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EDITORIAL

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We would like to thank to the editorial board of EJMSTE for their voluntary support. Please do not hesitate to send us your valuable comments and suggestions. The journal will publish refereed papers, book reviews and information about conferences, and provide a platform for exchanging views related to educational research.

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EURASIA
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Welcome to the ***Eurasia Journal of Mathematics, Science and Technology Education***. We are happy to launch the first issue with the contribution of individuals from all around the world both as authors and reviewers. Both research and position papers, not excluding other forms of scholarly communication, are accepted for review. The long term mission of the EJMSTE is to continue to offer quality knowledge and research base to the education community and increased global availability of the articles published each issue. The editors and review board hope that you find the published articles academically and professionally valuable.

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PRESERVICE AND EXPERIENCED BIOLOGY TEACHERS' GLOBAL AND SPECIFIC SUBJECT MATTER STRUCTURES: IMPLICATIONS FOR CONCEPTIONS OF PEDAGOGICAL CONTENT KNOWLEDGE

Fouad Abd-El-Khalick

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ABSTRACT. This study aimed to describe preservice and experienced secondary biology teachers' global and specific subject matter structures (SMSs) and elucidate the relationship between these structures and teaching experience. Teachers' global and specific SMSs respectively designate their conceptions and/or organization of their disciplines and of specific topics within those disciplines. Two preservice and two experienced secondary biology teachers were chosen to participate in the study. Participants were administered two open-ended questionnaires and were individually interviewed to assess their conceptions of biology and photosynthesis. The data were qualitatively analyzed through several rounds of category generation, confirmation, and modification. Teachers' global SMSs fell on a continuum from poorly articulated to well integrated and thematically organized. Contrary to global SMSs, specific SMSs separated the participants into their preservice and experienced groups. Unlike their preservice counterparts, the experienced teachers did not emphasize the details of photosynthesis and viewed the process as part of larger biological processes and systems. Analyses indicated that teaching experience and attention to student needs explained these latter differences. The present results indicate that the role of teaching experience in developing teachers' pedagogical content knowledge (PCK) should be emphasized and incorporated into theorizing the construct of PCK.

KEYWORDS. Pedagogical Content Knowledge, Subject Matter Structures, Science Education, Teacher Education.

INTRODUCTION

Current efforts to reform teacher preparation programs continue to emphasize the centrality of teachers' knowledge of subject matter (e.g., National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Research Council, 2000). Renewed emphasis on teachers' subject matter knowledge had gained momentum in the 1980s through efforts that aimed to professionalize teacher education (e.g., Carnegie Forum, 1986; Holmes Group, 1986). During the latter period and on a conceptual level, Shulman (1986, 1987) attempted to accentuate the focus on the role of subject matter knowledge in teaching by

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advancing several categories of what he considered to be the knowledge base needed for teaching. Among these categories was pedagogical content knowledge (PCK), which he believed identify "the distinctive bodies of knowledge for teaching" (Shulman, 1987, p. 8). Shulman (1987) also presented a model of teaching centered about the process of pedagogical reasoning, which he believed guides teacher decisions and behaviors both prior to instruction and inside the classroom.

Since the introduction of this construct, many researchers have studied the PCK of teachers, including science teachers (e.g., Clermont, Borko, & Krajcik, 1994; de Jong, van Driel, & Verloop, 2005; Geddis, Onslow, Beynon, & Oesch, 1993; Hashweh, 1987; Smith & Neale, 1989; van Driel, de Jong, & Verloop, 2002). Researchers have focused on various aspects of Shulman's PCK and/or model of teaching. Several of these research efforts, however, were based on some assumptions, such as that PCK is a separate domain of knowledge and that teachers' knowledge of subject matter directly translates into their teaching practices. These assumptions have been challenged by empirical research (e.g., Gess-Newsome, 1999; Gess-Newsome & Lederman, 1993, 1995; Lederman, Gess-Newsome, & Latz, 1994). Recently, more work has been directed toward re-conceptualizing the originally vague construct of PCK (e.g., Bromme, 1995; Gess-Newsome, 1999; Mulhall, Berry, & Loughran, 2003; van Driel, Verloop, & de Vos, 1998) and empirical research has, to some extent, taken these assumptions into consideration albeit indirectly (e.g., de Jong et al., 2005). Still, such assumptions linger on and before proceeding to discuss them, a brief description of Shulman's knowledge base, PCK, and teaching model is presented.

The Knowledge Base for Teaching

Shulman and his colleagues (e.g., Grossman, Wilson, & Shulman, 1989; Shulman, 1986, 1987; Wilson, Shulman, & Richert, 1987) enumerated several categories of the professional knowledge base needed for teaching. Their categories included content knowledge; general pedagogical knowledge; curricular knowledge; knowledge of learners (their characteristics, cognition, motivation, and development); knowledge of educational contexts; knowledge of educational aims, goals, and purposes; and PCK.

Shulman (1987) noted that the "key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy" (p. 15). Content knowledge was defined as knowledge of the substantive and syntactic structures of a discipline. Substantive knowledge refers to knowledge of the global structures or principles of conceptual organization of a discipline. It includes knowledge of facts, concepts, and principles within a content area and knowledge of the relationships among these foundational ideas (Wilson et al., 1987). Syntactic knowledge, on the other hand, refers to knowledge of the principles of inquiry and values inherent to the field, and of the methods with which new ideas are added and deficient ones are replaced by those who produce knowledge in that field. Under general pedagogical knowledge, Shulman and his colleagues included knowledge of the theories and principles of teaching, and strategies of classroom management and organization that transcend subject matter. Curricular knowledge was defined as knowledge of the "programs designed for the teaching of particular subjects" (Shulman, 1986, p. 10) and knowledge of alternative curriculum materials. This knowledge also included lateral curricular knowledge (knowledge of the various subjects being taught within a certain grade level in a given year) and vertical curricular knowledge (knowledge of what has been and what will be taught in the same subject in earlier and following years). It should be noted that the way these categories interrelate was, however, not explicated. In fact, Shulman and colleagues noted that "how these kinds of knowledge relate to one another remains a mystery to us . . . they are just [terms] floating on a page" (Wilson et al., 1987, p. 118).

Pedagogical Content Knowledge

Of all the categories of the knowledge base for teaching advanced by Shulman, PCK was the one that gained the greatest attention from researchers. PCK was defined as the "special amalgam . . . [or] the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). PCK was presented as a separate domain, "a new type of subject matter knowledge" (Wilson et al., 1987, p. 114). Nevertheless, the above definition seems to be more consistent with the contention that PCK lies at the intersection of content and pedagogy as it is used in teaching, rather than it being a separate domain of knowledge. Under PCK, Shulman included "the most regularly taught topics in one's subject area" and the alternative and useful ways of representing those topics to make them understandable to students. These alternative representations include "analogies, illustrations, examples, explanations, and demonstrations" (Shulman, 1986, p. 9). Also included under PCK was knowledge of students' misconceptions about the topics most commonly taught and the "instructional conditions necessary to overcome and transform those initial conceptions" (Shulman, 1986, p. 10).

However, Shulman and his colleagues noted that PCK is not limited to a representational repertoire of the subject matter to be taught. It rather is characterized by a way of thinking that allows teachers to transform their subject matter knowledge into forms that students can understand. This way of thinking was labeled "pedagogical reasoning" (Wilson et al., 1987, p. 118) and was presented as central to Shulman's (1987) model of teaching.

Shulman's Model of Teaching

Shulman (1987) presented a model of pedagogical reasoning and action that he considered necessary if teachers were to transform their personal understandings of subject matter into forms that are comprehensible to students. The process of pedagogical reasoning and action features six aspects of teaching: comprehension, transformation, instruction, evaluation, reflection, and new comprehension. Teaching begins by comprehension. Teachers should first understand the subject matter for themselves and should understand it in several ways. They should understand how the ideas within their discipline are inter-related and connected (substantive knowledge). Teachers should comprehend what is to be taught, and how to teach it. Comprehension also comprises an understanding of the aims and purposes of teaching. Transformation follows comprehension. Teachers should be able to transform their understanding of the subject matter into forms that are attainable by the students and that are simultaneously "pedagogically powerful" (Shulman, 1987, p. 15). This will allow students to grasp an undistorted and non-isolated portion of the subject matter being taught. Shulman (1987) noted that at least two aspects of transformation are directly related to content knowledge. Preparation or interpretation of the ideas to be delivered, and the representation of these ideas. Preparation and representation are achieved by restructuring and segmenting the material, by "cloth[ing] it in activities and emotions, in metaphors and exercises, and in examples and demonstrations" that are suitable to the students' level (Shulman, 1987, p. 13). This movement from the teacher's personal comprehension to "preparing for the comprehension of [students] is the essence of the act of pedagogical reasoning" (Shulman, 1987, p. 16).

This process of pedagogical reasoning does not end when the act of teaching begins. It rather is integral to the whole process of teaching. After comprehension and transformation comes instruction, which includes the most important forms of pedagogy: classroom management and explanation. Evaluation follows instruction and requires a firm grasp of subject matter. The final step is reflection on all of the aforementioned activities. Shulman (1987) suggested that such reflection is not a disposition, nor is it a set of strategies. Content-specific analytical knowledge is needed to reflect on the teaching activities. This process ends by reaching a new comprehension: A new cycle of teaching then commences at a higher level of understanding and performance. It should be noted that central to all of the above actions, as Shulman (1987) contended, is content knowledge. It was thus assumed that a teacher's subject matter knowledge would directly translate into his/her classroom teaching practices.

Pedagogical Content Knowledge and the Axis of Experience

Attempts to articulate the construct of PCK and to explicate the relationship between the categories of the knowledge base of teaching were the focus of the 'knowledge growth in teaching' project spearheaded by Shulman. In that project teachers were followed from being "teacher education students to becoming neophyte teachers" (Shulman, 1987, p. 4). Moreover, case studies of experienced teachers were accumulated. This latter effort was undertaken with the intent of informing the articulation of the knowledge base of teaching and the sources of that knowledge. In describing one veteran teacher, the subject of one of the case studies, Shulman (1987) noted that she "seemed to posses a mental index for [the] books that she taught so often . . . . Her combination of subject-matter understanding and pedagogical skill was quite dazzling" (Shulman, 1987, p. 2). Such a statement, among others, makes clear the impact that observing experienced teachers has had on shaping the concept of PCK. Furthermore, experience seems to play a major role in developing a teachers' PCK. Wilson et al. (1987) noted that PCK "emerges and grows as teachers transform their content knowledge for the purpose of teaching" (p. 118). As novice teachers plan their lessons, teach, adapt instruction to meet student needs, and reflect on their classroom experience, they seem to develop "a new type of subject matter knowledge, . . . pedagogical content knowledge" (Wilson et al., 1987, p. 114). Shulman and his colleagues, however, did not explicitly explain the role of experience in developing a teachers' PCK.

Before taking this argument further, it is important to emphasize the distinction between teaching experience and teaching expertise. The years of teaching experience are not necessarily a good measure of teaching expertise. Gess-Newsome and Lederman (1995), as a result of their study of experienced science teachers, concluded that the kind and quality of experiences in which teachers are involved, and the opportunities and disposition they have to reflect on their content knowledge during their careers affect their conceptions of subject matter more than the number of years they have taught. This contention is supported by other research studies. For instance, in their study of novice and experienced science teachers, Hoz, Tomer, and Tamir (1990) reported that teachers' subject matter and pedagogical knowledge did not improve with their years of teaching experience.

The above distinction, however, was not overlooked by Shulman. His model of teaching emphasized the importance of the quality of the teaching experiences in developing teachers' PCK. PCK develops as teachers comprehend and transform their subject matter knowledge for the purpose of teaching, and then as they evaluate and reflect on their teaching. In other words, active and reflective teachers develop PCK as they experience teaching their content area firsthand. This is the case, of course, if those teachers have a good grasp of their content knowledge. This point was clearly emphasized. But Shulman and colleagues did not make the point that teaching experience plays a major role in the development of PCK.

Many researchers agree that the construct of PCK as presented by Shulman (1986, 1987) and later articulated by his colleagues (e.g., Grossman et al., 1989; Wilson et al., 1987) was, at best, vaguely defined and lacking at the theoretical level (Bromme, 1995). In an attempt to address some of these concerns, Gess-Newsome (1999) advanced two different models to theorize PCK. The first is integrative and suggests that PCK results from the interaction between subject matter knowledge, and knowledge of context and pedagogy. This first model, it could be argued, is somewhat lacking in terms of explanatory power because it does not articulate a mechanism for how such interaction leads to the development of PCK. The second model is transformative and explicitly introduces the axis of experiences into conceptualizing PCK. Gess-Newsome suggested that PCK develops as knowledge of subject matter, context, and pedagogy are assimilated as a result of teaching experience. Empirical evidence in support of one or the other model remains to be presented.

Nevertheless, if teaching experience proves to be significant in the development of PCK, then questions about the implications that this added axis of experience would have for conceptions of PCK and its usefulness in preparing teachers gain special significance. It can be argued that a first implication is that PCK would seem less likely to be a separate domain of knowledge. This is in line with some empirical evidence (e.g., Gess-Newsome & Lederman, 1993; Lederman et al., 1994). Content knowledge and pedagogical knowledge appear to be prerequisites to PCK: PCK appears to be what distills of a teacher's content and pedagogical knowledge as these are utilized to plan, deliver, reflect on, and adapt instruction. A second implication has to do with the role Shulman (1987) ascribed to a case-study-of-exemplary-teachers approach to informing our knowledge of PCK. It would be difficult to assume that 'a PCK' for a certain content area, or for a specific topic within that content area for that matter, can be explicated. As teachers transform their content knowledge of a certain discipline (or of a specific topic within that discipline) for the purpose of teaching it in different contexts and for different goals and as they tailor that knowledge to meet the needs and abilities of various students, they are more likely to develop distinct PCKs (if the plural can be appropriately used here) rather than a single, manageable body of representational and instructional repertoires.

Moreover, even if it is manageable to collate such knowledge for a specific content area (or for a specific topic within that content area), the question to follow would be: Is it desirable, or even possible, to add another body of knowledge to the list of things student-teachers have to learn during their teacher preparation? But some may argue, as Wilson et al. (1987) would, that PCK is characterized by a way of thinking (pedagogical reasoning) rather than being a repertoire of representations. However, taking into account that pedagogical reasoning is directly related to a set of teaching acts (comprehension, transformation, instruction, etc.), the question to follow would be: Is it possible to provide student-teachers during teacher preparation programs with the experiences and opportunities that experienced teachers have had as a result of years of active, reflective teaching?

The implications presented above are not exhaustive, nor are they assertive in any respect. They are meant to be suggestive in nature; questions to be asked of the construct of PCK and its usefulness for the purpose of preparing teachers as the axis of experience is assumed to be integral to its development. Such questions become more urgent as more items are added to an already extensive list on the agendas of teacher education programs. Answering all of these questions is beyond the scope of this study, or any single study for that matter. However, preservice and experienced teachers' content knowledge and its relationship to their teaching and teaching experience remains a central issue to all that has been presented. As far as science teaching is concerned, preservice and experienced teachers' substantive knowledge of their disciplines and their knowledge of specific topics within those disciplines are intimately related and equally relevant both to early (e.g., Shulman, 1987) and more recent (e.g., Gess-Newsome, 1999) discussions of the categories of the knowledge base of teaching in general, and to the categories of content knowledge and PCK, in particular.

PURPOSE

The present study aimed to describe preservice and experienced secondary biology teachers' global and specific subject matter structures (SMSs) and elucidate the relationship between these structures and teaching experience. The guiding research questions were: How do the global and specific SMSs of preservice and experienced teachers look like? Are the global and specific SMSs of preservice and experienced teachers different? If yes, in what ways? If not, in what ways are they similar?

The study focused on preservice and experienced secondary biology teachers in an attempt to shed light, given the preceding arguments, on teachers' content knowledge and the role that reflective teaching experiences may play in developing teachers' PCK. For the purposes of the present study, science teachers' global SMSs designate their conceptions and/or organization of their discipline (Gess-Newsome & Lederman, 1993). On the other hand, teachers' specific SMSs are conceived of as their conceptions and/or organization of specific topics within their disciplines. To assess teachers' specific SMSs, their conceptions of the topic of photosynthesis was assessed. The choice of this topic was based on its centrality and importance to the discipline and on the fact that it is regularly taught in high school biology.

The present study gains significance in light of the fact that very few studies have simultaneously focused on preservice and experienced secondary science teachers' global and specific SMSs. For instance, Gess-Newsome and Lederman (1993), Lederman et al. (1994), and Lederman and Latz (1995) focused on preservice secondary science teachers' global SMSs. Gess-Newsome and Lederman (1995) studied experienced secondary science teachers' global SMSs. Lederman and his colleagues, however, have not focused on preservice or experienced teachers' specific SMSs. By comparison, de Jong et al. (2005) and van Driel et al. (2002) focused on preservice secondary chemistry teachers' knowledge of the particulate theory of matter but not on their global SMSs. Smith and Neale (1989) investigated teachers' specific SMSs of light and shadows as well as their PCK. Their study, however, focused on elementary teachers. Hashweh (1987) focused on experienced secondary science teachers' conceptions of their disciplines (biology and physics) and of specific topics within those (photosynthesis and levers). However, several criticisms of his approach of using card sort tasks to assess teachers' conceptions of subject matter have been advanced (see Gess-Newsome & Lederman, 1993). In particular, it was argued that card sort tasks restrict respondents' conceptions of their subject matter to a list of ideas pre-determined by the researcher. Moreover, Hoz et al. (1990) attempted to investigate the relationship between experienced science teachers' content knowledge and years of teaching experience. However, the same criticisms that were advanced in the case of Hashweh's study apply to this study in which structured concept mapping tasks were employed to assess teachers' content knowledge.

More importantly, seeking relationships between preservice and experienced science teachers' SMSs may shed some light on the implications and questions that were suggested with respect to emphasizing a role for teaching experience in the development of teachers' PCK. This investigation was undertaken with the hope of informing conceptions of the construct of PCK and its usefulness for the purposes of preparing science teachers.

METHOD

This study was qualitative and exploratory in nature. Open-ended questionnaires and semi-structured individual interviews served as instruments for data collection (Bogdan & Biklen, 1992).

Participants

Purposive sampling was used to identify two preservice and two experienced secondary biology teachers to participate in the study (Bogdan & Biklen, 1992). Sampling focused on creating the needed variance in terms of teaching experience and equivalence in terms of subject matter taught to answer the guiding research questions. The preservice teachers, Pam and Paula (all names are pseudonyms), were enrolled in the final semester of a fifth-year, Master of Arts in Teaching (MAT) program in a mid-size state university in the Northwestern United States. Pam, 26 years of age, holds a BS degree in microbiology and had completed two years of graduate coursework in molecular and cellular biology. For one term during her graduate work she was a teaching assistant in both undergraduate and graduate biology courses. She discontinued her graduate studies to pursue certification to teach secondary biology. Paula, also 26 years old, holds a BS degree in zoology. She joined the teacher education program two years after her graduation. During those two years she worked in a non-educational establishment.

The two experienced biology teachers, Eric and Ellen, teach in a mid-size high school in a small rural region in the same state. Eric is 50 years old. He earned his BS degree (with special emphasis on marine biology and ecology) about 10 years before he went back to get his teacher certification. Between graduation and formal teaching he worked as a forest ranger, tree surgeon, farmer, and substitute teacher. He has taught high school biology (mainly botany) for 12 years. His knowledge of botany is primarily self-taught as his interest in this field came after formal college studies. Ellen is 34 years old. She holds a BS degree in general science with coursework in chemistry, microbiology, and geology. She also has completed about 70 graduate hours in marine biology, botany, and microbiology. She taught middle school biology and high school mathematics for one year after graduation, during which she completed coursework needed for certification. Since then she has taught high school biology for eight years.

Procedures and Instruments

Participants were first briefly interviewed to collect the demographic data necessary to develop a general profile for each. They were then individually administered two questionnaires consecutively: One to assess their global SMSs and the other their specific SMSs. The order of administering the two questionnaires was counterbalanced among the two groups of teachers. One preservice and one experienced teacher were randomly assigned to respond to the questionnaire on global SMS first, followed by that on specific SMS. This order was reversed for the other two participants. A few days after the administration of the questionnaires, the participants were clinically interviewed. They were asked to explain and clarify their responses to each questionnaire. Again, the order of discussing the questionnaires in the interview was counterbalanced. This was achieved by reversing the order of filling the questionnaires on the initial administration and discussing them in the interview for each participant. This counterbalancing was intended to assess the effect (if any) of the order of administering the questionnaires or discussing them in the interview.

The questionnaires. The open-ended questionnaire used by Gess-Newsome and Lederman (1993) and Lederman et al. (1994) was used to assess participants' global SMSs. A similar questionnaire was utilized to assess their specific SMSs. On the first questionnaire, participants were asked to respond to the following questions: (1) What topics make up your primary teaching content area (biology)? If you were to use these topics to diagram your content area, what would it look like? (2) Have you ever thought about your content area in the way you were asked to do above? The second questionnaire asked the participants to respond to the following questions: (1) What concepts and/or ideas make up photosynthesis? If you were to use these concepts and/or ideas to diagram photosynthesis, what would it look like? (2) Have you ever thought about photosynthesis in the way you were asked to do above?

As noted above, photosynthesis was chosen to assess participants' specific SMS because of its centrality to the discipline (its role in the transformation and flow of matter and energy, etc.) Moreover, photosynthesis is a regularly taught topic in high school biology. While experienced teachers are most likely to have taught photosynthesis, preservice teachers will most probably be asked to do so when they start teaching.

Participants were given up to 30 minutes to complete each questionnaire. Before responding to the questionnaires, the researcher explicitly informed participants that the terms 'topics' and 'concepts' should not be limiting in any respect. It was emphasized that they were free to use themes, procedures or any other context to represent their knowledge structures. Participants were also asked to use any form they wished to diagram these topics, themes, etc. No specific form like concept mapping or otherwise was suggested or required. Participants were overtly assured that they had the liberty to choose their own topics and or concepts and arrange them in which ever ways they deemed appropriate. This methodology was intended to provide as clear a portrait of participants' conceptions of biology and photosynthesis as possible. More importantly, this methodology was undertaken with the intent of ameliorating, though by no means completely eliminating, the problems associated with other approaches, like card sort and structured concept mapping tasks, that were employed by other researchers (e.g., Hashweh, 1987; Hoz et al., 1990). Such approaches were criticized for limiting the nature and form of the participants SMSs (Baxter & Lederman, 1999; Gess-Newsome & Lederman, 1993). The second item on the questionnaires was intended to assess whether the participants have had any previous opportunities in which they have thought about their content area or photosynthesis in the way required by the questionnaire.

