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Do Pre-service Chemistry Teachers Reflect their Beliefs about Constructivism in their Teaching Practices?

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Abstract This study aimed to explore pre-service chemistry teachers' beliefs about constructivism and the influence of their beliefs in their teaching practice. For this purpose, semi-structured interviews were carried out with eight pre-service teachers in order to understand their belief structures. Pre-service teachers' beliefs about constructivism were classified in three categories which are weak, moderate, and strong conceptions of constructivism. For detailed exploration, three cases of pre-service teachers representing these three categories were selected. The findings of this study showed that most pre-service teachers in this study did not have a strong conception of constructivism and the relationship between the pre-service teachers' beliefs and their practice was not clear-cut.

Keywords Teacher beliefs · Science teacher education · Teaching practice · Constructivism · Pre-service teachers

Constructivism is a theory about learning that guides instructional practices for many teachers. However, there are practical difficulties with implementing instruction based on constructivist beliefs, particularly for novice teachers. Practical applications of constructivism have led to some misuses of constructivist principles because lesson plans that teachers identify as being constructivist do not include sufficient characteristics of constructivist theory. Constructivism does not embody a recipe for teaching, instead it is a theory explaining learning—implementation of this learning theory becomes the most important characteristic of well-

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designed lessons (Baviskar et al. in press). While teacher education and professional development programs highlight the implementation of constructivism and change in teachers' beliefs about constructivist teaching, the teaching practices of novice teachers frequently do not reflect this change (Simmons et al. 1999). Considering the importance of the role of teachers' beliefs on their instruction (Nespor 1987; Pajares 1992; Richardson 1996), understanding teachers' beliefs about constructivist teaching becomes critical. Therefore, in the present study, pre-service Chemistry teachers' beliefs about constructivist teaching strategies and the relationship between those beliefs and actual practices are examined.

Constructivist Teaching

There are many teaching practices identified with constructivism. However, simply applying these practices in a cookbook fashion will not result in constructivist instruction or learning (Baviskar et al. in press). Constructivist teaching is first and foremost, student-centered (Yager 1991; Driscoll 2005). However, Baviskar et al. (in press) addressed four additional elements common in constructivist lessons. First, constructivist teaching elicits students' prior knowledge because constructivism claims that knowledge construction requires creating connections with prior knowledge (Driscoll 2005). Students come to their classes with some pre-existing ideas and these ideas interact with their current learning. Driver et al. (1985) state that children develop these prior ideas through everyday experiences, the media, and the people with whom they talk. When new knowledge contradicts prior knowledge it is difficult for the learner to make connections with his or her existing knowledge.

Second, constructivist teaching seeks to create cognitive dissonance between the new knowledge and the prior knowledge of a learner. Teachers need to select activities that have the potential to dissatisfy students' existing ideas (Wheatley 1991). Constructivist teaching provides resources that create a context and motivate students for learning (Wheatley 1991; Windschitl 2002). Lorsbach and Tobin (1993) claimed that if students' prior knowledge is inadequate or incorrect to explain a phenomenon, then, students will experience cognitive dissonance and this situation can motivate students to learn. Therefore, constructivist teaching practices could support the process of conceptual change. Conceptual change occurs through judging existing views against a new conception rather than merely adding the new knowledge to existing ideas (White and Gunstone 1989). If the new conception is found more intelligible, plausible and fruitful than the old one, the learner can abandon or restructure his/her existing views (Posner et al. 1982). In other words, as Hewson and Thorley (1989) state, conceptual change occurs when the status of a new conception is higher than that of the existing conception. However, in order to judge the status of the new conceptions and compare them with existing knowledge, the learner needs to be aware of the learning process; this is where metacognition comes into consideration. In order to achieve long-term learning, metalearning—learning about learning—is really necessary for conceptual change (White and Gunstone 1989). Constructivist teaching, giving importance to prior knowledge for the construction of new knowledge, helps students face their conceptions and change them if they are not adequate to explain some new phenomenon.

Third, constructivist teaching provides opportunities for immediate application of the new knowledge (Windschitl 2002; Yager 1991). Teachers implementing constructivist practices allow students to apply their new knowledge through quizzes, presentations, discussions, or activities where students integrate that knowledge with new situations. Lastly, constructivist teaching provides reflection on learning. Teachers encourage students to be aware of what they have learned via meta-cognitive activities such as reflection

papers, dissonance creating activities, or having the student explain a concept to another student (Lord 1994). Although constructivism has usefully informed science teaching, it should be mentioned that the impact of constructivist teaching strategies on learning should not be overemphasized and should be interpreted cautiously (Jenkins 2000). For example, lecturing may be an efficient method for learning if the goal is to present a large amount of information to large groups of high achievers (Richardson 2003).

Given these elements, characteristics of constructivist teachers can be summarized as follows: (a) giving value to the quality of learning instead of quantity and focusing on the learner not the subject; (b) promoting social interactions, providing meaningful experiences, and helping learners elaborate on their prior knowledge; (c) monitoring and evaluating learning process, and establishing learning environments that encourage learners to learn in productive ways; and, (d) encouraging "a plural, tentative and contingent view of scientific knowledge" (Watts and Jofili 1998, p.175).

Teaching from a constructivist framework also requires teachers to abandon the strategies through which they were taught (Gieryn 1999). Levitt (2001) stated that because teachers have a tendency to teach in the way that they were taught, they face a dilemma of teaching science first as content, as emphasized in many science courses, or process, as emphasized in many teaching method classes. Indeed, literature related to teaching indicates that teachers enact their beliefs in their instruction (Bryan and Abel 1999; Nespor 1987; Pajares 1992; Richardson 1996). Therefore, it is necessary to describe what teacher beliefs are and how those beliefs about constructivist teaching affect their instruction.

Teachers' Beliefs About Teaching

Beliefs are described as dispositions to actions and as the most important determinant of behavior (Brown and Cooney 1982). Sigel (1985) also stressed the role of beliefs on behavior stating that beliefs are "mental constructions of experience" (p. 351) that shape behavior. Beliefs can also be viewed as psychological constructions that involve understandings, assumptions, or a proposition one feels to be true (Kagan 1992; Richardson 1996). Tobin et al. (1994) defined beliefs as a form of knowledge that enables people to meet their goals. However, beliefs are different from knowledge because they do not need to be true (Richardson 1996). Beliefs are personal, stable, not under individual control, and hardly influenced by persuasion. They are based on episodic memory, which consists of personal experiences, episodes or events. Teacher beliefs, therefore, may grow as a result of personal experiences, both in school and out of school (Nespor 1987). Teachers may have different beliefs about teaching as a profession. If differences in these beliefs are not recognized, it may be difficult to understand a teacher's teaching perspectives. In the context of the present study, prospective teachers' beliefs about constructivism refer to their conceptions and understandings about constructivism.

