive view of schooling from the mentor teacher and young learners perspectives. During their school placements, the interns conduct disciplinary crafted core assignments with the young learners that are assessed by both university personnel and school-based personnel. During the spring semester, the interns spend five days a week in their PDS placements, and they progressively take over full instruction of the young learners. The interns are assessed periodically by university and school-based personnel and by review of a comprehensive professional portfolio at the end of the internship.

## Literature Review

Current recommendations made by prominent teacher educators such as Cochran-Smith, and Zeichner (2006) and Darling-Hammond (2000) are for teacher preparation programs to pay attention to the demographic profile of their interns and graduates. Concomitantly, they stress the need for teacher preparation programs to place special attention on teaching instructional strategies that take in account cultural differences of young learners. What follows is a concise literature review structured along three lines relevant to our baseline study: teachers' demographic profile; reforms in teacher preparation programs; and teachers' beliefs towards science and science teaching.

### *Teachers' Demographic Profile*

PN highlights the importance of recruiting underrepresented populations (African-American candidates) for teacher preparation programs. Therefore we decided that we needed to collect baseline data that identified the type of sample at the two differing teacher preparation institutions in the project. The undergraduates at both the HBCU and the PWCU institutions earned the degree of Bachelor of Arts in elementary education. The undergraduates who were enrolled in the teacher education programs did not hold any other post-secondary degrees when they were recruited.

Survey methodology is designed to accomplish this task efficiently (Smith & Glass, 1987). The baseline data then could be compared later to assess the impact of the project in targeted areas. Currently, although the student population is increasingly diverse, 1999-2000 data indicate that US "public school teachers were predominantly White, non-Hispanic (84%). Of the remaining proportion, 7.8% were African-American, 5.7% Hispanic, 1.6% Asian American, and 0.8% Native American" (Zumwalt & Craig, 2006, p. 114).

As articulated by the National Research Council (NRC, 2002) and the Education Commission of the States (Allen, 2003) there is an imperative need for those involved in science teacher education to report empirically based research. More specifically, as articulated by Zeichner (2005), there is a concomitant call for research in teacher education to examine how to prepare teachers successfully to teach the diverse students who are in US public schools and how to recruit a diverse teaching force.

In 1996, Lewis pointed out that proportionally there were many more students of color (31%) than teachers of color in the teaching force (13%). More recent data on US school populations as reported by Guarino, Santibanez, and Daley (2006) shows that by 2000, 39% of students were members of minority groups (17% Hispanic, 17% Black, and 5% were members of other racial/ethnic group). Linda Darling-Hammond (2000) and others such as Kirby, Berends, and Naftel (1999) have chided schools for poor recruiting strategies and for schools of education for not responding to market pressures quickly enough to remedy this imbalance in the ethnic/racial backgrounds of students and their teachers.

Historically, teaching has been a popular career among African-Americans. After World War II, 79% of black female college graduates were employed as teachers. As other career opportunities became available, however, by the mid-1980s, this percentage fell to 23% and the proportion of minority teachers in general had dropped considerably. As result of this negative trend in the diversity of the teaching staff, the gap of ethnic background representation (particularly impacting students of color) between US students and their teachers is large and widening.

*Reforms in Teacher Preparation Programs*

In many nations, science education is currently going through a process of change (van Driel, Beijaard, & Verloop, 2001). The reform efforts in different countries (e.g., in the USA - AAAS, 1993; NRC, 1996; in United Kingdom - *Beyond 2000*, Millar, & Osborne, 1998) share important characteristics related to dissatisfaction with how science traditionally is taught. To change the status quo, efforts in the last decade have focused on the professionalization of teaching, under the assumption that upgrading the profession will increase teachers' commitment and motivation. It is assumed that these changes in teacher preparation and professional development results in better teaching, as defined by the major reform documents, and improved student learning (National Science Foundation, 1998).

According to this scenario the literature suggests that teacher professionalization should move forward on two main levels:
(1) *Reforms in teacher preparation programs* (Adamson, Banks, Burtch, Cox, Judson, Turely, Benford, & Lawson, 2003). Such reforms have different foci, from developing extended graduate level teaching programs, with emphasis on additional content courses, to programs with emphasis on pedagogical aspects such as promoting innovative teaching approaches (i.e., active learning teaching approaches).

(2) *Professional development services to support teachers that begin through the inductive years, advanced to the early and mid-career stage, and culminates in the master teacher or late career phase* (Luft, Roehrig, & Patterson, 2003). This effort assumes that learning to teach is a developmental process during which teachers progressively refine their beliefs and practices during their years of practice (Yerrick, Parke, & Nugent, 1997).

PN is located primarily under the first type of reform since it is concerned with formulating new content and pedagogy courses that modeled inquiry-based and interdisciplinary approaches. The current approaches to reform in science teacher preparation programs, and in service teacher professional development programs have led to unprecedented interest in research on the efficacy of such reforms (Simmons, et al., 1999). Gallagher and Richmond (1999) stated, "Despite the seeming efficacy of the goals and claims that underlie current reform, there has been little formal, scholarly effort on the part of the science [education] community to ground the reform carefully in research" (p. 753). One way to evaluate and understand the role of teachers with respect to educational reform is to examine their beliefs and views towards the discipline that they teach as well as towards teaching and learning (Tobin & McRobbie, 1996).

*Teachers' Beliefs Towards Science and Science Teaching*

In the design of our baseline study we focused primarily on the teachers' beliefs towards science and science teaching. A variety of terms are used to define teacher beliefs. These include preconceptions, implicit theories, and orientations. Research articles include discussions from psychological and cognitive science perspectives by Abelson (1979) and Nespor (1987), as well as research reviews by Kagan (1992) and Pajares (1992); and the role of attitudes and beliefs in learning to teach by Richardson (1996). This literature contributes to a consensus that beliefs are part of a group of constructs that describe the structure and content of a person's thinking and are presumed to drive her/his actions (Bryan & Atwater, 2002). Whatever the definition, it is generally agreed that what teachers believe (as it relates to their philosophy of teaching, their role within that process, the role and expectations of the students for learning, and the role of the school, science curricula, and context for instruction) will be an essential foundation for what occurs in the classroom (Blake, 2002).

Currently, there is substantial evidence that teachers' performances at school are influenced by their beliefs about teaching and learning (Pajares, 1992; Richardson, 1996; Wilkins, 2004). Nespor (1987) argues that beliefs are structured from previous events and experiences. A teacher's past events create "guiding images" that act as a filter for new information. A belief structure created from an earlier experience may also be resilient enough to become the standard to which newer information is compared. For example, if a teacher changes conceptions of what quality teaching is, from a traditional whole group approach to a cooperative learning orientation, all new information about practice will be filtered through the cooperative learning belief structure (Blake, 2002).

Bryan & Atwater (2002) demonstrate in their research on teacher thinking that teachers' beliefs about the teaching-learning process play a significant role in determining the nature of teachers' purposes in the classroom and directly affect many aspects of their professional work, including lesson planning, assessment, and evaluation. In addition, teachers' beliefs influence their decision-making during classroom interactions with students (Leinhardt, 1990).

Bybee (1993) maintained that teachers are the "change agents" of educational reform and that teachers' beliefs must not be ignored. According to Bandura (1986), beliefs are the best indicators of the decisions people make throughout their lives. Clusters of beliefs form attitudes and action agendas (Ajzen, 1985; Pajaras, 1992). Theory holds that people tend to act according to their beliefs. More accurately then, as Haney et al. (2002) suggest, the beliefs that teachers hold regarding science reform ideas are truly at the core of educational change.

While certain belief systems are promoted in teacher education programs, the actual beliefs teachers bringing into their classroom might not be exactly the same. In Cobern and Loving's (2002) survey of "Thinking about Science," they found many of their sample's preservice teachers did not believe women and minorities were as welcome as White males in the scientific community. McIntosh & Norwood (2004) sampled only minority teachers' responses to certification examination questions. Their analysis of the "Teacher Belief Survey" revealed that the belief systems of African-American preservice teachers were teacher-oriented rather than student-oriented. These two studies suggest that teacher preparation programs need to take into account other factors outside of what was surveyed that might influence teachers' beliefs about teaching practice and student outcomes.

Tosun (2000) measured preservice elementary education students' beliefs about teaching before and after a discipline-integrated methods course. The instrument used was the "Science Teaching Efficacy Belief Instrument." Tosun found that the methods course played a limited role in improving the science teaching self-efficacy. Earlier, Stevens and Wenner (1996) used the "Science Teaching Efficacy Belief Instrument" to compare preservice teachers' beliefs with their knowledge of science. While the elementary teacher education students showed relatively high confidence in teaching science, their general understanding of the content knowledge was insufficient to support their teaching. Measuring preservice teachers' beliefs at different stages in the teacher preparation programs may reflect a clearer picture of the changing process of attitudes and beliefs over time.