Clinical Interviews. A few days after the initial administration of the questionnaires, the researcher individually interviewed each participant. The interview aimed to clarify participants' responses to the questionnaires and was guided by a set of general questions. Participants were first provided their completed questionnaires, one at a time, and then were asked to respond to the following questions (Gess-Newsome & Lederman, 1993, pp. 29-30): (1) Describe what you have written/diagrammed in your questionnaire; (2) What did you mean by each of the topics (or themes, concepts, etc.) that you have chosen to include in your diagram? (3) Why did you select these topics (or themes, concepts, etc.)? (4) What do these lines (or arrows, etc.) between the topics (or themes, concepts, etc.) represent? (5) You indicated that you have (have not) thought about your content area (or photosynthesis) before in the way asked of you on the questionnaire. If you have, when and why? If you have not, why? Digressions in the interviews were common. Participants' lines of thought on relevant ideas were pursued. An interview was typically one hour long. All interviews were audio-taped and transcribed verbatim for analysis.

Some methodological qualifications are in order. Asking participants to construct diagrams served two major purposes. First, the diagramming activity partially addressed concerns associated with over-reliance on quick recall, which might compromise the validity of assessing teachers' SMS. Indeed, diagramming was intended to provide participants ample time to think about the topics that make up their discipline or topics within the discipline and then contemplate ways in which those topics were interrelated. Second, the diagram itself provided a meaningful context to discuss participants' ideas during individual interviews rather than asking participants to (a) come up with the topics they deem important, (b) think about ways in which these topics connect, and (c) explicate their thinking about these connections, all in the same interview. Thus, in a sense, the diagrams were more of a means to an end. It is true that participants' diagrammatic representations could shed some light on their SMS. However, these representations can only be meaningfully interpreted in light of participants' discussions of, and reflection on, the diagrams. For instance, as noted below, some participants generated seemingly complex and integrated representations, but were not able to meaningfully elucidate the connectedness and integration of their knowledge of the discipline or specific topics within the discipline.

Data Analysis

All data analyses were was conducted after data collection was concluded. This was intended to avoid limiting or directing data collection during the interviews in any fashion as a result of preliminary analysis of any questionnaire or another interview. The questionnaires and interview-transcripts were qualitatively analyzed. In this analysis, each participant was treated as a separate case. Data for each participant was searched for patterns or categories. The generated categories were checked against confirmatory or otherwise contradictory evidence in the data and were modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data (Auerbach & Silverstein, 2003). These categories were employed to describe each participants' global and specific SMSs. The categories and patterns were compared and contrasted within and across the two groups (preservice and experienced) and within and across the SMSs (global and specific). Relationships, patterns, similarities, and differences were sought.

RESULTS

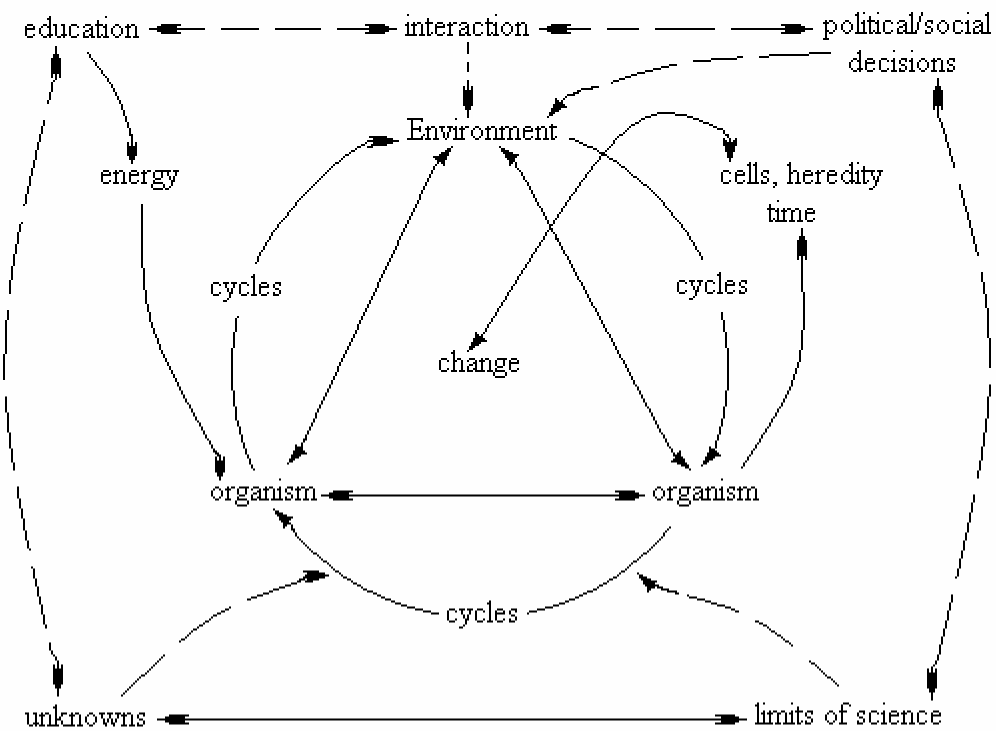
Participants' conceptions of biology and photosynthesis are presented in separate sections. Participants' views are elucidated, and differences and/or similarities between and among preservice and experienced teachers' conceptions, where evident, are also presented. Computer-generated replicas of participants' diagrams for global SMSs are also included (see Figures 1-4). The original format and substantive content (including spelling errors) of the diagrams were maintained.

Global SMSs: Conceptions of Biology

Conceptions of biology fell on a continuum with Paula's (preservice) and Eric's (experienced) on the two extremes. Structures provided by Pam and Ellen were in-between. On one end, Paula's views were ad hoc and represented isolated bits of information retained from some undergraduate biology courses. The structure provided by Pam was fluid and comprised a list of discrete college biology courses with related sub-topics arranged in a web-like format. Connections were, however, very few and themes were absent. Ellen presented a topical structure of biology that mirrored the linear organization of high school biology textbooks. Although Ellen claimed her views were connected, she was unable to elucidate interrelationships between the listed topics and concepts. On the other extreme, Eric's conceptions of biology were well integrated and organized about a few themes.

Eric. Two overriding themes characterized Eric's conceptions of biology: Interactions and nature of science (NOS). The theme of interaction was evident in Eric's diagram (see Figure 1) and was elaborated during the interview. He emphasized the interaction between organisms, the interaction of organisms with their environment, and the interaction of science and society. The latter interaction highlighted several aspects of NOS. Eric was the only participant who articulated a clear, themes-based conceptual framework with which he viewed biology and approached its teaching.

Figure 1. Eric's diagram for the structure of biology



In the center of his diagram, Eric represented the content he emphasized. Under cycles, he presented his students with the cycles of matter, and the life cycles of plants and insects. Eric aimed to familiarize students with the interdependence of organisms and their interactions with the environment. The choice of which organisms to present was driven by Eric's emphasis on interaction and student interest. Entomology figured prominently in his class as it offered students with opportunities to study interactions: Human interactions with insects which brought to light issues about health and disease, and insects interactions with crops which highlighted issues in plant management. Students' interest in entomology was also a major factor in stressing its study. In the school greenhouse, Eric and his students grew a lot of plants and conducted many experiments. Selling the grown plants also helped finance Eric's science class. Knowledge of how insects benefit or harm plants helped students to care of their plants.

The interaction between organisms and their environment was also explored at the microscopic and molecular levels. Students explored DNA, cells, heredity, and evolution (presented as "change over time"). Eric noted that the interaction between DNA and the environment (e.g., random mutations) is essential in shaping the development of species through evolutionary mechanisms like natural selection.

The interface between science and society was a major component of Eric's conceptions: The manner in which the content that students learn related to their everyday societal life and informed their interactions with the environment. Eric believed that science can inform students' decision making. It can help them make or support social and political decisions that are consistent with a healthier interaction with nature. Energy use was a case in point. Eric felt that students should understand that biological systems are driven by energy, that the available energy is finite, and that it can be appropriately used, misused or overused. Such an understanding, he continued, can help students make conscious, and more responsible decisions regarding energy expenditure as future citizens. Eric believed that although science can inform decision making in issues of social and political importance, it nevertheless does not provide definite, absolute answers. Factors other than scientific knowledge always play a role in such decision making. Policy makers may choose either to completely adopt what scientists say or to ignore it altogether depending on other economic and political factors. Eric thought that scientists themselves usually take different sides on the same issue depending on where they come from and what stakes they have in the issue debated.

Science as a way of knowing was another component in Eric's views. He aimed to convey an accurate image of science by emphasizing several aspects of NOS. He wanted his students to understand that science has limits, and that questions of great importance cannot be resolved through scientific investigations. Religious and philosophical issues, where people have different belief systems, served as examples. Moreover, science has a limited ability to explain and predict human experience and behavior. Eric also emphasized the tentative NOS by highlighting the role of models and unknowns. Science makes use of models which are not necessarily correct depictions of nature. And even though those models are functional, many unknowns, of which we are unaware, may be at work. As these unknowns become apparent, or as new models more consistent with the phenomena studied are devised, old conceptions are dropped and new ones are adopted. Eric also demonstrated understanding of the theory ladenness of observations when he noted that scientists might interpret the same data differently.

Ellen. Ellen emphasized that her views of biology and the way she teaches it were different. Student needs figured highly in this incongruity. She claimed to maintain an integrated view of the discipline. Her approach to biology, however, was linear and resembled the organizational structure of many high-school level biology textbooks. Her views, in general, lacked connectedness. It is noteworthy that Ellen did not diagram the concepts that she thought were important. She rather presented a topical list of those concepts (see Figure 2).

Figure 2. Ellen's response to the questionnaire on biology

The topics that make up my primary teaching content in biology include:

a. Ecosystems: specifically streams, forest, wetland.

b. Survey of Kingdoms and comparisons between organisms. As we survey kingdoms we look at:

populations
communities
adaptations
evolution
animal behavior
classification

c. Skills: microscope use, lab techniques, scientific writing.

d. Cells: within this unit we look at:

Cell structure and function
DNA / Protein synthesis
Genetics
Respiration / Photosynthesis

e. Entomology: Unit is designed to look at how insects impact humans and environment in a positive way. Also the unit ties in concepts learned through the year to a specific class of organisms.

If I were to use these topics to diagram my content area, my diagram would center around DNA as the main theme hoping the idea that living organisms are genetically related would be evident. I would include ecosystems as units coming from the DNA strand and show ecosystems as interrelated. In various ecosystems I would incorporate more specific topics. There are some topics that might not fit in this diagram . . . specifically the "skills" content. But, most content areas would fit this diagram.

2. I have though about the idea that most of the biological science concepts are taught are very interrelated, but I have not actually formed a mental picture or diagram of my content area as described above.

Similar to Eric's case, student needs were prominent in shaping Ellen's approach to the discipline: "I would like to teach biology on the basis that life is genetically related as far as we all contain DNA . . . [however] . . . this might not be the best way to teach it, so I don't teach it in this order . . . [because] . . . I don't think that students will understand." Once and again, Ellen emphasized that she wanted her students to know "that things are interrelated," and that DNA was the common factor. Students, she thought, lacked the prerequisite knowledge necessary to develop an understanding of this connectedness. When explicitly asked, however, she failed to elucidate ways in which DNA can be used to connect the topics and concepts on her list if her students had the prerequisite knowledge. She rather said that: "I think that we together will come up with something as a group . . . we come up with some sort of image rather than enforcing my image down their throats." And even though the question of how things were connected came up several times during the interview, Ellen did not provide an answer.

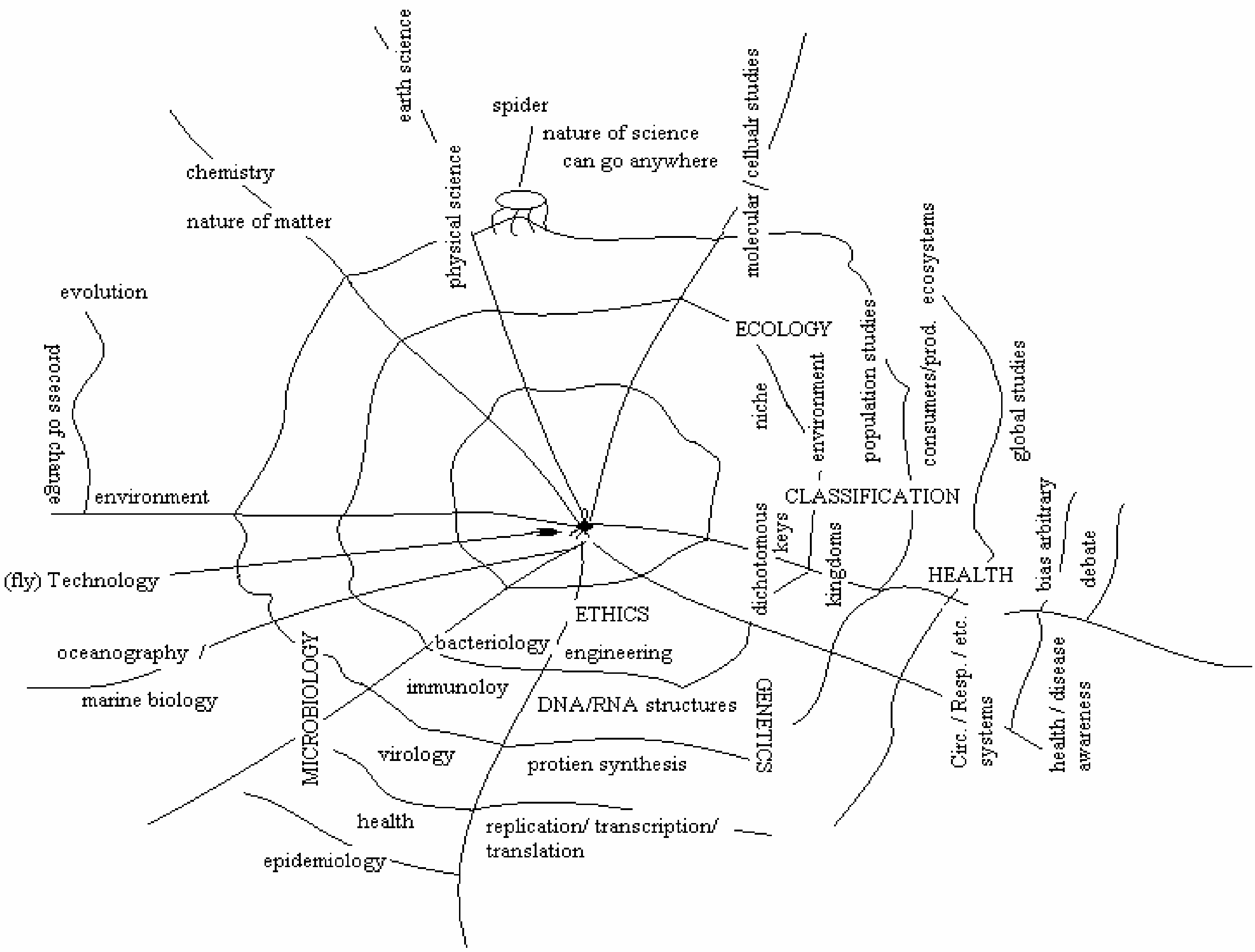
In her questionnaire, Ellen presented a topical view of biology. Her organization was consistent with the structure of many high school biology textbooks. Ellen noted that she would start with an overview of ecosystems, populations, and communities. A survey of the kingdoms followed. Again, the role of student needs was apparent. When asked about the concepts that she stressed when surveying the kingdoms, she, rather than answering the question, said they spent time covering organisms that students were not familiar with, since otherwise "they will be bored." After classification, the interaction of species within populations and communities, and the adaptation of organisms to their environments (evolution) are presented. Ellen would then move to the cellular level and then to ecosystems. The skills (e.g., lab skills, "scientific" writing) that she included are likewise usually presented in most biology textbooks.

It was evident that Ellen was only starting to articulate her conceptions of biology. She noted that she, after several years of teaching, started to look at things differently. She started to realize that topics in biology are interconnected, that themes are important, and that a sequential approach is not necessarily appropriate. However, her views in this regard were yet to be elaborated. Ellen noted that thinking of subject matter in this fashion is not possible in the early years of teaching where a teacher is usually overwhelmed with issues of classroom management: "When you first start teaching, you're busy just trying to keep order in the classroom. By the time you get to be, you know, to be in the classroom for five or six years then you start looking at things in a different way."

Ellen was not short on experience, she had been in classrooms for more than eight years. She, however, might not have had ample opportunities to reflect on her subject matter. And the opportunities she had were not consistent with developing an integrated view of biology. For instance, she noted that even though she thinks of biology thematically (not evident in the data), she had to write sequential curricular proposals (consistent with the data) because the latter were preferred by school boards.

Pam. Pam noted that she attempted to construct a diagram of biology in a course in her MAT program. She claimed to maintain an interconnected view of biology. She correspondingly used a spider web to represent this view (see Figure 3). Pam's conceptions of biology were, however, not integrated. Her lack of a conceptual, organizing framework of the discipline was evident when she was asked to explain how the topics on her web were connected. She answered, "I have a hard time with this because there is a lot of overlap . . . it is hard to represent [these relationships] in two dimensional. It is three dimensional because there is too much overlap."

Figure 3. Pam's diagram for the structure of biology



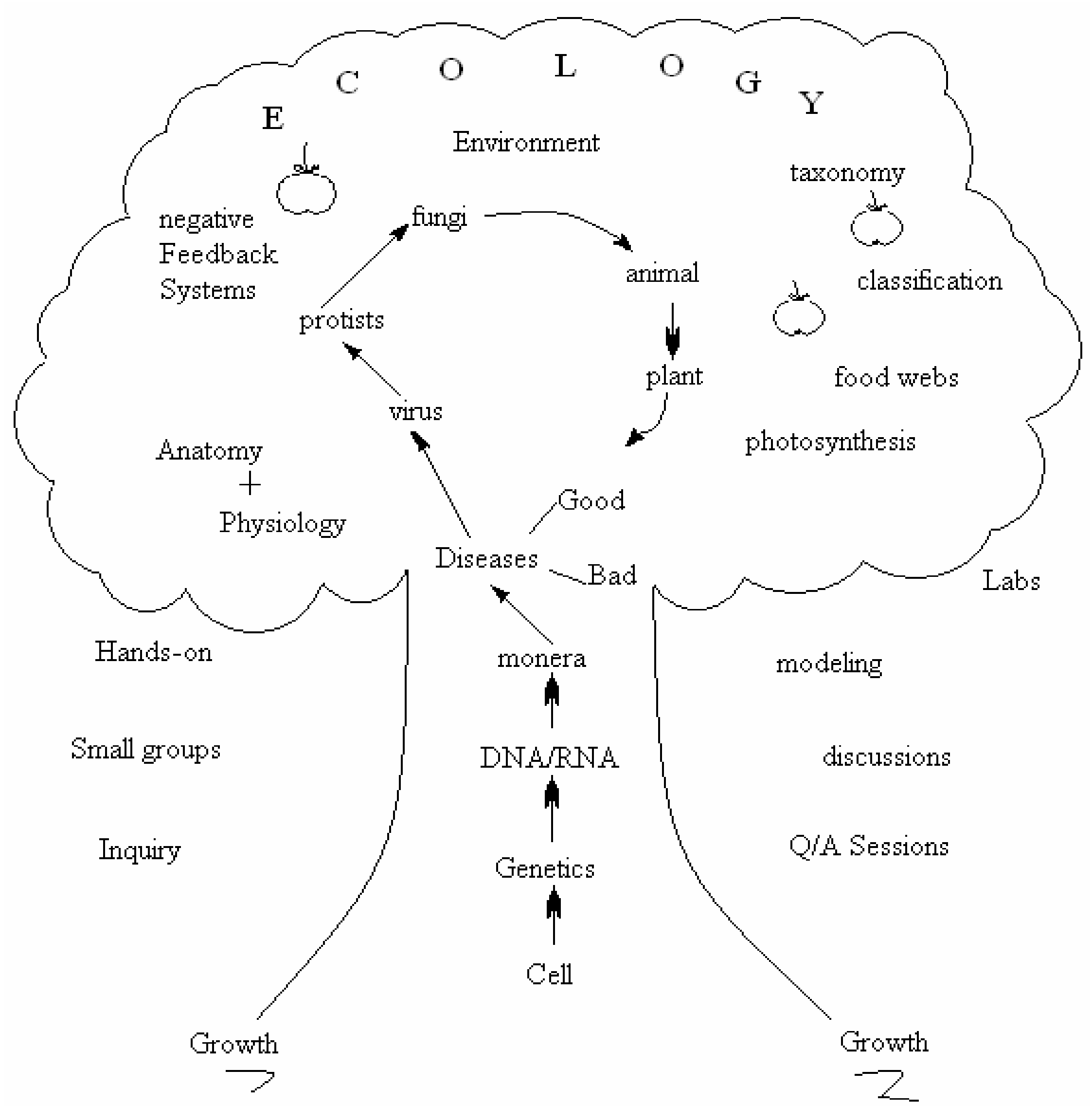
Pam often struggled when attempting to verbalize relationships. She felt overwhelmed, and just like Ellen, she expressed the view that everything in biology is interconnected but was not able to elucidate these connections. In fact, a closer look at her web reveals that the concepts and terms included depict topical listings of discrete college biology courses. These elaborate listings were consistent with Pam's extensive coursework in both undergraduate and graduate studies in biology. When asked to explain what she meant by the topics on her web, she typically listed sub-topics that were related to a certain term. For instance, to the question: "What do you mean by microbiology?" she replied: "In microbiology we have bacteriology, immunology, radiology, health, epidemiology and I think that molecular studies go here also." The same thing was repeated when asked about other terms and/or topics.

Moreover, Pam's conceptions were fluid. As she was tying to explicate the relations between pairs of concepts or topics, she often shuffled the concepts and moved one concept from one part of the web to another. For instance, in the above example, when asked whether she would include molecular studies under microbiology or not, she answered: "Yes. Or separate!" As expected, it was apparent that Pam has not thought about these concepts and the relations that may exist between them. In fact, when asked why she chose to include these topics, she noted that these were the concepts current in her mind at the time.