There are two views of research studies regarding the relationship between teacher beliefs and their practice in the literature. Some research studies report that teachers' beliefs are reflected by their classroom practice (Crawford 2007; Cronin-Jones 1991; Dillon et al. 1994; Hashweh 1996; Mitchener and Anderson 1989; Richmond and Anderson 2003; Zipf and Harrison 2003). For example, Cronin-Jones (1991) found that teachers who believed that students learned best through transmission of correct knowledge were unable to implement constructivist teaching strategies in their class. Hashweh (1996) indicated that teachers with constructivist beliefs used teaching strategies reflecting characteristics of constructivism. Haney and McArthur (2002) studied pre-service teachers to investigate the development of constructivist beliefs and to find out whether these beliefs are consistent with classroom

practice. During their student teaching experience, they applied some characteristics of constructivist teaching such as student negotiation, scientific uncertainty, and personal relevance to their beliefs about constructivist teaching. However, they did not implement their beliefs about involving students in classroom decision-making into their teaching practices.

Other research studies reported contradictions between teachers' beliefs and practice in some cases. For example, Louden and Wallace (1994) stated that teachers supporting constructivism had a traditional role in class and instructed students traditionally. Similarly, Abell and Roth (1995) indicated that although teachers had strong commitments to constructivism, their teaching practice did not reflect those beliefs. Moss and Kaufman (2003) stated that pre-service teachers with progressive views of teaching did not reflect these views in their practice. Simmons et al. (1999) supported the contradiction, claiming that beginning teachers held student-centered teaching beliefs whereas their practice was based on teacher-centered instruction. In addition, regarding the use of models, Justi and Gilbert (2002) reported a mismatch between teachers' beliefs and their practice. As Lederman (1992) states, situational factors may influence the transfer of teachers' beliefs into practice. For example, school culture, culture of the classroom and the nature of the curriculum have been found to affect teachers' beliefs (Munby et al. 2000; Tobin and McRobbie 1996). Moreover, the assessment regime used by teachers can influence how their beliefs are translated into practice.

If students' learning were assessed by summative examinations, which favor recall of facts, then this would prevent the application of constructivist principles by the teachers and cause them to retain traditional teaching methods. Zhang et al. (2003) revealed that the implementation of inquiry-based instruction in China was hindered by the college entrance examination, which does not assess inquiry skills. Moreover, As Jenkins (2000) stated, use of assessment techniques, which reflect constructivist approaches would favor the application of constructivism in school science. Therefore, the link between beliefs and practice is not straightforward.

Although there are qualitative studies related to pre-service teachers' beliefs regarding teaching and learning (Bryan 2003; Wallace and Kang 2004), there is still a gap related to pre-service chemistry teachers' beliefs about constructivism and how these beliefs influence their teaching practices. Therefore, this study will be helpful in terms of revealing some realities about pre-service chemistry teachers' beliefs about constructivism and how they reflect their beliefs through their teaching practices.

Purpose of the Study and Research Questions

The purpose of this study was twofold. First, this study aimed to explore pre-service chemistry teachers' beliefs regarding constructivism. Second, the study investigated how those beliefs were embedded in and affected practice teaching. The following research questions guided this study:

1. What are the beliefs of pre-service chemistry teachers about constructivism?
2. How do pre-service chemistry teachers translate their beliefs into their teaching practice and how did their beliefs influence their practice?

Methodology

In an effort to address these research questions for individual subjects, a qualitative method was employed (Bogdan and Biklen 2007; Patton 2002) with results presented in the form of case studies. Merriam, Yin, and Stake (as cited in Bogdan and Biklen 2007) state that a case study

is a detailed examination of one setting, or a single subject, a single depository of documents, or one particular event. In this study, case study design was selected in order to examine the complex structure of individual belief, better understand belief structure, identify components within beliefs, and explore the ways teachers reflect their beliefs. Data for the study were collected from semi-structured interviews, observation notes, and lesson plans.

Participants

Eight pre-service chemistry teachers taking a practice teaching class in the Department of Secondary Science and Mathematics Education at a university in Turkey were the participants of this study. Pre-service chemistry teachers from the Department of Secondary Science and Mathematics Education follow a 5-year integrated program. In the first seven semesters, they complete subject matter courses in General Chemistry, Analytical Chemistry, Physical Chemistry, Organic Chemistry, and Inorganic Chemistry from the Department of Chemistry. In the remaining three semesters, they take pedagogical courses such as Introduction to Teaching Profession, Learning and Development, Instructional Planning and Evaluation, Methods of Science Teaching, Classroom Management, Guidance, Analysis of Secondary Education Textbooks, Instructional Media and Material Development. In addition, they take three practical courses: School Experience in Secondary Education I and II, and Practice Teaching in Secondary Education from the Department of Secondary Science and Mathematics Education. The aim of the School Experience I and II courses is to give pre-service chemistry teachers an idea about the teaching profession and the school environment. Pre-service chemistry teachers are placed at a high school for 40 h a semester in order to observe chemistry classes in terms of the way their mentors teach. In addition, they carry out group work with high school students, prepare a test and evaluate the results of the test. For their Practice Teaching course, pre-service teachers are placed in high schools for 72 h a semester. Different from other practical courses, pre-service teachers were supposed to teach chemistry at high schools. The aim of the Practice Teaching course is to give pre-service teachers the opportunity to apply their theoretical knowledge of learning theories in real classrooms. Before this course, the pre-service teachers learned different teaching methods such as the learning cycle, cooperative learning, and inquiry for chemistry teaching, basic aspects of effective teaching, such as classroom management techniques, questioning techniques, and how to increase students' attention and motivation. Therefore, they know a variety of different teaching methods and have had some experience about how to apply those practices when teaching chemistry.

Instruments

Several different sources of data were collected from semi-structured interviews, observation notes, and lesson plans.

