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Literature Review on Inquiry-Based Learning in Science Education

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Abstract

Today, what is expected from education is raising individuals who learn how to learn. In this situation, traditional learning approaches and traditional methods could not supply this demand because in traditional education, the teacher who is in the active position uploads lots of information which students are not curious about or interested in. The students in this situation acquire the information without questioning and internalizing it, and thus cannot learn how to learn because of the passive position they are in. Therefore, new approaches to curriculum programming enable students to learn how to learn, to acquire high level thinking skills and positive attitudes towards the lesson. In this study, it is aimed to review literature related to inquiry-based learning. In order to reach this aim, this topic will be reviewed under twelve main headings within the current study. These are definition of inquiry, inquiry-based learning, types of inquiry-based learning, models that are used in the process of inquiry-based learning, methods and techniques used in inquiry-based learning, evaluation in inquiry-based learning, the importance of inquiry-based learning in science education, different roles of teachers in inquiry-based learning, different roles of students in inquiry-based learning, inquiry-based learning environments and its characteristics, misconceptions concerning inquiry-based learning and challenges encountered in inquiry based learning. Moreover, some sub-headings will follow the main headings.

Key Words: Inquiry-based learning, literature review, science education

Fen Eğitiminde Sorgulama Dayalı Öğrenme Hakkında Literatür Taraması

Öz

Çağımızda eğitimden beklenen öğrenmeyi öğrenen bireylerin yetiştirilmesidir. Bu durumda geleneksel öğrenme yaklaşımları ve geleneksel yöntemler beklenen bu ihtiyacı karşılayamamaktadır. Çünkü geleneksel eğitim anlayışında aktif olan öğretmen öğrenciye merak ve ilgisinin olmadığı birçok bilgi yüklemesi yapmakta, öğrenci ise bu durumda sorgulamadan veya içselleştirmeden doğrudan bilgiyi almakta ve dolayısı ile pasif durumda olduğundan öğrenmeyi öğrenememektedir. Dolayısıyla öğrenmenin öğrenilmesi, üst düzey düşünme becerilerinin ve derse karşı olumlu tutumların kazandırılması ihtiyacıyla müfredat programları yeni yaklaşımlarla yapılandırılmaktadır. Bu çalışmada, sorgulamaya dayalı öğrenme ile ilgili literatürün gözden geçirilmesi amaçlanmıştır. Bu amaca ulaşmak için, bu konu mevcut çalışma kapsamında on iki ana başlık altında incelenecektir. Bunlar sorgulamanın tanımı, sorgulamaya dayalı öğrenme, sorgulamaya dayalı öğrenmenin türleri, sorgulamaya dayalı öğrenme sürecinde kullanılan modeller, sorgulamaya dayalı öğrenmede kullanılan yöntemler ve teknikler, sorgulamaya dayalı öğrenmede değerlendirme, fen eğitiminde sorgulamaya dayalı öğrenmenin önemi, sorgulamaya dayalı öğrenmede öğretmenlerin farklı rolleri, sorgulamaya dayalı öğrenmede öğrencilerin farklı rolleri, sorgulamaya dayalı öğrenme ortamları ve özellikleri, sorgulamaya dayalı öğrenme ile ilgili kavram yanılgıları ve sorgulamaya dayalı öğrenmede karşılaşılan zorluklar. Ayrıca, bazı alt başlıklar ana başlıkları takip edecektir.