The effect of text-driven, college coursework was also evident when Pam explained how she would go about teaching biology. The sequence that she suggested was typical of most introductory college biology textbooks: Starting with basic chemistry, moving to cellular structure and function, then to organisms, and next to ecology. Finally, Pam noted that she used the spider on her web (see Figure 3) to represent NOS because it affects all the disciplines. She, however, was not able to explicate her views about NOS, which as it turned out, was not a pervasive theme in her conceptions of biology. When asked about it, Pam said that she would start her teaching with a discussion about NOS, "just a little bit about what it is about and . . . some demonstrations to practice observation versus inference."

Paula. Paula's conceptions of biology were ad hoc and not well thought out. When asked in the interview to describe her diagram, she replied: "Since this was a few days ago, I don't remember what I was thinking . . . so I guess your guess is as good as mine." She was not able to justify her choice of the concepts that appeared in the diagram or explicate many of the relations that she mapped between those concepts. Paula used a tree analogy to represent biology (see Figure 4). When asked about the reasons for her choice, she replied: "Because we did this in one of the classes and because the tree represents life, something growing and using energy." The tree, Paula continued, represented her attempt to start with 'smaller' concepts and move to 'larger' ones along lines of structural complexity. This, she noted, was the way the central concepts on the tree were organized (cell, genetics, DNA/RNA, Monera, diseases, viruses, Protists, fungi, animals, and plants-in this order). She explained: "I have put these in a circle because they can follow one another and they are related." Paula, however, was not able to explain how these terms were related. For instance, she was not able to explain the link between DNA/RNA and the kingdom Monera, or why she moved from Monera to viruses and then to Protists. The way she arranged these terms was not even consistent with her intent to represent

Figure 4. Paula's diagram for the structure of biology



an increasing level of complexity. For example, in her diagram, cells came prior to DNA and RNA. In fact, the center of the tree mirrored the five-kingdom classification system proposed in 1957 by Robert Whittaker (Whittaker & Margulis, 1978). Whittaker's five kingdoms are Monera, Protista, Fungi, Plantae, and Animalia. There certainly are serious doubts about Paula's conception that these kingdoms were organized on the basis of increasing structural complexity. The tree analogy, as it turned out, did not reflect any conceptual framework of biology. It rather represented isolated chunks of information that Paula has retained from her undergraduate course work. This claim is especially plausible in light of the fact that Paula majored in zoology where she was necessarily exposed to classification systems.

Ecology, Paula noted, was the encompassing concept in the diagram. When asked why, she answered: "Because ecology is the largest concept . . . Anything you talk about should be related to ecology [italics added]." She, however, was not able to elucidate any relations between ecology and several other concepts/topics in her diagram. On the tree Paula also included several concepts (e.g., food webs, photosynthesis, negative feedback systems) that were not connected to any other concepts. These concepts, Paula noted, were essential for understanding the larger picture. When asked to elaborate on this idea, and after a long pause, she answered briefly: "These are concepts that I have kind of thought of." Paula was unable to even give examples of these concepts. When asked about the inclusion of photosynthesis among these concepts, she said: "I have done photosynthesis [on the first questionnaire] and it was still in my mind." It is noteworthy that this was the only instance in which the order of administering the questionnaires had an effect on the views elucidated by participants.

Around the tree, Paula put several pedagogical concepts related to teaching (e.g., hands-on, inquiry, small groups). When asked how these concepts fit with what she has diagrammed, she answered that these were needed to teach biology. Overall, Paula felt inadequate about her conceptions. She pointed out that teaching experience would have made things easier: "I guess that one of the biggest problems is having to do this [diagram] and you are not an experienced teacher. Everything I would put here would of course come out of a textbook."

Specific SMSs: Conceptions of Photosynthesis

All four teachers, preservice and experienced, shared some elements as far as conceptions of photosynthesis were concerned. First, they all emphasized the essentials: Knowing the inputs and outputs of the process. In photosynthesis, light energy from the sun is utilized to convert carbon dioxide "from the atmosphere" and water "from the soil" into energy-rich, carbon-based compounds. Second, all participants limited their discussion of the process to green plants. They did not mention that photosynthesis also occurs in cyanobacteria and algae.

The differences, however, were more substantial than the above similarities. The first difference was the level of detail that teachers in the two groups considered. The preservice teachers, Pam and Paula, emphasized various structural and chemical details of photosynthesis. They included the specific sites (e.g., thylakoids, grana) where the process occurs, and the various chemical reactions (e.g., light and dark reactions, electron transport chain) and intermediary molecules (e.g., ATP, NADPH) involved in photosynthesis. On the other hand, the experienced teachers, Eric and Ellen, presented a much simpler account, an account limited to inputs and outputs. The second difference was that Eric and Ellen viewed photosynthesis as part of a larger picture. They emphasized the critical role of photosynthesis in providing the food supply and oxygen necessary for the survival of the most familiar life forms on earth: Plants and animals. This role was only partially emphasized by Pam (who stressed the importance of the byproduct oxygen in cellular respiration) and was not mentioned by Paula. What is more important was that teaching experience and student needs were the most important factors in the data to explain these differences.

The preservice biology teachers' emphasis on the details of photosynthesis was clear in their diagrams and stressed in the interviews. This was particularly the case with Pam. She, contrary to the others, used specialized terminology. For instance, she used the term 'photons' rather than terms like 'light energy' or 'solar energy' employed by the other three teachers. She also went into many details, such as emphasizing the formation of ATP and NADPH. She thought it was important for students to understand the role of these energy carriers: that it is critical to transfer energy in infinitesimal packets in order to avoid damaging the cell through releasing all the available energy in one large packet. When asked whether she would go into these details with high school students she answered in the positive. One can argue that Pam's preoccupation with details is consistent with her elaborate background on the topic (especially her graduate studies in cellular biology). However, a comparable level of detail was also emphasized by Paula. This was the case despite the fact that Paula indicated that her knowledge of photosynthesis was limited. She had no botany courses in her undergraduate studies. Yet, Paula thought it was important to, and did, include details about the various structures and reactions involved. This was the case even though she was unable to explain most of the details she emphasized. For instance, when asked to explain the relation that she mapped between chloroplasts and thylakoids she answered "I don't know . . . I am not sure." She also erroneously included the Krebs cycle under photosynthesis. So, despite lacking specialized knowledge about the topic and the fact that she indicated having not thought about photosynthesis in this manner before, Paula did not limit herself to the basics as one would anticipate. On the contrary, she went for the details. So the inference that the tendency to include details is related to a participant's elaborate knowledge can be ruled out. Teaching experience would in fact serve as a more plausible alternative. This was quite clear in the case of the experienced teachers.

Ellen, and as was the case with her views of biology, emphasized that what she put in the questionnaire reflected her view of photosynthesis but did not represent what she would actually teach about the topic. In her questionnaire, and consistent with her elaborate background in biology, Ellen gave a detailed account of photosynthesis. She included many details such as the specialized structures that plants have evolved to allow for and enhance photosynthesis, the seasonal dependency of the process, and the various chemical reactions taking place inside a leaf. However, it turned out that in her teaching she just stressed the overall equation that sums up the reactions and did not go into the details of the light and dark reactions saver their dependency on light or otherwise. The central idea that she wanted to get across was that photosynthesis is an energy transfer system by which solar energy is converted into chemical energy. Ellen's elaborate knowledge of photosynthesis seemed to have been purposively adjusted to fit her students' needs.

That teaching experience was a major factor in placing less emphasis on the details of photosynthesis was particularly evident in Eric's case. His view of photosynthesis, as Eric noted, was rather simple: "What goes in . . . and what goes out, and the importance of it." These elements were clearly presented in his diagram of photosynthesis. Solar energy is used by chloroplasts found in the leaves of plants to change carbon dioxide and water into food, releasing oxygen in the process. Eric noted that he avoided going into the details of the various chemical reactions. He only presented "the chemistry of the reactions in the form that [he] would expect kids to understand it." He added:

> As a newer teacher I got into more details, and as I taught it just seemed that kids never could really remember too much about photosynthesis. It was too abstract for them even if you did experiments . . . I just never could get kids to really understand it, even my better students. So I simplified my expectations.

The effects of teaching and having to deal with students' needs was further evident in shaping Eric's views. In his diagram, Eric included minerals as one of the reactants in photosynthesis. Though this can be thought of as simply a misconception, another more plausible explanation has precedence. As noted above, Eric and his students grew a lot of plants in their greenhouse that serves as their laboratory. Many experiments are usually run in the greenhouse all year long. Moreover, an end-of-year sale of the grown plants helps finance the science class. So, for Eric, photosynthesis is a way to teach his students how to keep their plants healthy:

> In my botany classes this is important for kids to understand these are the requirements for plants to remain healthy . . . We need always to evaluate if a plant is not growing healthy. We look at it in terms of the things the plant requires: It doesn't have enough light, enough moisture, it doesn't have enough air circulation, it doesn't have the water, etc.

So, the practical knowledge that Eric felt his students should derive from learning about photosynthesis may explain why he thought of minerals as a reactant in photosynthesis.

The importance of teaching in shaping teachers' views of specific topics in their content areas was realized even by preservice teachers. When asked to elaborate on some aspects of photosynthesis that she has included in her diagram, Paula answered: "I don't know, I haven't taught this yet."

The second difference was that experienced teachers saw photosynthesis as one link in a larger chain of events. They also made more connections between photosynthesis and other areas in biology. That photosynthesis is "the driving force of life on earth" was emphasized by Eric. The words "food and life" and the food chain depicted (autotrophs, herbivores, and carnivores) in his diagram clearly reflected this idea. Ellen similarly stressed the point that sugars produced in photosynthesis are utilized by plants and other organisms that feed on them. This forms the basis of elaborate food chains. Ellen also depicted the reciprocal relationship between photosynthesis and cellular respiration: that the products of the former are the reactants of the latter and vice versa. She also felt it was important to compare and contrast these reactions especially in plants and humans to understand the flow of energy and the cycling of matter. While Paula did not mention any of these relations, Pam focused on the relation of photosynthesis and respiration. She, however, limited this relation to the use of oxygen produced in photosynthesis by other organisms in cellular respiration. There was no mention of other organisms using the products of photosynthesis as a food supply. Finally, it should be noted that Eric, Ellen, and Pam indicated that they have thought about photosynthesis though they have not actually diagrammed it. Alternatively, Paula had not previously thought about photosynthesis in the manner asked by the questionnaire.

DISCUSSION AND IMPLICATIONS

The results of this study were, in many respects, consistent with previous research on preservice biology teachers' conceptions of subject matter. That preservice teachers' global SMSs mainly comprised discrete listings of college biology courses (e.g., Pam) or isolated chunks of information delivered in such courses (e.g., Paula), and that these listings and bits of information lacked connectedness or conceptual organization were consistent with findings reported, for example, by Gess-Newsome and Lederman (1993), Lederman et al. (1994), and Lederman and Latz (1995). However, the authors of these latter studies reported that toward the end of the teacher preparation program, the conceptions of biology elucidated by their subjects showed evidence of connectedness and thematic integration. This was not the case in the current study. The participant preservice teachers were about to graduate from the MAT program at the time the present study was conducted, yet their global SMSs showed very few connections and a complete absence of a thematic nature. In fact, these conceptions were similar to those reported by Lederman and his colleagues to be characteristic of biology teacher-candidates as they joined teacher preparation programs. It should be noted that initially Pam and Paula's diagrams of biology conveyed an integrated view of the discipline. Further probing during the interviews, nonetheless, revealed no evidence of integrated conceptions. This was the case even though both preservice teachers noted that they had opportunities in their MAT classes to reflect on and to attempt explicating their conceptions of biology. Such opportunities, it seems, were not enough to generate an integrated view of the discipline.

The findings of this study were also consistent with previous research on experienced biology teachers' global SMSs, especially the study by Gess-Newsome and Lederman (1995). In this latter study, as well as in the present one, it was evident that experienced biology teachers' global SMSs varied greatly. While some teachers maintained a linear, topical view of biology with sequences that resembled the structure of materials in popular high school biology textbooks (e.g., Ellen), others presented more integrated views of the discipline that showed evidence of connections and pervasive themes (e.g., Eric). Gess-Newsome and Lederman (1995) reasoned that having opportunities to reflect on subject matter was crucial in developing more integrated views of one's discipline. The frequency, variety, and quality of those opportunities, they continued, were more important than years of teaching experience in explaining the observed differences between experienced teachers' conceptions of subject matter.

The explanation advanced by Gess-Newsome and Lederman (1995) serves equally well to account for the different global SMSs furnished by the experienced teachers in the present study. In fact, as he noted, Eric had several opportunities to reflect on his subject matter in his career. He often evaluated biology textbooks for adoption in his course. On such occasions, Eric contacted many publishers and reviewed as many textbooks as was possible. He literally spent a few summers going over the materials and activities in such textbooks to see whether and how these can fit his and his students' needs. Such opportunities were also augmented by his unique experiences in other fields, especially as a forest ranger, tree surgeon, and farmer. These experiences played a crucial role in shaping and focusing Eric's conceptions. This was evident in his emphasis on interactions between insects and crops, plant management, and the utilitarian approach to the study of photosynthesis. These topics were mainly geared to help his students take care of their greenhouse. Ellen's years of teaching experience (eight years) were not substantially fewer than Eric's (10 years). Ellen experiences, however, were fewer. The opportunities she had to reflect on her subject matter (e.g., writing curricular proposals), we have seen, were not consistent with developing a conceptual view of biology. These experiences, it seemed, served to reinforce her topical, linear approach to biology.

So, having opportunities to reflect on subject matter, and acting on these opportunities, seem to play a major role in developing a teacher's conceptions of his/her discipline. In addition, having ample time to do so, seems crucial. Both preservice teachers had opportunities to generate a conceptual view of biology in their teacher preparation program. These experiences were, however, short-lived and insufficient to make any significant impact on their views. After all, such views were nurtured over several years in college science courses. However, it is imperative to re-emphasize that time alone is not sufficient: Ellen's eight years in the classroom, likewise, made little impact on her global SMSs.

In the present study, global SMSs did not discriminate preservice and experienced biology teachers. Their conceptions of biology, as noted earlier, fell on a continuum. This, however, was not the case with specific SMSs. Conceptions of photosynthesis clearly separated the participants into the two groups: preservice and experienced. The views presented were consistent within each group and differed from those of the other group in two major ways. First, was the level of detail emphasized. The preservice teachers emphasized various structural and chemical details of photosynthesis while the experienced teachers presented a much simpler account that was limited to inputs and outputs. Secondly, the experienced teachers viewed photosynthesis as part of a larger picture. They emphasized its critical role in supplying the food energy and/or oxygen necessary for the survival of almost all living organisms. This role was overlooked by the preservice teachers. As noted earlier, teaching experience and student needs were the most important factors in the data to explain these differences.

In the case of photosynthesis, and contrary to the discipline as a whole, participants in each group seem to have had similar experiences. Both experienced teachers did teach the topic over the course of several years to students in the same school with similar backgrounds. As they taught, they had to respond to their students' needs and abilities. And, as they made explicit, they had to modify their expectations. Their conceptions of what is worth emphasizing in their classrooms were modified accordingly. Ellen and Eric's views of photosynthesis were much more similar than their conceptions of biology. Both preservice teachers, on the other hand, probably had similar college experiences with photosynthesis, and having not taught it, their views on the topic were very similar. All this makes stronger the contention that teachers' conceptions of subject matter are affected by their reflecting and acting on it.

It should be noted that reflection on subject matter does not always guarantee depth of understanding or more accurate conceptions. As teachers respond to idiosyncratic student needs and modify their expectations accordingly, and as they read into new materials based on prior conceptions or from within certain perspectives, they may end up developing idiosyncratic conceptions. Eric's inclusion of minerals as a reactant in photosynthesis is a case in point.

Implications for Conceptions of PCK

In as far as photosynthesis is typically taught in high school biology courses, and to the extent that PCK is concerned with "the most regularly taught topics in one's subject area" (Shulman, 1986, p. 9), the results of this study were consistent with the contentions advanced by Shulman. Shulman and his colleagues argued that as teachers plan their lessons, teach, adapt their instruction to meet student needs, and reflect on their teaching, they develop PCK. This was evident in the present study. Teaching experience and student needs were the most important factors in the data to explain the differences between the preservice and experienced teachers' conceptions of photosynthesis. Thus, essential to the development of PCK, as presented by Shulman, is the component of experience (even though Shulman and his colleagues did not highlight the importance of this component). Teachers, as was the case with Ellen and Eric, would have to go through several cycles (i.e., over several years) of teaching and reflection to develop the desired knowledge of the topics they teach.

If a teacher's PCK could only be developed through teaching experience, then the usefulness of this construct for teacher education purposes would be severely limited. It is obvious that teacher preparation programs cannot provide prospective teachers with the equivalent of years of classroom teaching experience in order to develop their PCK. No doubt, a case-study-of-exemplary-teachers approach to teacher education, as advanced by Shulman (1987), can be useful. This approach, however, cannot possibly result in preparing exemplary teachers. Stories of innovative instructional strategies and activities, and vignettes of creative representations, metaphors, and analogies of subject matter devised by classroom teachers, would serve to enrich prospective teachers' experiences. Such pieces, nevertheless, cannot equip them with the kind of knowledge they will need in their own classrooms.

However, teaching experience may not be the only factor crucial to the development of teachers' conceptions of subject matter. As far as global SMSs are concerned, teaching expertise figured more prominently than teaching experience in accounting for the observed differences in the experienced teachers' conceptions of biology (also see Gess-Newsome & Lederman, 1995). Ellen's views of biology were not significantly impacted by her substantial teaching experience. As noted earlier, opportunities to reflect on subject matter are essential to the development of more integrated views of a discipline. Such interconnected views are necessary for teachers to be able to present the 'most regularly taught topics' as undistorted and non-isolated portions of a larger whole (Shulman, 1987). Thus, opportunities to reflect on subject matter should be part of teacher education. Nevertheless, the frequency, variety, and quality of those opportunities weigh heavily in developing the desired conceptions. This, we have seen, was the case with Pam and Paula. Their short-lived experiences with attempting to conceptualize their subject matter in the MAT program did not have a notable effect on their global SMSs. Teacher preparation programs cannot allocate ample time for those opportunities amidst their already packed agendas. What is alternatively needed is an explicit, theoretical model for the development of PCK. When incorporated in teacher education, such a model can help prospective teachers take responsibility for developing their own conceptions of subject matter.

As presently conceived, PCK largely remains an atheoretical construct. Even though all the components of a possible theoretical model for the development of PCK were advanced by Shulman (1987), the necessary links between the components were not explicated. This probably resulted from conceiving PCK as a separate domain of knowledge. Attempts to theorize PCK, such as those advanced by Gess-Newsome (1999), go some way in providing a viable alternative framework, but more is needed. For example, Gess-Newsome's integrative model does not provide a viable mechanism for bringing about the integration of teacher's knowledge of content, context, and pedagogy. Similarly, the results of the present study only provide partial empirical support for Gess-Newsome's transformative model. These results indicate that teaching experience is not enough to account for the development of PCK as was the case with Ellen.

The following is by no means a re-conceptualization of PCK as advanced by Shulman (1987), it rather is a minor change of perspective. This change, however, may prove to have some implications for teacher preparation programs. The idea advanced here is that PCK is not a separate domain of knowledge. PCK develops as a result of the interaction of the other components of the knowledge base as teachers use that knowledge in their teaching. It follows that the components of the knowledge base for teaching, as articulated by Shulman, are prerequisite to the development of PCK.

The above point is more evident when we consider the way Shulman and his colleagues noted that PCK develops: As teachers plan their lessons, teach, adapt their instruction to meet student needs, and reflect on their teaching, they develop "a new type of subject matter knowledge, . . . pedagogical content knowledge" (Wilson et al., 1987, p. 114). The same point is also evident in Shulman's model of teaching and the associated set of activities. In this respect we have seen that subject matter knowledge, both substantive and syntactic, is essential for comprehending what is to be taught. In addition, curricular knowledge is prerequisite to planning. General pedagogical knowledge, including knowledge of teaching strategies and classroom management, is critical for teaching. Knowledge of learners is essential for transforming subject matter and adapting instruction to meet the diverse student abilities and interests. Both evaluation and reflection, as Shulman (1987) noted are not dispositions. They rather require content-specific analytical knowledge, and knowledge of the purposes and aims of teaching. It can thus be seen that the development of PCK is crucially linked to teachers' familiarity with the other components of the knowledge base. (It should be noted that the way the various types of knowledge were assigned to the above activities is schematic. It is recognized that the various categories of knowledge overlap in their application to those activities.) In addition, Shulman noted that PCK is characterized by a way of thinking, which he labeled as pedagogical reasoning. As such, PCK develops as teachers think about and act on their knowledge for the purpose of teaching it.

The components of the knowledge base for teaching as advanced by Shulman are already on the agendas of teacher preparation programs. Capitalizing on this point to promote PCK is, nevertheless, related to explicating the model underlying its development, be it Shulman's contention of pedagogical reasoning or his model of teaching. But, what are the components of pedagogical reasoning? What kinds of knowledge about teaching and learning are demanded by Shulman's model of teaching? What does it mean for teachers to comprehend the subject matter for themselves? How can they comprehend it in several ways? What does it take for teachers to be capable of transforming their knowledge of subject matter into forms that students can attain? What is the role of reflection in developing teachers' conceptions? What are the content-specific analytical knowledge that Shulman deemed necessary to enable teachers to engage in reflection; a crucial aspect of their professional development? How do the other components of the knowledge base relate to all of the above? Further research is needed to shed light on these questions. If answers to such questions prove helpful in theorizing the construct of PCK, then teacher preparation programs would have a better chance of helping teachers develop the desired conceptions of subject matter. Equipping teachers with the kind of theoretical knowledge that can help them take responsibility for their own professional development may prove more useful than adding another type of knowledge that prospective teachers will have to know (given that we can collate this kind of knowledge in the first place), even if it comes under the attractive label of PCK.