Semi-structured Interviews Semi-structured interviews were carried out with the pre-service teachers in order to probe their beliefs about constructivism in depth (see Appendix). To fulfill this aim, questions relating to beliefs about learning, a definition of constructivism and constructivist learning environment, the role of the teacher and the student in a constructivist class, constructivist teaching strategies, and teaching practices consistent with constructivism were included in the interview. However, during the interview, some questions were added in response to the pre-service teachers' responses. Each pre-service teacher was interviewed individually for about 45 min and each interview was audio-taped and transcribed in full. At the beginning of the interview, the purpose of the interview was explained to the interviewees as seeking genuine and

detailed information about their beliefs regarding constructivism, and participants were assured that their responses were confidential and would not be used in determining a grade for the course. Interviews were conducted in Turkish and translated into English. For accuracy of the translations, experts in English examined the translations, back-translated the quotes into Turkish and compared the quotes to provide conceptual equivalence.

Lesson Plans Pre-service teachers in this study were asked to prepare a lesson plan before their involvement in high schools. The lesson plan included teaching objectives, teaching materials, teaching strategies, pre and post assignments, order of the topics, and evaluation of student learning. The pre-service teachers were supposed to explain how to teach the topic step by step, how to use the teaching aids, how to implement the teaching strategy to the topic, and how to attain each learning objective. The lesson plans were used to obtain information about their intended teaching practice and to compare their plans with their actual instruction in class.

Observation Notes In order to understand whether or not pre-service teachers reflected their beliefs about constructivism during instruction, they were observed during their school placement throughout the semester. Using a standard observation form, two researchers observed each pre-service teacher. Observation forms include items to be rated in terms of self-confidence in teaching, use of voice, classroom management, competency in chemistry content, effectively using teaching methods, application of constructivist approaches, taking into account the students' misconceptions regarding the subject, and promoting interaction among students. The maximum score for the observation form was 100. Getting a high score on this form indicated effective use of teaching methods and strategies.

In addition to completing the observation form, each researcher took notes about each pre-service teacher's instruction with students.

Data Analysis

For data analysis, firstly, interviews of eight pre-service teachers were transcribed. Then, each of the researchers read the transcripts and analyzed them with respect to pre-service teachers' beliefs about constructivism in an effort to find patterns and develop a category system (Patton 2002). Researchers constructed general categories and subcategories independently. Meetings then took place in order to compare the categories, discuss conflicts between categories constructed when necessary and reach consensus. To explore how pre-service teachers translated their beliefs into practice, their lesson plans were examined and their practices in high schools were observed by two researchers using an observation form. During observation, each researcher rated each pre-service teacher's practice independently and assigned a score out of 100. Then, researchers came together, discussed the pre-service teachers' instruction, and reached consensus.

Results and Discussion

Based on Table 1, pre-service teachers' overall beliefs about constructivism were placed in one of three categories—weak, moderate, or strong conceptions of constructivism.

(a) Weak conception of constructivism

Pre-service teachers in this group have a weak understanding of constructivist principles. Pre-service teachers with this view believe in the transmission of knowledge to students by

Table 1 Categories of pre-service chemistry teachers' beliefs about constructivism

Categories	Arda	Nihat	Ezgi	Ceren	Hale	Engin	Tolga	Burhan
Beliefs about learning	Change in learner's behavior; transfer of knowledge from teacher to students	Change in learner's behavior	Being able to link pre-existing knowledge with new knowledge; to use knowledge out of class	Being able to comprehend the topic; being able to give examples	Acquisition of new knowledge	Being able to use of knowledge	Being able to use of knowledge	Being able to use of knowledge
Beliefs about constructivism								
Definition of constructivism	Use of different instructional strategies in class	Student-centered approach in which instruction is based on students' answers to teachers' questions	Construction of knowledge by individuals considering holistic nature of science	Construction of knowledge by students	Learning by doing	Construction of knowledge by using previous knowledge	Use of different instructional strategies in class	Construction of knowledge by using previous knowledge
Constructivist learning environment	Participation of students to instruction; teachers as an authority; small-sized classroom; no interaction among students in class	Responsibility of students with reading textbook before class; teacher as a guide; consideration of individual differences; small-sized classroom	Self-regulated learners; expression of ideas freely; teacher as a guide for students; consideration of individual differences	Active role of students; teacher as an expert; interaction among students	Active role of students; teacher as an expert and guide	Active role of students; teachers as a facilitator; small-sized classrooms	Active role of students; teacher as an authority	Interest of students to the topic; teacher as a guide; relaxed classroom environment
Constructivist teaching strategies	Methods involving students' participation in class	Methods based on asking questions and getting answers	Methods based on conceptual change; concept mapping; learning cycle	Methods based on inquiry; concept mapping	Cooperative learning; hands-on activities	Discussion; questioning	Questioning; demonstration, analogy	Analogy; cooperative learning

the teacher. They do not consider students' prior knowledge in learning and they think that the aim of science instruction is presenting known facts about science. They think that students are passive listeners and they do not consider the importance of active student participation in terms of knowledge construction.

(b) Moderate conception of constructivism

Pre-service chemistry teachers in this category do not have a sound understanding of constructivist views of teaching. Although their statements and instructional materials show some understanding of constructivism, this understanding is not fully internalized. In a way, pre-service teachers' in this group show inconsistencies. For example, a pre-service teacher may state the role of the teacher in terms of a constructivist perspective. However, in the context of assessment, the same pre-service teacher may believe in the use of traditional assessment techniques.

(c) Strong conception of constructivism

Participants in this group have a strong understanding of constructivist principles. They believe in the importance of students' prior knowledge to learning and describe learning as a process where students are actively involved in their learning. They state the role of the teacher as a guide or supporter. They believe in the necessity of a relaxed class environment where students share their ideas. Similarly, they mention the importance of group work and the importance of interaction among students in knowledge construction.

Figure 1 shows the distribution of pre-service teachers' beliefs. Based on the criteria described above, three pre-service chemistry teachers, one from each category, were selected to illustrate the range of constructivist beliefs. Please note that all the names of participants have been changed to pseudonyms in the analysis that follows. Ezgi, 23 years old, had beliefs closest to the strong conception of constructivism. She attended pedagogical classes regularly, participated in class discussions, and asked additional questions during or after the class, which indicated her interest in the subject. Her grades in these courses were higher than the average of the class. Nihat, 24 years of age, having views close to the moderate conception of constructivism, was not as interested as Ezgi in classes. Although he attended classes regularly, he seldom contributed to class discussions. On the other hand, he seemed confident during student teaching and behaved as if he was an experienced teacher. Lastly, Arda, 23 years old, was the representative of the weak conception of constructivism category. He showed less interest in pedagogical courses than Ezgi and Nihat. He came to class unprepared and tended to submit assignments late.