Anahtar Kelimeler: Sorgulamaya dayalı öğrenme, literatür taraması, fen eğitimi

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Definition of Inquiry

The term inquiry pertains to the general attributes of student-directed questioning and problem solving. Llewellyn (2005) mentioned that inquiry defines a learning process which involves an active interaction with the environment and a constant construction and reconstruction of knowledge through this interaction. Anderson (2007) pointed out that "what is called inquiry learning in the literature is very similar to what others call constructivist learning" (p. 809). In accordance with this definition, constructivist methods of learning set the base for inquiry-based learning. Besides being student-centered, these methods operate by connecting new learning to existing cognitive structures, they are dependent on discursive, socialized instructional environments, and they involve a collaborative and cooperative learning process between students, teachers and other disciplinary masters (Bruner, 1961; Dewey, 1997; Piaget, 1972; Prince & Felder, 2006; Vygotsky, 1978). Despite having been defined in many different ways, inquiry has not been defined clearly, and neither have its uses in different educational contexts (National Research Council [NRC], 1996). To shed light on this problem, National Research Council (2000) has published a book titled *Inquiry and National Education Standards: A Guide for Teaching and Learning*. A clear rationale for the use of inquiry in instructional settings has been provided in this book. Nevertheless, differences still exist in the way researchers interpret inquiry.

According to Anderson (2007), three different forms of inquiry exist in the National Science Education Standards (NSES), namely scientific inquiry, inquiry learning, and inquiry teaching. Although having many similarities, these three forms of inquiry are also different from one another. Firstly, scientific inquiry refers to the work of scientists, the nature of scientific investigations and science processing skills. Secondly, inquiry learning relates to an active process of learning based on constructivist learning. Lastly, although there are various types of inquiry teaching such as partial inquiry and full inquiry, the National Science Education Standards mention that there is no clear distinction between them.

The points mentioned below are noted as the fundamental features of classroom inquiry in the "Inquiry and the National Science Education Standards":

1. Learners are engaged by scientifically oriented questions.

2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.

3. Learners formulate explanations from evidence to address scientifically oriented questions.

4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

5. Learners communicate and justify their proposed explanations. (NRC, 2000, p. 25)

The educational reforms (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996, 2000, 2012) underline that the primary objective of science education is to develop an understanding of scientific inquiry for all students until they graduate from high school. Moreover, these reforms highlight that if students develop their understanding of scientific inquiry, they will easily participate in complex practices in the science classroom. Argumentation is a significant feature of the scientific inquiry process, which is often neglected in the classroom. Argumentation in science is neither a heated dispute between rivals that

result in a winner and a loser, nor an effort to reach a compromise. It is basically a mode of "logical discourse whose goal is to tease out the relationship between ideas and evidence" (Duschl, Schweingruber, & Shouse, 2007, p. 33). As a result, scientific argumentation is the basis for the development, evaluation, and justification of scientific knowledge, and it is what makes science a different way of knowing (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002).

Inquiry-Based Learning

When educational activities are observed from past to present, it is seen that the roots of inquiry-based learning extend back to the famous philosopher Socrates and that it is not exactly a new method. Socrates pioneered this method by using the inquiry-based learning approach, also known as "Socratic Learning" that gives the opportunity to deeply examine ideas and opinions. Inquiry-based learning, which has often been brought to the agenda since the first years of the 20th century, has been a topic taken up by many famous scientists like Dewey (1933), Bruner (1960), Suchman (1961). Today, the focus is on teaching and learning processes that are rooted in the rapid development of scientific knowledge and on teaching "how to learn", how to do research and find information, how to use the information by applying inquiry-based learning. Along with individual skills, it aims to develop team work and communication skills (Bozkurt, Orhan, & Kaynar, 2008).

Inquiry-based learning is a learning approach that enables the learners to be active throughout the learning process by making them ask questions, analyze the information and inquire. It develops the skill of using scientific processes (putting forth the problems, planning experimental processes, making guesses, generating hypotheses, collecting and analyzing data and interpreting the results) and it makes the learners use their creativity (Bass, Contant, & Carin, 2009; Burden & Byrd, 2003; Duran, 2015; Hammerman, 2006; Llewellyn, 2002; Marek & Cavallo, 1997; Perry & Richardson, 2001). Inquiry-based learning approach is handled as a centralized and effective approach in science education by National Science Education Standards (NSES), which is assigned by the National Research Council (NRC) in the United States. It is also described as a multi-dimensional process in which students make observations, ask questions, research the already existing information from books and other sources, plan their research, compare already existing information with experiment results, use tools to analyze, interpret, discuss and put forth hypotheses, explanations and results (NRC, 2000, 2007).