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Fouad Abd-El-Khalick

Department of Curriculum and Instruction

University of Illinois at Urbana-Champaign

311 Education Building, MC-708

1310 South Sixth Street

Champaign, IL 61820

USA

Phone: (217) 244-1221

Fax: (217) 244-4572

E-mail: fouad@uiuc.edu

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EVOLUTION OF THE STUDENTS' CONCEPTUAL UNDERSTANDING IN THE CASE OF A TEACHING SEQUENCE IN MECHANICS: CONCEPT OF INTERACTION

Asuman Küçüközer

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ABSTRACT. This study aims to better understand the construction of the meaning of physics concepts in mechanics during a teaching sequence at the upper secondary school level. In the teaching sessions, students were introduced to the concepts of interaction and force. During this teaching sequence the models called "interactions" and "laws of mechanics" are successively introduced in the framework of tasks involving a variety of material situations. The hypothesis "students' initial knowledge on the verb "to act" is a founder notion, to the extent that its meaning plays a crucial role in constructing the concept of interaction" has been set. The research questions are: a) Does the verb "to act" plays a founder role in the construction of the concept of interaction? b) What are the other notions that intervene in the structured set of knowledge that students use to construct the concept of interaction in the teaching sequence? The results of the study show that, for the two students of the observed dyad, the notions of object and the concept of gravitation are simultaneously founder notions. Additionally, the two students of the same dyad who work together all along the sequence use different categories of knowledge and construct different meanings of the concepts.

KEYWORDS. Conceptual Understanding, Mechanics, Interaction, Newton's Third Law, Types Of Knowledge.

INTRODUCTION

Reviewing the related literature, a considerable number of studies are found on students' conceptions in Newtonian mechanics (see bibliography of Pfundt and Duit 2000). One of the main results of these empirical investigations of teaching and learning in mechanics was that few changes in conceptual understanding appear after teaching even at university level (Viennot, 1979; Clement, 1982; McDermott, 1984; Halloun and Hestenes 1985). Several articles focus particularly on students' understandings of Newton's third law (Terry & Jones, 1986; Brown, 1989). The findings commonly indicate that most students have a poor understanding of Newton's third law and of the force concept in general. The concept of force often remains a characteristic of objects (Terry and Jones, 1986); it is not a physical quantity characterizing interaction between systems. Many students don't believe that an inanimate and inert object can exert a force, for instance, they may think that a table does not exert a force on a book (Brown, 1989; Minstrell, 1982).

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This study aims to understand the construction of the meaning of physics concepts in mechanics during a teaching sequence at the upper secondary school level. In the teaching sessions introduce to the concepts of interaction and force. During this teaching sequence the models called "interactions" and "laws of mechanics" are successively introduced in the framework of tasks involving a variety of material situations. In this study, the author focuses mainly on the concept of interaction.

In the following sections, first the theoretical framework dealing with the students' knowledge, then the teaching sequence and the categories to analyse students' knowledge will be discussed.

THEORETICAL FRAMEWORK

Understanding the students' construction of the meaning of physics concepts leads one to focus on the teaching situation and on the students' previous knowledge. The studies of other authors (Niedderer and Schecker, 1992; Richard, 1998, etc.) indicate that construction of meaning of concepts is produced by the interplay of the situation and the students' previous knowledge.

From a constructivist view of learning, students' previous knowledge is of central importance in learning. This leads us to carry out research into the role of students' initial knowledge in their construction of physics concepts using the approach of "founder notions". The "founder notions" approach, introduced by Tiberghien and Baker (1999), involves two different aspects: (1) the fundamental notions on the side of the knowledge to be taught; (2) founder notions on the side of the students' knowledge. The founder notions are supposed to constitute basic elements from which students construct new meanings to phenomena or new ways to solve problems. For these authors, these notions correspond to a set of structured knowledge. The "fundamental notions" are defined from an analysis of the knowledge to be taught. This analysis leads to consider that some pieces constitute "fundamental notions" that have to be understood by the learner in order that s/he acquires the knowledge to be taught. Consequently, it is necessary to analyse the knowledge to be taught and the students' knowledge. These analyses are based on several theoretical choices on modelling, on semiotic registers, and in linguistics.

Concerning modelling (Tiberghien, 1994, 2000), two main categories were used "the theory/model world" and "the objects/events world" involved in the verbal (oral and written and gestural productions). The following hypothesis is made: when a person or a group of people explain, interpret, or predict situation(s) in the material world, most of the time their productions entail observable objects or events, and/or physics parameters, and/or relations between them, which involves a modelling activity. This is why the aspects of the taught knowledge relative to each of these two worlds are distinguished; in particular the theoretical aspects are made explicit as such to the students. This activity involves both the world of objects and events and the world of explanatory or theoretical frameworks, as well as models derived from these explanatory or theoretical frameworks (Tiberghien, 1994). The world of objects and events refers to all observable aspects of the material world, whereas on the other hand, the world of theories and models refers to theoretical aspects and elements of the constructed model of the material situations, in terms of various principles, parameters or quantities.

Concerning the semiotic registers (Duval, 1995), the learning hypothesis is that the relations between different semiotic registers of the same concept (natural language, schemas, graphs, etc.) favour the learner's construction of concepts.

Concerning linguistics, the distinction used by the linguists (for example see Ligozat, 1994) between the linguistic knowledge and the extra-linguistic knowledge is taken. The linguistic knowledge applies to sentences and their constituents; it is directly linked to language itself: syntactic knowledge, semantic knowledge and pragmatic knowledge. In this study, our analysis is based on the semantic knowledge, which takes the indication on the possible meaning for each word.

Consequently, to better understand the role of students' knowledge in the construction of meaning of concepts, different types of students' knowledge were considered:

- conceptual knowledge involving "concepts" and "notions" (which are not necessarily scientifically correct),
- knowledge on the material world directly involving objects and events,
- linguistic knowledge,
- knowledge related to the way to treat-interprets situations involving the different types of reasoning (causality, ontology).

Teaching Sequence

The literature shows how much the construction and the evolution of the meaning of the concepts depend on the teaching situations (Brousseau, 1986; Duit et al., 1998; Welzel and von Aufschnaiter, 1996). In this framework, the students' construction of meanings of the concepts was influenced by the interplay of many elements: physics content of the task, settings or objects and events at hand, material actions or interactions between students and between students-teacher. Each element of the situation is a resource of information for the students. During the construction, the use of all these elements depends on the student.

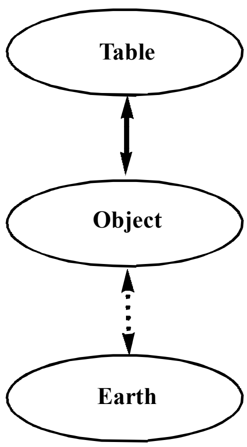
The teaching sequence was designed within a long-standing group in which teachers and researchers collaborate to develop "tools" for teachers. The main features of this design were to develop students' conceptual understanding and to give the possibility to interact with each other and/or with the objects and events at hand.

In generally, Newton's third law is introduced after Newton's first and second laws in teaching. For some researchers the force concept might be more effectively taught by emphasizing forces as interactions between objects (Brown, 1989; Reif, 1995, Savinainen, A. Et al. 2005). For instance, Reif (1995) suggested analyzing a physical system by describing both motion and interactions. In the framework of the teaching sequence, from an analysis of the knowledge to be taught it is considered that to construct an understanding of laws of mechanics, the concept of interaction is a fundamental notion. During this teaching sequence the models called "interactions" and "laws of mechanics" are successively introduced in the framework of tasks involving a variety of material situations.

From the studies on the students' linguistics knowledge, the verb "to act" is used in the text of model in this study. As a matter of fact, Guillaud (1998) showed that, on the one hand for a majority of students (14 - 15 years old) the word "interaction" is unknown, without meaning, and on the other hand the verb "to act" is known with its everyday meaning. In its everyday meaning the agent who (or which) acts should be a living being or a moving object. This meaning is different from the meaning given in physics (for example a pen can act on a table).

In the text of the model the concept of interaction is defined as the following: "in an interaction, when a system A acts on a system B, simultaneously B acts on A in an opposite sense; the action of A on B (written A/B) is in opposite sense to the action of B on A (written B/A)". These models involve symbolic representations: diagrams called "system - interactions" with a "set diagram" representing a system and arrows. As an example of the diagrams "system - interactions", figure 1 illustrates the case of an object is on the table.

Figure 1. A diagram "system - interactions" of "an objetc is on the table"



The double-sided arrows representing the interactions with a distinction between contact interactions (thick double arrow) and at distance interactions (dotted double arrow). It was emphasised that both objects participate in the interaction and that the interaction is symmetrical.

Research Questions

Taking the concept of interaction as a fundamental notion, it is necessary to study what the founder notions that allow the learner to acquire a sufficient meaning of interaction are in order that, later in the teaching sequence, the students use this meaning of "interaction" as a founder notion to acquire the laws of mechanics.

In the framework of this teaching sequence, the hypothesis that the verb "to act" is a founder notion to construct the concept of interaction has been set. The following research questions asked to guide the study:

- does the verb "to act" play a founder role in the construction of the concept of interaction ?
- what are the other notions which intervene in the structured set of knowledge that students use to construct the concept of interaction in the teaching sequence?
- how do these founder notions and students' previous knowledge intervene in the student's construction of the meaning of the fundamental notions?

Method and Samples

This study aims to understand the construction of the meaning of "in an interaction when a system A acts on a system B, simultaneously B acts on A in an opposite sense". In order to capture, to describe the entire process in as much detail as possible and to reconstruct the students' construction of the meaning, a case study methodology is used.

The data is collected continuously all along the teaching sequence at the first year of the French upper secondary school (15 years old students). One class was observed during instruction of a mechanics unit during 4 weeks. The students were encouraged to discuss and to verbalize their thoughts. Instructional activities included teacher presentation of activities, hands-on activities, and whole-class discussions. A dyad (F and L) is the subject of this case study. The dyad while engaged in hands-on activities and whole-class discussions were videotaped. All written productions of this dyad were collected. Field notes were taken based on classroom observations which focused on classroom discourse and activities.

The video sequences were transcribed. In this transcription observable activities (spoken words and sentences, gestures) are listed in chronological order for each student and teacher.

Data from multiple sources (field notes, transcripts of classroom discourse from videotapes, transcripts of dyad discourse from videotapes, and students' written productions) were used in relation to each other; this served to triangulate the data and to help enhance the credibility of the findings. For example, observation field notes and transcripts of classroom discourse used as secondary data sources provided a context for the interpretation of data. The dyad's transcriptions and written productions were analysed. In this analysis, it is aimed to see what previous knowledge the students use and what information they take from the situation during their construction of the meaning of the concept of interaction. Two different examples are given here.

The first example comes from the first task of the teaching sequence. The following elements of the situation were taken into account by the author of this article: the experimental setting (a stone hanging from an elastic attached to a support) and the associated questions: "what is acting on the stone (?) and on what the stone is acting (?)", actions of the students on the stone and interactions between F-L and/or F-L-teacher.

To carry out this task the students use their previous knowledge, the teaching sequence does not introduce theoretical knowledge at this step. Some extracts of the dialogue are taken.

They read the questions and start to discuss on the question "what is acting on the stone". They begin to discuss:

F: What does to act mean?

L: which does something?

F: which holds which?

It is observed that L starts from his knowledge on language, the meaning of "to act" is "to do something". F starts from what he sees (the experimental device), the meaning of "to act" is "to hold".

For the two students the elastic acts on the stone. They touch the stone several times and they observe the experimental setting. For F, the elastic holds the stone; he uses the information coming from the situation. For L, the elastic acts on the stone because the elastic prevents it from falling; he uses a linear causal reasoning involving his knowledge on the material world and the information coming from the situation.

Later on, the teacher says to the whole students:

T: … generally, everything can act on the stone in a visible or invisible way

F: The air, the air it acts / look when you make the air (he waves his arm)

L: There is the attraction, the attraction, there is the elastic, yes, otherwise the stone would be flying

For L, the attraction acts on the stone, he uses his conceptual knowledge. For F, the air acts on the stone, he uses his knowledge on the material world.

They begin to discuss on the attraction:

F: Not the attraction

L: Ben yes, if there is no attraction, it (the stone) would be flying the stone

F: Ben not the attraction, there is the heaviness of the stone/ the stone is heavy at the origin.

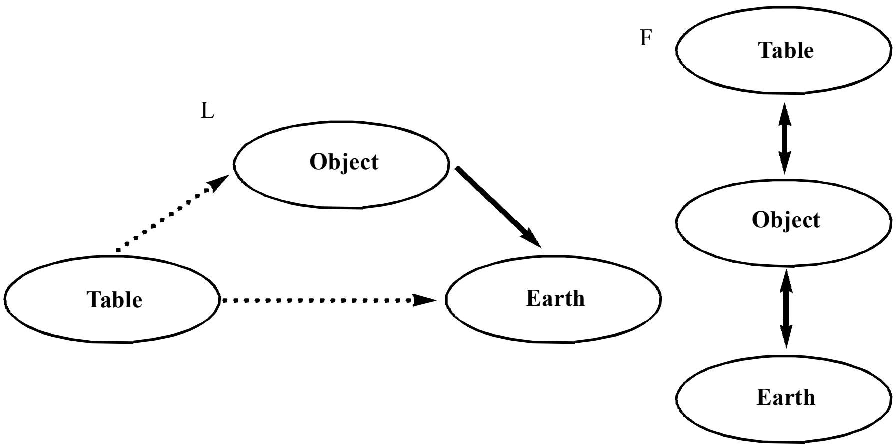
F, L use their knowledge related to the way to treat-interpret situations. L uses his conceptual knowledge and a linear causal reasoning: the earth acts on the object then the object doesn't fly. F focuses particularly on the property of objects.

The second example comes from the second task of the teaching sequence. Before this task, teacher distributed a sheet giving the text of the model. We take the following elements of the situation: the experimental settings (for example a pen is on the table), interactions between F, L and/or F, L, teacher and the physics content of the activity (the text of the model). This task asks to draw diagrams the called "system-interactions" for "an object put on the table". Here is an extract of the dialogue:

L: The earth acts on the table, the earth acts on the object too / the object acts on the table

F: But not the object, it doesn't act on the table, if there was no table the object would fall to the ground

Figure 2 : The written productions of F and L for "an object is on the table"



Analysis of their diagrams (figure 2) and their verbal productions shows that F and L use the elements of the situation and their previous knowledge differently.

For L, the earth acts on the table and on the object, he uses his conceptual knowledge of attraction, the meaning of "to act" is "to attract". To state that the object acts on the table, he uses his conceptual knowledge and a linear causal reasoning: the earth acts on the object then the object doesn't fly, and it acts on the table since it is attracted by the earth, consequently the object pushes the table. The meaning of "to act" is "to push".

For F, the object does not act on the table, the table acts on the object, because the table prevents it from falling. He uses his knowledge on the material world and the information coming from the situation. The meaning of "to act" is "to prevent from falling".

RESULTS

At a global level it appears that all along the successive tasks (12 tasks), the cognitive processes of the two students F and L are very different. It seems that L constructs the meaning of "in an interaction when a system A acts on a system B, simultaneously B acts on A in an opposite sense " better than F.

In particular, having a look at the evolution of the meaning of the verb "to act", the following differences between L and F are seen.

L associates it to "to do something (x3)", "to make move (x1)", "to prevent from falling (x3)", "to prevent from flying (x3)", "to attract (x12)", "to be pulled (x1)", "to tighten (x4)", "to pull (x1)", "to push (x4)", "to maintain (x1)", "to carry (x5)", "to make fly up (x2)", "to come back up (x1)", "to hold (x1)", "to make pull (x1)", "to keep (x2)".

F associates it to "to hold (x5)", "to tighten (x3)", "to prevent from falling (x1)", "to maintain (x6)", "to make fly up (x1)", "to push (x2)", "to make push (x2)", "to lean (x1)", "to slow down (x1)".

L associates it to 16 different meanings and he uses this verb 45 times. F associates it to 9 different meanings and he uses this verb 22 times.

During the construction of the interaction concept the way they use it corresponds to different categories of knowledge. L uses his linguistic knowledge, his knowledge on the material world, his conceptual knowledge whereas F uses his knowledge on the material world mainly and his conceptual knowledge very rarely. Again, there is differences between F and L in their ways to treat-interpret situations, to comment information taken from the situation, L uses his previous knowledge with a linear causal reasoning and when it is useful, a hypothetical reasoning. He wonders what will be the effect if the causal agent is removed, that is the change of the effect (state of the patient). F does not seem to use the linear causality. He comments on the information taken from the situation using his previous knowledge (particularly his knowledge on the material world) and taking the role of objects.

When looked at the types of the elements of the situation: generally F uses material actions and/or the interaction between F-L and F-teacher as source of information but not the physics content of the activity; L attempts to use all these sources. Concerning the physics content of the activity, F and L use much more the symbolic representations introduced in the model than the text. L chooses the systems and uses the symbolic representations more and more efficiently. It seems that F draws the double arrows according to the didactical contract and not according to the meaning that he gives to the concepts.

Reconstructing the evolution of the students' meaning of "in an interaction when a system A acts on a system B, simultaneously B acts on A in an opposite sense" in relation to the other notions which were introduced, the analysis of the data shows that the two concepts, those of object and of gravitation also play an important role in the construction. For F and L, their initial meaning of "object" is not sufficient. From the two students' point of view at the beginning of the teaching sequence, the elastic or the stone are objects but the Earth is not. An object has small-scale dimensions in order to be handled. Two students show an evolution of the understanding of the concept of object. F's difficulty in understanding the concept of gravitation leads him to another difficulty in understanding the interaction between the earth and the systems and in the distinction between contact interactions (thick double arrow) and at distance interactions (dotted double arrow).

CONCLUSIONS AND DISCUSSION

In this article, it is attempted to understand and to analyse the students' construction of the meaning of the concept of interaction all along a teaching sequence in mechanics starting from the construction of the conceptual meaning is produced by the interplay of the situation and the students' previous knowledge.

From the approach of the "founder notions" and from the analysis, the founder notions students use to construct the concept of interaction in the teaching sequence have been attempted to determine. It is hypothesized that, in its everyday meaning, the verb "to act" was a founder notion to construct a physics meaning of the concepts of interaction. Our analysis shows that this verb "to act" is a founder notion. Finally, the linguistic aspect was important. The verb "to act" was used in a highly interactive based on dyad discussions. The students had opportunity to talk through their developing understanding, with the support of the different source of information on the situation.

The verb "to act" is not the single founder notion, the notion of object, the concept of gravitation, are simultaneously founders. The better understanding of the interaction concept necessitates the understanding of the notion of object and of the concept of gravitation. Moreover, the diagram "system - interactions" had a role in their understanding of the interaction concept. The representation provides support to the construction of deeper understandings (Ainsworth, 1999). This symbolic representation provides simultaneous use of multiple representations; students were encouraged to combine diagrammatic representations with verbal representations. However, this was not investigated in this study.

In order to understand this construction the decision to analyse each student of a dyad has been made by the author. It is shown that the cognitive processes of the two students F and L were very different. L constructs the meaning of the interaction concept better than F. The analysis of the data showed how much the use of the different physical and conceptual resources such as several categories of knowledge, the elements of the situation, influences the construction of the meaning. It is also shown that the "way of interpreting situations" prevents the students to attain the meaning of the concept of interaction. In conclusion, this study has provided further information on the finer differences between two students concerning the use of the different categories of knowledge and the elements of the situation. This information could help teachers to become more perceptive towards their students' learning approaches. On the other hand, this study draws careful attention to use of tasks which include various types of knowledge and resources.

This work put in evidence about various founder notions. Although this work came out from the point of view of the "microanalyses" of a set of situations, the results are needed to be generalized to a wider field. The author of this article believes that this kind of research, involving careful and detailed examination of both instructional design and considerations of the founder notions in specific areas of subject matters, is of considerable importance in the development of effective teaching approaches.

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Asuman Küçüközer

UMR GRIC, Equipe COAST, Université Lyon 2, ENS-LSH

Tel: 0 266 244 51 50

E-mail: asuman_kucukozer@yahoo.fr

www.ejmste.com

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RELATIONSHIP BETWEEN STUDENTS' SELF-BELIEFS AND ATTITUDES ON SCIENCE ACHIEVEMENTS IN CYPRUS: FINDINGS FROM THE THIRD INTERNATIONAL MATHEMATICS AND SCIENCE STUDY (TIMSS)

Alexandros Mettas
Ioannis Karmiotis
Paris Christoforou
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ABSTRACT. The attitudes and self-beliefs revealed in science education can affect students' achievements. Several studies have found that students' self-beliefs are significantly associated with achievement outcomes. The purpose of this study was to investigate the relationship between their attitudes and self-beliefs and science achievements based on TIMSS 1999 results concerning Cyprus. Links between evidence of students' achievements and their relation on positive attitudes and self-beliefs towards science education have been investigated. A number of parameters concerning the effects of attitudes and self-beliefs in relation with their achievement were identified from the study. Several specific self-beliefs were examined and variance estimation statistical techniques were employed. The analysis of the results was based on Varimax factor analysis and stepwise multiple regression analysis. The results of this study indicate that several specific self-beliefs and attitudes were associated with higher levels of science achievement of the Cypriot students in this sample. In addition, these findings provide a number of directions for further research.

KEYWORDS. Science, TIMSS, Self-Beliefs, Attitudes, Education.

INTRODUCTION

Students' self-beliefs and attitudes play an important role in the teaching and learning process of science. Those factors can affect students' progress and interest within the subject and as a result students' achievements and learning. The results from the third international mathematics and science study, TIMSS 1999, give a great opportunity for researchers to analyse the effect of students' self-beliefs and attitudes on science achievement test scores.

The Third International Mathematics and Science Study (TIMSS) represents the largest, most comprehensive and most ambitious international comparison study yet conducted (Martin et al 2000; Papanastasiou, 2000). The study provides the participating countries with a solid basis for examining their students' performance from an international perspective.

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About TIMSS

TIMSS 1999, also known as TIMSS-Repeat or TIMSS-R, is a reproduction of TIMSS (1995) at the lower -secondary, the eighth grade in most countries. The International Association conducted the original TIMSS and TIMSS 1999 for the Evaluation of Educational Achievement (IEA). As follow-up to the earlier study, TIMSS 1999 adds to the richness of the TIMSS data. The aim is to improve the teaching and learning of mathematics and science for students everywhere by providing data about what types of curricula, instructional practices, and school environments result in higher student achievement.

The number of countries that participated in TIMSS 1999 was 38 with more than half a million students included in the sample. Each participating country designated a national center to conduct the activities of the study and a National Research Coordinator (NRC) to implement in accordance with international procedures. The quality of the study depends on the work of the NRCs and their colleagues (Martin et al., 2000).