Case 1: Ezgi

Beliefs About Learning

Ezgi described learning as linking pre-existing knowledge with new knowledge and that knowledge should be used outside of class. She also criticized the way teachers teach in high schools in that they do not consider students' pre-existing knowledge and do not promote meaningful learning in their classes. She described meaningful learning as:

> If the student learns by linking new knowledge with previous knowledge, then meaningful learning occurs. For example, if a student at the second year of a high school can make a link between what she is learning now with what she learned in the

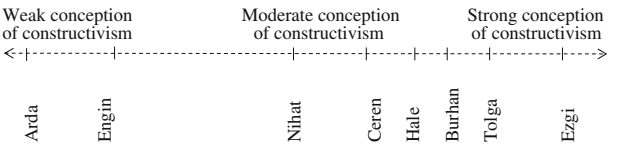

Fig. 1 Pre-service teachers' beliefs about constructivism

previous years, learning would be meaningful for her. In addition, connection of knowledge learned in science classes with daily life is also important for meaningful learning. To promote meaningful learning, teachers can use analogies and concept maps.

Beliefs About Constructivism

Definition of Constructivism When asked the definition of constructivism, Ezgi indicated that students are not empty vessels and that they already had some ideas before class. Therefore, she said, it was not possible that students would understand everything the teacher taught. She explained a constructivist approach in terms of the holistic nature of science:

> Constructivism is constructing knowledge to reach the whole. Chemistry is not an isolated subject, it is related to other areas in science such as physics and biology. In chemistry classes, photosynthesis can be given as an example demonstrating this interrelatedness between different sciences. Thus, constructivism is being able to integrate all science areas. Using this approach, students should be able to link these areas with each other.

Constructivist Learning Environment Ezgi stressed the importance of students' choices, and that students should select elective chemistry classes depending on their interest. Moreover, she believed that students should be given opportunities to express their ideas freely in class. She contrasted constructivist and traditional teachers as follows:

> Constructivist teachers are not an authority figure in the classroom; instead they allow students to express their ideas in class. They help and support students in their study. In addition, they are aware of individual differences and try to teach accordingly. However, in traditional teaching environments, teachers lecture on topics without considering individual differences. Also, they do not deal with whether students have understood concepts or not. Teachers do not expect mental engagement of students during instruction. On the contrary, they consider instruction as a mere transfer of a body of knowledge to the students. We can say that in traditional teaching instruction is one-way.

As far as the student's role from a constructivist perspective is concerned, Ezgi said that students should be mentally active in class and determine the flow of class. She added:

> Students should be able to interpret situations considering different perspectives and to think about areas in which they can develop their understanding. Teachers should not interfere with students' study. Students should decide when, what and how to study on their own. They should make a plan for how they learn best, follow this plan and then evaluate themselves at the end.

Ezgi's views of teaching reflect constructivist theory well. Her ideas about students' roles are crucial in emphasizing self-regulation processes and she indicated that students should make a plan for how to study. Also, this explanation stressed students' responsibility

for their own learning which is in line with constructivism. Ezgi understood and internalized constructivism well although some of her ideas reflected textbook definitions and she may have memorized some terms. For instance, she used the term "empty vessels", which most of the books use to explain constructivism, throughout the interview.

Constructivist Teaching Strategies During the interview, Ezgi could explain constructivist teaching strategies and it appeared that she was eager to use these strategies as indicated in the following excerpt:

> Researcher (R): In your opinion, what teaching strategies are based on constructivism?
>
> Ezgi (E): We learned [constructivist strategies] in methods courses. Conceptual change came to my mind first. For example, students have wrong conceptions in their minds, teachers make students aware of these wrong ideas by creating dissatisfaction, presenting the correct ones, and realizing the plausibility of the new knowledge. Then, students use this newly-learned knowledge. What else? There is analogy, too... Also, concept map, learning cycle, 3E, 5E, and 7E, and cooperative learning...
>
> R: Why do you think these methods are constructivist?
>
> E: Because teachers who use them to consider students' prior conceptions and individual differences. By concept mapping, students can see the previous, current and further knowledge and the relationship among these concepts; students can also give examples... For example, in cooperative learning, students learn from each other and reach the correct knowledge. It is student-centered. However, there is an important role for the teacher, she/he should guide the groups.

She also emphasized the role for students' misconceptions in the following:

> In constructivist teaching strategies, before instruction, teachers get an idea about students' misconception on that day's topic by searching the literature. Keeping these misconceptions in mind, teachers try to find out whether their students have these misconceptions or not by observing students' reactions to an explanation. Therefore, these strategies are different from traditional methods.

When asked about the effect of constructivist teaching strategies on learning, she gave the following explanations by referring to her experience in the methods courses:

> For example, in the methods course, topic of the particle nature of matter was taught using a drama method and I realized that I did not understand this concept properly until then. We were actively involved in learning and we reached the correct knowledge instead of the teacher telling us. That was based on constructivism and I believe that real learning occurs by constructivist teaching strategies.

Ezgi was aware of constructivist teaching strategies since she could list a lot of strategies that aligned with constructivism. She explained why these strategies were constructivist: "These strategies considered students' prior knowledge and an active role for students in the learning process." These characteristics have similarities with the constructivist view. She articulated the conceptual change approach referring to Posner et al.'s (1982) model which includes dissatisfaction, intelligibility, plausibility, and fruitfulness. Therefore, it can be concluded that Ezgi's conception of learning is consistent with the constructivist view. On the other hand, she perceived conceptual change as a teaching method rather than a process in which one's conceptions change by capturing new conceptions, restructuring or

exchanging existing conceptions for new conceptions (Hewson 1982). During the interview, she recalled information presented in her teaching methods classes at the university frequently, which suggests that her beliefs about constructivist teaching strategies were shaped by the teaching method courses she took at the university.