## Methodology

### *Instrumentation*

Survey methodology was used in this study to establish baseline data. Survey methodology is a recognized "venerable tradition" (p. 225) in social science research when the goal is to collect and report characteristic data for an identified sample (Smith & Glass, 1987). In this study we used an established instrument that was crafted for previous studies and was used to compare between groups of UMD graduate students, The Maryland Collaborative for Teacher Preparation (MCTP), and a national sample of teachers (National Science Foundation, 1998; McGinnis, 2002; McGinnis & Marbach-Ad, 2007; Marbach-Ad & McGinnis, 2008). The "MCTP beliefs and practices in science and mathematics" instrument aimed to measure the constructs of interest of the program's graduates.

To craft the "MCTP teacher's beliefs and practices in mathematics and science" instrument we searched existing reported survey items that practicing teachers had previously responded[2]. This strategy required us to examine the literature for accepted and reported surveys that measured practicing teachers' constructs that we targeted and then develop a new survey, consisting primarily of items taken verbatim from those reported surveys.

We found success in our search when we inspected survey data reported in the National Science Board's 1998 Science & Engineering Indicators (NSF, 1998). Specifically, we found existing valid and reliable surveys that measured: *Teacher beliefs about the nature and teaching of mathematics and science: 1994-95* [46] ; *Teacher perceptions of student skills required for success in mathematics and science: 1994-95* [47]; *Teachers' knowledge of the standards: 1994-1995* [48]; *Percentage of science and mathematics teachers implementing reform activities: 1996* [49-50]. Upon inspection, we determined that these instruments were based on items used in the TIMSS study.

From these surveys we crafted a new 51-item survey, "MCTP teachers' actions and beliefs of mathematics and science," consisting of 44 previously administered items taken from those reported surveys. We added two items to our survey that related to a unique aspect of the MCTP, making connections between mathematics and science in instructional practice. We added another item that asked about the teacher's familiarity with the National Science Education Standards. We also included 4 items that asked background information.

In the current study we eliminated the questions about teachers' actions and beliefs of mathematics, since the focus of the study is on science teacher preparation program. To establish face validity of our "New Teachers Beliefs And Practices Of Science" instrument (i.e., that there existed a connection between the surface features of the instrument's content and the theoretical construct, Smith & Glass, 1987), we provided for inspection the draft instrument to a sample of science content experts and a sample of science pedagogy experts (we reported on its reliability in McGinnis & Parker, 2001).

Our theoretical constructs consisted of beliefs about the nature and teaching of science. Namely, we sought to determine if the graduates held beliefs about science content that aligned with a traditional view of science as a static and codified body of knowledge or a view of the discipline as a dynamic way of knowing driven by inquiry. Regarding the teaching of science, our aim was to measure if our graduates held beliefs

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[2] Material drawn from McGinnis & Marbach-ad, 2007.

about the teaching of science that were teacher-centered or learner-centered, as characterized by passive learning (lecture) or active learning (problem solving), respectively. The surface content of the instrument consisted of the items selected from a limited number of existing instruments as well as two new items that measured beliefs about subject matter integration and knowledge about the major standards documents. The content specialists included a chemistry professor, a physics professor, and a life science professor and three doctoral students, one from each science discipline respectively. The pedagogy experts included two associate professors of science methods and two doctoral students in science methods. The result of the inspection by our sample strongly supported the face validity of our instrument.

The constructs we measured using Likert scale for five level responses were “Teachers’ beliefs about science (Items 7-15),” “Teachers’ perceptions about student success in science (Items 16-21),” “Teachers’ knowledge of the science standards” (Items 22, 23), “Teachers’ intentions about implementing reform activities in science classes (Items 24-30),” and 6 items that asked for background information (Items 1-6). Innovatively, we added an open-ended question that asked our participants to respond to how they thought their career decision might have been influenced by their ethnicity/race.

*Instrument Administration*

We analyzed the survey responses in different ways – using t-test and chi square analyses, and using analysis for the whole survey and for separate group of questions. We decided that due to the small sample and the large variability between the different items in the survey that it was most appropriate to only compare percentages for each of the items.

For the open ended question, “In reflecting on what influenced you to pursue a career that involves significant science teaching responsibilities, how was your decision affected by consideration of your ethnicity and/or gender?” we used a modified content analysis strategy that did not engage in hypothesis testing. Classical content analysis comprises techniques for reducing texts to a unit-by-variable matrix and analyzing that matrix qualitatively to test hypothesis (Ryan & Bernard, 2000).

*Sample*

During Spring 2006, we administered the survey to our recent graduates from the elementary education teacher preparation programs at UMD and BSU (certification levels, grades 1 to 8). Due to unexpected reasons we had to move in the second year of the program to FAMU, a different HBCU institute. As earlier reported, this change resulted in an opportunity to increase our sample size for the HBCU. It also brought us some challenges. As an opportunity FAMU offered us a much larger elementary teacher education teacher preparation program, which helped to augment our original sample size from the HBCU. The challenge was that we could only gather information from FAMU intern students enrolled in their upper level undergraduate teacher preparation program and not from those who had graduated.

Nevertheless, we believe that this augmented baseline data set is an acceptable good basis for comparison, since it is derived from similar populations and it reflects teacher education interns who are benefiting from reforms that have been recommended in the last few years. We also decided to compare our recent baseline data with a larger, sample of practicing elementary and middle school science teachers (national sample) since graduates from the PWCU and the HBCU elementary programs were certified to teach grades 1 to 8.

The 1995-6 national data were collected by administration of valid and reliable survey instruments (NSB-1998). We used relevant sections of those instruments verbatim as the platform for our researcher-crafted survey with the goal of comparison of the different populations (HBCU, PWCU and the national sample) (McGinnis & Parker, 2001; McGinnis & Marbach-Ad, 2007; Marbach-Ad & McGinnis, 2008).

In late fall 2005, the survey instrument was administered electronically by website, delivered e-mail and as a hard copy to our BSU and UMD teacher education graduates from 2005. The response rate for this administration was for UMD - 60 out of 116 for BSU - 8 out of 19. While ideally a higher response rate from the sample would be desired (particularly for our participating HBCU institution, BSU), it should be acknowledged that arguably this is an acceptable level of response for this difficult to locate and measure population (first-year teachers). We attribute the high level of response to the strategies for increasing return rates to mail-in surveys suggested by Dillman (1978). Strategies included offering an inducement (a lottery with 5 randomly selected winners of prizes) and repeated invitations by e-mail and by mail. In fall, 2006, we administered and collected hard copy surveys from 28 FAMU interns randomly selected from a cohort of upper level education majors. Table I shows the background information of the respondents. The national sample was different for each section of the survey (see Results).

Table I
*Demographic distribution of the baseline study participants*

| | UMD (PWCU) Percentage of graduates (N=60) | BSU (HBCU) Percentage of graduates (N=8) | FAMU (HBCU) Percentage of Interns (N=28) |
|---|---|---|---|
| Grade level taught | | | |
| Lower elementary school | 51 | 25 | 75 |
| Upper elementary school | 27 | 50 | 21 |
| Middle school | 5 | 12.5 | 4 |
| Not teaching | 17 | 12.5 | |

| | | | |
|---|---|---|---|
| Gender | | | |
| Females | 83 | 75 | 89 |
| Males | 17 | 25 | 11 |
| Age | | | |
| Between 20 to 25 | 88 | 75 | 68 |
| Between 26 to 30 | 5 | - | 11 |
| Above 30 | 7 | 25 | 21 |
| Ethnicity | | | |
| African–American | 8 | 62.5 | 93 |
| Asian | 10 | - | |
| Caucasian | 75 | 37.5 | |
| Hispanic | 3.5 | - | 7 |
| Others | 3.5 | - | |

## Results

We report our findings according to the four sections in the survey.

*1. Teachers' beliefs about the nature and teaching of science.* In this section teachers were asked to rate on a scale from 1 to 5 (1= strongly disagree…5=strongly agree) 7 statements concerning their beliefs about the nature and teaching of science (Appendix, 7-15). Items 14, 15 were opposite statements to items 10, and 13 to assure students' reliable response. Table II shows the participants responses. The percentages in this table reflect the combined proportion of teachers who either agree or strongly agree with the statements. The national sample group, in this section, was science eighth grade teachers (n=232) who were surveyed in 1995 as part of the Third International Mathematics and Science Study.

Overall, the recent BSU graduates and FAMU interns were *less likely to believe*: science is primarily a formal way of representing the real world (48.3% UMD; 25% BSU; 42.8% FAMU – 84.3% National) and that it is primarily a practical and structured guide for addressing real situations (55% UMD; 62.5% BSU; 46.4% FAMU – 88% National). Interestingly, the FAMU interns were *more likely to believe:* "some students have a natural talent for science and others do not (62% National; 46.7% UMD; 37.5% BSU – 85.7% FAMU) and "It is important for teachers to give students prescriptive and sequential directions for science experiments" (75.8% National; 70% UMD; 75% BSU – 92.9% FAMU). For the rest of the statements there was a similar response rate for all groups.