Students in science courses use inquiry not only to understand the truths about nature and the things that are happening around them, but also to reach the ideas and theories that will help them in explaining the factual situations they have observed like scientists (Harlen, 2004). Thanks to inquiry-based learning, the focus of science education has changed from memorizing concepts and phenomena to effectively using both scientific processing skills and critical thinking skills (Zacharia, 2003) because inquiry-based science learning moves away from book-based, passive observations of phenomena, directly focuses on teaching the principals and laws of science, and adopts a student-based, active understanding that makes students develop their research by thinking on their own (Jorgenson, Cleveland, & Vanosdall, 2004). In science courses where inquiry is the focus, students not only learn science topics, but also skills such as logical thinking, asking questions, doing research and solving daily problems (Germann, 1994). Howe (2002) stated that the use of inquiry-based learning approach in science teaching in all levels of education is highly suggested and explained the rationale of inquiry-based learning as making students acquire the ability to ask questions, determine the learning material, collect information about the unit and reach

conclusions. He also stated that when the students are given the opportunity to discuss the results, learning becomes more meaningful and permanent.

Many researchers stated that inquiry-based learning approach is effective in making students learn to do scientific research like scientists and in developing their higher-level thinking skills (Bevevino, Dengel, & Adams, 1999; Bonner, 2005; Bransford, Brown, & Cocking, 2000; Carin & Bass, 2001; Cuevas, Lee, Hart, & Deaktor, 2005; Çalışkan, 2008; DeBoer, 1991; Domjan, 2003; Feldman, Chapman, Vernaza-Hernández, Ozalp, & Alshehri, 2012; Gordon & Brayshaw, 2008; Jensen, 1998; Keselman, 2003; Lawson, 1995; Llewellyn, 2005; Şaşmaz-Ören, Ormancı, Babacan, Çiçek, & Koparan, 2010; Tatar & Kuru, 2006; Wallace, 1997; Walker & Zeidler, 2007; Wenk, 2000). Llewellyn (2002) stated that inquiry-based learning approach makes students gain the required skills to become free individuals and life-long learners. Martin, Sexton, Franklin and Gerlovich (2005) indicated that in inquiry-based learning, examining, inquiry and discovery processes are indispensable for an effective science education. They also stated that students grow up to become individuals who learned how to learn when they structure their learnings with these processes. According to Tatar (2006), students develop their psycho-motor skills by interacting with instruments and develop their cognitive skills by paying attention to the process and interpreting cause-effect relations. Lawson (2010) defended that inquiry-based learning approach develops students' creativity, academic success, critical thinking skills and problem-solving skills by putting forth many research findings. In addition to these, inquiry-based learning approach is effective on the development of scientific literacy and understanding of scientific processes (Alkan-Dilbaz, 2013; Domjan, 2003; Laipply, 2004; Lim, 2001; Lindberg, 1990), strengthens vocabulary and conceptual knowledge (Lloyd & Contreras, 1987), develops critical and creative thinking skills (Babadoğan & Gurkan, 2002), develops their understanding of the nature of science (Bianchini & Colburn, 2000), and enables them to have a positive attitude towards science and science education (Narode, Heiman, Slomianko, & Lochhead, 1987).

Since it is a student-centered learning approach that prioritizes critical thinking, solving problems, making decisions and asking questions, inquiry-based learning allows students to develop the skills they need throughout their lives. Thus, it helps students to handle the problems they encounter (Branch & Solowan, 2003). One of the skills that is used and developed in the process of inquiry-based learning is the skill of creative thinking. Creative thinking skill enables the individual to approach the events from different perspectives, understand them differently and enables them to think what hasn't been thought. In inquiry-based learning, creative thinking is required in order to generate hypotheses about the stated research problem. Creative thinking skills need to be used in trying to apply new methods for collecting data, creating solutions and reaching a conclusion by interpreting findings (Hassard, 2005; Lim, 2001).