Practice of Constructivism

During the school placement, the researchers observed Ezgi in order to get information about whether or not she was applying constructivism in a classroom environment. For example, in one class, she was teaching the "Chemical Reactions" topic to tenth grade students. She applied concept mapping, analogy, and demonstration when teaching this topic. The demonstration was about producing bubbles of H_2 gas when HCl acid reacts with Mg metal. During the demonstration, she asked several questions, such as "What happened here?" or "Is matter created or destroyed in a reaction?" in order to engage the students.

In the interview, Ezgi mentioned the importance of students' pre-existing knowledge and described learning as being able to link new knowledge with students' prior knowledge. During her teaching, our observations indicated that she also gave importance to this issue. For instance, while teaching the "Chemical Reactions" topic, she assessed students' prior knowledge by the help of a concept map. Therefore, it can be said that Ezgi's beliefs about the need to consider students' prior knowledge was consistent with her actions regarding how to elicit prior knowledge.

In addition, during the interview, she mentioned the importance of considering students' misconceptions. While preparing the lesson plan, she extensively searched the literature for misconceptions and listed the common ones. On the other hand, in her practice teaching, although she tried to take students' misconceptions into account, the way she applied to eliminate these misconceptions were different from the perspective of constructivism as represented by the conceptual change model. For example, she explained the difference between dissolving and melting rather than expecting students to find this difference by themselves. In addition, she tried to make students active in class by asking questions continually. This was consistent with her belief about the role of students as demonstrated in the interview. Although she explained her role as a guide in the interview, her role sometimes diverged from a guide in the class. She sometimes offered correct knowledge rather than giving students the chance to explore competing ideas themselves. Her lack of experience in teaching might have led to this deviation from a constructivist approach. In sum, her practice did not always reflect her belief about the role of the teacher when implementing constructivist practices.

During her teaching of "Solubility" however, she mostly lectured as she had indicated she would in her lesson plan. She explained that the large class size was her reason for preferring this method. In the lesson plan, she stated that she would link the topic to daily life. Our observations showed that in class, she tried to link the topic with daily life through questioning. Her beliefs about the teaching strategies were not embedded in her practice because she mostly criticized the traditional method throughout the interview session. On the other hand, there were consistencies between her beliefs about the role of the student; she believed the necessity of the active role of student, which was also observed during her instruction. During her teaching, it was seen that she had a misconception; she identified salt as a molecule. Since she did not feel competent in this topic, she may not have preferred to use constructivist teaching strategies. Also, during the interview, Ezgi pointed out her incompetence in some chemistry topics:

> …Unfortunately, I am not good at Chemistry. Actually, I am upset with it. I mean I passed my Chemistry courses with good grades and thought that I had no difficulty in Chemistry.

> However, when I started taking "Method of Teaching" courses, I realized that my Chemistry knowledge was not enough. As well as knowing how to use methods, competence in a major area is important. Constructivist teaching strategies require good subject-matter knowledge. Lecturing on a topic is easy, you study on it and then explain… but using alternative methods is not easy, studying the topic is not enough; you should establish the connections among concepts and analyze situations, which require higher order skills. Thus, in order to implement constructivist teaching strategies, your Chemistry knowledge should be good….Therefore, I am preparing well before practical sessions.

Ezgi's mean score for the observation form was 86 out of 100. Her score was highest for common misconceptions, involvement of students, and linking the topic to daily life as well as previous and subsequent topics. On the other hand, her score about competence in the topic was lowest as she also pointed out her incompetence in some chemistry topics during the interview.

In sum, it appeared that Ezgi's beliefs about the role of the student, consideration of prior knowledge and misconceptions of students were in line with her practice. However, the teaching strategy she used to remedy the alternative conceptions differed from her beliefs about constructivist teaching strategies. In addition, her practice did not reflect her beliefs about the role of the teacher and the choice of teaching strategies.

Case 2: Nihat

Beliefs About Learning

Nihat defined learning as a change in behaviors. He added that learning could be measured in the following statement:

> At the beginning of the lesson, it is necessary to measure students' knowledge and identify their misconceptions by a pre-test. You can analyze the results and plan your instruction based on this. If students have many misconceptions about a subject, you can devote the whole class to students' misconceptions. At the end of the course, you can apply a test. If students' achievement is above 70%, I think it can be said that the subject is learned. That is, we can measure learning in this way.

Although Nihat considered students' misconceptions, he did not use this information to explain how learning occurs. It seems that Nihat's definition of learning does not align completely with constructivism. In relation to assessment, he did not focus on students' progress. Rather, he suggested using pre-tests just to identify students' misconceptions and plan instruction accordingly. Nevertheless, in constructivism, assessment is part of the learning process in which students evaluate their own progress. Constructivism emphasizes using alternative assessment techniques, such as performance tasks, concept maps, and portfolios instead of standardized testing only (Brooks and Brooks 1999; Chiappetta and Koballa 2002).

Definition of Constructivism According to Nihat, constructivism includes a student-centered approach:

> Researcher (R): What do you understand about constructivism as an approach to teaching?
>
> Nihat (N): Constructivism is a student-centered approach. It is based on the student and it is different from rote learning. While teaching a concept, teachers ask questions and students are supposed to answer these questions and construct knowledge.

R: So, in your opinion, constructivism means that teachers ask questions and students answer them?

N: It also involves inquiry. Teachers give clue to students...For example, in order to explain the factors affecting solubility, teachers can ask different students how much sugar they add to their tea and want them to infer the relation between the amount of solute and solubility. Constructivism is suitable for certain daily life topics. However, if you ask questions, such as "What do you think about this?" or "Why does it occur?" about a topic students have no prior knowledge of, you may not get any response. For example, students say that the common ion effect decreases solubility, but when you ask the reason, they have no answers.

Nihat grasps the main idea of constructivism—the construction of knowledge by students. He stated that teachers direct students' construction of their knowledge by asking questions and giving clues. This view is consistent with constructivism. However, he believes that students may come to class with no prior knowledge about a topic, which is not consistent with constructivism. This learning theory claims that students bring their ideas about the natural world which they develop through daily life experiences, media, and interaction with other people in class. These ideas are the starting point for effective instruction in which students change their current ideas for more scientific conceptions (Chiappetta and Koballa 2002; Driver et al. 1994). Therefore, Nihat does not have a complete understanding of constructivism as we define it.