Table II
*Comparison between the groups' (2005 graduates, the national sample and the FAMU interns) responses, to the "Teachers' beliefs about the nature and teaching of science" section, by percentage responding "Agree" and "Strongly agree."*

| Item | | National | 2005 Graduates: PWCU[1] | 2005 Graduates: HBCU[2] | HBCU[3] interns |
|---|---|---|---|---|---|
| 7. | Science is primarily a formal way of representing the real world. | 84.3% | 48.3% | 25% | 42.8% |
| 8. | Science is primarily a practical and structured guide for addressing real situations. | 88.0% | 55% | 62.5% | 46.4% |
| 9. | Some students have a natural talent for science and others do not. | 62.0% | 46.7% | 37.5% | 85.7% |
| 10. | A liking for and understanding of students are essential for teaching science. | 89.6% | 80% | 87.5% | 67.8% |
| 11. | It is important for teachers to give students prescriptive and sequential directions for science experiments. | 75.8% | 70% | 75% | 92.9% |
| 12. | Focusing on rules is a bad idea. It gives students the impression that the sciences are a set of procedures to be memorized. | 32.0% | 26.7% | 12.5% | 12.5% |
| 13. | If students get into debates in class about ideas or procedures covering the sciences, it can harm their learning. | 2.8% | 0% | 0% | 0% |

[1] University of Maryland [2] Bowie State University [3] Florida A&M University

*2. Teachers' perceptions about students' skills required for success in science.* In this section teachers were asked to rate on a scale from 1 to 5 (1 = Not at all…5 = Extremely) the importance of particular kinds of skills for success in the discipline. These skills have elements ranging from remembering through understanding to thinking in sequential manner. Table III shows the participants responses. The percentages in this table were rounded and they reflect the percentage of teachers who choose the categories "Moderately" or "Extremely." The national sample group, in this section, was eighth grade teachers (232) who surveyed in 1995 as part of the Third International Mathematics and Science Study.

Table III
*Comparison between the groups' (2005 graduates, the national sample and the FAMU interns) responses to the "Teachers' perceptions about students' skills required for success in science" section, by percentage responding "Moderately" or "Extremely.".*

| How important do you think it is for students: | National | 2005 Graduates: PWCU[1] | HBCU[2] | HBCU[3] interns |
|---|---|---|---|---|
| 16. …to remember formulas and procedures? | 25.5% | 40% | 50% | 60.7% |
| 17. …to think in sequential manner? | 79.6% | 55% | 75% | 53.6% |
| 18. …to understand concepts? | 84% | 85% | 87.5% | 96.4% |
| 19. …to be taught in a culturally responsive manner? | - | 61.6% | 87.5% | 50% |
| 20. …to understand science use in the real world? | 79.2% | 80% | 87.5% | 75% |
| 21. …to support their explanations/arguments with evidence? | 86.1% | 86.7% | 62.5% | 78.6% |

[1] University of Maryland [2] Bowie State University [3] Florida A&M University

The recent graduates and interns were *more likely to think*: it is very important for students to remember formulas and procedures (40% UMD; 50% BSU; 60.7% FAMU – 25.5% National). They were less likely to think, however, it is very important for students to think in sequential manner (55% UMD; 75% BSU; 53.6% FAMU – 79.6% National).

Since our new baseline data intended also to measure differences between a Predominately White College/University [PWCU] and a Historically Black College/University (HBCU), we added in the instrument a statement regarding the importance of being taught in a culturally responsive manner. Interestingly, we found that more BSU graduates (87.5%) thought it is very important to be taught in a culturally response manner than UMD graduates (61.6%). It is noteworthy that 9 UMD graduates didn't answer this question, even though they answered all other questions. On the other hand, inspection of the upper level FAMU interns responses to this question shows that only 50% reported that it is very important to be taught in a culturally response manner.

*3. Teachers' familiarity with standards documents and benchmarks for science.* In this section teachers were asked to rate their familiarity with standards documents and benchmarks on a scale from 1 to 5 (1 = not at all familiar…5 = familiar to great extent). Table IV summarizes the participants' responses. The percentages in this table were rounded and they reflect the percentage of teachers who choose categories 3-5 from "fairly familiar" to "familiar to great extent". The national sample group, in this section, was science and mathematics eighth grade teachers (n=478) who answered to a survey in 1995.

Table IV
*Comparison between the groups' (2005 graduates, the national sample and the FAMU interns) responses to the "Teachers' familiarity with standards documents and benchmarks for science" section, by percentage responding "fairly familiar" to "familiar to great extent."*

| Item | National | 2005 Graduates: PWCU[1] | 2005 Graduates: HBCU[2] | HBCU[3] interns |
|---|---|---|---|---|
| 22. What is your familiarity with the Science standards document National Science Education Standards? | NA | 38.3% | 25% | 7% |
| 23. What is your familiarity with the reform document Benchmarks for Science Literacy? | 26% | 23.3% | 12.5% | 11% |

[1] University of Maryland [2] Bowie State University [3] Florida A&M University

We found that most of the national and the 2005 graduates' teachers and interns were not familiar with the standards documents and benchmarks for science. We speculate that the difference between the two HBCU institutions regarding the familiarity with the *National Science Education Standards* (BSU-25% and FAMU-7%) may be explained by the fact the FAMU interns had not yet finished their studies. We hope to find differences in this area with our Nexus graduates.

*4. Teachers' reports of their instructional practices in science classes.* In this section teachers were asked to report on the kind of reform activities they are implementing in their classrooms. The National sample groups, in this section, were science and mathematics public elementary and secondary schools mathematics and science teachers who answered to a survey in 1996. We included only the responses of graduates who reported that they are already teaching (HBCU=7; PWCU=50), since we ask them to reflect on their instructional practices in class. First we compared the responses of the 2005 graduates to the responses of the National to document the ten years difference, and then we compared between the group of 2005 students who graduated from BSU and the group of 2005 students who graduated from UMD, to evaluate demographic differences. The percentages in Table V were rounded and they reflect the percentage of teachers who choose to answer from "Fairly" to "Great extent".

Table V
*Comparison between the 2005 graduates' responses (all and divided by institution) to the "Teachers' intentions about implementing reform activities in science classes" section and the national sample responses, by percentage respon*ding from "Fairly" to "Great extent."

| Item | National | 2005 Graduates | PWCU[1] | HBCU[2] |
|---|---|---|---|---|
| 24. Assisting all students to achieve high standards. | 71% | 87.8% | 88% | 85.7% |
| 25. Providing examples of high-standard work. | 48% | 87.5% | 88% | 71.4% |
| 26. Using performance-based assessments. | 44% | 82.1% | 82% | 71.4% |
| 27. Using standards aligned curricula. | 66% | 80.3% | 82% | 57.1% |
| 28. Using standards-aligned textbooks and materials. | 58% | 83.6% | 84% | 57.1% |
| 29. Using computer-supported instruction. | 17% | 62.5% | 64% | 42.9% |
| 30. Making connections with mathematics. | - | 77.2% | 78% | 71.4% |

[1] University of Maryland (N=50) [2] Bowie State University (N=7)

We found that among all statements the 2005 graduates reported that they are more likely to use the mentioned practices, which are all recommended by the latest national reform documents (i.e., AAAS, 1993). The 2005 graduates were *more likely to*: assist all students to achieve high standards (87.8% 2005; Grad – 71% National); provide examples of high-standard work (87.5% 2005 Grad – 48% National); use performance-based assessments (82.1% 2005 Grad – 44% National); and use standards-aligned curricula (80.3% 2005 Grad – 66% National). The Largest difference between the 2005 Graduates and the national sample was seen regarding the use of computer-supported instruction (62.5% 2005 Grad – 17% National). These results probably reflect the time difference. Contemporary educators (teachers, developers, researchers, students) are much more aware of the potential of web technology than they were ten years ago (Mioduser, Nachmias, Lahav, & Oren, 2000).

Overall, along most measures the UMD graduates had higher percentages than did the BSU graduates.

*Influence of Race/Ethnicity on Career Decision Making*

Regarding the open-ended question, “How was your decision to be a science teacher affected by consideration of your ethnicity and/or gender? Most of the new graduates (BSU- 5 out of 8; UMD- 42 out of 60; FAMU- 19 out of 28) stated that they saw no influence of gender and race on their decision making. An example of such a response follows:

> [Neither] my gender nor ethnicity influenced my decision. I always wanted to teach elementary school and I knew that science is a part of school and unlike the upper grades I knew I would teach all subjects to my students. I felt and still feel comfortable teaching (African-American female, BSU).

A few students from both Universities (BSU- 1 out of 8; UMD- 6 out of 60; FAMU – 9 out of 28) reported that they did see an influence in their choices of teaching career, or that they started to think about ethnicity and gender while learning or teaching. Several examples for such a response follow:

> As an African American female I am well aware of how influential gender and race is on being successful in the field of Science. Stereotypically females and minorities are not urged to pursue science related careers and this is a real shame (African American female, BSU).

> I want to be a positive Black role model for kids because I know I did not have one when I was a child (African American male, FAMU)

> I was not influenced [by] ethnicity or gender when considering pursuing a career with science teaching responsibilities. However, [now that I am] working in a predominantly black school I do take into great consideration both ethnicity and gender (White female, UMD).

> Growing up I was taught equality by my family. Very little in my life was motivated by race. However, I have wanted to teach for a long time. Early on I realized that being a male in a female dominated profession would be interesting (White male, UMD).

