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WHAT CONCEPT MAPS TELL US ABOUT CHANGES IN PEDAGOGICAL CONTENT KNOWLEDGE OF PROSPECTIVE CHEMISTRY TEACHERS PARTICIPATING IN AN INQUIRY-BASED WORKSHOP?

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Abstract. In this study, we aimed to investigate if prospective chemistry teachers' participation in a professional development workshop changed their knowledge of inquiry-based teaching as a subject-specific instructional strategy. For this aim, as part of a project that intends to enhance science teachers' knowledge of inquiry pedagogy, we firstly developed an inquiry-based professional development workshop for supporting chemistry teachers in their effort to implement inquiry-based approach in their chemistry classrooms. Twenty pre-service chemistry teachers were selected as participants of the study. The concept maps which were constructed at the beginning and at the end of the workshop were used to expose the changes in the participants' knowledge of inquiry-based teaching. The result of the Paired Samples T-Test indicated significant difference between the mean of pre- and post-concept map scores. Furthermore, when the structures of the concept maps were classified as linear, spokes, tree and network, it was determined that after the professional development workshop more improved knowledge about inquiry-based teaching were constructed in their minds. Based on all data from concept maps, there is support for assertion that the professional development workshop provided considerable improvement in participants' knowledge of inquiry-based teaching as a type of pedagogical content knowledge.

1 Introduction

In science education, knowing *how* to teach science concepts to students and to make science concepts understandable for them is one of the most important issues. Therefore, science teachers should not only know what to teach, but also they should know how to teach. For science teachers, the issue of "how to teach" requires specialized knowledge that distinguishes them from subject matter specialists. For this reason, it is not sufficient for teachers to have knowledge about content and pedagogy separately. It is important to have sufficient knowledge about combination of content and pedagogy.

In this respect, Shulman (1987) argued what knowledge teachers need to have for teaching, and proposed pedagogical content knowledge (PCK) as a form of teachers' special knowledge needed to help students understand specific content. Shulman described pedagogical content knowledge as "special amalgam of content and pedagogy that is uniquely the providence of teachers ..... Pedagogical content knowledge …. identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to diverse interests and abilities of learners, and presenting for instruction." (Shulman, 1987). According to Tamir (1988), PCK involves knowledge about students' common difficulties in a topic, curriculum knowledge, instructional strategies knowledge and methods of assessment knowledge. These definitions are putting forward that PCK constitutes the intersection between content knowledge and pedagogical knowledge, and it is a critical concept for effective science teaching.

According to Magnusson et al. (1999) PCK for science teaching consists of five components: (a) orientation toward science teaching, (b) knowledge and belief about science curriculum, (c) knowledge and belief about students' understanding of specific science topics, (d) knowledge and belief about assessment in science, and (e) knowledge and belief about instructional strategies. They describe these components and their relationships through a concept map as in shown Figure-1. Since the instructional strategies have a robust impact on students' success, and teachers' understandings related to components of PCK determine how the components are utilized in classroom teaching, "knowledge about instructional strategies" component of PCK appears to have a considerable importance. Also, Van Driel et al. (1998) emphasize that teachers' knowledge about teaching strategies is one of two key elements of PCK. Therefore, for science teachers it is essential to have sufficient knowledge and understandings with respect to instructional strategies.