Constructivist Learning Environment In terms of creating a constructivist learning environment, Nihat mentioned the necessity for small class size in order to increase student interaction and maintain classroom order. According to Nihat, seating order in a classroom should be U-shaped so that students and teacher can see each other and not become distracted. When asked about the role of the teacher in creating a constructivist learning environment, Nihat stated that the teacher should be a guide and direct students to think, which is in line with constructivist views. As far as the learner's role is concerned, Nihat mentioned that students should come to class ready by having read their textbooks:

Students must have some knowledge about the subject before coming to the classroom. If students read their books related to the subject before coming to the classroom, they can understand the subject better and also they can make comments on the subject. If a student is a fundamental part of constructivism, the teacher does not have all the responsibility for teaching; students should have half of the responsibility.

According to constructivism, learners are actively involved in constructing their own knowledge. However, Nihat described students' responsibilities in terms of reading the necessary text about a subject before class. This places students in a passive role, one that contradicts basic principles of constructivism.

Constructivist Teaching Strategies When Nihat was asked to explain constructivist teaching strategies, he identified inquiry and demonstrations in the following way:

N: Demonstration and inquiry are two constructivist teaching strategies. By using inquiry, you can ask questions and the students will be familiar with inquiry method in time. Inquiry is simple and not expensive. Inquiry is the most appropriate and the best method. In a class, there are individual differences among students. Some

students may be visual learners, some may learn individually.... Therefore, you must find a solution including all of the students. This solution is inquiry.

R: Does inquiry mean always asking questions and getting answers?

N: Teachers should not give answers but direct students to find out the correct answers by giving clues or asking questions. You get students to think while applying inquiry. For example, in a system, if the concentration of the reactants increases, then the system shifts to the right. "Why does the system shift to the right?" You must ask questions like this. The students may answer incorrectly but they will find the truth in the end.

Nihat characterized inquiry as only asking questions and getting answers. However, inquiry is a multifaceted activity and should not be defined too narrowly since it is not only about investigating students' ideas through questioning. Scientific inquiry involves understanding nature and using this knowledge in society. The purpose is to enhance students' learning about science concepts, principles, and theories and to develop students' science process skills and curiosity. Therefore, instruction should move more towards minds-on learning activities (Chiappetta and Koballa 2002). Thus, Nihat's view of inquiry does not match with definitions in the literature. In addition, Nihat indicated that it is easy to implement the inquiry method. However, Chiappetta and Koballa (2002) stated their concerns related to implementation of inquiry successfully. Inquiry requires more time for planning and conducting lessons, schools should have adequate facilities for hands-on activities, group work, and projects, and class size should be small. From this point of view, it can be said that Nihat did not reveal an understanding of inquiry through his interview statements. In addition, Nihat identified only his version of inquiry and demonstrations as constructivist teaching strategies. However, there are a variety of strategies used in constructivism, like the learning cycle, concept mapping, and cooperative learning. On the other hand, Nihat was aware of the individual differences in students, which reflects a part of a constructivist view of learning. However, he also indicated that inquiry methods could help to minimize individual differences. Moreover, Nihat emphasized that he learned these teaching strategies in the teaching methods class at his university.

In addition, Nihat mentioned that inadequate school facilities, such as inadequate computer and laboratory facilities, overloaded curriculum and inexperienced teachers impact the application of other constructivist teaching strategies. Nihat did not believe that constructivist teaching strategies could be easily applied to chemistry courses except through his version of inquiry. However, many constructivist teaching strategies have been applied in chemistry classrooms in Turkey (Akkus et al. 2003; Bilgin and Geban 2006; Uzuntiryaki and Geban 2005). On the other hand, Nihat thought that his chemistry knowledge was not sufficient for the application of constructivist teaching strategies in the classroom.

Practice of Constructivism

After the researchers interviewed Nihat they observed how he put his beliefs into practice. For this purpose, the researchers observed Nihat's instruction and examined his lesson plans. Nihat taught chemical bonding concepts to 11th grade students. During his instruction he chose to lecture. Nihat stated that because of the abstract nature of bonding concepts, he preferred to use lecture as the method of instruction for that particular topic. In his lesson plans, he embedded questioning and demonstrations; however, during instruction he used only the lecture method.

In fact, Nihat was aware that he was not using constructivist strategies during this instruction. Apart from the nature of the concept, he proposed that the school facilities were not sufficient for constructivist teaching strategies. Indeed, there are some strategies based on constructivism that do not need complex school facilities for hands-on activities. Therefore, even if the concept is abstract or the school facilities are limited, teachers can use constructivist strategies when helping students construct knowledge. In addition, he said that his mentor should guide and support him towards using such strategies. Nihat observed that his mentor was mainly using lecture in her classes. Although Nihat wanted to use inquiry and demonstrations, he had to follow his mentor and this prevented him from using constructivist teaching strategies.

In addition, during the instruction, Nihat did not mention his students' misconceptions although he referenced them in his lesson plan. This proved that he only transmitted what he knows about chemical bonds to the students without considering what his students understood. For example, while he was teaching hybridization, he did not ask students what they understood by an orbital, he merely drew circles with lines in them on the board, saying that the orbital was shown in this manner.

Another topic he taught using the lecture method was chemical reactions. His justification for choosing lecture was again due to the abstractness of this concept. Although in his lesson plan he indicated he would use analogies, power point slides and animations, he used none of these in his instruction. Rather the students simply copied the notes he provided to them.

Nihat's mean score on our observation form was 71 out of 100. He got high scores on items related to enthusiasm about lessons, self-confidence in teaching, and classroom management but his scores for emphasis on misconceptions, involvement of students in instruction, linking the topic to daily life, previous and subsequent topics were low.

In sum, we conclude that his responses during the interview did not match his teaching practice. Nihat's instruction reflected a more traditional approach than any constructivist convictions. Though he described the role of the teacher as a guide and director for students to think in the interview, his instruction was not consistent with this statement/belief. Similarly, during the interview, he mentioned that the teacher should give clues to students so they can construct knowledge. This belief also showed divergence from his practice because students were not actively engaged in his class. Although he believed that constructivist teaching strategies, especially the inquiry method, could be used in classes, he did not use them, saying the abstractness of the concepts was a major reason for not doing so. This result is consistent with Pavon (as cited in Mellado 1998), which suggests that experienced teachers' beliefs show more consistencies with their practice than novice and pre-service teachers, who tend to apply traditional teaching methods despite their stated beliefs in the use of more constructivist approaches.

