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TEACHING SCIENCE IN AN INQUIRY-BASED LEARNING ENVIRONMENT: WHAT IT MEANS FOR PRE-SERVICE ELEMENTARY SCIENCE TEACHERS

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ABSTRACT. This research examines Turkish pre-service elementary science teachers' understandings of teaching science in an inquiry-based learning environment. Thirty-five prospective teachers who attended to one of the big teacher training institutions in Istanbul participated in this study. Data were collected via course assignments and in-class activities in teaching science. These were pre- and post-philosophies of teaching science, Nature of Science Card Game and a discussion centered on an inquiry-based teaching scenario. Open-coding of data helped to note patterns to identify categories and form assertions. Inquiry-based learning environment changed participants' traditional views about not the nature of science but teaching science.

KEYWORDS. Teacher Education, Science Education, Teaching Science, Nature of Science, Scientific Inquiry.

INTRODUCTION

How teachers perceive teaching and learning and how they really teach are influenced with their understandings of the nature of science (Brickhouse, 1989). Specific instructional behaviors, activities and decisions implemented within the context of a lesson are the most important variables that influence students' understanding of the nature of science. Therefore, teachers need to have an adequate understanding of the nature of science. All reform movements in the United States emphasized that an understanding of the process and the nature of science, accompanied with the ability to do scientific inquiry, is a requirement for effective science teaching (AAAS, 1990). Duschl (1990) defines nature of science as two faced: products of science and processes of science. Products of science refer to knowledge claims generated throughout history, such as facts, principles, concepts, theories, and laws, whereas processes of science refer to the methods used to make these knowledge claims. Within this framework, scientific inquiry is one knowledge construction method (Duschl, 1990).

Being a knowledge construction and validation method, scientific inquiry is a connection between an individual's understandings of the nature of science and scientific literacy (Meichtry, 1993). According to Duschl (1990), when individuals understand the developmental nature of science, which suggests that scientific knowledge is never proven in an absolute and final sense and changes over time, it may be easier for them to accept reformulation of scientific

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ideas (as cited in Meichtry, 1993). Given this, scientific inquiry as a way of generating new knowledge claims may help individuals to reformulate these ideas.

When individuals reformulate their ideas via scientific inquiry, Driver suggests that they need to have an explicit understanding of the essential components of scientific inquiry which consist of the nature of scientific knowledge (as listed in Nature of Scientific Knowledge Scale-NSKS), the role of observation and experiment (science is empirically based and demands evidence), the nature of theory (theories are inventions of scientists which describe, explain and predict scientific phenomena), and the relationship between evidence and theory (if evidence conflicts with the theory, either evidence is ignored or theory is modified) (Driver, 1996).

Since the 1950's scientific inquiry has been recognized as an essential component of science education reform movements. Joseph Schwab, an educational theorist who played an important role in generating changes in curriculum reform movements, focused on the organized content of science and stressed the processes by which scientists generated scientific knowledge. He presented his ideas concerning the teaching of science as "enquiry" in 1961. Schwab argued that scientific knowledge should not be perceived as stable truths to be discovered and verified by many scientists. Therefore, science teaching in schools should focus on principles of enquiry -- That is, the conceptual structures of scientific knowledge are changeable and should be revised when sufficient evidence warrants reconsideration (DeBoer, 1991).

Scientific inquiry and its essential components are also recognized in current reform efforts. For example, current science education reform documents, such as, Project 2061 (1990) and National Science Education Standards- NSES (1996), place an emphasis on knowledge construction via scientific inquiry. According to recommendations for scientific literacy as described in Project 2061, a scientifically literate person must be able to think about physical matters of life in a way consistent with scientific inquiry. Project 2061 specifies features of scientific inquiry:

> Science explains and predicts. The duty of a scientist is to construct explanations of observations consistent with the currently accepted scientific theories that fit the observations and have predictive power on evidence. Scientists try to identify and avoid bias. Scientists must be aware of their biases. What kinds of evidence are necessary, and how this evidence is interpreted are influenced by biases like nationality, sex, ethnic origin, age, political convictions. Science is not authoritarian. There is no scientist who is empowered to make decisions for other scientists (American Association for the Advancement of Science, 1990, pp.3-8).