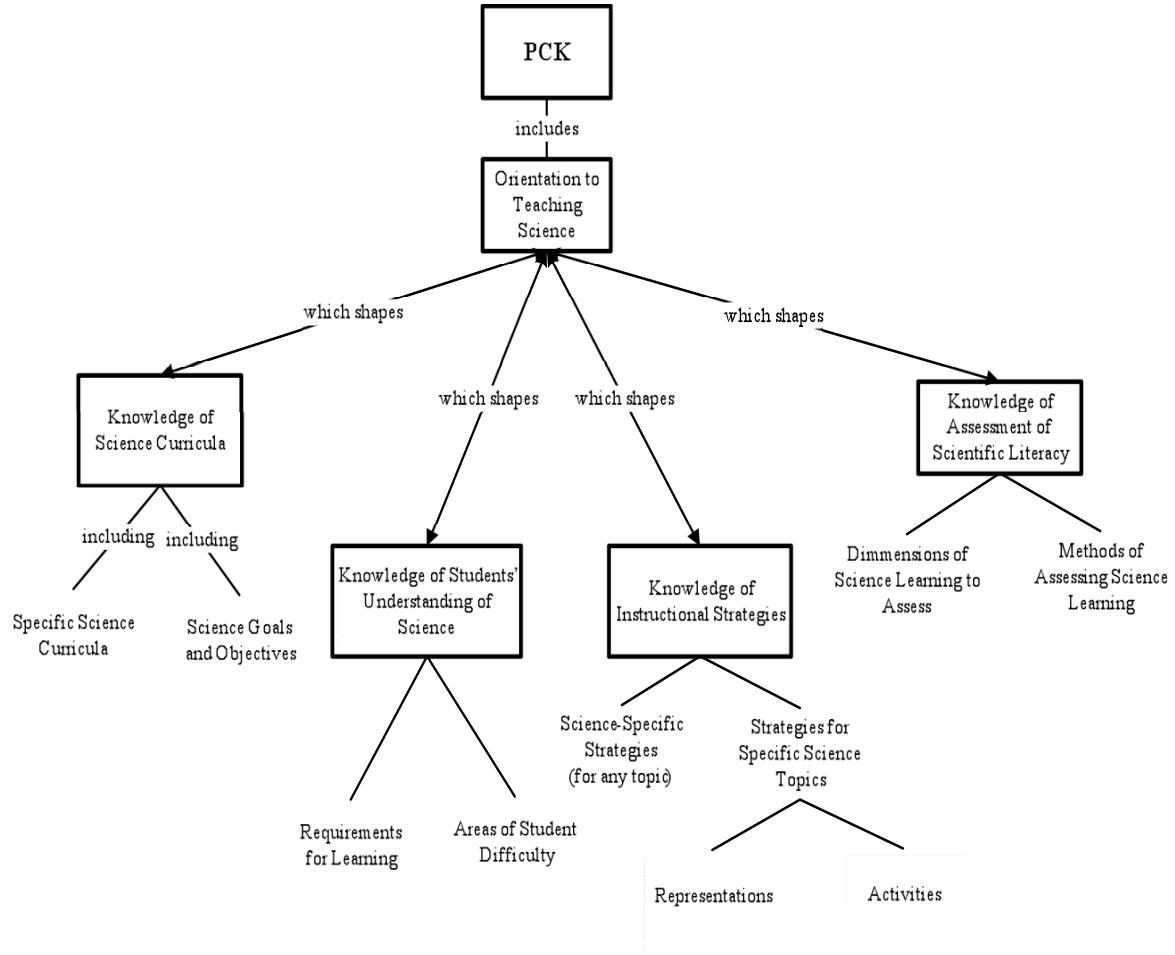

Figure-1. Components of pedagogical content knowledge for science teaching (Magnusson et al., 1999)

Knowledge of instructional strategies which is one of the components of PCK is consists of two categories: knowledge of subject-specific strategies and knowledge of topic-specific strategies. Subject-specific strategies are more comprehensive than topic-specific strategies and represent general approaches to science instructions. They are specific to teaching science as opposed to other subjects (Magnusson et al., 1999). When the science education literature is examined, it is seen that a number of subject-specific strategies have been developed. We assert that the most appropriate and promising one for science teaching is inquiry-based teaching. For this reason, we focus on is inquiry-based teaching in our studies (e.g. Budak & Köseoğlu, 2007a, 2007b).

Inquiry-based teaching focuses on actively searching for knowledge to satisfy curiosity and it is supported by the constructivist approach. It includes practices that promote learning of scientific concepts and processes as well as "how scientists study the natural world" (NRC, 1996). In many studies it is found that inquiry-based science teaching had positive effects on students' science achievement, cognitive development, laboratory skills, science process skills, and understanding of science knowledge (Budak & Köseoğlu, 2007c; Chang & Mao, 1998; Mattheis & Nakayama, 1988; Padilla, Okey, & Garrand, 1984; Saunders & Shepardson, 1987). For this reason, inquiry is a word that has been used by science educators for many years to describe good science teaching and learning. Also recent science education reform documents in many countries emphasize the importance of inquiry-based science teaching. This implies that both pre-service and in-service teachers must be prepared with the knowledge of inquiry-based teaching which is a type of subject-specific strategy.