## Discussion and Implications

In this report we documented our research of year 1 of Project Nexus. In year 1 the research focus was on collecting and analyzing baseline data of all the previous year’s graduates of the two institution’s (HBCU and PWCU) and compared them to a broader national sample. We believe that it is important to collect and analyze baseline data for studies in which interventions are used. By comparison of pre- and post- empirical data sets, social scientists can assert more convincingly "to citizens, business leaders, politicians and educators " (p. 22) that their work is credible and represents "scientific education research" (National Research Council, 2002, p. 97).

To summarize our results we will discuss: 1. the differences between the national sample and our two types of institutions, and. 2. The specific elements of our teacher preparation program that we believe would lead to teachers who are trained to adopt and convey, to their workplace, the desired practices that are recommended by newly science education reforms.

*1) The differences between the national teachers and the PWCU and HBCU graduates' and interns' results*

Our baseline data indicated that the two participating institutions' 2005 graduates were more likely to apply a range of practices that are recommended by national latest reform documents (e.g., *National Science Education Standards*) in their classrooms than the national sample. We believe these differences could be explained in different ways. The national group teachers were surveyed ten years prior to the current study (1995), at that time the recommendations for active learning approaches and inquiry-based learning (AAAS, 1993; NRC, 1996) just started to be recognized. Also, programs for teaching based technology were started to be developed for schools and were not integral part in the school system or in private homes like nowadays.

That overall finding was encouraging by showing some of the strengths of the existing teacher preparation programs; however, the percentages in the desired direction were higher for the graduates of the PWCU than for the HBCU graduates. We find that troubling on the local level, but inconclusive on a national level due to the sample size for the HBCU.

Of particular importance for those who seek to promote a more equitable science education, we found that more of the HBCU interns and graduates thought it was very important to be taught in a culturally responsive manner than did the PWCU graduates. Documentation of this finding is significant for those involved in teacher preparation, because the findings shed light on possible differing outcomes of teacher preparation programs that serve different populations. The results for both the HBCU and the PWCU in this important area were dissatisfying, however, since we would hope that all newly graduated teachers with science teaching responsibilities would see the value of teaching science in a culturally responsive manner. How to achieve this aim is a critical need in teacher preparation that PN will seek to address throughout its activities.

2) *The specific elements of Project Nexus influenced by the baseline data.*

One of the key assumptions commonly held in science education is that science educational practices require systemic reform within undergraduate science subject matter and education classes, prospective teachers' field-based experiences, and professional development during new teachers' induction years (NSF, 1998; NRC, 1996).

Marilyn Cochran-Smith and Kenneth Zeichner (2006) in their recent report "Studying Teaching Education" included under their topic "*The research we need"* made the call for a reform in teacher preparation with a focus on the subject matter and a rigorous program examination. They recommended paying attention to the demographic profile of teacher education students and entering teachers. Although there is evidence that teachers who do not share their learners' racial, cultural, or linguistic backgrounds can be successful, we are persuaded by scholars such as Cochran-Smith and Zeichner (2006), as well as Darling-Hammond (2000) that a priority should be to recruit and prepare teacher interns of color. For that reason, we are implementing and testing our science teacher preparation continuum model at two types of universities, a Historically Black College/University [HBCU] and a Predominately White College/University [PWCU].

Our aim, which we are testing — and influenced in our implementation by the baseline data — is to improve our teachers' preparation programs by implementation of the innovative features in the Project Nexus: recruitment into teaching of individuals with background in science, particularly those of color; connection of transformative undergraduate science content courses with reform-aligned science method courses, supported internship experiences with adolescent students in informal education contexts, field placements in urban professional development schools, and ongoing innovative educational experiences that target the needs of minority and urban students. In particular, our baseline data suggested to us the need to customize the degree of implementation of our project's key features at the participating institutions. For example, the baseline data showed that at the PWCU more respondents were supportive of the need for explanations/arguments with evidence in their teaching than were the respondents at the HBCU. Conversely, more graduates from the HBCU were supportive of teaching in a culturally responsive manner than were the respondents at the PWCU. As a result, we have learned that it is important at the different types of institutions to regulate at differing levels of intervention (higher or lower emphasis) for particular instructional innovations based on where they begin. We see this as analogous to the differentiation movement in pedagogy for individual students, but at an institution level guided by careful attention to baseline data disaggregated by institution.

We believe these initial findings and ruminations of our Project Nexus 5-year study are intriguing as well as important to report. Our initial decision to collect baseline data has resulted in a promising idea of a way to intervene most productively in the differing types (HBCU and PWCU) of teacher preparation institutions collaborating in this innovative science teacher preparation project.

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# Appendix

## New Teachers Beliefs and Practices of Science

Directions: Please select the letter response that best represents your beliefs and practices.

SECTION I. Background Information

1. If you win a lottery drawing of returned surveys which prize would you prefer?
   A. i-pod
   B. B Kodak digital camera + Printer Dock
   C. Either is acceptable
   D. Neither, no thanks

2. Institution from which you graduated:
   A. Bowie State University (BSU)
   B. University of Maryland (UMD)

3. What grade level are you teaching?
   A. 1, 2, or 3
   B. 3. 4 or 5
   C. 6 (elementary school)
   D. 6,7,8 (middle school)
   E. not teaching

4. Your gender:
   A. Female
   B. Male

5. Your age:
   A. 20-25
   B. 26-30
   C. 31-35
   D. 36 or older

6. Your ethnicity:
   A. African-American or Black
   B. Asian or Pacific Islander

C. American Indian or Native American
D. Caucasian or White (not of Hispanic Origin)
E. Hispanic or Latino
F. Other

Note: For the next four sections (II, III, IV, and V), please think of your vision of science and science teaching before you respond to the items.

SECTION II.

To what extent do you agree or disagree with each of the following statements?

Choices:

| (A) | (B) | (C) | (D) | (E) |
|---|---|---|---|---|
| **Strongly disagree** | **Disagree** | **Neutral** | **Agree** | **Strongly agree** |

7. Science is primarily a formal way of representing the real world.

8. Science is primarily a practical and structured guide for addressing real situations.

9. Some students have a natural talent for science and others do not.

10. A teacher's understanding of students is essential for teaching science effectively.

11. It is important for teachers to give students prescriptive and sequential directions for science experiments.

12. Focusing on rules is a bad idea. It gives students the impression that the sciences are a set of procedures to be memorized.

13. If students get into debates in class about ideas or procedures covering the sciences, it can harm their learning.

14. A teacher's understanding of students in not essential for teaching science effectively.

15. If students get into debates in class about ideas or procedures covering the sciences, it can benefit their learning.

SECTION III.

Choices:

| (A) | (B) | (C) | (D) | (E) |
|---|---|---|---|---|
| **Not at all** | **Slightly** | **Fairly** | **Moderately** | **Extremely** |

16. How important do you think it is for students to remember formulas and procedures?

17. How important do you think it is for students to think in sequential manner?

18. How important do you think it is for students to understand concepts?

19. How important do you think it is for students to be taught in a culturally responsive manner?

20. To do well in science at school, how important do you think it is for students to understand science use in the real world?

21. To do well in science at school, how important do you think it is for students to support their explanations/arguments with evidence?

SECTION IV.

Choices:

| (A) | (B) | (C) | (D) | (E) |
|---|---|---|---|---|
| **Not at all** | **Small extent** | **Fairly** | **Moderate extent** | **Great extent** |

22. What is your familiarity with the Science standards document National Science Education Standards?

23. What is your familiarity with the reform document Benchmarks for Science Literacy?

SECTION V. Instructional Practices

To what extent do you use the instructional strategies in science teaching that are listed below?

Choices:

| (A) | (B) | (C) | (D) | (E) |
|---|---|---|---|---|
| **Not at all** | **Small extent** | **Fairly** | **Moderate extent** | **Great extent** |

24. Assisting all students to achieve high standards.

25. Providing examples of high-standard work.

26. Using performance-based assessments.

27. Using standards aligned curricula.

28. Using standards-aligned textbooks and materials.

29. Using computer-supported instruction.

30. Making connections with mathematics.

SECTION VI. Brief Responses

31. In reflecting on what influenced you to pursue a career that involves significant science teaching responsibilities, how was your decision affected by consideration of your ethnicity and/or gender?

32. If you were at one time an undergraduate science major, what influenced you to pursue a career in teaching?

# Preschool Teacher-Child Verbal Interactions in Science Teaching

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Abstract

This study examined verbal interactions between 20 preschool head teachers (N = 20) and their students in 13 Midwestern child care centers; preschool head teachers were videotaped for two consecutive days during morning free play time. By operationalizing Neuman's concept of "sciencing", this study used The Preschool Teacher Classroom/Sciencing Coding Form, The Preschool Teacher Verbal Interaction Coding Form, and The Preschool Classroom Teacher Interview Form to analyze preschool teachers' verbal interactions with children in science teaching and teachers' perspectives about science teaching. During the observation period, the most frequent verbal interaction entailed giving learning guidance. Teachers used more verbal statements than questioning statements; they tended to interact with children mostly in the art area. Comparing teacher verbalizations on Day 1 and Day 2 revealed that on Day 1 in typical activities teachers used more praise, acknowledge statements, and closed questions than on Day 2 when a science activity was provided for the head teachers. On Day 2 they used more learning guidance, information talk statements, and more attention-focusing questions. The study showed that preschool teachers tended to use more measuring and counting questions in the block and manipulative areas and used more reasoning questions in the dramatic play area.