Literature Review

The study of attitudes began in social psychology during the early part of the twentieth century. From the beginning the study of attitudes has been "characterized by an embarrassing degree of ambiguity and confusion" (Fishbein and Ajzen, 1975, p. 1). One of the earliest definitions came in 1928 when Louis Thurstone defined attitude as the "sum total of a man's inclinations and feelings, prejudice or bias, preconceived notions, ideas, fears, threats, and convictions about any specific topic" (p. 531).

Triandes (1971, p. 2), defined attitude as, "an idea charged with emotion which predisposes a class of actions to a particular class of social situations." Triandes (1971) suggests that attitudes consist of three components: (a) a cognitive component, which is a way for humans to categorize ideas, (b) an affective component, which is the emotion that charges the idea, and (c) a behavioral component, which guides behavior. As Mueller (1986) points out "while there is not total consensus among social scientists regarding the definition of attitude, there is substantial agreement that affect for or against is a critical component of the attitude concept" (p. 2).

A belief can be a statement of known fact, a hypothesis about nature or social institutions, a statement about one's own objectives and beliefs, a statement about another decision maker's objectives and beliefs, or an axiom of logic. The decision maker's ability to define its own objectives entails certain self-beliefs (for example, in knowing their own preference).

Several studies that followed the publication of the TIMSS study as well as many previous studies, have indicated that there is a significant association between student self beliefs and attitudes with achievement outcomes. For example, House (1993), found that students self-appraisals of their overall academic ability were significantly related to grade performance in their science courses. Gardner (1975), presented reviews that suggest the correlation between science attitude and various achievement measures is positive. Bloom's (1976) educational theory provided a historical basis for science educators' investigations on these relationships. According to another survey based on the TIMSS data, 8th grade students with more positive attitudes show higher average mathematic achievement (Cheng and Seng 2001). Furthermore it has been supported that learner's beliefs about their capacities exert a strong influence on task performance (Seggers and Boekaerts, 1993). Finally, there is an increasing recognition of the relationship between students' affective characteristics and their subsequent achievement outcome. The belief that positive affect might lead to positive achievement outcome is fairly widespread.

Studies by Fraser and Butts (1982) contradict the views presented above and thus conclude that the empirical evidence is insufficient to support the claim that attitude and achievement are highly related. Moreover, studies have revealed that attitudes and beliefs cannot be used to predict students' outcome in mathematics (Papanastasiou, 2000). Supporting this view, the findings by Fraser and Butts (1982) showed little correlation between attitudes and achievement. Finally, Eisenhardt's (1977) research indicated that achievement influences attitudes more than attitudes influence achievement in mathematics.

Researchers have operationalized self-beliefs and attitudes towards science in many different ways. This has lead to a diversity of the studies outcomes, making it difficult to compare results. According to the results of TIMSS 1999 (Martin et. al, 2000), there is a clear positive association between self-concept and science achievement. Internationally, 26 percent of students on average have a high self-concept in the sciences. The relationship concerning the country level was more complex. Several countries with high average science achievement, including Singapore, Japan, Hong Kong, Chinese Taipei, and Korea, have relatively low percentages (21 percent or less) of students in the high self-concept category. Since all of these are Asian Pacific countries, they may share cultural traditions that encourage a modest self-concept.

Generating positive attitudes towards science among students, there is an important goal of science education in many countries. To gain some understanding about students view regarding the utility of positive attitudes towards the sciences, TIMSS-R study indicated a number of related statements (Martin et. al, 2000). From the results it can be seen that students generally have positive attitudes towards the sciences. Countries with large percentages of students at the high level included Malaysia, Philippines, Tunisia, Jordan, South Africa, Iran, and

Indonesia, with more than half the students in this category. The countries with the least positive attitudes were Japan and Korea. Australia, Chinese Taipei, and Hong Kong were also low in percentages. Since all these are countries with high average science achievement, it may be concluded that the students follow a demanding science curriculum, one that leads to high achievement, but have little enthusiasm for the subject matter. However, there was a clearly positive association between attitudes towards the sciences and science achievement on average and in many of the countries overall.

The purpose of this study is to investigate the relationship between students' self -beliefs and attitudes towards science with their academic achievements in science. In the study data from the Cyprus model of the Third International Mathematics and Science Study is used. Previous research findings from students enrolled at single institutions have indicated that significant correlations exist between students' beliefs and their achievement outcomes. This study intended to examine the generality of those findings in a cross-cultural context.

Method Used

This paper is dealing with the results of the third international mathematics and science study for Cyprus. For the purpose of this study the population used (population 2) consists of 13-year-old students studying in their eighth year (the second of the three years in the lower high schools). The students completed questionnaires on home and school experiences related to learning mathematics and science. This study examined data gathered from students' tests in science. The number of schools that participated in this project was 61 and consists of the entire high schools in Cyprus.

Procedure Used

The Varimax Factor Analysis Method is used in order to categorize the questions into factors, due to the fact that there were various parameters that aimed the definition of attitudes and self-beliefs. The Factor Analysis is a generic name given to a class of multivariate statistical methods, whose primary purpose is to define the underlying structure in a data matrix. Broadly speaking, it addresses the problem of analyzing the structure of the interrelationships (correlations) among a large number of variables by defining a set of common underlying dimensions, known as factor (Hair, Anderson, Tatham and Black 1995).

According to the factors that came up from the above analysis, stepwise multiple regression procedures were used to simultaneously assess the relative contribution of each factor towards the explanation of the science achievement.

ANALYSIS OF THE RESULTS

Grouping the variables

A number of statements from the questionnaire, within TIMSS study, are grouped together into a number of factors in order to make the analysis of the results more reliable. For the purpose of this study, student variables - included in the model - are determined on the basis of factor analysis. The method used is based in Varimax Factor Analysis. On the basis of the TIMSS-R data about Cyprus, one of the variables, which had been assumed as part of the above factors, was excluded from further analysis so that out of the 18 observed variables only 17 remained for further analysis. The results from the analysis are shown in Table 1.

Table 1. Results from the Factor Analysis

Rotated Component Matrix[a]

	Component			
	1	2	3	4
I would like science if it were not so difficult	.655			
Although I do my best, science is more difficult for me than for many of my classmates	.752			
Nobody can be good in every subject, and I am just not talented in science	.754			
Science is not one of my strengths	.742			
To do well in science at school you need lots of natural <talent/ability>			.843	
To do well in science at school you need good luck			.828	
To do well in science at school you need lots of lots of hard work studying at home				.815
To do well in science at school you need to memorize the textbook or notes				.718
How much do you like science	.626			
I enjoy learning science	.539	.559		
Science is boring	.601			
Science is an easy subject	.526			
Science is important to everyone's life		.651		
I would like a job that involved using science		.694		
To get the job I want		.827		
To please my parents				
To get into the <secondary school> or university I prefer		.774		
To please myself		.653		

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

The question stating, "I need to do well in science to please my parents" is excluded from further study because it is unable to fit within the factors specified above. The question "I enjoy learning science" is found in both the first and the second factor. In the following analysis, this variable will be included only in the second factor due to its higher value compared with the one given in the first factor.

The four categories arising from the factor analysis are discussed below.

1. Students' self-concept in Science. This factor includes the variables related with personal views of students about science. The statements related to this factor are:

- I would like science if it were not so difficult

- Although I do my best, science is more difficult for me than many of my classmates.

- Nobody can be good in every subject and I am just not talented in science.

- Science is not one of my strengths.

- How much do you like science?

- Science is boring.

- Science is an easy subject.

2. The importance of science in everyday life and the educational expectations of the students'. This factor includes variables regarding students' future plans and the significance of science in everyday life. The statements related to this factor are:

- I enjoy learning science.

- Science is important to everyone's life.

- I would like a job that involves using science.

- To get the job I want.

- To get into the secondary school or university I prefer.

- To please myself.

3. Beliefs of students' concerning the ability to do well in science related with good luck and natural talent. This factor concerns the association of non-academic variables that may affect students' scores in science. The statements related to this factor are:

- To do well in science at school you need lots of natural talent.

- To do well in science at school you need good luck.

4. Beliefs of students' concerning the ability to do well in science related with hard work and memorizing textbook notes. This factor concerns variables, which are associated with the effort needed in order to achieve high scores in science. The statements related to this factor are:

- To do well in science at school, you need lots of lots of hard work and studying at home.

- To do well in science at school you need to memorize the textbook or notes.

Factor Scores

Further analysis for the factors obtained was carried out estimating the factor scores. A factor can be described in terms of the variables measured and the relative importance of each variable for that factor. Therefore, we should be able to calculate a person's score on a factor, based on their scores for the constituent variables (i.e., a "composite score" for each individual on a particular factor). Stepwise regression analysis was conducted for the factor scores.

Findings from the multiple regression analysis of the relationship between self-concepts and science achievements are summarized in Table 2.

Table 2. Stepwise Regression analysis for the factor scores

Step	Variable	R Sq	Adj RSq	B	Beta	F
1	Factor 3: Students' belief concerning the ability to do well in science related with good luck and natural talent.	.182	.182	-32.326	-.427	618.475*
2	Factor 1: Students' self-concept in Science	.254	.253	-20.249	-.267	471.626*
3	Factor 4: Students' belief concerning the ability to do well in science related with hard work and memorizing textbook notes	.315	.314	-18.717	-.247	424.728*
4	Factor 2: The importance of science in everyday life and the educational expectations of the students	.325	.324	-7.705	-.102	333.945*

Note: * $p < .01$.

When all four factors included in the analysis were considered simultaneously, all of them significantly entered the multiple regression equation. The table above shows that factor 3, Beliefs of students concerning the ability to do well in science related with good luck and natural talent, appears to contribute to the prediction of the performance in science, within the frame of the TIMSS study. The contribution of this factor to R^2 was .182. When the factor 1 entered the R^2 became .254, suggesting that this variable added .072 (.254 - .182) to R^2. The factor 4 added a further .061 (.315 - .254). Finally, the second factor contributed a further 0.01 (.325-.315) to the explanation of the variance in science achievements test scores, indicating that 32.5 per cent of the variance in science was explained by these four factors.

Analysis of the Factors Obtained

Further analysis included least squares multiple regression procedures. Stepwise regression analysis was conducted for the entire sample including the four factors mentioned above.

Factor 1: Students self concept in Science

Findings from the multiple regression analysis of the relationship between self-concepts and science achievements are summarized in Table 3.

Table 3. Stepwise Regression analysis for the first factor

Step	Variable	R Sq	Adj RSq	B	Beta	F
1	Although I do my best, science is more difficult for me than for many of my classmates	.262	.262	-28.220	-.334	1031.418*
2	I would like science if it were not so difficult	.289	.288	-11.845	-.132	589.236*
3	Science is not one of my strengths	.303	.302	-8.813	-.110	420.227*
4	Nobody can be good in every subject, and I am just not talented in science	.309	.308	-8.913	-.102	324.333*

Note: * $p < .01$.

When all seven variables included in the first factor were considered simultaneously, four variables significantly entered the multiple regression equation. This is a result of the stepwise selection, which eliminates variables that reduce the significance of independent variables already considered.

The table above shows that the students' self-concept in Science appears to contribute to the prediction of the performance in science, within the frame of the TIMSS study. The contribution of the first variable to R^2 was .262. When the second variable --- entered the R^2 became .289, suggesting that this variable added .027 (.289 - .262) to R^2. The third variable added a further .014 (.303 - .289). Finally, the fourth variable contributed a further 0.06 (.309-.303) to the explanation of the variance in science achievements test scores, indicating that 30.9 per cent of the variance in science was explained by these four variables. From the above results it is possible to conclude that students who tended to show lower science achievement test scores were more likely to indicate that they were facing difficulties in the understanding of the nature of science.

Factor 2: The importance of science in everyday life and the educational expectations of the students.

Findings from the multiple regression analysis of the relationship between the importance of science in everyday life and the educational expectations in science achievements are summarized in Table 3.

When all six variables included in the second factor were considered simultaneously, five variables significantly entered the multiple regression equation. The Table 3 shows how the importance of science in everyday life and the educational expectations of the students in science

Table 3. Stepwise Regression analysis for the second factor

Step	Variable	R Sq	Adj RSq	B	Beta	F
1	I enjoy learning science	.068	.068	-16.219	-.174	220.818*
2	To get into the <secondary school> or university I prefer	.080	.079	-12.726	-.159	130.949*
3	To get the job I want	.089	.089	15.572	-.190	98.514*
4	Science is important to everyone's life	.099	.098	-10.571	-.107	82.987*
5	I would like a job that involved using science	.106	.104	-8.318	-.106	71.019*

Note: * $p < .01$.

appear to contribute to the prediction of the performance in science, as part of the TIMSS study. The contribution of the first variable to R^2 was .068. When the second variable was entered the R^2 became .080, suggesting that this variable added .012 (.080 - .068) to R^2. The third variable added a further .009 (.089 - .080). The next variable contributed a further 0.01 (.099-.089). Finally, the fifth variable added a further .007 (.106-.099) to the explanation of the variance in science achievements, indicating that 10.6 per cent of the variance in science was again explained by these five variables.

From the above results it is possible to conclude that students who tend to show higher science achievement test scores were more likely to indicate that they enjoyed learning science. They were also expected to consider science as an important subject for their future career.

Factor 3: Beliefs of students concerning the ability to do well in science, related with good luck and natural talent

Findings from the multiple regression analysis of the relationship between the importance of the students' beliefs related with good luck and natural talent, in association with their achievements in science, are summarized in Table 4.

Table 4. Stepwise Regression analysis for the third factor

Step	Variable	R Sq	Adj RSq	B	Beta	F
1	To do well in science at school you need good luck	.110	.109	-30.707	-.367	364.036*
2	To do well in science at school you need lots of natural <talent/ability>	.113	.112	5.449	.070	188.582*

Note: * $p < .01$.

The table above indicates how the students' beliefs concerning the ability to do well in science related with good luck and natural talent appear to contribute to the prediction of the performance in science, in the TIMSS Exams. The contribution of the first variable to R^2 was .110. When the second variable entered the R^2 became .113, suggesting that this variable added .003 (.113 - .110) to R^2, indicating that 11.3 per cent of the variance in science was explained by these two variables.

From the above results it is possible to conclude that students who indicated that to do well in science at school you need good luck and lots of natural talent, tented to show lower achievements test scores.

Factor 4: Students' beliefs concerning the ability to do well in science related with hard work and memorizing textbook notes.

Findings from the multiple regression analysis of the relationship between the ability to do well in science related with hard work and memorizing textbook notes, in association with their achievements in science, are summarized in Table 5.

Table 5. Stepwise Regression analysis for the fourth factor

Step	Variable	R Sq	Adj RSq	B	Beta	F
1	To do well in science at school you need good luck	.110	.109	-30.707	-.367	364.036*

Note: * $p < .01$.

When the two variables included in the fourth factor were considered simultaneously, only one variable significantly entered the multiple regression equation.

The contribution of the variable shown above to R^2 was .031, indicating that 3.1 per cent of the variance in science was explained by this variable.

CONCLUSIONS

These findings indicate that students' self-beliefs and attitudes are significantly related to science achievement and should be given consideration by instructional designers, when developing science materials and curriculum. These factors should be in mind of any science teacher in order to enable him promote the discussed positive attitudes and beliefs through teaching.

From the analysis of the study, using the least squares multiple regression procedures for the factor scores, we can conclude that the most important factor that affects students' achievement is the factor relating with beliefs of students concerning the ability to do well in science related with good luck and natural talent.

Students who indicated that they enjoy learning science, tended to show higher achievement test scores. Similarly, students who felt that science is important tended to have higher achievement test scores. This is in accordance with the study of Bloom (1976), who predicted that the attitude and subject related self-concept would account for up to 25 per cent of the variability in students' achievement scores. However, students who indicated that either good luck or lots of natural talent are necessary for success in science at school, tended to show lower achievement test scores. When the entire set of variables was considered simultaneously, it was found that student self-beliefs and attitudes towards science were significantly related to science achievement test scores.

These results are consistent with previous research that found significant relationship links between students' attitudes and their achievement outcome (Fraser and Butts, 1982; Cheng and Seng, 2001; House, 1993, Gardner, 1975). According to those studies, positive attitudes towards science could promote better performance and vice - versa. The results were in accordance with other researchers' studies increasing the general application and validity of these findings.

Although Cypriot students show a positive attitude and a high self-confidence for science, their academic achievement is not actually correlated with these factors. The TIMSS data shows that the Cypriot students were listed below the average of the student achievement level in science. Therefore, although attitudes and self-beliefs were positive for the majority of the students, achievement did not duplicate this pattern. However, there are many researchers (Lester et al., 1989) who support that attitudes and beliefs are important factors in the student achievement.

These findings also provide a variety of directions for additional research. For example, these results suggest that students' self-beliefs are significantly related to science achievement test scores. Further study is required in order to determine how self-beliefs and attitudes are related to other types of outcome. Similarly, adequate research is needed to determine whether these relationships can be noted for / applied to students in other countries, within the TIMSS research scheme.

Although TIMSS study gives a great opportunity to investigate various aspects of students' attitudes and self-beliefs in science education, further research is needed with qualitative methods in order to explore in deeper way those important aspects that could affect students' achievements in science education.

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Alexandros Mettas, Ioannis Karmiotis, Paris Christoforou

Department of Educational Sciences

University of Cyprus

Phone: 0035722892160

E-mail: mettas@ucy.ac.cy, karmioti@hotmail.com, parchri@cytanet.com.cy

www.ejmste.com

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PROBING PRESERVICE TEACHERS' UNDERSTANDINGS OF SCIENTIFIC KNOWLEDGE BY USING A VIGNETTE IN CONJUNCTION WITH A PAPER AND PENCIL TEST

Mehmet Fatih Tasar

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ABSTRACT. The purpose of this study was to examine how prospective middle school science teachers understood and identified types of scientific knowledge in a presented vignette. Also, their definitions and views of the relationships between types of scientific knowledge (i.e. scientific facts, concepts, generalizations, theories, and scientific laws) were investigated through open-ended questions. Additionally, participants were given the Nature of Scientific Knowledge Scale (NSKS) after they responded the open-ended questions. Therefore both qualitative and quantitative data were obtained about their understandings and views about scientific knowledge. Thirty six participants responded the questionnaires at the end of the spring semester 2005. During this semester participants were in their junior year and enrolled in a 'history and nature of science' course in which 16th and 17th century scientific revolution and the historical background leading to those developments were discussed. Participants received no specific instruction about the definitions of types of scientific knowledge like theories and laws. Analysis of the quantitative data obtained via NSKS show that participants hold a view favoring the tentativeness of scientific knowledge and mostly appreciate the developmental nature of science. While, on the other hand, analysis of the qualitative data obtained through the open-ended questions illustrate that participants hold a stepwise development view in science assigning the tentativeness in science to theories and lower steps. Overwhelmingly they emphasize that scientific laws reflect proven truth and in a sense absolute. These findings show the usefulness of utilizing appropriate vignettes for probing views. The results are disscussed in the light of existing literature and implications are provided.

KEYWORDS. Nature of Science, Assessment, Vignette, Tentativeness, Science Literacy.

INTRODUCTION

Today science is an inevitable part of our lives and a constant school subject around the world. Educators responding to how science education should be organized around central ideas put forth many proposals. Among them Victor Showalter and his colleagues in the Unified Education Movement determined seven dimensions for scientific literacy (Showalter, 1974 as cited in Bybee, 1997, p.57). These dimensions are i) the nature of science, ii) concepts in science, iii) processes of science, iv) values of science, v) science and society, vi) interest in science, and

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vii) the skills of science. Within the nature of science dimension they included tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, and empirical characteristics of science (Lederman, Wade & Bell, 2000). Later, the National Research Council (NRC) explained the personal relevance of scientific literacy as "[it] entails being able to read with understanding articles about science in the popular press and to engage in social conversations about the validity of the conclusions. (…) A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it" (NRC, 1996, p.22).

Recently, McComas and Olson (2000) qualitatively analyzed eight international science education standards documents to determine the recommendations towards including aspects of the nature of science in teaching and learning. As a result of a qualitative analysis they found that 38 distinct statements could be made to summarize the elements of the nature of science claimed in the documents. They further categorized these statements under four groups: philosophical, sociological, psychological, and historical. These findings show that many aspects of the nature of science are strongly recommended by the standards documents. It is also known that such notions are becoming more and more visible in science textbooks. It then can be concluded that the nature of science is an integral part of teaching and learning science in schools today.

THEORETICAL BACKGROUND

Paper-Pencil Tests in Assessing the Views About the Nature of Science

Several ways of assessing understandings of the nature of science have been developed and used so far. In addition to paper-pencil tests, alternative assessment techniques were also developed and utilized. Lederman, et. al. (2000) list and critique two dozens of nature of science instruments developed and used between 1954 and 1995. Their critique of 13 of them focuses on the validity of the instruments and they suggest using those in conjunction with other more valid instruments. Consequently, they consider the remaining 11 instruments as valid and reliable.

One of such paper and pencil instruments is the Nature of Scientific Knowledge Scale (NSKS) developed by Rubba (1976). He developed a six sub-scale model of the nature of scientific knowledge by reducing the nine factors Showalter previously advocated. Rubba's six sub-scales are amoral, creative, developmental, parsimonious, testable, and unified characteristics of the scientific knowledge. This instrument contains 48 items. The concerns raised by Lederman, et. al. as threats of validity for this instrument center around the high number of items it includes and half of them being just negatively worded versions of the rest. However, the NSKS have been widely used in numerous studies since its development.

Qualitative Research in Nature of Science Assessment

Instead of usual Likert scale measures of views Aikenhead (1987) took a different approach and presented the subjects statements upon which for them to comment and give extended written responses. One pair of such statements (item 15) is about the tentativeness of scientific knowledge and contains the following two opposite statements much like NSKS style:

15.1 When scientific investigations are done correctly, scientists discover knowledge that will not change in future years.

15.2 Even when scientific investigations are done correctly, the knowledge that scientists discover may change in the future.

In the researcher's eyes while 15.1 presented an absolute view of scientific knowledge, 15.2 expressed a tentative view. The analysis of data obtained from the large sample of senior high school students showed that although nearly all of the students believed that today's scientific knowledge is subject to change they accounted different reasons for their respective views (categorized into six main paraphrased codes of student expressions.) Another notable result was that, as the researcher himself admits, percentages of students varied in each category in their responses for the two statements, which shows that student responses were influenced by the wording of the statement. One can also note, by reading the above statements, that it is assumed that the subjects uniformly understand the term "scientific knowledge." As a result statements do not contain terms like hypotheses, scientific law and/or theory. It would be very interesting to see the results if one statement included scientific law and the other theory. In this form the above statements are too generic and coarse to allow a more detailed analysis of students' views about tentativeness in scientific knowledge.