However, the studies indicate that science teachers' knowledge of inquiry-based teaching has not been sufficiently developed (Keys and Bryans, 2001). As it can be anticipated, planning and enacting an inquiry-based science lesson is difficult for teachers who have inadequate knowledge of inquiry teaching. For inquiry to be effective in providing students with a conceptual understanding of science, science teachers must first understand what inquiry is and then apply this knowledge in science lessons as a pedagogical tool. Therefore, through the professional development courses which were developed in the light of researches about effective professional development programs, knowledge and skills needed to carry out inquiry-based learning should be

provided for science teachers. Thus, teachers can transport this knowledge from the professional development programs into their classrooms.

Although many researches about professional development programs focusing on inquiry-based science teaching are already available, there is little research on what knowledge teachers learn in these programs. More research should be devoted to examining how such programs affect teachers' knowledge of inquiry-based teaching. Teachers' knowledge of subject-specific strategies for science teaching contains the ability to describe a strategy (Magnusson et al., 1999). By using an instrument such as concept map which allows teachers to describe inquiry-based teaching, their knowledge can be explored in professional development programs. Concept mapping is one of the primarily useful research tools used for examining teachers' knowledge base (Baxter & Lederman, 1999; Wee et al., 2007). Morine-Dershimer (1989) suggests that concept maps can provide valuable feedback on teachers' knowledge. Concept maps have been used by cognitive researchers to measure knowledge structures which are represented by key terms and the relationships among them (Baxter & Lederman, 1999). According to Novak & Gowin (1984) concept maps are schematic devices for representing a set of concept meanings embedded in a framework of propositions. They provide a "picture" of how key concepts in a domain are mentally organized/structured (Ruiz-Pimo et al., 2001). For these reasons, in our pre-service and in-service teacher education workshops about inquiry-based teaching we used concept mapping as the main assessment method for probing the development of science teachers from various aspects.

2 Purpose

Concept maps are thought to be reliable indicators of knowledge structures constructed in mind. In this study we utilized this feature of concept maps and aimed to investigate if prospective chemistry teachers' participation in a professional development workshop enhanced their knowledge of inquiry-based teaching as a subject-specific instructional strategy which is a component of PCK.

3 Methodology

As part of a project, funded by Gazi University, that intends to enhance science teachers' knowledge of inquiry pedagogy, we firstly developed an inquiry-based professional development workshop for supporting chemistry teachers in their efforts to implement inquiry-based approaches in their chemistry classrooms. The workshop was structured in such a form that could be used in both pre-service and in-service teacher education (extracts from video recordings of the workshop with English subtitle will be displayed in the presentation). It is organized in six sessions. Each session focuses on a different aspect of inquiry-based teaching. The six sessions are as follows:

Session-I: Activities Based-on Inquiry:
Session-II: What is Inquiry?
Session-III: Scientific Process Skills in Inquiry
Session-IV: Asking Question in Inquiry
Session-V: Models and Strategies Which Support Inquiry
Session-VI: Opinion Sharing About Inquiry

The focus of the sessions and the way they were delivered are described via a concept map in Figure-2. As it is seen, in the sessions participants are engaged in a number of activities; the video recordings which involve some examples of the implementations of inquiry in high school science classrooms were displayed; knowledge about inquiry-based science teaching was introduced through a power point presentation and involving teachers to participate by discussing their ideas. The topic of how the concept maps can be used in inquiry-based science instructions was given a special emphasis in Session-V.