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## Introduction

The traditional adage "I hear and I forget. I see and I remember. I do and I understand" indicates that children learn best through direct experiences (Croft, 2000, p. 219). Children have innate curiosity and as soon as children realize that they can discover things for themselves, their first encounter with science has occurred. Experiences in science provide opportunities for young children to develop an appreciation and awareness of the world around them and develop science inquiry skills, such as "wondering, questioning, exploring and investigating, discussing, reflecting, and formulating ideas and theories" (Chalufour & Worth, 2003, p. 4). Many professional societies, such as the National Science Foundation, the U.S. Department of Education, the American Association for the Advancement of Science (AAAS), and the National

Association for the Education of Young Children (NAEYC), emphasize the importance of science in the lives of young children and believe the early years are prime for active learning and that science can play a valuable role in a child's development.

*Science-related Activities*

Neuman (1972) believed that "sciencing involves children in full and active participation in a variety of experiences" (p. 6) and used the term "sciencing" to describe science-related activities for young children. He divided sciencing into three categories: formal sciencing, informal sciencing, and incidental sciencing. Table 1 describes the classification of Neuman's three science-related activities and examples are provided by the researcher. Kilmer and Hofman (1995) also used the term "sciencing" to emphasize children's active involvement in learning about science.

Table I
*Categories of science-related activities*

| Type of science-related activity | Definition | Example |
|---|---|---|
| Formal sciencing<br>(Neuman, 1972) | Teacher plans lessons, prepares materials, presents the activities to the children, and then encourages the children to do the activity, and as much as possible, to make discoveries. | -Providing a cooking activity<br>-Introducing a pet<br>-Setting up an incline<br>-Providing a melting/freezing activity |
| Informal sciencing<br>(Neuman, 1972) | Teacher sets up a corner or section of a room or outdoor area as the "sciencing center." The teacher selects materials and makes them available to the child who is interested in using them. The child freely chooses to use the materials and explore them in a variety of ways. | -Magnifying glasses with nature materials (e.g., bird's nests, feathers, nuts, and seeds)<br>-Scales with a variety of objects (e.g., objects of different sizes and weights)<br>-Magnets with different items (e.g., paper clips, markers, metal spoons) |
| Incidental sciencing<br>(Neuman, 1972) | The incident is not planned by the teacher but is the result of an occurrence that is interesting to one or more children and is elaborated and | -The class pet died over the weekend.<br>-An animal is unexpectedly brought to the classroom. |

| | | |
|---|---|---|
| | expanded by the teacher. | -A rabbit is seen hopping by the classroom window.<br>-The weather suddenly changes. |

Lind (2000) believes that children learn concepts through three types of activities that are consistent with Neuman's three types of sciencing. In addition, "structured learning experiences are preplanned lessons or activities," "informal learning experiences are initiated by the adults as the child is engaged in naturalistic experiences," and "naturalistic experiences are those initiated spontaneously by children as they go about their daily activities" (Lind, 2000, p. 17-18). Therefore, teachers need to "take advantage of the unplanned experiences" which comprise incidental sciencing and "select planned activities from the children's daily experiences" which are formal and informal sciencing (Eliason & Jenkins, 2003, p. 278). It's teachers' responsibility to capitalize on teachable moments "when an opportunity for instruction presents itself by chance" (Lind, 2000, p. 17). Pedagogical responsibilities accompany children's sciencing: teachers play a very important role in expanding and supporting children's learning. For instance, teachers design an environment rich with science activities, equipment, materials, and "once the environment is in place, children's explorations lead them in many directions--and many ideas, questions, and challenges arise" (Worth & Grollman, 2003, p. 158).

*Teachers' Roles*

The role of teachers is crucial in expanding and supporting children's learning in science and it includes socializing with children, modeling the behavior they want to teach, encouraging children's play activities, monitoring children's behaviors for safety, and asking questions to promote critical thinking (Kontos & Wilcox-Herzog, 1997; Riley & Roach, 2006). Vygotsky (1962) believed that children are helped and influenced in their knowledge construction by the people around them and he also believed that teachers must take an active role in children's play to help them reach their learning potentials.

Teachers, like children, are learners and researchers. According to Hill, Stremmel, and Fu (2005), when teachers work with children, they "develop their own questions based on their curiosity about children's learning" (p. 45). While teachers investigate questions with children and guide them to document what happens, both teachers and children grow and learn together in that process. Teachers also learn through self-constructed knowledge, which means "knowledge is self-constructed by each individual, through reflection on their actions on the world around them" (Riley & Roach, 2006, p. 364). Teachers need to reflect their experiences in working with children on the regular basis and continue to seek any appropriate and possible learning opportunities for children.

*Teacher─child Verbal Interaction*

According to Bredekamp and Copple (1997), adult-child interactions promote trial-and-error learning, self-regulation through many opportunities to inquire questions, make decisions, and solve problems. The teacher verbalization statements are including learning guidance (McWilliam, Scarborough, Bagby, & Sweeney, 1998), Information talk, Praise (McWilliam, et al., 1998), Acknowledge statement (Abraham & Schlitt, 1973; McWilliam, et al., 1998), and Follow-up statement (Carman, 1990; McWilliam, et al., 1998). Learning guidance is a teacher providing the information of activity procedures and expectations, such as "Today I am going to give each of you a piece of play dough, and I want both of you to…" Information talk is a teacher responding a child's comments by describing a child's exploration or answering a child's question with specific information. For instance, "I am rolling out my play dough so it is very flat." Praise is a teacher praising a child by conveying pleasure or admiration for the child, the child's behavior, or the child's work product; such as, "good job," "great," or "wonderful." Acknowledge statement is a teacher using statements that acknowledges the child's activity or approves the child's verbal behavior without elaboration, such as "you are working hard," "ok," or "all right," Follow-up statement is a teacher eliciting verbal or behavioral responses related to a child's activity. These statements are extensions related to previous specific statements stated by a child. For example, a child says, "Roll play dough." A teacher replies, "Oh, you want me to roll the play dough into a ball for you."

Kontos and Dunn (1993) examined teachers' verbal interactions with children and found that the most frequent teacher─child interaction was positive guidance (e.g., praise, nurturance, and redirection). The least frequent interactions involved divergent questions and elaboration of children's play activities. They suggested that teachers' interactions with children tended to give guidance instead of facilitating children's cognitive development.

Researchers have shown that teacher─child verbal interaction, especially asking questions, is the key component leading to positive outcomes for children (Trawick-Smith, 1994; Vandell, 1996). According to Eltgeest (1985) a productive question stimulates and provides scaffolding for children who are beginning to build their own understandings. His definition of productive questions is related to the learning cycle and sciencing processes described by Bredekamp and Rosegrant (1995). The comparison of the relationship between questioning and learning in the science process is showed in Table II.

Table II
*Science-related questions identified to elicit children's science process skills*

| Eltgeest (1985) | Bredekamp and Rosegrant (1995) | |
|---|---|---|
| Productive questions | Learning Cycle | Sciencing Processes |
| Attention-focusing question | Awareness | Observing |
| Action question | Inquiry / experimentation | Relating |
| Problem-posing question | Inquiry / experimentation | Relating |
| Measuring and counting question | Exploration | Quantifying |
| Comparing question | Exploration, Inquiry / experimentation | Comparing, Organizing, Classifying, Inferring |
| Reasoning question | Utilization | Applying, Communicating |

One particularly powerful format for verbal interaction involved engaging children with questions. Good questions promote children's observation skills, develop their problem-solving skills, and encourage them to share ideas (Branscombe, Castle, Dorsey, Surbeck, & Taylor, 2000). According to NAEYC's DAP guidelines, teachers pose problems, ask questions, and make comments and suggestions that stimulate children's thinking and extend their learning (Bredekamp & Copple, 1997).

However, in the early childhood settings, teachers seemed to spend considerable time facilitating children's play, but talk with rich and stimulating content seemed to be lacking (Massey, 2004). Jones (1990) also indicated that many teachers do not ask questions effectively. Teachers fail to reach children's potential by "early childhood error" (Bredekamp & Rosegrant, 1992, p. 3), which Kontos (1999) described as occurring "when early childhood educators prepare an appropriate, stimulating environment for young children but then stand back and fail to follow up with guidance 'scaffolding' or supportive, responsive interactions with the children as they play" (p. 364).

### *Research Questions*

This study investigated teacher-child verbal interactions in preschool settings during morning free play time and proposes to address the following questions:

1) What types of verbal interactions do teachers have in the classroom with their preschoolers in light of children's "sciencing" experience?

2) What types of questions do teachers ask in different classroom areas?

3) What are teachers' perspectives about science teaching in preschool classroom settings?