Afterwards Lederman and O'Malley (1990) developed a 7-item open-ended questionnaire and used it in conjunction with follow-up interviews. They noted, by using this method, that there are unavoidable interpretation problems associated with having participants to respond in written form to researcher generated questions. Consequently they validated the questions by follow up interviews. Notably, the seven-item questionnaire included the following two questions:

(Item 1) After scientists developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to learn about theories. Defend your answer with examples.

(Item 3) Is there a difference between a theory and a scientific law? Give an example to illustrate your answer.

In fact, when examined carefully it can be seen that these seven questions (as listed in Lederman, et. al. 2000, p.342) are lined and worded in a way that they may lead the participants towards the answer the researchers had in mind. Surely, researchers wished to investigate and understand how participants viewed the tentativeness (or the developmental aspect as Rubba referred to) of scientific knowledge. But asking questions in this way has a great potential of cueing the participants. For example item 1 does not ask participants to tell their views if they believe theories do not change. Therefore it pushes the subjects to respond in one way only. Moreover, the question includes the keyword "change." When a person who has not paid any attention to such issues before reads a question of this sort s/he is inevitably prompted to the change idea in scientific knowledge. Thus, when the paper and pencil test is used alone the researcher will have no means to figure out if the answer totally stems from the respondent's existing understandings (a well considered self view) or if it is the result of cueing (a made up answer at that moment). When all seven items are considered together the questionnaire looks more like a teaching experiment (Steffe & Thompson, 2000) interview protocol, where researchers are also considered as research instruments.

Subsequently another qualitative method was employed by Nott and Wellington (1996). They used critical classroom incidents in their alternative technique in order to elicit teachers' views about science. They wanted to create familiar contexts in which teachers can respond to issues related to the nature of science. These contexts are labeled as "critical incidents" and they portray descriptions of actual classroom events. The incidents are so created as to reveal beliefs when a teacher responds to it in a real like (simulated) classroom setting. This way of assessing views about the nature of science is indeed an indirect one and righteously opens the way to raised concerns (see for example Lederman, et. al., 2000). Another characteristic of this method is that it can only be used with teachers since the method employs teachers' pedagogical content knowledge as the tool to extract their understandings of the nature of science. Therefore it is not suitable for usage in other contexts except perhaps using it with prospective teachers.

Defining the Tentativeness of Scientific Knowledge

The National Research Council (NRC) explained how the tentativeness should be understood: "Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, *in principle,* subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore *unlikely to change* in the areas in which they have been tested" (p.201, emphasis added). This is the very definition adopted in this research study.

National Academy of Sciences (NAS) (1999) defined the terms of law and theory as follows:

Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.

Theory: In science, a well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypothesis.

These definitions are in line with the NRC's position and complement it.

McComas (2003) further dealt with the issue of defining these terms sufficiently in considerable length and effort. So those issues will not be taken further here. When he examined 15 U.S. secondary school biology textbooks by designing model definitions of both "law" and "theory" and comparing these definitions to those found or portrayed in the textbooks he noted that

"The term "law" is rarely defined in any text but various laws such as those found in genetics are frequently included as examples. The term "theory" is frequently defined but with a wide range of completeness of the definitions. Only rarely are theories in biology included as examples."

He also noted that some of the examined books included misleading language about theories suggesting the notion that as support mounts hypotheses become theories and as more evidences are gathered eventually they become laws. In order to draw attention to important points in teaching and learning the nature of science McComas (2000) determined and explained 15 "myths" (widely -held and incorrect ideas) about the nature of science. Six of them refer to the views about tentativeness in science: Hypotheses become theories that in turn become laws (myth 1); scientific laws and other such ideas are absolute (myth 2); evidence accumulated carefully will result in sure knowledge (myth 5); science and its methods provide absolute proof (myth 6); science is procedural more than creative (myth 7); science models represent reality (myth 13).

Blanco & Niaz (1997), Bell, Lederman, & Abd-El-Khalick (1998) and Lederman (1999) also found that the concepts related to the tentativeness of scientific knowledge are very confusing and that such understandings are common among both students and teachers.

All these previous works and Lederman's 1992 review clearly show that although teaching and learning about the nature of science is encouraged, attaining desired outcomes is not straightforward and there are still problems ahead of us. Attempts in measuring understandings have shown a way to follow and much has been learned from them. The messages derived here from the previous works are that instruments need to measure what the subjects know, how they know it, and how they apply it. Creating newer valid and reliable techniques that show a potential in measuring parts of nature of science notions can help overcoming the difficulties in interpretation and can make contributions by showing the right directions.

Usages of Vignettes in Assessment and Learning

Vignettes so far were utilized to collect data in various forms in studies from different areas in education in recent years. Their advantages particularly in qualitative, in-depth, small sample studies are obvious as will be seen below.

Case (1997) investigated the relationship between teacher beliefs and attitudes and the implementation of cooperative learning. She showed a videotaped vignette of teacher's classroom practice and interviewed the participants subsequently about its meaning for them. Bodur (2003) investigated preservice teachers' beliefs and attitudes about teaching culturally and linguistically diverse students. As part of his data collection strategy he used three multicultural vignettes in addition to other data sources. He applied certain criteria to choose the vignettes. By conducting an extensive search for them he chose the ones that best portray the issue in hand; that are relatively short (3 vignettes 143, 111 and 204 words in length); and that come from credible outside sources rather than being created by the researcher. This last criterion was mandated in order to avoid researcher bias. For each vignette he directed two short questions "Issues present in the vignette: (space below)" and "Your personal response to the issues you identified: (space below)" and provided half page blank space for each. As seen he does not mention any aspect of the issue at all in the questions, not even a key word.

As complementary data sources Harlan (1996) used three vignettes (around 500 words in length) in her study that represented distinct approaches to teaching art. Participants were asked to study each vignette and then respond to six Likert type questions. After completing this part they were also asked to respond to 3 final questions to compare and contrast their ideas and experiences about teaching to the ones presented in the vignettes. Veal (1997), on the other hand, focused on a small sample of prospective chemistry and physics teachers (two of each) and studied their development by utilizing multiple data collection methods. Among them he created content specific, situational vignettes in order to follow prospective teachers' development of pedagogical content knowledge. The vignettes in this study were rather lengthier as compared to the ones used in previously mentioned studies (around 2500 words). Participants in this qualitative study were asked 11 questions after reading the vignettes. The questions asked them to speculate (what would happen, how would happen, what would they do) and explain their ideas on specific points.

In contrast Roach, (1993) and Chan (2000) used interactive historical vignettes as teaching tools rather than assessment tools and obtained desirable results for students' learning and understanding the nature of science without impeding their achievement in science as compared to control groups.

In the light of this literature base the researcher in this study wished to pursue the following research questions:

How do prospective science teachers,

1) understand and identify different types of scientific knowledge (i.e. scientific facts, concepts, generalizations, theories, and laws)?

2) define and view the relationships between different types of scientific knowledge?

3) view the tentativeness of scientific knowledge?

4) make their views evident by responding to open-ended questions about a vignette and NSKS? How do the two types of responses compare to each other?

It is deemed that the methodology employed here will serve as a magnifying lens that will focus on some tinier part of the previous research and by doing so it will enhance our understanding of assessing views about scientific knowledge.

METHOD

This research study took place in Turkey at a large teacher training institution (a university faculty) in a metropolitan city at the end of spring semester 2005. Participants were first asked the following question:

> Please explain five most important characteristics of science you determined based on your readings about history of science and in-class discussions by giving examples from historical cases.

After collecting responses students were distributed another sheet containing a vignette. This is still another qualitative technique developed and used by the researcher for assessing understandings of the nature of scientific knowledge by utilizing a one-page piece (Newman, 2005, p.17) from a popular magazine as a vignette (see appendix for the English original). This magazine is published simultaneously as international edition in English and as one of the local editions in Turkish. The vignette was taken from the Turkish edition of the monthly magazine and presented to the participants. Therefore the translation belongs to the publishing company and the researcher made no change in the translation. The following question was directed to the participants about the vignette:

> Please carefully read the reading piece given below. Are there any facts, concepts, generalizations, theories and/or scientific laws mentioned in the vignette? Identify the ones directly related to the main theme of the vignette and explain why you think they are. (For example, explain why you think a particular case mentioned in the vignette is a concept or scientific law, etc.) If one or more of them are not present in the vignette, explain why you could not find them.

This particular vignette was chosen because first it was from an outside source rather than being created by the researcher, and second, the story told in the vignette was deemed to be culturally and scientifically entirely new for the participants. So it is thought that they could look at it and evaluate the issue without bias and prejudice.

Following the vignette the 48 item NSKS was administered to the participants to allow a comparison of the results obtained in both ways. The Turkish version was initially based on two separate translations from two native Turkish speaking experts of the field. It was then piloted several times on both undergraduate and graduate students. In two years by continuously giving several try outs and making refinements in the language ensured the reliability (the cronbach alpha was measured to be 0.71) of theTurkish version of the instrument.

While analyzing the extended responses to the two open ended questions the researcher looked for emerging themes. Several passes were conducted over the whole set of data and during each reading new understandings (categories and codes) were formed. The researcher initially did not know what he would face in the data. But the themes became clear slowly as the researcher was immersed in the data.

Data analysis was based on the original participant responses in Turkish. The excerpts given below are the researcher's translations. A verbatim translation without interpretation is presented here for the readers' convenience.

Participants

A course entitled "the history and the nature of science" is offered in spring semesters by the researcher in his institution. In this course various aspects of science and issues in the history of science are dealt with. During the semester in which the data were collected Turkish translations of two books were used: "The Construction of Modern Science" (Westfall, 1977) and "The Double Helix" (Watson, 1969). Thirty seven junior students majoring in middle school science teaching took the course and 36 of them participated in the study (one student was absent during the data collection day). They were prompted to pay attention to and study the relations between the different types of scientific knowledge two weeks before data collection. However, these issues were not covered intentionally or explicitly during the semester. In their responses they solely depended on their own previous knowledge and/or the information that they obtained as a result of their own research.

ANALYSIS AND FINDINGS

Responses to the First Open-Ended Question

For the five characteristics of science the most cited ones, related to the current discussion, were the progressive and accumulative nature of science (13 participants) and the changing nature of science (9 participants). Below are excerpts from three different respondents:

"There is nothing like things thought to be true in science will stand like that forever as long as they do not become laws they are not absolutely true. They can be improved and changed by making use of previously proved theories. For example Copernicus believed in the existence of crystal spheres. But later works disproved it."

"Science can change. This is the most outstanding feature of science. Scientific findings and knowledge have continuously changed throughout history. We can see how a scientific fact has changed from Aristotle's understanding of motion to the Newton's laws of motion. (…) Surely this change was based on many experimental and observational facts."

"Science is open to changes: Initially men were being executed when they claimed that earth was spherical. However, this is now a truth accepted by everyone."

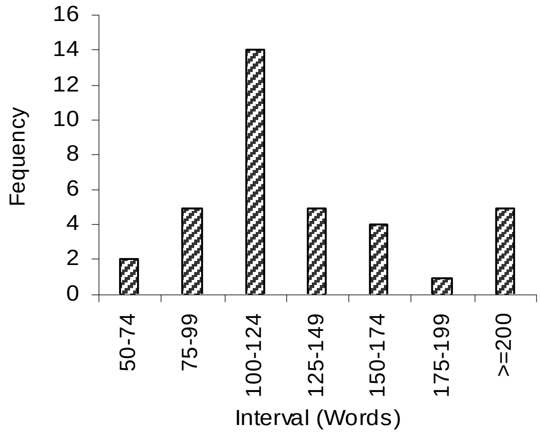
These responses clearly indicate that in the past scientific ideas have changed. But there is a certain objective truth (that can be accepted by everyone). Once, by way of science, ideas get tested they evolve to become absolute. This final stage is expressed in scientific laws. Such responses reflect participants' understanding of tentativeness. The tentativeness mentioned here can be regarded as partial: pertaining to "unproven" ideas. It is hard to tell from these findings that they see all scientific ideas being subject to change even in principle.

Responses to the Vignette

Figure 1 below shows the number of words the participants used in answering the open-ended questions about the vignette. While explaining their views in written form the participants used 131 words on the average with a standard deviation of 44 words. The minimum and maximum numbers of words used were 61 and 245 respectively. This analysis shows that they were indeed very articulate and tried to explain their ideas as thoroughly as possible.

When the qualitative data obtained via the vignette are analyzed it is seen that except one student all other participants indicated that laws represent proven, unchanging, certain truth about phenomena and that theories are subject to change since they are not final or proven (therefore tentative). That one participant considered both scientists' conclusions as theories but did not comment on any laws and did not explain his line of thinking about laws and theories. Twenty-nine participants stated that they could not find a law in the vignette, while the remaining seven extracted some definitive sentences (that fugu is poisonous and causes death when eaten) and labeled them as laws. Hence, they did not differ in the definitions but examples of laws present in the vignette.

Figure 1. The distribution of number of words used in participant responses.



Below are examples of participant responses:

<u>Participant #A:</u> "Theory is the developed state of hypothesis. If data confirms the hypothesis, it becomes a theory. For example, experiments were conducted and non-poisonous fish were produced by controlling the food they ate. (…) There is no law here. Because a theory can turn into a law when it is completely and certainly obvious. However, since there is no certain, unchanging idea in this piece, there is no law."

<u>Participant #B:</u> "In the third paragraph it is indicated that the source of the poison of the fugu fish is how it is fed. Research was conducted on this, when fish were fed by different food it became non-poisonous. This was verified by many people. It is confirmed by experiments. However, someday someone can disprove this theory. The reason is that it has not yet become a law. Theories can be disproved.

In the fifth paragraph there is also a theory. It is said that fugu's poison comes from the "poison glands beneath its skin." It is said that "in this case some fugu are poisonous and some are not." This is also a theory. This result was reached through the conducted experiments. But this is not a law either. It can be disproved. Someday, anyone might say that it is not so, and can prove what s/he says.

Concepts are the abstract forms of objects in our minds. It can be said that poison is a concept. In this piece there are examples of facts, generalizations, concepts and theories. But I could not found an example of law. Law is the step that comes after theory. Laws emerge when all scientists reach the same conclusion as a result of their experiments and they cannot be disproved, their truth has been established (proved). In this piece there are assumptions, theories; any moment some people come up and disprove. However, there is no implication that everyone has reached the same conclusion, it has been accepted by the whole world, that is, there is no law."

One participant's point of view is rather interesting and different from all others:

Participant #C: "Tamao Naguchi is saying that fugu's poison comes from the way it is fed. This is a theory. Because he says that blowfish eats organisms that eat poisonous bacteria called vibrio. Naguchi grew fish by controlling their food and obtained non-poisonous fish. This is a law. Because he proved his theory as a result of experiment. That is, he applied and showed the truth of his idea."

She logically applied the "theory becoming a law" myth to the presented case in the vignette and reached her conclusion. In fact 33 students expressed, either by directly stating or explicitly implying, this very idea.

The typical rationale for not seeing a law in the vignette was expressed as follows:

Participant #D: "No law is mentioned in the vignette. The truth of the proposed theories are not proven. The proposed theories do not contain absolute (certain) truths. We call a generalization closest to the truth as law."

Participant #E: "There is no law. Because why the fish kills could not be fully proven. Laws cannot be criticized."

Existence of two different ideas coming from two scientists perplexed the participants. This was the main reason for not finding a scientific law present in the vignette.

As to the presence of theories in the vignette 19 participants regarded only Naguchi's work as a theory while 12 students expressed that both Naguchi's and Matsumara's works are theories. One student understood both works as hypotheses. Two students found different statements as theories in the vignette. The remaining two students did not mention of any theories.

Responses to the NSKS

The results of the NSKS survey for the items related to tentativeness of scientific knowledge yielded mostly desirable outcomes (see Table 1). In this subscale there are 8 items four of which are positive (items 16, 26, 37,and 42) and the remaining four items being negatively worded (items 25, 27, 31, and 43). Participants consistently seem undecided only for items 16 and 27 which are the positively and negatively worded versions of the same idea.

One criticism that can be directed to the above NSKS items is that it puts all eggs in the same basket. Namely it either mentions "scientific knowledge" or as in item 26 contains all types of scientific knowledge in the same statement. The problem with this is that when participants accept this statement we have no idea whether participants mean theories or laws or both as changing. This point has overreaching consequences and crucial in determining participants' understanding and notion of tentativeness. Another criticism is that although participants did not favor unchanging scientific knowledge or belief notions we do not know whether they mean it by only looking at the past or by also ascribing to the future. Here the word future is a keyword that the subjects need to tackle and explain.

Table 1. NSKS items related to tentativeness in science and respective scores.

Item #	Item Expression	Mean Score
16	We accept scientific knowledge even though it may contain error.	2.71
25	The truth of scientific knowledge is beyond doubt.	2.03
26	Today's scientific laws, theories and concepts may have to be changed in the face of new evidence.	4.18
27	We do not accept a piece of scientific knowledge unless it is free of error.	2.18
31	Scientific beliefs do not change over time.	1.76
37	Scientific knowledge is subject to review and change.	4.24
42	Those scientific beliefs which were accepted in the past, and since have been discarded should be judged in their historical context.	4.18
43	Scientific knowledge is unchanging.	1.74

RESULTS

From the qualitative data it is seen that participants make a distinction between scientific laws and other types of scientific knowledge. Although the former is seen as almost absolute the rest is regarded as being subject to change. From this point of view scientific laws are considered as the final destination that a scientific program can reach. Once this point is reached they see no further effort to be put on the same subject. Moreover they hold a naïve conception that a universal consensus can be attained on a scientific issue and it can remain like that afterwards. Although scientists assume that their generalizations are invariant over time and space it does not mean that a universal agreement is/can be achieved. It is a formal basis and a framework for scientific enterprise. They also naively assume that all successful scientific efforts are going to end by establishing a scientific law.

Participants see a hierarchical relationship between different types of scientific knowledge. In their scheme scientific laws lie at the top and are not disprovable. Theories hierarchically come after scientific laws and can be disproved. In this view both theories and scientific laws are in fact the same sort of scientific knowledge but with different levels of acceptance.

As to the tentativeness of scientific knowledge different positions are expressed in qualitative and quantitative responses. When the NSKS item 26 is considered it can be concluded that participants highly favor the tentativeness idea in science. But this item includes all types of scientific knowledge. On the other hand, it is evident from the qualitative data that participants do not see scientific laws as changing. This result shows that the different data sets are contradicting on participants views of tentativeness of scientific knowledge.

DISCUSSION

This study showed that first, carefully selected vignettes can be used as powerful tools for probing understandings of the nature of science. This is also meaningful in that subjects were asked to apply their knowledge to a novel case. Hence, by this method, not only rote memorization of formerly presented ideas about the nature of science, but also meaningful understanding was probed. Analyzing and evaluating such vignettes also has a potential to promote and teach higher order thinking skills.

Secondly, participants have expressed that theories can be disproved while laws cannot. The support for this opinion was that there were two contradicting explanations coming from two different scientists. They understood this situation as "not yet proven" but could be proven once and for all at some point in time later. This position is distinctively different from the one favored by NRC as stated above.

It is obvious from the data that the participants' minds were preoccupied with the false hierarchical relationship between facts, hypothesis, theories and laws (McComas, 2000). In this view laws are discovered by almost an automatic process (or machinery) starting from observations and ending up with laws (this notion is also related to myth 7). The findings that support this conclusion are that participants were overwhelmingly seeking whether a definitive conclusion about the problem was reached and stated by scientists. If they had not seen a difference of findings and hence difference of opinion in the vignette about the same phenomenon (i.e. if only one of the works of the mentioned researchers was to be presented to them or both scientists had agreed) they would most probably call it a new law since it is a result of a scientific work and no objection was being raised.

This way of regarding laws is in fact a large deviation from actuality. Laws in science are the core ideas. Although scientific laws are a special class of generalizations, not all generalizations are called laws in the scientific enterprise. For example the earth's shape is spherical. Although it was debated in the history we now have some undeniable data (e.g. the earth's picture taken from outer space) that show us that the shape of the earth is without doubt spherical. All physicists agree on this as well (there is no current contrary view or effort to prove otherwise). The problem is settled and the case is closed. However, this definite statement is not regarded as a scientific law. Moreover, there is not a law that states that all planets are (or must be) spherical in shape. Another example that can be given is the statement "all human beings die." There is no exception to it that we know of or we expect to see in the future. Yet this generalization is not called or labeled as a scientific law either. Not because it is not as much certain as we would like it to be to gain universal validity or research/debate is continuing on the issue. But just because scientific laws represent core ideas in science and in a way they are just some labels for some of the scientific generalizations (inductions).

Lederman et. al. (2000) took in their categorization an either/or approach for a students view and accordingly coded individual student responses as being "absolute" or "tentative" as a whole as a result of their interpretation of the interview data. However, the distinction between theory and law and their relationship to each other is a central and crucial point in understanding the nature of science as McComas (2000) has explained. Another way to explain the Lederman et. al. data could be to look at them from a different perspective as they partially did. As data from the current study also shows contrary to the accepted view subjects may adhere to an alternative notion that some scientific knowledge are tentative (i.e. hypotheses and theories) while others are absolute (i.e. scientific laws) since the former evolves into the latter under certain conditions (myth 1) and becomes absolute (myths 2, 5, and 6). Viewing the data from this perspective shows a potential to resolve the interpretation problems and conflicts in the analysis of data obtained via paper and pencil tests mentioned by Lederman et. al. They state that:

> "The data gathered during the pretest seem to indicate that the students, as a group, do not uniformly adhere to either an absolute or tentative view of scientific knowledge. That is responses to questions two and three strongly favored an absolutist view while the responses to questions one and four were more aligned with a tentative view. This might indicate that it is possible for students to compartmentalize their views with respect to the type of scientific knowledge or it could simply indicate that students are in a state of transition."

Lederman and O'Malley emphasized over and over again that using paper and pencil alone has crucial pit falls that often mislead researchers. Hence they conducted follow up interviews in order to elicit in depth what the participants had in mind when they used specific words like 'theory' and 'law'. This way they were able to elicit in depth the participants' views. In the present study the vignette provided a context for the students to respond. So that the questions were not just some "dry stuff." It can be claimed that the story took the role of the interviews in that study without the presence of the researcher.