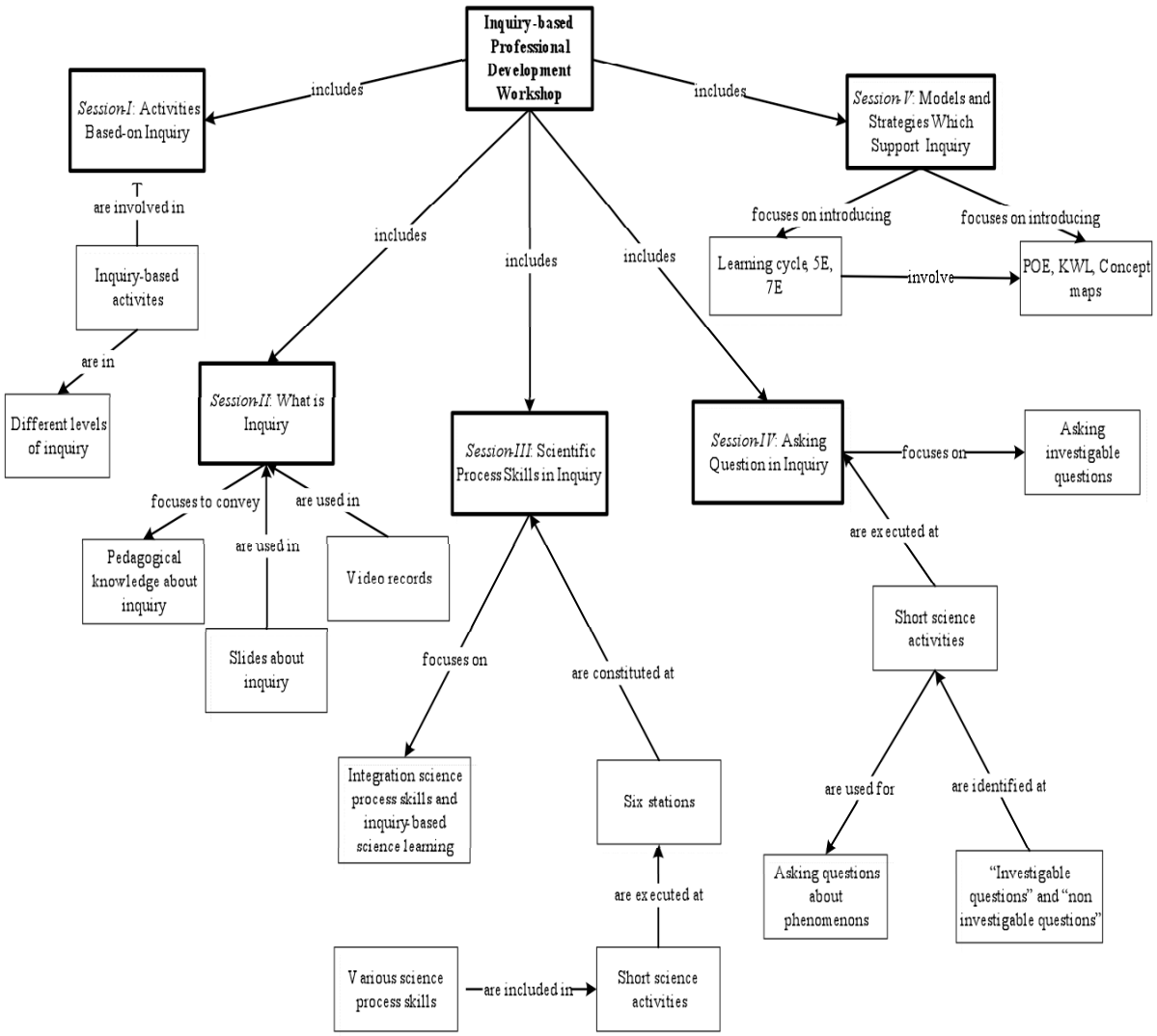

Figure-2. Structure of the sessions of inquiry-based professional development workshop

Since students are deemed to learn best when they are actively involved during the learning process, teachers probably will learn inquiry-based teaching when they are engaged in this methodology personally. In order to both engage participants in inquiry-based teaching and modeling the methodology, sessions were designed in the learning cycle format. In this way, through the variety of activities it is allowed that participants firstly experience one of the aspects of inquiry-based teaching that we expect them to use in their science lessons (*exploration phase for one of the aspects of inquiry-based teaching*). Secondly, participants are expected to construct knowledge and understanding by discussing and using their experiences (*concept development phase*). Lastly, participants are provided opportunities such as in-workshop activities or in-class activities to apply what they learned about different aspects of inquiry-based teaching (*concept application phase*). Throughout the workshop, participants sometimes act as a teacher and sometimes as a student.