## Methods

### *Participants and Demographics*

The participants were 20 (N = 20) head teachers of 3-to 5-year-old preschoolers from 13 child care centers in Midwest. These centers included children center, university-based lab school, community child care, nursery, children learning center…etc. Seven out of 13 child care centers were NAEYC accredited programs. The teachers had completed at least one year of teaching in their center and were selected for participation in this study by their child care director. All the participants were White/Caucasian females. The majority of the teachers had bachelor's degrees (60%); 15% had attended junior college or the equivalent; and 25% had a high school diploma. Thirty-five percent of preschool teachers had 1-3 years of teaching experience, 40% of the preschool teachers had 4-10 years of teaching experience, and 25% of the preschool teachers had more than 10 years of teaching experience. Seven preschool teachers had teaching certificate or licensure for birth through PreKindergarten/K or Early Childhood (birth to 8 years) while three preschool teachers had Elementary Education (K-8 grades) teaching licensure.

*Instruments*

The present study the researcher created three measurements: the Preschool Teacher Classroom/ Sciencing Coding Form, the Preschool Teacher Verbal Interaction Coding Form, and the Preschool Classroom Teacher Interview Form.

*The Preschool Teacher Classroom/Sciencing Coding Form* was developed for identifying the different areas of the classroom where teachers interact verbally with children and for indicating whether activities are related to science activities (see Appendix A). The nine typical areas identified were art, blocks, computer, manipulative, science, dramatic play, language and reading, sensory, and other. Two coders viewed the videotape to record where teachers stayed for 15 seconds or longer and what type of science activity was taking place. Based on Neuman's (1972) classification as illustrated in Table 1, the researcher provided examples on each classification. Activity not related to science was coded as: none of the above. The videotape was viewed by coders to record the classroom area during every 30-second interval. When more than one activity area was observed, the activity was occurring 15 seconds or longer was coded (see Appendix A).

*The Preschool Teacher Verbal Interaction Coding Form* was developed to code the teachers' verbal interactions with children, specifically focusing on the preschool teachers' questioning statements (see Appendix B). Verbal interaction was coded for the type of verbal statement teachers used in five categories and these verbal statement categories were developed from several researchers, such as learning guidance (McWilliam, et al., 1998), information talk (Carman, 1990), Praise (McWilliam, et al., 1998), acknowledge statement (Abraham & Schlitt, 1973; McWilliam, at al., 1998), follow-up statement (Carman, 1990; McWilliam, et al., 1998) and other. When a teacher talks to a teaching assistant, parent, the child's siblings or herself/himself, it was coded as other. There were seven categories in question asking, such as closed questions (Carman, 1990) and Eltgeest's (1985) productive questions, such as attention-focusing, action, problem-posing, measuring and counting, comparison, and reasoning. The coding was done at every 15-second interval across the 10-minute videotaped segment. A mark was placed in one box next to each verbalization statement category as it occurred. This coding of behaviors was done as the verbal statement was observed and was repeated when the verbal statement observed again (see Appendix B).

*The Preschool Classroom Teacher Interview Form* was designed to collect demographic information from the teachers, and to record their perspectives about science teaching in their classroom settings (see Appendix C). Specific questions regarding the experimental science activity provided by the researcher on the second day of observation were asked. The teachers were also asked to rank their preferences for subject areas, using a list of seven categories: language and literacy; mathematics; science; health, safety, and nutrition; social studies; aesthetic expression (art, music, drama, and movement); and gross motor and outdoors. The interview required about 15 minutes on the second day of the videotaping and the interviews were audiotaped.

*Procedure*

A pilot study was conducted with two multiage preschool head teachers in a Midwestern university based laboratory school. The pilot study videotapes were used later for interobserver agreement training prior to beginning the actual coding of the participants' videotapes.

The directors in Midwestern child care centers were contacted by telephone to seek their approval for the participation of their center in this study and to schedule an information meeting with the director and one or two teachers of 3 to 5-year-old preschoolers. All the teachers in the study were nominated for participation by the director of their respective centers. The teachers needed to have worked in the center for at least one year. Following verbal consent from the directors, information about the study and the letter of consent were distributed to each director and head teacher. In addition, written consent was obtained from the classroom teacher assistant and the parents since it was likely that the assistant teachers and preschoolers would inadvertently be included on the videotape. Each teacher was videotaped for 60 minutes for two consecutive days during morning free play time. The videotape time was slightly different between 8 to 10 o'clock depends on each classroom's free play time schedule. Day 1 of videotaping began when at least half the children were present. The teacher engaged in her typical class routine and interactions with children. Day 2 followed the same procedure except that the teacher was asked to implement a pre-planned science activity that was provided by the researcher. The pre-planned science activity involved making green play dough without green food coloring. The purposes of using the pre-planned science activity were to investigate preschool teachers' verbal interactions with children, especially science-related questions. This activity was selected because it was a familiar activity involving scientific skills, such as measuring, counting, experimenting, and predicting. Following the activity, the teachers were interviewed for about 15 minutes to gather demographic information and their views of science for preschoolers in group settings.

*Data Analysis*

The data analysis including establishing interobserver reliability and interobserver reliability of videotapes, and analyzing interview questions. Interobserever reliability was established independently by the researcher and a graduate student specializing in Child Development. To establish interobserver reliability, the graduate student was trained in coding the data using videotapes from the pilot study. During the training phase, the interobsrever reliability was 86% for the Preschool Teacher Classroom measurement and 95% for the Preschool Teacher Sciencing measurement. The interobser reliability was 84.94% (verbal statement) and 95.32% (question) for the first day Preschool Teacher Verbal Interaction measurement. The interobsrever reliability for the second day of Preschool Teacher Verbal Interaction measurement was 81.25% (statement) and 92.50% (question). During the coder training phase, discrepancies in coding were discussed and solutions were mutually agreed upon. Interobserver reliability was 95.83% for the Preschool Teacher Classroom Coding and 100% for the Preschool Teacher Sciencing

Coding. The Interobserver reliability was 97.81% (verbal statement) and 99.6% (question) for the Preschool Teacher Verbal Interaction measurement. The entire interviews were transcribed. There were minor differences in the interview transcriptions between the researcher and the other coder, such as in the use of prepositions, definite articles, and interjections. After the interview was transcribed, the researcher and the other coder searched for similar patterns and phrases to conclude the results.

## Results

Finding 1: Preschool teachers used more praise statements, cknowledgement statements, and closed questions during free play on Day 1, and on Day 2 during formal science activity preschool teachers used more learning guidance statements, information talk statements, and attention-focusing questions.

The most frequent teachers' verbal interaction for Day 1 and Day 2 combined involved giving learning guidance (M = 2.07) followed by information talk (M= .92); they used more verbal statements than questioning statements (see Table 3). Some of the examples of statements in providing learning guidance were, "You need to stop and listen." "You need to think about your choices." "Now what we need to do is to put food coloring, water, and oil." "Now we need to figure out how to make green play dough." "You can come over here and pour it in." "We are going to make play dough today." "We need 3 cups of flour." "It's your turn, Sally." The examples of information talk were "We don't want to put our finger in because it will make our finger red." "This is a measuring cup. These are also called measuring cups." "This is 1/3 cup so we put 2 of them in it; then, it makes 2/3 cups." "You put your hands like this, and this is called kneading." "We always need a recipe to tell us what to put in." The two most frequent questioning statements comprised closed questions (M = .88) and problem-posing questions (M = .34). The closed questions teachers used, for instance, were "Do you want to start with the snack?" "Are you going to swim?" "Do you want to make a picture?" "What color is our salt?" "Do I have green food coloring?" "Do you get your turn yet?" "Does everyone agree that is green?" The problem-posing questions teachers used were, for instance, "What do you think?" "What are you going to make?" "We don't have green food coloring, so what should we do?" "What should we do so we can make sure we have three cups of flour here?" "What do you think we need more of, Molly?" "What else do you think we need more of?" Teachers seldom used follow-up statements, action questions, comparison questions, and reasoning questions.

Analysis of teachers' verbal interactions showed significant differences ($p < .05$) between teachers' verbal statements during free play on Day 1 and the formal science activity on Day 2. Teachers used more praise statements and acknowledgement statements during free play on Day 1 and used more learning guidance statements and information talk statements during formal science activity on Day 2.

Table III
*Frequency of teacher verbal interactions*

| | Day 1 & Day 2 Combined | Day 1 | Day 2 | | |
|---|---|---|---|---|---|
| | *M* | *M* | *M* | *F* | *P* |
| Verbal statement | | | | | |
| Learning guidance | 2.07 | 1.48 | 2.66 | 101.971 | <.001** |
| Information talk | 0.92 | 0.84 | 1.00 | 4.816 | .028* |
| Praise | 0.28 | 0.35 | 0.21 | 10.274 | .001* |
| Acknowledge | 0.58 | 0.66 | 0.50 | 10.000 | .002* |
| Follow-up | 0.06 | 0.07 | 0.05 | .550 | .459 |
| Other statement | 0.39 | 0.04 | 0.33 | 3.389 | .066 |
| Questioning | | | | | |
| Closed | 1.00 | 1.11 | 0.88 | 9.019 | .003**. |
| Attention-focusing | 0.10 | 0.05 | 0.15 | 11.416 | .001** |
| Action | 0.02 | 0.02 | 0.02 | .044 | .834 |
| Problem-posing | 0.36 | 0.37 | 0.34 | .377 | .539 |
| Measuring & counting | 0.07 | 0.05 | 0.08 | 1.786 | .182 |
| Comparison | 0.03 | 0.03 | 0.03 | .000 | 1.000 |
| Reasoning | 0.03 | 0.04 | 0.02 | 3.750 | .053 |
| Other question | 0.01 | 0.01 | 0.02 | .828 | .363 |

In addition, the findings indicated significant differences ($p< .05$) for teacher questioning statements. Teachers used more closed questions during free play on Day 1 and more attention-focusing questions during formal science activity on Day 2.