Furthermore we cannot explicate participants' views as tentative or absolute just by looking at what they say about the state and role of change in scientific knowledge. Their understandings of scientific laws and theories and most importantly the relationship(s) between the two are, indeed, crucial in making such inferences as the current study shows.

Implications for Further Research

Lederman and O'Malley showed that students' understandings and use of scientific proof was in line with practicing scientists' use. In that study it was shown that students did not mean to use the word in an absolute sense. However in this study students' views cannot be regarded as tentative. They regard theories as tentative and laws as absolute as the presented data shows. Future research should take the responsibility to find the source of this discrepancy: Namely, why the Turkish preservice middle school science teachers hold an absolutist view? Is this view common among Turkish high school and college students and science teachers? How are such notions, if any, presented or described in Turkish curricula and textbooks? How practicing Turkish scientists view the tentativeness in science?

Future research should also address several issues about views of tentativeness. While probing understanding of tentativeness of scientific knowledge participants must be explicitly questioned on whether they see a distinction between hypotheses, theories and scientific laws; whether they see a distinction between results of scientific work belonging to the past, present and future; and whether they hold a hierarchical view between different types of scientific knowledge. This way a more holistic understanding can be obtained and subjects' mental models about tentativeness can be extracted.

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APPENDIX

Vignette

12 TOXIC TALES

"a delicacy to die for"

(…) Fugu, or puffer fish, as it is commonly known, is a delicacy in Japan. It can also be deadly. Those who eat the liver, ovaries, gonads, intestines, or skin swallow tetrodotoxin, a powerful neurotoxin that jams the flow of sodium ions into nerve cells and stops nerve impulses dead in their tracks. They run the risk of suffering the fate of the famous Kabuki actor Mitsugoro Bando, who in 1975 spent a night feasting on fugu liver because he enjoyed the pleasant tingling it created on his tongue and lips. The tingling was followed by paralysis of his arms and legs, difficulty breathing, then, eight hours later--death. There is no known antidote.
(…)
The source of the fugu's poison is a subject of debate. Tamao Noguchi, a researcher at Nagasaki University, believes the secret lies in the fugu's diet. Puffer fish, he explains, ingest toxins from small organisms-mollusks, worms, or shellfish--that have in turn ingested a toxic bacterium known as vibrio. In experiments, Noguchi has raised fugu in cages, controlled their diet, and produced toxin-free fish.
He hopes his research will result in the state-sanctioned sale of fugu liver. "A great delicacy; once you eat, you cannot stop," he says. Japan has forbidden the sale of fugu liver since 1983; before the ban, deaths of those who overindulged in the liver, or ate it by mistake, numbered in the hundreds.
(…)
Kendo Matsumura, a research biologist at the Yamaguchi Prefectural Research Institute of Public Health, discounts Noguchi's deadly diet explanation*. He says the fugu's toxicity comes from poison glands beneath its skin. Some fugu are poisonous, he says, some aren't, but even experts can't tell which is which.
Place your bets. Matsumura has never eaten fugu. "I am not a gambling man," he says. However, Noguchi considers it the ne plus ultra of fine dining.
When it comes to fugu, one man's poisson is another man's poison.

* In the original text "theory" was used here. It was purposefully replaced by "explanation" in order not to cue the participants.

Mehmet Fatih Tasar

GAZI ÜNIVERSITESI

Address: Gazi Egitim Fakültesi

K Blok 228, Teknikokullar

06500 ANKARA

TURKEY

Phone: +90 (536) 234 9827

Fax: +90 (312) 222 8483

E-mail: mftasar@gazi.edu.tr

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

Esra Macaroglu Akgul

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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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Esra Macaroglu Akgul

Yeditepe University

E-Mail: emacaroglu@yeditepe.edu.tr

www.ejmste.com

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MATHEMATICS EDUCATIONAL VALUES OF COLLEGE STUDENTS' TOWARDS FUNCTION CONCEPT

Yüksel Dede

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ABSTRACT. Mathematics is usually seen as a field in which there is value-free. Such a situation causes only a few studies about values teaching to be done in mathematics education. But, mathematics is a field that has various values in it, and that must be considered seriously from this perspective. Values are taught implicitly rather than explicitly in mathematics classes when comparing to others. Function concept also take place among the most essential concepts of mathematics. It concept has affected the whole maths cirruculum. Therefore, being unable to comprehend this concept will make mathematical concepts understanding harder. Knowledge defiencies of teachers and undergrade students this concept understanding much harder. So, in this article, it has been tried that the mathematics students' mathematics educational values towards function concept have been determined. The subject of this work consist of undergrade students who have studied at Cumhuriyet University in Sivas and also Cumhuriyet University's Mathematics Educational Department in Sivas. Data were collected from 10 open-ended and 11 items reasons of question choose. As a result of this research, it was realized that the students from all grades preferred, in terms of learning the function concept, those questions that hold the formalistic view values, relavance values, instrumental understanding/learning values, accessibility values, and reasoning values.

KEYWORDS. Values, Mathematical Values, Mathematics Educational Values, Function Concept.

INTRODUCTION

Affective aims in courses that are hard to be comprehended by students, like mathematics, should not be neglected. In studies about teaching mathematics'affective field, attitude, belief and motivation dimensions have also been usually taken into consideration and its values teaching dimension is neglected (Seah & Bishop, 2000). However, values is the most important element of raising mathematics learning and teaching qualities (Seah, 2002). Then, what are values? According to Brown (2001), identifying values is hard. For this, we need some concepts such as "good" and "bad" (Swadener & Soedjadi, 1988). The word "value" has been used in different meanings. "The value"of unknown in an equation, the "value"of listening a conversation and moral "value" of an individual can be given as an example (Seah & Bishop, 2000). Swadener and Soedjadi (1988) identify values as a concept or an idea about value of anything. Mattthews (2001) also sees them as leaders and means of behaviours. When looking these identifications, it can be described as personel choices considering value or importance of

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a behaviour or idea, or general aims that are adopted or followed by an individual as a member of a society. Therefore values have reflected concepts or ideas about anything. Values can be categorized into two. These are aesthetic and ethical. Aesthetic values are about beauty concepts. Ethical values are about concepts which can be expressed as good or bad and they are interested especially in good and bad sides of a behaviour. This part of values forms a wholeness with education. They cooperate with education and so they make society formation possible (Swadener & Soedjadi, 1988).

Similarities and Differences among Value, Attitude and Belief

Terminology used about attitude, belief and value concepts becomes complementary (Bishop et al., 1999). Generally, there is a close relation between values and attitudes. Values have affected emotional components of cognition, emotion and behavior inclination elements of attitudes. And also all of the attitudes has no social side, while values come into existence at two phases as personal and social. Yet, attitudes about social values are social (Tavşancıl, 2002).

Tavşancıl (2002) describes belief as a whole cognition of an individual about a topic. Thus, values can be seen as a practicing tool of beliefs. (Clarkson et al., 2000). Attitudes and beliefs can undergo some changings as a result of human's experiences during their life. Especially, in adolescence period of individuals, these changes take place much. Yet, we cannot tell the same things about values.Values take root within human souls deeper and they are become more integral by human (Seah, 2003). Values are interested in being important of fact or not being important of fact. For instance, just like a teacher's taking care about using logical thinking, problem solving or technology in accordance with his/her own teaching techniques or vice versa (Seah, 2002). Differences between values and beliefs are given below at table 1.

Table 1. Possible ways of differentiating beliefs from values

	Belief	Value
It is about the degree to which something is	... true	... important
It exists...	... in a context	... in the absence of any context

(Source: Seah, 2002; Seah &Bishop, 2002)

Similarities between values and beliefs are also given below at table 2. It provides some examples of beliefs. For each belief, the possible value(s) associated with it is/are suggested. (Seah & Bishop, 2002).

Table 2. Examples of beliefs and corresponding values

Belief	**Value(s)**
Mathematical proofs need to be taught to students.	Rationalism
What is important in mathematics has been and will be shown by mathematicians.	Mystery
All that matters in mathematics is getting the right answer(s), nevermind the methods used.	Product
Mathematics assessment should focus on multiple-choice and short-answer questions.	Product
Full marks should be awarded for correct method shown, even if the numerical value is wrong.	Process
What is learnt in school mathematics is relevant to life and work.	Relevance
The new Maths Methods (CAS) is what school mathematics should be about.	Relevance
School mathematics is about understanding and learning ideas.	Concept
The role of the mathematics teacher is to teach concepts and demonstrate associated skills.	Authority
School mathematics provides us with tools for successful problem-solving.	Tool
As a teacher, I believe that student group work is essential in their mathematics learning experience.	Communication
Students in my class are free to work with the manipulatives at any time.	Responsibility

(Source: Seah &Bishop, 2002)

Mathematics and Values

Modern mathematics has a deductive-axiomatic structure and generally shows a hierachical consruction. So, it is hard to understand a mathematical concept wihout being aware of its preliminary subjects. This deductive-axiomatic structure of mathematics depends on undefined terms, definitions and logical rules (Swadener& Soedjadi, 1988). Absolutist philosophers; who see mathematics from this perspective, appreciate it as an abstract science and also they think that it is interested in generalization, theory and abstractions. So, mathematics is seen as a field which has no social choice and with which only a few people concerns. And mathematics is value-free; that is to say, it is neutral (Bishop, 1998; Bishop, 2002; Ernest, 1991). In fact, mathematics is loaded with values. It is not neutral. Yet, values are generally taught implicitly rather than explicitly in mathematics. However, values are rarely taken seriously at mathematics educational discussions and mathematics teachers are generally interested in operations that has only one answer. They don't believe values teaching in mathematics lessons (Clarkson et al., 2000). Nowadays, cirruculum programmes are prepared in this way.

Programmes prepared usually focus on students'achievements. At cirruculum, although there some expressions about values teaching, we meet a little information about their developments. But, it is an obligation that one has more information about values which play a vital role in mathematics educational development (Bishop et al., 2000). They play an important role in students gaining their personal and social identities. Especially, this side of values can be seen at front side in mathematics lessons. Because values affect students' choices about concerning about mathematics or not concerning about it significantly (FitzSimons & Seah, 2001). Sam and Ernest (1997) classify the values about mathematics education into three such as; i) Epistemological Values: They are the values which are about theoretical side of mathematics learning and teaching such as; accuracy, systematicness, and rationalism and also characteristics, appreciation and acquiring of mathematical knowledge. For example; accuracy, being analytical, rationalism and problem solving. ii) Social and Cultural Values: They are the values that indicate human's responsibilities about mathematics education for society. Such as; compassion, integrity, moderation and gratitude. iii) Personel Values: Values that affect person as an individual or a learner. Such as; curiosity, thriftiness, patience, trust and creativity.

Bishop classifies values taught in mathematics lessons into three different types by making them more specialized than that of Sam and Ernest. These are; general educational values, mathematical values and mathematics educational values (1996; cited in Bishop et al., 1999).

a) General Educational Values

They are the values which help teachers, schools, culture, society and students to improve. Generally, they contain ethical values such as; good behaviour, integrity, obedience, kindness and modesty (Bishop et al., 1999; FitzSimons et all., 2000). Warning a student who has been cheating during exam can be given as an example for such kind of values (Seah & Bishop, 2000).

b) Mathematical Values

Mathematical values are the values that reflect the nature of mathematical knowledge. They are produced by mathematicians who have grown up in different cultures (Bishop et al., 1999). Proving Pythagorean Theorem in three different ways and their appreciation are an example to mathematical values (Seah &Bishop, 2000). Culture stands as a powerful determiner of mathematical values. Researchs show that basis values of all cultures have not been shared. So, mathematics teachers work in different cultures do not teach the same values, even if they have taught them the same cirruculum (Bishop et al., 2000). Bishop classifies mathematical values taught in Western culture into three categories as complementary of each others (1988; cited in Seah & Bishop, 2000). These are;

i) Rationalism-Objectism: Rationality values indicate the values that people have about mathematics. According to this value, mathematics has the ideas which depend on theory, logic and hypothesis (Bishop et al., 2000). Shortly, rationalism value shows a deductive logic which concerns about only correctness of results and explanations. Objectism value shows; because of its nature, objects and symbols which is an instrument to concretize mathematics that has an abstract language (Bishop et al., 1999 ; Seah & Bishop, 2000).

ii) Control-Progress: Control value shows that mathematics be applied, not only on phenomena about its nature but also on problems, solutions in social areas (Seah & Bishop, 2000). Mathematics' results have correct answers that can always be controlled (Bishop et al., 1999). However, mathematics with its other aspect is open to progress everytime and it can be used in other fields especially in school lessons,

iii) Openness- Mystery: Openness value shows discussing and analyzing mathematical theorems, ideas, results and argumentations. And such a situation leads us to reach corrects and to find new theorems (Seah & Bishop, 2000). Mystery value indicates mathematics own relation, pattern and surprises in its own nature. Such as; dividing every circle's perimeter into its diameter gives the same number (p number) or Pythagorean triangles that have 3, 4, 5 or 5, 12, 13 cm edge lenght gives always a multiple of 60 when they are multiplied with each other. Mathematics has always such kinds of mystery and surprise in itself (Bishop et al., 1999).

Sub-components of mathematical values cited above are fixed by Bishop at table 3;

Table 3. Mathematical values

1.a) Rationalism: Reason, hypotetical reasoning, logical thinking, explanation, abstractions, theories.
1.b) Objectivism: Atomism, materialism, determinism, analogical thinking, objectivising, concretising, symbolising.
2.a) Control: Prediction, knowing, security, mastery over environment, rules, power.
2.b)Progress: Growth, cumulative development of knowledge, generalisation, questioning, alternativism.
3.a) Openness: Facts, articulation, demonstration, verification, universality, individual liberty, sharing.
3.b) Mystery: Abstractness, unclear origins, dehumanised knowledge, wonder, mystique.

(Bishop, 1988; Source: Clarkson et al., 2000)

c) Mathematics Educational Values

Teaching mathematics educational values may show differences according to countries, cities, school types and grades. For example; choice of problem solving strategies may show differences according to the environment. So, the number of mathematics educational values can increase to that rate. In this paper, five complementary mathematics educational values will be emphasized. The first two of them can be considered as values about pedagogical side of mathematics education and the other three can be considered as values about its cultural side.

These are;

i) Formalistic view- Activist view: Formalistic view value shows the deductive and receptive learning values of mathematics, while activist view value shows its intuition and discovery learning; that is to say, its inductive sides.

ii) Instrumental understanding/learning-Relational understanding/learning: Instrumental learning indicates learning rules, operations and formulations in mathematics education and their applications to special questions. Relational learning shows displaying the relationships among concepts and forming appropriate graphics.

iii) Relevance - Theoretical knowledge: Relevance value shows the importance of mathematical knowledge in solving daily problems. Daily problems and demands show different at societies and cultures. Thus, mathematics can provide special solutions to cultural needs and demands. Mathematical education's theoretical value suggests teachings mathematics at theoretical basis and far from daily events.

iv) Accessibility -Special: These values indicate doing and preparing mathematical activities by either everyone or just by people who has talent in it.

v) Evaluating - Reasoning: Students are asked to realise the steps of knowing, applying routine operations, searching solving problem, reasoning and communicating in order to solve a problem. The first three of this five steps demonstrate using mathematical knowledge about evaluating an unknown answer; while the last two demonstrate the capability of using mathematical knowledge, reasoning more and the ability of spreading the knowledge (Seah & Bishop, 2000).

The most general demonstration of values taught in mathematics lesson is given at table 4 below:

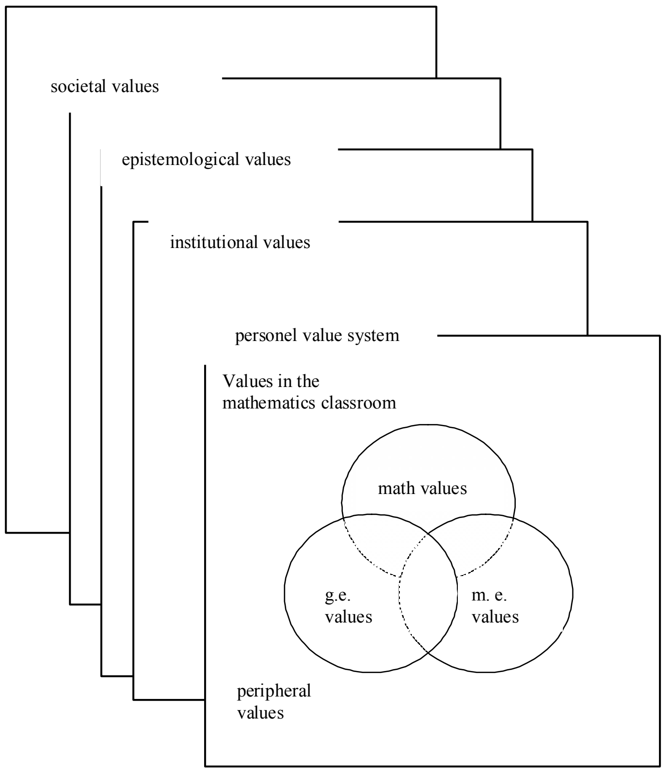
Table 4. Values in Mathematics Education

General meanings of 'value'	Mathematical values	Mathematics educational values
To value: to command to praise to heed to regard A value is: a standard a thing regarded to have worth a principle by which we live/act a standard by which we judge what is important something we aim for qualities to which we conform	Rationalism Objectivism Control Progress Mystery Openness	Accuracy Clarity Conjecturing Consistency Creativity Effective organization Efficient working Enjoyment Flexibility Open mindedness Persistence Systematic working

(Source: Seah et al., 2001)

Values taught in mathematics lessons and values that people, institutes, and societies have are given at figure 1 below:

Figure 1. Relationship of values



Note.
math values : mathematical values
m.e. values : mathematics educational values
g.e. values : general educational values

(Source: Seah & Bishop, 2000)

As will be seen from figure 1, general educational values don't have mathematical and especially mathematics educational values. Some values may appropriate for two or three of these categories. For example; progress and creativity values are both mathematical, mathematics educational and general educational values (Seah & Bishop, 2000).

Function concept also is one of the most important subjects in mathematics and it affects the whole mathematics curriculum (Beckmann, Thompson & Senk, 1999; Cooney, 1999; Dossey, 1999; Hitt, 1998; Knuth, 2000; Laughbaum, 2003). However, it seems students have some problems in understanding function concept (Eisenberg, 1991; Even, 1988; Hauge, 1993; Gaea, Orit & Kay, 1990). One of the reasons of these problems is that definition of function concept has change in historical period. At the beginning, function concept which contains dependent and independent variables was defined by Euler as a procedural concept demonstrating input-output relations and then as a concept representing one to one matching between real numbers by Dirichlet (Kieran, 1992; Stallings, 2000) and a century later as a certain subset of Cartesian product by Bourbaki in 1939 (1986; cited in Kleiner, 1989) as followings:

> Let E and F be two sets, which may or may not be distinct. A relation between a variable element x of E and a variable element y of F is called a *functional relation* in y if, for all there exists a unique which is in the given relation with x. We give the name of *function* to the operation which in this way associates with every element the element which is in the given relation with x; y is said to be the *value* of the function at the element x, and the function is said to be *determined* by the given functional relation. Two equivalent functional relations determine the *same* function (p.298).

As it can be seen in above definition, definition of function concept is considered as a set of ordered pair. In 1960's, by "new mathematics" reform frame, it was tried to make definitions of mathematics concepts more clear, making them comprehensible for students. Definition of function concept was given as following (Tall,1992):

> Let A and B be sets, and let AXB denote the Cartesian product of A and B. A subset f of AXB is a function if, whenever (x_1, y_1) and (x_2, y_2) are elements of f, $x_1=x_2$ and $y_1=y_2$, then (p. 497).

By this way, in contrast to past times, the definition was not limited to equations which define relationships between two variables in algebraic expressions. (Even, 1988). However, this modern definition did not meet expectations either, as a matter of fact it sometimes caused to students not to understand the concept. For, although this modern definition of 1960's has a perfect mathematical base, it does not have a cognitive origin (Tall, 1992). At this point, below statements of Sierpinska (1988; cited in Tall, 1992) attract attentions:

> The most fundamental conception of a function is that of a relationship between variable magnitudes. If this is not developed, representations such as equations and graphs lose their meaning and become isolated from one another... Introducing functions to young students by their elaborate modern definition is a didactical error an anti-didactical inversion (p. 497)

It has been seen that the problem that students have in comprehending function concept arises from ideas which individuals develop about mathematical concepts rather than the words used in definitions (Tall,1992). At this point, it seems that there exists differences between a formal concept definition and a concept image and this differentiation is conveyed by Tall &Vinner (1981) as below:

> ... the term *concept image* to describe the total cognitive structure that is associated with the concept, which includes all the mental pictures and associated properties and processes. It is built up over the years through experiences of all kinds, changing as the individual meets new stimuli and matures... The definition of a concept (if it has one) is quite a different matter...*the concept definition* to be a form of words used to specify that concept. It may be learnt by an individual in a rote fashion or more meaningfully learnt and related to a greater or lesser degree to the concept as a whole. It may also be a personal reconstruction by the student of a definition (p. 152).

As it can be concluded from above statements , giving a definition of a concept to students is not enough for them to comprehend it. This is especially valid for the function concept since the function concept have been represented as geometric using graphs, numeric using tables, and symbolic using equations. Namely, it is multiply represented (DeMarois& Tall, 1996). This case makes it difficult for students to comprehend the function concept. In addition, the fact that functions have many kinds such as polynomial (as constant, linear, quadratic, cubic), trigonometric and reciprocal etc is one of the factors that make the function concept hard to perceive.

One of the reasons why students do not understand the concept of function well is the fact that the mathematical values tought to students through curriculum textbooks, teachers etc. during the teaching of this concept are overlooked for instance, the teaching of functions through graphics and tables contains the activist value of the teaching of mathematics whereas their symbolic representation contains its rationalism value. Likewise, while questions such as "is every function an equation? Is the opposite true? Contains relational understanding/learning value related to the teaching of functions. A question related as " $f(x)=3x+1$ is given defined in R. What is $f(1)$=? " Contains both instrumental understanding/learning value and accessibility value. In this respect the prominence of determining which educational values of the function concept mentioned above are brought forth is understood.