In order to investigate the effect of the professional development workshop on knowledge of inquiry-based teaching 20 pre-service chemistry teachers at Gazi University in Ankara, the capital of Turkey, were selected as participants of the study. The workshop was conducted in a chemistry teaching laboratory during 10 weeks and 3 hours in a week. During the workshop participants were directed for learning to apply inquiry-based pedagogy within various chemistry themes. Before the workshop, participants were provided a specific training by the researchers on constructing concept maps. In this training, it is focused on chemistry themes in constructing concept maps. Both at the beginning and end of the workshop, participants were asked to construct a concept map that reflects their knowledge of inquiry-based teaching. The reason for us to prefer the "construct-a-map from scratch" technique was that this technique better reveals the differences between the knowledge structures than "fill-in-the-map" technique (Ruiz-Primo et al., 2001).

4 Results and Discussion

For the purpose of identifying the effect of our inquiry-based professional development workshop on the participants' knowledge of inquiry-based teaching, pre- and postconcept maps of participants were analyzed by utilizing the approach used by Novak & Gowin (1984), whose primary basis is Ausubel's cognitive learning theory. This is a popular approach for analyzing concept maps and getting quantitative measures. By taking this approach into account, concept maps of the participants were analyzed and scored according to the following factors: a) number concepts: 2 points for every concept relevant to the subject, b) overall hierarchical structure: maximum 10 points for arranging concepts according to the degree of relevancy to each other, c) number of meaningful proposition: 1 point for every valid proposition and 1 points for every clear proposition.