Case 3: Arda

Beliefs About Learning

Arda defined learning as a change in a learner's behavior. While explaining the learning process, he did not consider the effect of prior knowledge and he believed that knowledge could be transferred from the teacher or any external source to the student: "Students can learn by listening to the teacher, studying on his own or reading from textbooks or using other sources such as television. This causes change in students' behaviors."

It can be said that Arda has a traditional view of learning since he believed knowledge transfer from external sources to students is essential for the learning process.

Beliefs About Constructivism

Definition of constructivism Arda described constructivism as the instructional strategies used in class and the way these instructional strategies are used. He explained how instructional strategies should be used in constructivism:

> I taught alkenes today. Since it is an abstract topic, it is really hard to teach. It would be difficult for students to learn by lecturing. However, I did lecture since the use of other methods is more demanding. But a demonstration would be better.

The above explanation indicates that Arda is not aware that constructivism is a theory explaining how knowledge is constructed by the learners. Instead, he perceived constructivism as a way of presenting information in class. Consistent with his belief about learning, Arda did not mention students' prior knowledge and the necessity for active involvement of learners in knowledge construction process during learning. Another interesting result from the above statements is that though Arda was aware that the teaching method he chose was inefficient, he continued to use it since other methods were more demanding of him. Therefore, it can be said that Arda is not eager to use alternative methods to lecturing.

Constructivist Learning Environment When asked about creating a learning environment that could support constructivist practices, Arda indicated that the classroom should not be crowded; there should be a computer and an overhead projector in the class: "The class should not be crowded and the classroom should contain overhead projector and computer in case the Internet will be used. Then, the teacher should arrange the equipment she/he would use before class." Arda's beliefs about the role of the teacher are mechanistic. He described the teacher as the most important factor for learning process. He believed that students could not learn without a teacher. Therefore, he stated that a teacher should play a dominant role in the class and give students the impression that he is an authority on the subject: "The teacher is the most important person in class. Learning does not occur without a teacher. Students cannot learn by themselves. Therefore, the teacher should be active in class and make students feel that she/he is the only power in the class."

In terms of a role for the students, Arda expressed the necessity for students to participate in class. He believed that an active role for students would help their teachers understand which part of the topic students did not learn:

> Some students do not want to participate in class much but if students participate in class, they would help their teachers because the teacher may understand whether or not they understand the topic or which part of the lesson they could not understand. Therefore, active participation of students is important.

In addition, Arda mentioned that participation was important in promoting student learning since students could learn better by both listening to the teacher and by participating in class: "Active participation is also important for students' learning. They learn better by both listening and participating rather than by listening only. This makes their learning easier." Though Arda indicated that active participation of students in class was important, he did not consider the importance of active participation in terms of student's knowledge construction.

Arda also added there should be an interaction between students and the teacher in class: "If the teacher explains the topic, students will lose attention because it is really hard to

listen to someone for 15 min. Therefore, if the teacher asks questions, students will pay attention." Again, Arda believes in the necessity of some interaction between the teacher and the students in terms of maintaining students' attention rather than guiding students in the construction of their knowledge.

However, Arda was opposed to facilitating interaction among students in his class. He believed that students should be respectful to the teacher and listen to him/her carefully: "Students should respect their teachers and should not talk to each other in class. If this does not happen, class does not interest them and learning does not occur." Arda's approach reflects a mechanistic view of teaching where students are passive listeners and receivers of information provided by the teacher.

Constructivist Teaching Strategies Arda's perception of the constructivist approach to teaching was one in which various teaching methods contrast with the use of the single teaching method common in traditional teaching. He stated that knowing about different teaching strategies is essential, however:

> You cannot use the same teaching method for each topic. For example, for both the mole and gases concepts, it is not good to use the same teaching method. While presenting some topics, you need to lecture; however, during the presentation of other topics, visual presentation is important. Therefore, teachers should use appropriate teaching methods depending on the topic.

Arda stressed the selection of appropriate teaching methods according to topic. Towards the end of the interview, Arda gave examples of questioning, cooperative learning and inquiry as the constructivist teaching strategies:

> R: Can you give more examples of constructivist teaching methods?
>
> Arda (A): As far as I remember from the methods classes in the university, we can also give questioning, cooperative learning and inquiry as constructivist teaching practices. We learnt these in methods courses.
>
> R: Why do any of these involve constructivist teaching methods?
>
> A: For example, in inquiry, we make students participate in class more since it involves asking questions and therefore students will not be bored and they learn more quickly. Also, questioning and cooperative learning would decrease the monotony of class by making students participate more in class and therefore they learn more.

When asked about the reason for including questioning, cooperative learning and inquiry as constructivist teaching methods, as the above explanations reveal, Arda indicated that these methods increased students' learning since students tended to participate more in class. He said that through the teaching methods class he took at the university he became aware of these teaching strategies. On the other hand, at no time did Arda emphasize students' construction of their own knowledge through a teaching method. Instead, he suggested that these teaching methods would increase students' learning by adding variety to a lesson.

Practice of Constructivism

When the researchers examined Arda's practice teaching they observed that he did not use constructivist teaching strategies. Although Arda mentioned some practices consistent with constructivist learning in his lesson plans we observed only lectures, demonstrations and

analogies in the classroom. While teaching chemical reactions concepts to ninth grade students, he used lecturing. He mainly introduced the concepts on the board, but not in detail and without invoking the students' prior knowledge. He rarely asked questions of students. Also, he did not link the topic in any way to daily life. In terms of misconceptions, he did not design instruction to address these. In addition, he did not present discrepant events in order to provide disequilibrium between students' alternative conceptions and he failed to provide an environment that challenged students to construct the scientifically accepted knowledge by themselves (Driscoll 2005).

Arda's mean score from our observation was 59 out of 100. He scored low on most of the items such as emphasis on misconceptions, involvement of students in instruction; linking topics to daily life, previous and next topics, and effective use of voice.