And therefore in this research, it has been searched that how much do mathematics educational values take place in the function concept teaching. For this purpose, the answer for questions below have been looked for;

1) For what mathematical education values towards the function concept do students qualify more?

a) Do the mathematical education values towards the function concept, which the students own, indicate a remarkable variation according to the grade levels of college students?

2) Does the students' rationality for choosing the questions on the Function's Test change according to the grade levels of college students?

METHODOLOGY

Subjects

The subjects for this study consist of three hundred and forty three students. The students count approximately seventy-seven, hundered and eight, seventy-five, and eighty-three. They are the first, second, third, and fourth-year students from the Primary Mathematics Education at Cumhuriyet University (CPME). The ages of these students change approximately between 17 and 25. The university also has a thirty-year old campus in Sivas, a province of the Turkish Republic in Central Anatolia.

Apparatus

In order to determine students' mathematics educational values towards the function concept, the students were given two tests. One was "the Function Test" that included ten open-ended questions. The students were asked to answer for five of the ten questions asked in total. Each of the questions in the test are organized according to consisting of the one of mathematical educational values mentioned above such as formalistic view value, activist view value etc. The other was "the Rationality Test" that asked the reasons for their choosing of particular questions to respond on the Function Test. The test consisted of the some choose items adapted from the research done Chin and Lin (2000). The answered questions were evaluated as one point and the blanks as nil.

The following four questions illustrate the questions given to the students on the test:

1. Graph the $f(x)=x^2$ and do the graphics of the functions below using this function. (This question intended to determine the students' formalistic view value)

i) $g(x)=x^2+3$ ii) $k(x)=x^2-\sqrt{3}$

4) The distribution of the number of the bus tickets sold to the students in the province of Sivas in the year 1998 is given in the table below. (The Municipality Activity Report of Sivas, 1998)

a) Graph this statistical information.

b) Is the function in the graphic one-to-one? And why? (This question intended to determine the students' relevance value)

Month	January	February	March	April	May	June	July	August	September	October	November	December
The number of tickets sold to the students	238.800	325.525	340.495	314.100	343.400	351.500	269.500	213.300	325.500	347.800	322.700	326.000

6) i) Is every function a relation? Discuss your answer.

ii) Is every relation a function? Discuss your answer. (This question intended to determine the students' relational understanding/learning)

7) A function of is given defined in. What is (This question intended to determine the students'accessibilty value)

FINDINGS AND CONCLUSIONS

Research findings will be given in light of the research questions.

Question 1: For what mathematical education values towards the function concept do students qualify more?

a) Do the mathematical education values towards the function concept, which the students own, indicate a remarkable variation according to the grade levels of college students?

Table 5. Choose of questions in function test

Question Number	First Class		Secondary Class		ThirdClass		Fourth Class	
	n	%	n	%	n	%	n	%
1	52	67,5	99	91,7	72	96,0	71	85,5
2	18	23,4	32	29,6	27	36,0	25	30,1
3	6	7,8	5	4,6	18	24,0	9	10,8
4	16	20,8	40	37,0	26	34,7	33	39,8
5	76	98,7	104	96,3	73	97,3	77	92,8
6	39	50,6	34	31,5	28	37,3	36	43,4
7	66	85,7	97	89,8	63	84,0	79	95,2
8	-	-	-	-	-	-	-	-
9	60	77,9	59	54,6	25	33,3	36	43,4
10	49	63,6	70	64,8	39	52,0	47	56,6

The first question demonstrates the abstracting nature of math education and the value of formalistic view. The second question displays the activist view value of math education. On the other hand, it was designated that the class level of students has a meaningful impact on the selection of the first question (F (3-334) =14.163, $p < .05$). According to the results of the Sheffe's test, which was conducted to determine in what groups the interclass differences are, the second-year ($\bar{x} = .92$), third-year ($\bar{x} = .97$), and fourth-year students ($\bar{x} = .90$) responded to the first question in greater number than the first-year students ($\bar{x} = .66$). This statistical data points to that the second and higher-year students go for the formalistic view value in math education. Then, this situation can be explained by the fact that the higher-year the students are, the more absract courses they take. On the other hand, it was designated that the class level of students does not have a meaningful impact on the selection of the second question (F (3-334) = 1.448, $p > .05$).

It has been seen from the Table 5 that the first greaders' sixty-seven point five (67.5) percent answered the first question and their twenty-three point four (23.4) percent answered the second. It has also been understood from the table that the second, third, and fourth-year students responded to the first question in greater numbers than to the second question. This situation acquaint with the fact that every student regardless of their class level has preferred the formalistic view value in math education more when compared to the active view value.

While the third question demonstrates the theoretical value in math education, the fourth question attributes to the relevance value. It was designated that the class level of students has a meaningful impact on the selection of the third question (F (3-339) =6.98, $p < .05$). According to the results of the Sheffe's test, which was conducted to determine in what groups the interclass differences are, a meaningful difference is observed in advantage of the third-year students among the first ($\bar{x} = .007$), second ($\bar{x} = .003$), and third-year students ($\bar{x} = .24$) in terms of selecting the third question. In addition, the level of class has a meaningful impact on the selection of the fourth question (F (3-337) = 2.872, $p < .05$). According to the results of the Tukey's test, which was conducted to determine in what groups the interclass differences are, a meaningful difference is observed in advantage of the fourth-year students between the first ($\bar{x} = .19$) and fourth-year students ($\bar{x} = .40$) in terms of selecting the fourth question. It can be argued that the difference between the two levels have resulted from the fact that the fourth-year students have practiced during the courses on Special Teaching Methods the activities concerning the abstraction in math teaching and its connection with the daily life.

It is observed from the Table 5 that every student regardless of their class-level responded to the fourth question in greater numbers than to the third question. This situation leads to the fact that all the students have preferred the question having the relevance value in math education more when compared to the question having the theoretical value.

While the fifth question indicates a process of the instrumental understanding/learning value, the sixth question signifies the relational understanding/learning value in math education.

It is designated that the class-level of students had a meaningful impact on the selection of the fifth question (F (3-336) = 2.80, $p < .05$). According to the results of the Tukey's test, which was conducted to determine in what groups the interclass differences are, a meaningful difference is observed in advantage of the third-year students between the third ($\bar{x} = .97$) and fourth-year students ($\bar{x} = .93$) in terms of having answered the fifth question. Whereas the class-level did not have a meaningful impact on the preference to answer the sixth question (F (3-339) = 2.53, $p > .05$), all the students responded from the Table 5 to the fifth question in greater number than to the sixth question. This situation points to the fact that every student regarless of his or her class-level prefers the question having a process of the instrumental understanding/learning value more when compared to the question having the relational understanding/learning value in math education.

While the seventh question refers to the accessibility value, the eighth question demonstrates the special value in math education. It has been designated that the class-level of students did not have a meaningful impact on the preference for the seventh question ($F(3\text{-}339) = 2.02$, $p > .05$). In addition, no student responded to the eigth question. This situation leads to the fact that every student regardless of his or her class-level prefers the question having the accessibility value more when compared to the question having the specialty value in math education.

While the ninth question illustrates the reasoning value, the tenth question signifies the evaluating value in math education. It has been observed that the class-level of students has a meaningful impact on the selection of the ninth question ($F(3\text{-}339) = 12.42$, $p < .05$). According to the results of the Sheffe's test, which was conducted to determine in what groups the interclass differences are, a meaningful difference has been found in advantage of the first-year students among the first ($\bar{x} = .78$), second ($\bar{x} = .55$), third ($\bar{x} = .33$), and fourth- year students ($\bar{x} = .43$) in terms of having answered the ninth question. Furthermore, a meaningful difference has been discovered in advantage of the second-year students between the second and third-year students. The selection of this question by the first-year students can be explained by the fact that the first-year students learned the notion of function in various lessons based on the first-year curriculum. It has also been observed that the class-level does not have a meaningful impact on the selection of the tenth question ($F(3\text{-}339) = 1.28$, $p > .05$).

Table 6. Reasons of choose of question 1 and 2

Choose	First class				Secondary class				Third class				Fourth class			
	Question 1		Question 2		Question 1		Question 2		Question 1		Question 2		Question 1		Question 2	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
it had a logic of induction	-	-			12	11,2	2	1,9	2	2,7	-	-	16	19,3		
it had a logic of deduction	-	-	5	6,5	1	0,9	13	12,0	1	1,3	7	9,3	-	-	19	22,9
it is related to daily life	-	-	-	-	-	-	1	0,9	-		2	2,7	-	-	1	1,2
it only addresses to the theory	3	3,9	-	-	4	4,7			3	4,0	1	1,3	6	7,2	-	-
it gave the opportunity to use the rules, operation, and formulas	10	13,0	1	1,3	8	7,4	3	2,8	8	10,7	1	1,3	8	9,6	1	1,2
it shows tha conceptual relations	3	3,9	-	-	10	9,3			4	5,3	2	2,7	5	6,0	2	2,4
it was so easy	10	13,0	2	2,6	10	9,3			11	14,7	2	2,7	6	7,2	1	1,2
it was a question that only those having the mathematical knowledge and skills could answer	3	3,9	3	3,9	11	10,2	4	3,7	7	9,3	5	6,7	6	7,2		
it looked familiar	19	24,7	3	3,9	36	33,3	3	2,8	30	40,0	1	1,3	20	24,1	2	2,4
the question let me make revisions on it	2	2,6	1	1,3	1	0,9	1	0,9					2	2,4	-	-
Other reasons	2	2,6	2	2,6	6	5,6	-	-	4	5,3	4	5,3	2	2,4	-	-

It has been seen from the Table 5 that all the second, third, and fourth-year students but the first-year students responded to the tenth question in greater numbers than to the ninth question. This situation concludes that all the students except the first-year students has preferred the question having the reasoning value to the questions having the evaluating value in math education.

Question 2: Does the students' rationality for choosing the questions on the Function's Test change according to the grade levels of college students?

The Table 6 has given the reasons for why the students chose the first and second questions in the Function Test. Here, it has been observed that the first-year students answered not the first alternative of the first and second questions but the ninth alternative of the first question by a twenty-four point seven (24.7) percent and the second alternative of the second question by a six point five (6.5) percent. As for others; the second-year students answered the first question for its ninth alternative by a thirty-three point three (33.3) percent and the second question for its second alternative by a twelve (12) percent, the third-year students answered the first question for its ninth alternative by a forty (40) percent and the second question for its second alternative by a nine point three (9.3) percent, and the fourth-year students answered the first question for its ninth alternative by a twenty-four point one (24.1) percent and the second question for its second alternative by a twenty-two point nine (22.9) percent.

Table 7. Reasons of choose of question 3 and 4

Choose	First class				Secondary class				Third class				Fourth class			
	Question 3		Question 4		Question 3		Question 4		Question 3		Question 4		Question 3		Question 4	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
it had a logic of induction	-	-	-	-	1	0,9	-	-	-	-	-	-	1	1,2		
it had a logic of deduction	-	-	-	-	-	-	1	0,9	1	1,3	-	-	-	-	1	1,2
it is related to daily life	-	-	7	9,1	3	2,8	17	15,7			14	18,7	1	1,2	20	24,1
it only addresses to the theory	-	-			1	0,9	2	1,9	1	1,3			5	6,0	1	1,2
it gave the opportunity to use the rules, operation, and formulas	1	1,3	1	1,3	1	0,9	5	4,6	2	2,7	1	1,3	-	-		
it shows tha conceptual relations	1	1,3	-	-	-	-	5	4,6	2	2,7	5	6,7	-	-	2	2,4
it was so easy	-	-	2	2,6	-	-	3	2,8	1	1,3	-	-	-	-		
it was a question that only those having the mathematical knowledge and skills could answer	-	-	1	1,3	1	0,9	-	-	2	2,7	1	1,3	1	1,2	2	2,4
it looked familiar	2	2,6	2	2,6	-	-	3	2,8	4	5,3			1	1,2		
the question let me make revisions on it	1	1,3	1	1,3	-	-	1	0,9			1	1,3	-	-	1	1,2
Other reasons	-	-		-	-	-	-	-	1	1,3	1	1,3	-	-	3	3,6

When the statistical data given above is analyzed, it is observed that the reasons of the students from all grades for choosing the first and second question appear in an order to be as "because it looked familiar" and "because it had the logic of induction." In fact, this situation is an expected result. Indeed, the first question might have looked familiar to the students because the lessons that the students from all grades took or are taking teach the abstract way of mathematics. Moreover, the students may well have responded to the second question having the logic of induction because they have been familiar with the methods of induction and deduction.

The Table 7 has given the reasons for why the third and fourth questions were chosen by the students. When the statistical data here is analyzed, it is observed that the reasons of the students from all grades for responding to the third and fourth questions appear to be as "because they are related to the daily life." This situation is an expected result for the fourth question. Indeed, the data for the fourth question was derived from the real life. But the data for the third question appeals to the theoretical aspect of math education. For this reason, it had been anticipated that the students would prefer this question merely because "it addressed to the theory."

Table 8. Reasons of choose of question 5 and 6

Choose	First class				Secondary class				Third class				Fourth class			
	Question 5		Question 6		Question 5		Question 6		Question 5		Question 6		Question 5		Question 6	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
it had a logic of induction	1	1,3	1	1,3	-	-	-	-	-	-	1	1,3	-	-	1	1,2
it had a logic of deduction	-	-	-	-			1	0,9	2	2,7	-	-	2	2,4	1	1,2
it is related to daily life	-	-	-	-			1	0,9	1	1,3	-	-	-	-	-	-
it only addresses to the theory	3	3,9	11	14,3	6	5,6	6	5,6	1	1,3	-	-	3	3,6	3	3,6
it gave the opportunity to use the rules, operation, and formulas	26	33,8	2	2,6	60	55,6	-	-	27	36,0	-	-	34	41,0	-	-
it shows tha conceptual relations	-	-	7	9,1	1	0,9	20	18,5	1	1,3	13	17,3	3	3,6	14	16,9
it was so easy	25	32,5	1	1,3	14	13,0			15	20,0	2	2,7	11	13,3	3	3,6
it was a question that only those having the mathematical knowledge and skills could answer	2	2,6	4	5,2	5	4,6	3	2,8	7	9,3	4	5,3	7	8,4	6	7,2
it looked familiar	17	22,1	10	13,0	11	10,2	3	2,8	12	16,0	6	8,0	10	12,0	4	4,8
the question let me make revisions on it	1	1,3	1	1,3	2	1,9			2	2,7	2	2,7	2	2,4		
Other reasons	-	-	-	-	-	-	3	2,8	1	1,3	-	-	-	-	1	1,2

The Table 8 has given the reasons for why the fifth and sixth questions in the Function Test were chosen by the students. When the data here is analyzed, it is observed that the reasons of the students from all grades to have answered the fifth question happen to be as "because it provided the opportunity to use the rules, operation, and formulas." This situation is an expected result for the fifth question. Indeed, this question asked to inverse a function and then to calculate the resultants of this inversed function with another. It is also observed that the students from all grades responded to the sixth question mostly because "it proved the relations among the concepts." This situation is an expected result for the sixth question too. Indeed, this question explores into the connection between the function and relation concepts.

Table 9. Reasons of choose of question 7 and 8

Choose	First class				Secondary class				Third class				Fourth class			
	Question 7		Question 8		Question 7		Question 8		Question 7		Question 8		Question 7		Question 8	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
it had a logic of induction	-	-	-	-			-	-			-	-			-	-
it had a logic of deduction	-	-	-	-			-	-			-	-			-	-
it is related to daily life	-	-	-	-			-	-	1	1,3	-	-			-	-
it only addresses to the theory	1	1,3	-	-	1	0,9	-	-	2	2,7	-	-	1	1,2	-	-
it gave the opportunity to use the rules, operation, and formulas	4	5,2	-	-	9	8,3	-	-	5	6,7	-	-	3	3,6	-	-
it shows tha conceptual relations			-	-	83	76,8	-	-			-	-	1	1,2	-	-
it was so easy	60	77,9	-	-			-	-	52	69,3	-	-	68	81,9	-	-
it was a question that only those having the mathematical knowledge and skills could answer	-	-	-	-			-	-	1	1,3	-	-			-	-
it looked familiar	3	3,9	-	-	2	1,9	-	-	4	5,3	-	-	2	2,4	-	-
the question let me make revisions on it			-	-			-	-			-	-			-	-
Other reasons			-	-			-	-			-	-			-	-

The Table 9 has given the reasons of the students for choosing the seventh and eight questions. When the data here is analyzed, the reasons of the students from all grades for responding to the seventh question appear to be as mostly "because they were very easy." This situation is an expected result for the seventh question. Indeed, this question is a question the answer of which is easy and it demonstrates the accessibilty value in maths. But the eighth question requires a higher-level knowledge in the function concept. It is observed from the Table 8 that this question was not preferred or answered by any student.

Table 10. Reasons of choose of question 9 and 10

Choose	First class				Secondary class				Third class				Fourth class			
	Question 9		Question 10		Question 9		Question 10		Question 9		Question 10		Question 9		Question 10	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
it had a logic of induction	-	-	-	-	2	1,9	2	1,9	-	-	-	-	1	3,1	3	3,6
it had a logic of deduction	-	-	-	-	1	0,9			-	-	-	-			1	1,2
it is related to daily life	-	-	-	-	2	1,9	1	0,9	-	-	-	-				
it only addresses to the theory	8	10,4	4	5,2	10	9,3	10	9,3	4	8,0	4	5,3	4	4,8	4	4,8
it gave the opportunity to use the rules, operation, and formulas	5	6,5	5	6,5	2	1,9	7	6,5	2	2,7	8	10,7	2	2,4	5	6,0
it shows tha conceptual relations	8	10,4	7	9,1	2	1,9	7	6,5	1	1,3	9	12,0	1	1,2	9	10,8
it was so easy	8	10,4	5	6,5	5	4,6	7	6,5			1	1,3	1	1,2	4	4,8
it was a question that only those having the mathematical knowledge and skills could answer	7	9,1	9	11,7	17	15,7	16	14,8	3	4,0	5	6,7	6	7,2	9	10,8
it looked familiar	17	22,1	8	10,4	16	14,8	11	10,2	13	17,3	3	4,0	12	14,5	3	3,6
the question let me make revisions on it	4	5,2	10	13,0	1	0,9	10	9,3	2	2,7	9	12,0	4	4,8	5	6,0
Other reasons	2	2,6	1	1,3	2	1,9	1	0,9	2	2,7	1	1,3	1	1,2	2	2,4

The Table 10 has given the reasons for why the ninth and tenth questions in the function test were answered by the students. When the data here is analyzed, the reasons of the students from all grades for responding to the ninth question are seen as mostly "because it looked familiar." This situation is an expected result for the ninth question. Indeed, this question is a question that the students always see and practice on as exercises. Also, the reasons of the students from all grades to have answered the tenth question appear to be mostly because "it was a question that only those having the mathematical knowledge and skills could answer" and "the question let me make revisions on it."

DISCUSSION

As a result of this research, it was realized that the students from all grades preferred, in terms of learning the function concept, those questions that hold the formalistic view values, relavance values, instrumental understanding/learning values, accessibility values, and reasoning values.

The findings of this research show some similarities and differences with the findings of a research that examines whether Seah and Bishop's (2000) Singapore and Victoria mathematics textbooks convey mathematics educational values or not. According to the research of Seah and Bishop, formalistic view, theoretical knowledge, instrumental understanding, specialism, and evaluating with larger emphases than their respective complementary values in both Singapore and Victoria mathematics textbooks. In present research, it is just seen that relavance, accessibility, and reasoning values towards the function concept are by students prefered more than complementary values as differences.

Moreover, the reasons of students for choosing particular questions in the function test are determined as because "it [a particular question] looked familiar," "it had a logic of induction," "it is related to daily life," "it only addresses to the theory," "it gave the opportunity to use the rules, operation, and formulas," "it shows tha conceptual relations," "it was so easy," and "it was a question that only those having mathematical knowledge and skills could do." This situation suggests that the students usually responded to the questions in the test by taking into consideration the mathematical educational values that they own. For instance, the fifth question has the instrumental understanding/learning value in math education, and the students responded to this question mostly because "it gave the opportunity to use the rules, operation, and formulas."

Implications for Education

In this research, the students were asked to answer five of ten open-ended questions relating to the function concept. In this way, it was intended to determine the selections of the students. The questions that the students preferred to answer on the test were, in an order, the seventh, first, tenth, ninth, sixth, fourth, second, third, and eight questions. The first five questions preferred have familiarity with the topics that the students studied in their maths textbooks and during the lessons. In addition, these questions generally reflect the abstract way of maths, its formalistic value. This fact illustrates that the students commonly hold the formalistic and theoretical values in maths. For this reason, the teachers need not only to bring to the fore not only the abstract way of topics and concepts that they are teaching in class but also to highlight their active and concrete values and their relevance to the real life.

Implications for Mathematics Education

Values are the crucial components of maths education. However, they are often neglected (Clarkson et al., 2000; Seah & Bishop, 2000). Therefore, it is intended in this research to determine the values in maths education in terms of the students' mathematical comprehension of functions. In this way, the results of the research are of primary concern. As observed from the results of the research, the students often preferred the questions showing the symbolic aspect of the function concept. These students may be the teachers of the future. Naturally, they will convey their own mathematical education values to their students either explicitly or implicitly. In other words, it may be expected that they will focus in their proceeding education more on the mathematical values such as formalistic view, theoretical, and instrumental understanding/learning values. This partiality may lead to the fact that the students' maths education may be deprived of the values like activist, relevance, conceptual learning/understanding, and reasoning values. However, these values opportune the students to comprehend and relate maths to the outside world. In fact, NCTM standards cannot focus only on the problem-solving, mental computation, numerical logic. At the same time, they should focus on the students' being able to understand mathematical values, mathematical connections, and mathematical reasoning (Kathleen et al., 1993). Moreover, these standards are valid for other fields like science, chemistry, physics, and history. Hence, it is necessary that an education should be realized to discover the students' values in other classes too. For instance, science is not thought as having traditionally established values. But, science just like maths has values (Michael, 1995). Thus, for instance, the teaching of the slope concept in science should be taught by using the daily objects as well as the theoretical explanations. In this way, students will have possessed, in terms of the slope concept, the formalistic, activist, and relevance values.

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Yüksel Dede

Cumhuriyet University, Education Faculty, Department of Mathematics Education

Sivas, Turkey

E-mail: ydede@cumhuriyet.edu.tr

Phone: (+ 90 346) 219 10 10 / 2261

Fax: (+ 90 346) 219 12 24

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