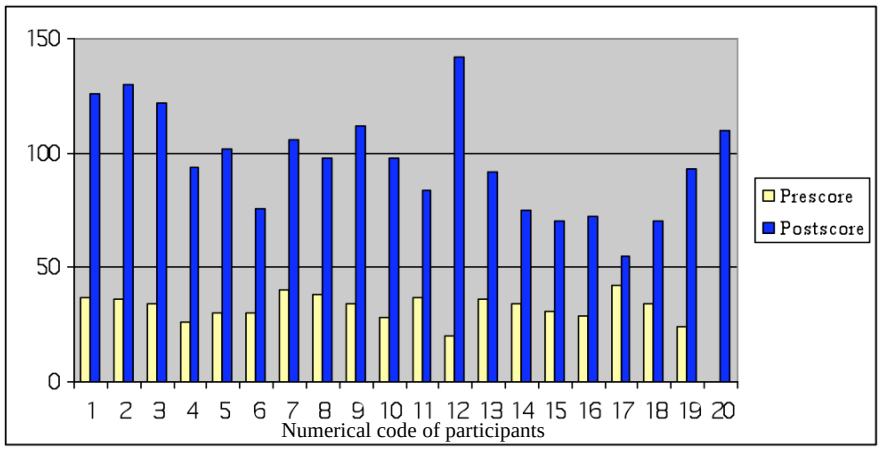

Figure-3. Distribution of the scores

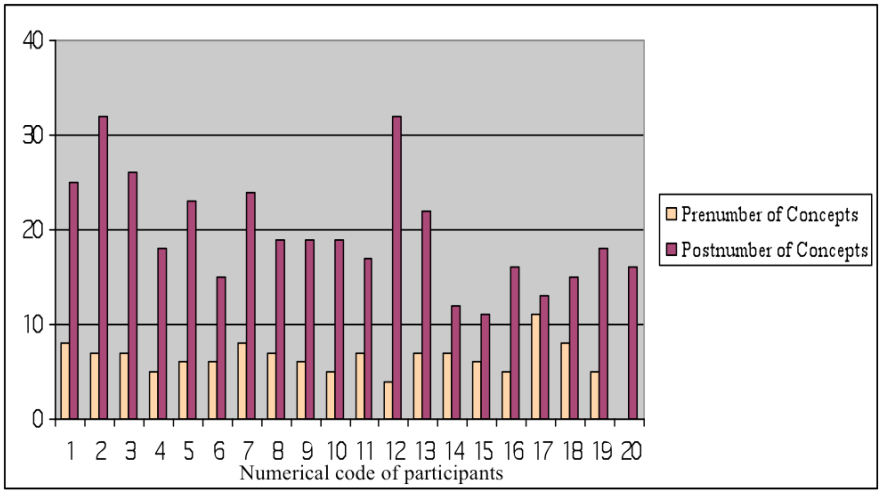

Figure-4. Distribution of the number of concepts

Each concept map was scored by the two of us jointly. It is determined that the scores obtained from the concept maps are distributed normally (for both pre- and post-concept map scores $p>0.05$) by using Kolmogorov-Smirnov Test in SPSS software. A paired samples t-test was used to investigate if prospective chemistry teachers' participation in professional development workshop changed their knowledge of inquiry-based teaching as a subject-specific instructional strategy. The result indicates a significant difference between the mean of pre- and post-concept map scores ($t_{(19)}$=-10,94; $p<.05$). It means that knowledge of the pre-service chemistry teachers about inquiry-based teaching had an important progress. Also the distribution graphs, belonging to the pre- and post-scores, and pre- and post-number of concepts, in Figure-3 and Figure-4 show this improvement.

Structures of all of concept maps were classified as linear, spokes, tree and network by us. We classified the concept maps into the structures by discussing and reaching an agreement. Pre-concept maps exhibited linear or spokes structure. But post-concept maps exhibited tree or network structure. According to Yin et al. (2005) among them, network structure is considered to be the most complex, while the linear structure is considered to be the simplest. Therefore, structures of the concept maps indicate that after the professional development workshop much more improved knowledge about inquiry-based teaching were constructed in pre-service teachers' minds. The concept maps of one of the participants as shown in Figure-5 and Figure-6 illustrate vividly how great this development is from pre- to post-concept maps. Despite the fact that participants had already participated in a science methods course in which they learned science teaching strategies before the workshop, pre-concept maps demonstrate that they did not have enough knowledge about inquiry-based teaching. The reason may be that in the science methods course science teaching strategies are introduced to

them roughly, and opportunities for experiencing the strategies are not given. On the other hand, it was seen from the post-concept maps that participants had many concepts concerning and connected to inquiry pedagogy as it can also be seen from Figure-6. Furthermore, post-concept maps such as in Figure-6 indicated that the key concepts focused in each session were learned by connecting the key concepts in other sessions.