Similarly, NSES put great emphasis on scientific inquiry and its components with the following argument:

Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments (National Research Council, 1996, p.105). 5-8

Both NSES and Project 2061, state that scientific inquiry is central in understanding the nature of science and in better science learning. According to constructivist theory, (Glasersfeld, 1996) students learn best by being directly involved in their own learning. Teaching students the processes of science- including the abilities and understandings necessary to engage in scientific inquiry- enable them to construct their own knowledge (NSTA, 1997). These abilities and understandings also serve students by giving them the tools to acquire additional knowledge (NSTA, 1997). Given the emphasis placed on scientific inquiry in Project 2061 and NSES, there is a trend in science education to weigh the products and processes of science equally. Therefore, the role of scientific inquiry in generating knowledge claims and validating these claims is recognized. Therefore, elementary science teachers must understand how scientists think and behave, then, they must develop methods to communicate this understanding to students.

Being engaged in science teaching and learning requires individuals to be able to carry out research projects by asking questions, constructing hypothesis, predicting outcomes, designing experiments, analyzing data, and reaching conclusions. Scientific inquiry, which is addressed by the components mentioned above, must be well understood and implemented by elementary teachers. In other words, elementary teachers need to bring the attitude and the worldview of scientists into the classroom. Therefore, they need to have a basic understanding of philosophy of science. A basic science background, an ability to carry out the process of science and a basic understanding of philosophies of science help teachers teach science as a conceptually oriented hands-on / minds-on, problem solving, critical thinking activity which will promote science literacy among students (Matson & Parsons, 1998).

Consistent with what Brickhouse (1989) argued, this research is based on the assumption that elementary teachers' ideas about teaching and how students learn are influenced with their understanding of the nature of science.

Research Objectives

The purpose of this research was to examine Turkish pre-service elementary teachers' understandings of teaching science in an inquiry-based learning environment. The research also aimed to determine the influence of inquiry-based science teaching courses on participants' understandings of a) nature of science b) teachers' roles in inquiry-based learning environment c) students' roles in an inquiry-based learning environment.

Research Design

Qualitative Nature of the Study

The research was designed in a qualitative manner for several reasons. First, the nature of research questions pushes the researchers to focus on specific situations or people. It also requires the researcher to put emphasis on words rather than numbers. Maxwell (1996) emphasized that focusing on specific situations, putting emphasis on words rather than numbers, and being inductive are the strengths of qualitative method. Along with the purpose and focus of the study, these strengths made qualitative approach more appropriate than quantitative one for the study.

Second, pre-service elementary teachers' understandings of teaching science were the selected issue to be examined. Because of the lack of predetermined categories of analysis, the research is more in-depth, open and detailed. Data collected throughout the research shaped data analysis and the rest of the research. All these characteristics make qualitative approach more appropriate, because qualitative method permits the researchers to study selected issues in-depth and detail (Patton, 1990).

Third, this research does not predetermine pre-service elementary teachers' understandings of teaching science in inquiry-based learning environments. Qualitative method enables researchers to use open-ended questions, which permits the researcher to understand and capture the points of view of other people (Patton, 1990, p.24). There is no standardized measure to be used in data interpretation.

Theoretical framework: grounded theory

This study does not claim that data need to fit a previously known theory. The assertions are generated during data collection process with a constant comparison of data sources across participants so that they are grounded in researchers' and participants' empirical world. The way these assertions are generated is very consistent with the generation of grounded theory which is defined by Strauss and Corbin (1990) as an approach in which "the researcher attempts to derive a theory by using multiple stages of data collection and the refinement and interrelationship of categories of information" (Creswell, 1994, p.12). Grounded theory is generated not only from data but most hypotheses and concepts of the theory generated in relation to the data (Patton, 1990, p.67).