Finding 2: Preschool teachers used more measuring and counting questions in the block and manipulative areas.

There were significant differences ($p < .05$) for teachers' use of science-related questions among classroom areas. Teachers used more measuring and counting questions in the block and manipulative areas, where these activities are most likely occur and more reasoning questions in the dramatic play area (see Figure 1). The study found that teachers tended to interact with students most often in the art area (24.8%), and the sensory area (19.3%). They interacted least often in the science area (.3%).

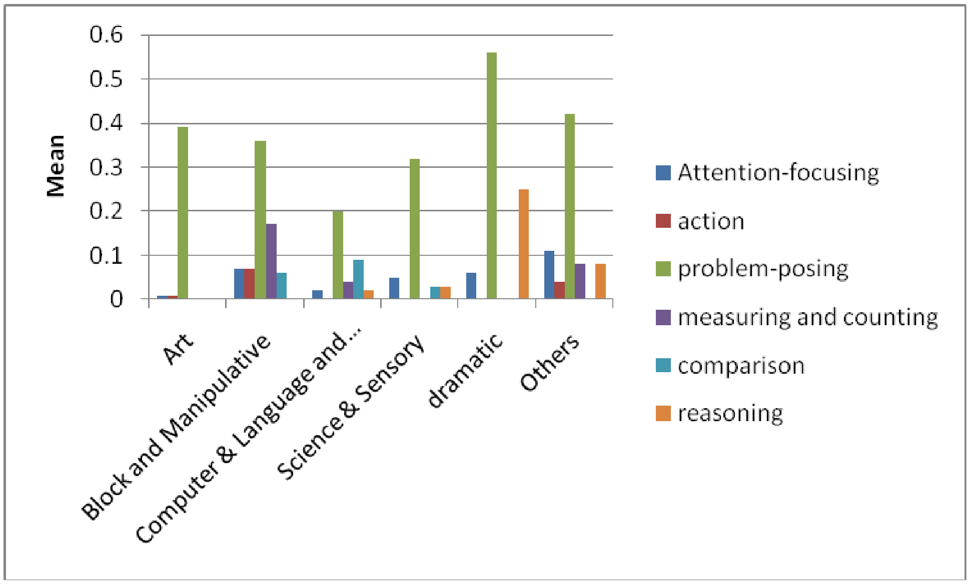


*Figure 1.* Differences in classroom areas on science-related questions

The study also investigated the science activities available to the children during morning free play time. The findings indicated that teachers spent most of their time engaged in activities not related to science (86.8%). Only 4.5% of the activities were related to formal sciencing. A total of 8.8% of the activities were related to informal sciencing, such as using sand box or a water table. No activities involved open-ended incidental science activities.

Finding 3: After providing pre-planned science activity to preschool teachers on Day 2, their perspectives about science teaching were of three specific kinds. They believed that science must offer opportunities in which children a) can be involved, b) can see what is going on, or c) predict what is going to happen.

The teachers were interviewed individually following Day 2 of videotaping. Examples of their responses included that:

- "Science for young children definitely has to be hands-on activity."
- "Science for young children probably is exploring and using their five senses."
- "Science is experimenting and asking questions. The goal is to predict outcomes and to see what happens if."
- "Science is a lot of exploring, experimenting, thinking, and discussion."

For the pre-planned science activities on Day 2, many teachers reported they were anxious about the science activity the researcher would provide, yet the planned experience with play dough was unexpected. For instance, on teacher stated, "I was surprised that it was a simple activity." Many teachers mentioned that they had previously prepared play dough, usually without children's help. One teacher reported, "Since I was familiar with making play dough, it made it easier for me to take that and try to do more experiments." Similarly, another teacher stated, "I knew how to make play dough, so I could really focus on what the children's questions were rather than looking back to the recipe and making sure I was doing it right." Participants did not elaborate on their lack of confidence in having a science experience chosen for them. And yet they seemed to agree that simple, familiar activities could have merit due to the opportunities for scientific exploration embedded within them.

The teachers evaluated the play dough activity as an age-appropriate and hands-on activity because the children were actively involved in mixing, touching, sharing, turn-taking, practicing problem-solving skills (i.e., which colors make green), and feeling proud about the completed play dough. When asked what they might do differently the next time, the teachers reported that they would have only a small group of children involved; and they might choose a different color, add flavor, or use pictures instead of words for the recipe. Some teachers reported that they did more science activities with the children than they had previously realized.

The teachers were asked to rank their preferences for subject areas, and the activity teachers most preferred to teach was Language and Literacy (45%), Aesthetic Expression (20%), Health, Safety, and Nutrition (10%), Gross Motor and Outdoors (10%), Science (5%), and Social Studies (5%).

## Discussion

### *Quality of Preschool Teachers' Verbal Interactions*

The study examined the types of preschool teacher-child verbal interactions in the classrooms during morning free play time. The findings indicated that the most frequent teacher-child verbal interaction was involved learning guidance. This finding was consistent with the study by Kontos and Dunn (1993) that the most frequent preschool teacher─child verbal interaction was providing positive guidance and few questioning statements. The present study shows that pre-planned formal science activity, by its very nature, was involved more learning guidance, information talk, acknowledge statements, and more attention-focusing questions, as observed on Day 2.

The findings also showed that teachers tended to interact most often in the art area. Preschool teachers used more measuring and counting questions when they were in the block and manipulative areas, where are relatively similar classroom areas. The present study also revealed that preschool teachers asked more reasoning questions in the dramatic play area, where children engaged in creative activity, allowing them "to hone their developing representational abilities through pretend actions and role enactments" (Kontos & Wilcox-Herzog, 1997, p. 251). Also, in the block area teachers might ask, "How many blocks will it take to build a tower?" to encourage children to use their estimation skills. Similar manipulative activities (e.g., stringing beads) could not only provide learning opportunities for measuring, counting, and pattern skills but also enhance a child's eye–hand coordination skills. Preschool teachers, therefore, tended to engage in more measuring and counting questions while interacting with children in the block and manipulative areas than in other areas. In the present study, the children did not sustain dramatic play when the teacher was uninvolved. This finding suggests that teachers' involvement and familiarity with the activity are important factors in teacher–child verbal interactions.

### *Teachers' Views of Science Activities for Young Children*

The findings of the teacher interviews were consistent with Tu (1997) that preschool teachers prefer language and literacy activities. The preschool teachers agreed on the importance of science and provided definitions involving hands-on experiences and the five senses for free exploration, but only one teacher ranked science activity as her most preferred activity. The researcher of the study suggests that preschool teachers need to expand their knowledge of science in order to increase their familiarity and comfort level and to integrate science more rigorously into their classrooms.

The DAP guidelines indicate that teacher preparation programs must provide teachers with information on how to construct appropriate curriculum for preschoolers. Therefore, preschool teacher preparation institutions need to make sure their early childhood education curriculum helps future preschool teachers be more knowledgeable, familiar, or even confident in teaching all subject areas, especially science. Also, it's helpful for preschooler teachers to know how to use community resources. For instance, the public library can help teachers find exactly the right books or teaching resources; the Public Health Service is a good resource to get health and nutrition aids; and farm organizations are helpful in scheduling field trips and providing information about farm animals (Holt, 1989). In addition, consulting with other teachers and children's family members and attending workshops or conferences are beneficial as a source of knowledge, artifacts, and expertise.

## Conclusion

This study videotaped preschool teachers during morning free play time. To understand what part of the day teachers use more science-related questions and whether teachers change their verbal interactions with children throughout the school day, future studies need to videotape the entire preschool day. Future researchers also might ask preschool teachers to create their own science lesson as the basis for empirical study. This would permit them to think through their questions and procedures that would enhance children's scientific thinking.

Even though this study had some limitations, it provided empirical evidence of preschool teachers' verbal interactions with children during morning free play time with and without a formal science activity. The research findings suggest that teachers need to engage in science-related questions with children in all classroom areas. The science-related questions are very similar to Eltgeest's (1985) productive questions, such as attention-focusing, action, problem-posing, measuring and counting, comparing, and reasoning questions. By offering more science activities, teachers would increase the use of verbal interactions and science-related questions with children. Through operationalizing Neuman's (1972) concept of sciencing, the researcher of this study suggests that teachers need to plan formal sciencing activities, introduce informal science experiences in daily routines, and use teachable moments that promote incidental sciencing activities. Along with this improved specialized knowledge, teachers must shift from sharing knowledge to co-constructing understanding with learners. As Hill, Stremmel, and Fu (2005) advocate that teachers are researchers, so it is acceptable for teachers to say "I don't know, why don't we find out together". This study suggests that to improve science teaching in the preschool classrooms, teachers need to reflect more on their own practices and become aware of their verbal interactions with children, especially questioning statements.