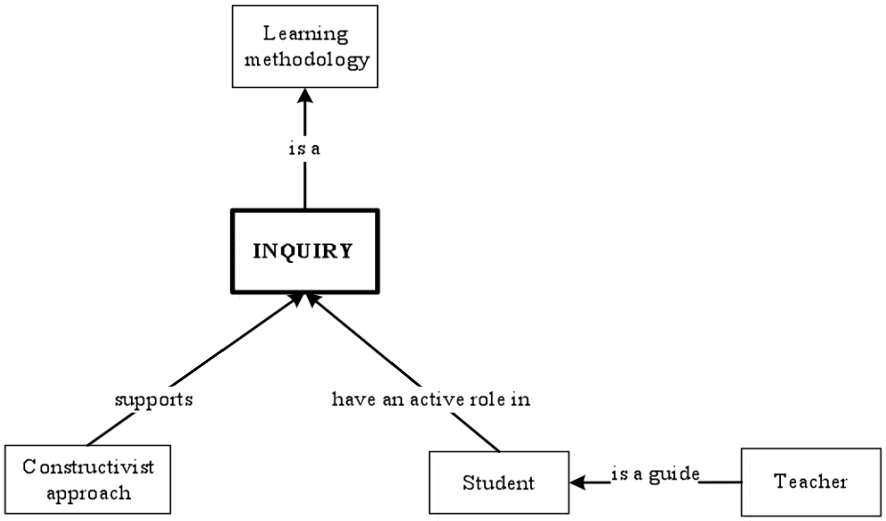

Figure-5. Pre-concept map of one of the participants

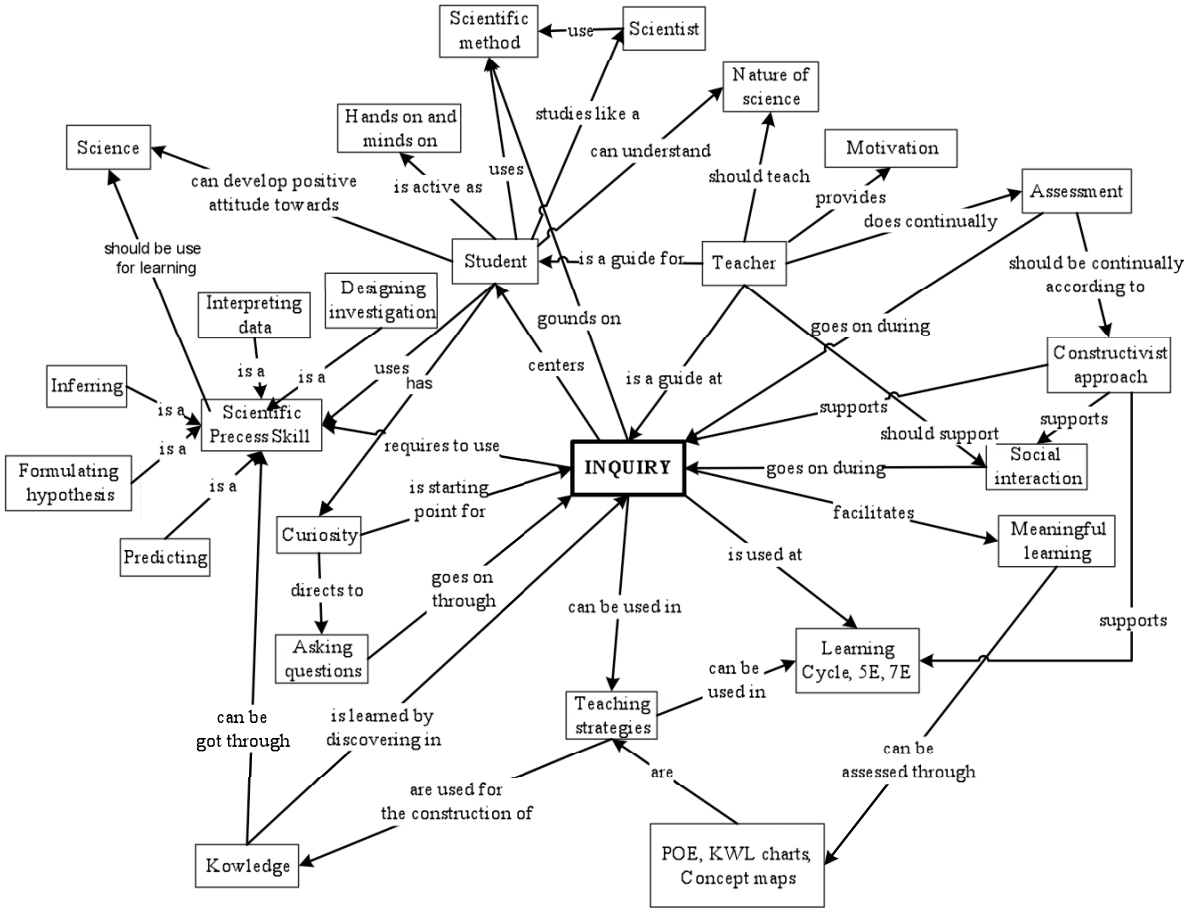

Figure-6: Post-concept map of one of the participants

Based on all the data from concept maps, there is support for assertion that the professional development workshop provided considerable improvement in participants' knowledge of inquiry-based teaching as a kind of PCK. The results of this study run in parallel with the results of our previous studies, which indicate that the inquiry-based professional development workshops contribute participants' improvement from various aspects (Budak & Köseoğlu, 2007a, 2007b). If the participants strive to use this new knowledge in designing inquiry lessons, they can implement inquiry-based teaching more readily.

Moreover, based on the results of this study, it was concluded from the dialogues with participants during the workshops that having the concept map which describes the structure of workshop as a hand-out before the workshop motivated them for participating to the workshop, and this concept map served as a roadmap for them through the workshop sessions. Therefore, we plan to distribute the concept map (Figure-2) to teachers in the future to provoke their participation to the workshops.

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