Patton (1990) argues that how one studies the world determines what one learns about the world. How the researcher interprets data is influenced by the theory used to explain the situation. In this study, contrary to existing theory, grounded theory is inductively developed. It is grounded in actual data (Maxwell, 1996, p.33). Therefore, the research design is informed by grounded theory. Thus, multiple data sources are first examined by paragraphs and concepts and categories emerged in each paragraph are listed. Then, across-participant comparisons are made within a data source. This procedure is replicated for each data source and the most frequently appearing concepts, categories and the links between them are summarized for multiple data sources. Comparison of multiple data sources with respect to a category illustrates change over time in participants' conceptions in different categories.

Methods

The research took place in spring 2001 semester, in a teacher training institution in Istanbul, Turkiye. Thirty five pre-service elementary teachers who attended to "teaching science" courses in Department of Elementary Education of the institution participated in this study. Course instructor was well informed about the inquiry-based teaching and learning. Therefore, she exemplified inquiry-based teaching in this course. The course was designed first to inform participants about how an inquiry-based learning and teaching environment looked like and, second, to influence their understandings of nature of science and teaching science. Therefore, the course designs would be counted as the cause of change over time. Data were collected through student-generated artifacts via class assignments, i.e., pre and post philosophy statements in which participants defined their understandings of nature of science, students' and teachers' roles in an inquiry-based learning environment and in-class activities, i.e., Nature of Science Card Game and reflection on a scenario which an inquiry-based learning and teaching environment was exemplified.

Pre-post philosophy Statements:

In pre-philosophy statements students were asked to identify, develop and reflect upon the aspects of science teaching and learning under the guidance of the following questions: 1. What is your past experience with learning science? Explain. 2.What is "science" for you? Is it different from other school subjects/disciplines? Why or why not? 3.How do children/people learn science? What kinds of things will you do in your classroom to assist students in becoming successful learners of science?

Post-philosophy Statements:

Similar to pre-philosophy statements, participants were asked to answer the following questions: 1.What is science?, Who does science? ,What does it mean to do science? Explain. 2. How do you plan to teach science for understanding in the elementary school? What key instructional features do you see as necessary for effective science teaching? Explain.

Nature of science Card Game:

It is the modified form of Cobern's card exchange which introduces teachers to the philosophy of science (Cobern, 1991, pp.45-47). The original Nature of Science Card Game constitutes over 200 cards containing 32 unique statements representing five categories: theoretical emphasis, empirical emphasis, antiscience view, scientism, and balanced view. The game starts with giving each participant randomly drawn six to eight cards. Participants evaluate the cards in terms of what they can most and least affirm. Then, they are given time to examine other participants' cards and making trades with the goal of trading the cards they like less for the ones they like more. In the second phase of the game, participants seek for someone with whom they can pair. They re-evaluate their cards and try to keep the one's they have relative agreement. Each member must contribute at least three cards, then, each pair hold eight cards and the remaining cards are discarded.

In the third phase of the game, participants repeat the phase two, except the pairs form quadruplets. Each foursome must hold eight cards with each pair contributing at least three cards. Then, they are asked to rank order their cards. If they wish they may discard the two bottom ranked cards. At the end, the groups are asked to write a paragraph on the nature of science based on this final set of cards. Then, they share their paragraphs with other groups.

These card statements were translated into Turkish by 3 experts whose second language is English and work in science education department at the same institution. Then other 2 experts at the same institution re-translated card statements from English to Turkish. After the researcher's final check on language, cards were used to obtain evidence about what participants know about scientific inquiry and nature of science.

Scenario to reflect:

Connecting Communities of Learners (CCL), an e-journal designed by the course instructor who is the researcher at the same time, is a class assignment used as data source to obtain evidence of what they know about scientific inquiry and how scientific inquiry might be used in an elementary science class as a way of teaching. Journal consists of Turkish version of a classroom vignette "Willie the Hamster" from National Science Education "Science as Inquiry" content standards:K-4 (NRC,1996, pp.124-125) translated by the researcher. An inquiry-based science lesson takes place in the vignette. The questions proceeding "Willie the Hamster" were used to understand the participants' perceptions about the most effective and problematic aspects of scientific inquiry approach displayed in vignette.