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# Appendix A

## Preschool Teacher Classroom / Sciencing Coding Form

Teacher ID #_________

Coder Name _________

Classroom area

A= Art area

B = Block area

C = Computer area

M = Manipulative

S = Science

DR = Dramatic play area

LR = Language and reading area

SN = Sensory area

O = Other

Sciencing

F = Formal sciencing

IF = Informal sciencing

IN = Incidental sciencing

N = None of the above

| | 0:00-0:30 | 0:31-1:00 | 1:01-1:30 | 1:31-2:00 | 2:01-2:30 | 2:31-3:00 | 3:01-3:30 | 3:31-4:00 | 4:01-4:30 | 4:31-5:00 |
|---|---|---|---|---|---|---|---|---|---|---|
| Area | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O |
| Sciencing | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N |
| | 5:01-5:30 | 5:31-6:00 | 6:01-6:30 | 6:31-7:00 | 7:01-7:30 | 7:31-8:00 | 8:01-8:30 | 8:31-9:00 | 9:01-9:30 | 9:31-10:00 |
| Area | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O | A B C M S DR LR SN O |
| Sciencing | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N | F IF IN N |

Classroom area

| Code | Score | |
|---|---|---|
| | Frequency | % |
| A | | |
| B | | |
| C | | |
| M | | |
| S | | |
| DR | | |
| LR | | |
| SN | | |
| O | | |
| Number of Agreement | | |
| Number of Disagreement | | |
| Reliability (Pt-Pd) /Pt | | |

Sciencing

| Code | Score | |
|---|---|---|
| | Frequency | % |
| Formal | | |
| Informal | | |
| Incidental | | |
| None of the above | | |
| Number of Agreement | | |
| Number of Disagreement | | |
| Reliability<br>(Pt-Pd) / Pt | | |

Pt: the total number of agreement and disagreement

Pd: the number of observed disagreement

## Appendix B

## Preschool Teacher Verbal Interaction Coding Form

Teacher ID #_________

Coder Name _________

| | 0:00-0:15 | 0:16-0:30 | 0:31-0:45 | 0:46-1:00 | 1:01-1:15 | 1:16-1:30 | 1:31-1:45 | 1:46-2:00 | 2:01-2:15 | 2:16-2:30 | 2:31-2:45 | 2:46-3:00 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Statement | | | | | | | | | | | | | |
| Give learning guidance (G) | | | | | | | | | | | | | |
| Information talk (I) | | | | | | | | | | | | | |
| Praises (P) | | | | | | | | | | | | | |
| Acknowledges (A) | | | | | | | | | | | | | |
| Follow-up (F) | | | | | | | | | | | | | |
| Other (O) | | | | | | | | | | | | | |
| Question | | | | | | | | | | | | | |
| Closed (C) | | | | | | | | | | | | | |
| Attention-focusing (AT) | | | | | | | | | | | | | |
| Action (AC) | | | | | | | | | | | | | |
| Problem-posing (PP) | | | | | | | | | | | | | |
| Measuring and counting (MC) | | | | | | | | | | | | | |
| Comparison (CP) | | | | | | | | | | | | | |
| Reasoning (RS) | | | | | | | | | | | | | |
| Other (O) | | | | | | | | | | | | | |

| | 3:01-3:15 | 3:16-3:30 | 3:31-3:45 | 3:46-4:00 | 4:01-4:15 | 4:16-4:30 | 4:31-4:45 | 4:46-5:00 | 5:01-5:15 | 5:16-5:30 | 5:31-5:45 | 5:46-6:00 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Statement | | | | | | | | | | | | | |
| Give learning guidance (G) | | | | | | | | | | | | | |
| Information talk (I) | | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Praises (P) | | | | | | | | | | | | | |
| Acknowledges (A) | | | | | | | | | | | | | |
| Follow-up (F) | | | | | | | | | | | | | |
| Other (O) | | | | | | | | | | | | | |
| Question | | | | | | | | | | | | | |
| Closed (C) | | | | | | | | | | | | | |
| Attention-focusing (AT) | | | | | | | | | | | | | |
| Action (AC) | | | | | | | | | | | | | |
| Problem-posing (PP) | | | | | | | | | | | | | |
| Measuring and counting (MC) | | | | | | | | | | | | | |
| Comparison (CP) | | | | | | | | | | | | | |
| Reasoning (RS) | | | | | | | | | | | | | |
| Other (O) | | | | | | | | | | | | | |

# Preschool Teacher Verbal Interaction Coding Form

Teacher ID #_________

Coder Name _________

| | 6:01-6:15 | 6:16-6:30 | 6:31-6:45 | 6:46-7:00 | 7:01-7:15 | 7:16-7:30 | 7:31-7:45 | 7:46-8:00 | 8:01-8:15 | 8:16-8:30 | 8:31-8:45 | 8:46-9:00 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Statement | | | | | | | | | | | | | |
| Give learning guidance (G) | | | | | | | | | | | | | |
| Information talk (I) | | | | | | | | | | | | | |
| Praises (P) | | | | | | | | | | | | | |
| Acknowledges (A) | | | | | | | | | | | | | |
| Follow-up (F) | | | | | | | | | | | | | |
| Other (O) | | | | | | | | | | | | | |
| Question | | | | | | | | | | | | | |
| Closed (C) | | | | | | | | | | | | | |
| Attention-focusing (AT) | | | | | | | | | | | | | |
| Action (AC) | | | | | | | | | | | | | |
| Problem-posing (PP) | | | | | | | | | | | | | |
| Measuring and counting (MC) | | | | | | | | | | | | | |
| Comparison (CP) | | | | | | | | | | | | | |
| Reasoning (RS) | | | | | | | | | | | | | |
| Other (O) | | | | | | | | | | | | | |

| | 9:01-<br>9:15 | 9:16-<br>9:30 | 9:31-<br>9:45 | 9:46-<br>10:00 | Total |
|---|---|---|---|---|---|
| Statement | | | | | |
| Give learning guidance (G) | | | | | |
| Information talk (I) | | | | | |
| Praises (P) | | | | | |
| Acknowledges (A) | | | | | |
| Follow-up (F) | | | | | |
| Other (O) | | | | | |
| Question | | | | | |
| Closed (C) | | | | | |
| Attention-focusing (AT) | | | | | |
| Action (AC) | | | | | |
| Problem-posing (PP) | | | | | |
| Measuring and counting (MC) | | | | | |
| Comparison (CP) | | | | | |
| Reasoning (RS) | | | | | |
| Other (O) | | | | | |

Appendix C

Preschool Classroom Teacher Interview Form

ID # ______________

Name of the Program ______________

Name of the Classroom ______________

Date ______________

NAECP accredited Yes ______ No ______

-or-

In self-study Yes ______ No ______

Age group__________ Total number Boys_________ Girls________

---

Head teacher's sex: 1 = Female ______ 2 = Male_____

Highest level of educational completed:

1. High school diploma
2. CDA
3. Junior college or equivalent
4. B.A./B.S. degree
   (Specify major___________________)
5. M.A./M.S. or professional degree
   (Specify major_____________)
6. Other
   (Please specify major_____________)

Teacher licensure(s):

1. None
2. Elementary Ed (K-8 grades)

3. Prekindergarten/K
4. Early Childhood (birth-8 years)
5. Early Childhood special Ed (Birth-6 years)
6. Other

Racial/Ethnic identification:

1. White/Caucasian
2. Black/African-American
3. Hispanic/Latino
4. Asian or Pacific Islander
5. Native American/American Indian
6. Other (Specify)

Years of teaching experience completed (include this year):

| | 1 = Head Teacher (years) | 2 = Teacher Assistant (years) |
|---|---|---|
| Day care (Full day) | | |
| (a) Infant/toddler (birth-36 month) | | |
| (b) Preschool (36 month to kindergarten enrollment) | | |
| (c) Kindergarten | | |
| (d) School-age | | |
| 2. Preschool (1/2 day) | | |
| 3. Kindergarten (1/2 day) | | |
| Total numbers of years taught | | |

Interview questions:

1. How would you describe this day? (schedule, children behaviors, interactions)

2. Is this a typical day or are there parts of it that are different in some way? If it has been different, what aspects have been different?

3. What has been the best part of self-selection time today? (Children, curriculum, programming, learning)

4. What is your definition of science for young children?

5. Please describe today's science activities?

6. How would you evaluate today's science activity? (interest level, level of suitability for the children, familiarity)

7. What were your expectations today for the children and the prepared science activity?

8. What would you do differently next time that you use this specific science activity with the children?

9. Please rank the activities that you prefer to teach from most preferred to least preferred.
   (A) Language and literacy (B) Mathematics (C) Science (D) Health, safety, and nutrition (E) Social studies (F) Aesthetic expression (G) Gross motor and outdoors

10. Was the number of science activities today about the same as most days? More? Fewer?

11. Which of the activities available during self-selection time today was the most cognitively challenging for the children?

12. How many of the storybooks in your classroom today are related to science? Total? (Provide a specific number)

13. How many science resource books for children are in your classroom today? (Provide a specific number)