As reasons for not using constructivist strategies, he stated that the classroom was too crowded and this might make classroom management difficult. Moreover, he stated that the facilities in the chemistry laboratories and access to the Internet were limited. He also added that the insufficiency in his chemistry knowledge caused him to prefer using lecture. Arda's beliefs about teaching were more consistent with his practice than Ezgi and Nihat. Arda had mechanistic beliefs about learning; he believed that transmission of knowledge from the teacher to student would be essential for the learning. Similarly, he described the role of the teacher as the authority in class. Consistent with these beliefs, during his practice, he lectured and did not provide opportunities for students to construct their own knowledge. Though he mentioned the use of demonstration and analogies in his lesson plan, his instruction did not include these. Though he stated the necessity of interaction between teacher and students in terms of gaining students' attention, his instruction provided only a passive role for the student.

Taking the results from all three case studies into consideration, it can be inferred that the relationship between these three pre-service teachers' beliefs and their practice is not straightforward as supported by Brickhouse (1990) and Tobin (1993). Teaching practice is affected by various situational factors such as the nature of the classroom and the curriculum (Lederman 1992; Munby et al. 2000; Tobin and McRobbie 1996). In addition, while reflecting their beliefs through instruction, pre-service teachers may prefer not to be involved in complex environments where they do not feel comfortable, therefore, they simplify their teaching practices (Wallace and Louden 1992). This condition would seem to prevent the transfer of beliefs into practice. However, in order to minimize the mismatch between beliefs and practice, the first step should be to make pre-service teachers' beliefs and their practice explicit by encouraging them to discuss their beliefs and practice in an effort to make them aware of any inconsistencies as Tobin and LaMaster (1995) have pointed out. Afterwards, the adequacy of these beliefs could be confronted and they could then be given the opportunity to practice new instructional strategies (Kagan 1992). In addition, the support of cooperating teachers for the implementation of constructivist teaching strategies is crucial. Stofflett (1994) and Haney and McArthur (2002) stated that pre-service teachers tended to integrate their beliefs into practice more like those of their cooperating teachers in the schools. Likewise, Luft et al. (2003) highlighted the importance of support programs which included reform-based practices for beginning teachers.

Some of the findings of this study are similar to results from previous studies. For example, Wallace and Kang (2004) indicate that inquiry-based teaching is difficult to implement. In addition, Tsai (2001) discusses science teachers' difficulties with implementing constructivist-oriented instruction. Similarly, the pre-service teachers in the present study stated that using inquiry-based teaching in high schools in Turkey seems to be difficult.

Conclusion and Implications for Science Teacher Education

The purpose of this study was to explore pre-service chemistry teachers' beliefs about constructivism and how those beliefs were reflected in practice. For this purpose, semi-structured interviews were carried out with eight pre-service teachers in order to understand their belief structures. In addition, their teaching practice was observed and lesson plans were examined. Ultimately, three case studies were presented here to represent weak, moderate, and strong versions of beliefs about constructivism and the impact of those beliefs on teaching practices.

The findings showed that most pre-service teachers in this study did not have strong conceptions of constructivism; instead, they had moderate or weak conception of constructivism. Since pre-service teachers developed their beliefs through science classes and laboratory activities their beliefs might tend to be more traditional or mechanistic rather than constructivist as also recognized by Tsai (2002). In the present study, one of the most important factors affecting the development of pre-service teachers' belief was their teaching method course at university. Pre-service teachers learned various teaching methods in those courses that served as a theoretical framework for their beliefs and practice.

Analysis of responses to the interview questions, lesson plans, and observations of actual teaching practice in the classrooms suggested that the relationship between beliefs and practice was not clear-cut. In general, actions in the classrooms were not aligned with the elements of constructivism that were suggested by interviewees during an interview. Although their interviews included statements about beliefs in constructivist teaching, their instruction departed from this view. However, there were some instances in which practice matched with beliefs. It appeared that teachers with strong or moderate beliefs (e.g., Ezgi and Nihat) had difficulty implementing their beliefs during practice; therefore, they tended to move from constructivist perspective to more traditional instruction. For example, Ezgi who believed the importance of prior knowledge in teaching identified her students' prior knowledge before instruction but her teaching strategy was to eliminate the misconceptions by presenting the scientific explanation. However, the teacher with a weak conception of constructivism (Arda) was more successful in integrating his (traditional) beliefs into his instruction.

The pre-service teachers participating in this study stated some reasons for not using constructivist teaching strategies in class. These included: inadequacy of Chemistry knowledge, abstractness of the topic, large class sizes, inadequate school facilities, and the difficulty of applying constructivist principles. Because these teachers had little teaching experience, they might need additional time to structure their beliefs, and integrate them into their practice.

This study has several implications for science teacher education. Pre-service teachers come to university with some beliefs about teaching and learning already developed in earlier years of their education. Since these beliefs influence their practice, identifying pre-service teachers' belief structures early on gains importance. In addition, pre-service teachers should be encouraged to be aware of their beliefs about constructivist teaching practices. We, as teacher educators, cannot understand whether pre-service teachers are ready to implement constructivist teaching strategies without understanding their beliefs. Crawford (2007) suggests that teacher beliefs should be examined in the context of practice. Thus, not only should the pre-service teachers comprehend constructivism as a learning theory, they should also practice constructivist teaching strategies. Teacher education programs should provide more practical courses in which pre-service teachers apply instructional strategies in real classrooms. This may help them shape their beliefs and integrate them into practice with continuous feedback from both mentors and instructors.

In addition, the pre-service teachers in this study mentioned their lack of content knowledge as an obstacle for implementing constructivism in instruction. Therefore, teacher education programs should emphasize subject matter knowledge more.

As a result, the present study contributes to the research on teachers' beliefs from a constructivist perspective. However, due to the complex structure of beliefs, longitudinal studies are needed in order to extensively investigate the relationships between teachers' beliefs and practice.

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Appendix

Interview questions

1. In your opinion, what is learning? How does it occur?
2. What do you understand about constructivism?
3. How is the learning environment created in a constructivist classroom?
4. What are the roles of the teacher and the students according to constructivism?
5. What do you understand from constructivist teaching strategies? Do you think they are important and necessary in instruction? Why or why not?
6. What are some teaching strategies based on constructivism? Why do you think they are parallel to constructivism? What are the differences between these strategies and other teaching strategies?
7. Do you apply constructivist teaching strategies in your teaching practice? How? If not, why?
8. In your practice teaching, how do you decide which teaching strategy you will use?
9. Which teaching strategies does your mentor in the high school use during the instruction? How?
10. Do you think competency in chemistry content is required in using constructivist teaching strategies? Why?

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