Data Analysis and Findings

Document analysis of the student-generated artifacts helped researchers to interpret the research findings. There were no standardized measures to be used in data interpretation. Data analyzed through open coding as defined in Strauss and Corbin (1990, p.62). First, participants' pre-philosophies were open-coded to determine the concepts and categories to be examined in the rest of data sources. Then, based on these categories the following initial assertions were made.

Assertion 1: Participants defined science as a static body of facts. The certainty of scientific knowledge cannot be discussed.

When asked to define science, participants placed heavy emphasis on science as a static body of facts. The following quote is representative of this perception.

"...science is physics, chemistry and biology. It requires asking questions **to find the truths** about the world. By asking questions and doing experiments to answer these questions we add new facts to science. The more we experiment the more we get the truths. Once we get the evidence, I mean, there comes no questions. **Nobody can question the evidence if it comes with the experiment and observation**..."

The above quote and underlined words display participant's limited understanding of the nature of scientific knowledge to one "right" answer to scientific questions. Competing scientific theories were not perceived in the way that they advance scientific knowledge. This view is consistent with the traditional model of the nature of science as described by Palmquist and Finley (1997, p.611). In this model, scientific knowledge corresponds directly to reality-absolute truth. Once it is proven, scientific knowledge is unchanging. Underlined words in the above quote exemplify this last statement of the traditional model.

Assertion 2: Participants perceived teachers' role as to transmit scientific knowledge to their students.

When asked to identify their experience with science participants perceived teachers as knowledge transmitters. Following quote illustrates this trend.

"...well, science is something we learn in schools. **What we need to learn depends on what our teachers would like to teach.** They know all scientific facts and laws and they make us know all of them. **For me, even if I listen to my teacher very carefully, it is always hard to learn science.** Whatever I learn depends on what my teacher knows best...".

Not surprisingly, consistent with perceiving science as a static body of facts, pre-service teachers entering perceptions about science teaching focused on learning the products of science from teacher. Number of research studies (Mellado, 1997; Nickels and Walter, 1998) display similar findings about pre-service teachers'. For example Nickels and Walter (1998) argue that pre-service teachers' naïve conceptions of learning and teaching science formed during their experiences as students. That is teaching science is to pass knowledge from teacher to students and learning is absorbing this knowledge.

Assertion 3: Participants perceived students' role, consistent with the teachers' role, as to receive scientific knowledge given them.

In their definitions of how people/children learn science and what does "doing science" mean, participants emphasized on traditional teaching environments in which teachers give the information and students receive whatever they were taught. They perceived students as passive knowledge receivers. This is exemplified in the following excerpt.

"...students need to be **actively engaged** in their learning. **The more they do experiments the more they absorb knowledge. Experimenting helps them retain more information.**"

This participant's understanding about how students learn heavily depends on student's active involvement Although almost all participants reported that students should be doing an activity in order to learn science, none of the participants emphasized what students should be thinking about when engaged in such an activity. They only mention physical engagement rather than being mentally engaged in an activity. Other science educators who worked with similar groups report that this "active engagement" is typical for pre-service teachers (Macaroglu, 1999). This point makes people think about naïve constructivist argument which says 'as long as children are active, then learning is going on'.

The initial assertions (1,2,3) explained above revealed that those participants' views of the nature of science, and teaching science were traditional as defined in Palmquist and Finley (1997).

During the semester, in-class activities, particularly, the Nature of Science Card Game, were used to collect more data about the assertions given above. Findings were consistent with the assertions.

With the purpose of determining change over time in participants' understandings of nature of science and teaching science, participants' pre and post philosophies were cross-compared. Then, based on these comparisons the following final assertions were generated.

Assertion 4: Inquiry-based science course did not make a significant contribution to participants' understandings of the nature of science. By the end of the semester, participants still believed that science was a static body of facts and certainty of scientific knowledge could not be discussed.

Participants continued to emphasize the factual nature of scientific knowledge throughout the research study. The following quote illustrates this point.

"...science is a means to explain and describe the phenomena observed in the natural world. **Concepts, theories and laws represent these explanations and descriptions.** Science is a process **in which knowledge is discovered,** explored and produced. It also involves experimentation to reach the scientific knowledge...".

This excerpt illustrates that participant perceives science as a process to find more truths or facts. Therefore, according to this participant, scientific knowledge expands with the proper use of scientific processes. Although issues related to nature of science were implicitly emphasized in the course, there was no impact on their perceptions of science. It might be argued that direct emphasis on nature of science may result with a change in their understanding.

Assertion 5: Inquiry-based science courses made a significant contribution to participants' understandings of teachers' role. By the end of semester, participants perceived that teachers' role was not to transmit the scientific knowledge but to prepare an inquiry-based learning environment in which students could inquire this knowledge.

It is important to recognize the change over time in their understandings of how teachers teach. Following quote explains how their perceptions of teachers' role have changed over time.

"…. teacher, I think, needs to facilitate. **I mean, not giving the knowledge but guiding to find the knowledge,** she can help her students. Nobody knows everything. It is not the teacher's role to know and teach. **Teacher's role is to facilitate the appropriate learning environment** in which students inquire the knowledge."

Change over time represented in the quote above might be explained by the course design. As the course instructor modelled a facilitating teacher, research participants might change their perceptions about teachers' role. This finding is consistent with what Tasar (2003) reported from Nott (1994). Nott asserts that "novice teachers teach in the same way they themselves were taught." Therefore, participants exited the course using the "teacher as facilitator" metaphor. Similar finding for pre-service elementary teachers cited in a research study (Macaroglu, 1999) argues that although pre-service teachers use the metaphor, participants were not able to elaborate how to facilitate learning.

Assertion 6: Inquiry-based science courses made a significant contribution to participants' understandings of students' role. By the end of the semester, participants perceived that students' role was not to receive scientific knowledge given them but to inquire this scientific knowledge.

Parallel to change in their perceptions about teachers' role how they perceive students' role has also changed over time. Last quote presented above also represents this change. Again this change about what students should be doing in class might also be explained by the course design. Last two assertions display that being exposed to an inquiry-based learning environment might change students' understandings about teaching and learning.

IMPLICATIONS

Findings of this research study support both Nott's assertion (as cited in Tasar, 2003) and Nickels and Walter (1998) argument about how novice and pre-service teachers were influenced with what they were taught. Assertions 5 and 6 reflect changes in participants' understandings about teachers' and students' role in class. This change over time can be explained by the course design. The course instructor modeled a teacher, facilitating an inquiry-based learning environment, and aimed to effect participants' images of "teacher". It seemed modeling worked for them. The instructor also tried to make participants realize the contemporary views about the nature of science implicitly. It seemed, this implicit try did not work well. Participants' resistance to change their understanding about scientific knowledge and the nature of science can be explained with their prior knowledge about scientific knowledge. As participants were used to learn with explicit instruction they did not get the instructor's implicit try. Findings of this research study inform science educators at two points:

- New programs in schools require applying constructivist approach to teaching and learning. Inquiry based learning environments seem to be the must of constructivism. To be able to teach constructively, pre-service teachers need to be engaged in this kind of environment when they were taught. Therefore; not only in science but also in all methods courses in teacher training institutions might be re-designed to model how a teacher becomes a facilitator.
- Explicitly emphasized contemporary views on nature of science will cause a change in pre-service teachers' understanding about the issue. Consistent with constructivist re-design in methods courses, course contents need to be re-evaluated. Nature of science need to be embedded in contents. Therefore, methods course instructors need to be well informed and equipped about the nature of science.

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