In activities based on inquiry, students investigate the events and phenomena both individually or in groups and reach conclusions. Students manage the research activities by themselves, ask questions, plan new activities, create conclusions and confirm the information that they have learned (Branch & Oberg, 2004; Bransford et al., 2000; DeBoer, 1991; De Jong & Van Joolingen, 1998; Jensen, 1998; Lawson, 1995). This situation makes students take responsibility, express themselves and increases their self-confidence. If students are provided with research experiences, positive changes can occur in both their cognitive structures and their attitudes towards science (Basaga, Geban, & Tekkaya, 1994).

Individuals who get the taste of learning and who are active in the process of learning by inquiry-based learning would desire to sustain this for the rest of their lives. They would take their places in society as solution-oriented, productive individuals who act bravely against the problems they face. After all, inquiry-based learning aims to prepare the learners as researchers, problem finders, problem solvers, thinkers who make their own interpretations and individuals who are confident in their fields (Mui, 2010; Spronken-Smith, Bullard, Ray, Roberts, & Keiffer, 2008).

Since scientific inquiry is a process that focuses on research instead of conclusion, it is very important for teachers who apply this method to help the students focus on the research itself instead of reaching absolute conclusions (Lim, 2001). Even though it is an undeniable fact that the most original scientific reasoning is the one in which students create their own questions, plan their experiments and reach conclusions by collecting data, when students' age groups and levels are considered, learning environments in which questions and data are given and students take an active part in analyzing and reaching conclusions are also based on scientific inquiry.

Inquiry-based learning can be applied by using different learning methods in the scope of the constructivist theory such as project-based learning, problem-based learning, cooperative learning and example-based learning. These methods start with a problem and stress the process of creation of information by students. All these methods include inquiry in different forms. These methods that support inquiry and constructivist approach make students learn science meaningfully (Brooks & Brooks, 1993; Eick & Reed, 2002; Mintzes, Wandersee, & Novak, 1997; Tobin & Tippins, 1993).

In order for learning-teaching processes that are structured by inquiry-based learning approach to reach their aims, both students and teachers have to know the roles that they were given in the process and fulfill their responsibilities.

Types of Inquiry-Based Learning

In literature, it is seen that there are different levels of learning inquiry, and teachers are classified with different names when the roles that they take on are considered (Çalışkan, 2008; Herron, 1971; Schwab & Brandwein, 1962). The most widely accepted classification is the one done by Colburn (2004). According to Colburn (2004), there are three main types of inquiry-based learning: structured inquiry, oriented (guided) inquiry and open inquiry. The teacher who has just started the inquiry-based learning process can start with inquiry activities with structured learning environments and then gradually move on to the open inquiry process. This gradual shift from structured inquiry to open inquiry process is significant in terms of the possible hardships (Küçüker, 2008).

Structured Inquiry

It is the type of inquiry in which the teacher determines the subjects and teaches the subjects step by step. Here, the teacher can structure and limit the scope of subjects and activities. This method is accepted as a teacher-based method since the teacher takes on an active role in the process. The teacher determines and provides everything, from the question he or she asks to the research method, from answering the questions to the method itself (Keller, 2001; Spaulding, 2001). Just like cooking a dish by looking at a book of recipes, these types of inquiries are made by students as they are. It is often used in classes since it is more convenient for teachers. These

are not the types of inquiry where students need to think when inquiring. Students are not mentally active in these inquiries. Thus, students may become demotivated during the process (Keller, 2001).

Guided Inquiry

It is stated by some researchers that this type of inquiry is a combination of structured and open inquiries. In this type of inquiry, the teacher states the focal questions and supervises the approaches that students use when answering these questions. Here, the teacher guides the students in choosing materials, research techniques, etc. and asks questions. The teacher does not directly give information to students but structures the new problems intended for the solutions of the problem he/she has asked. The teacher helps the students become responsible for their actions and learning. The students investigate the given questions, create solutions and make generalizations. Students gain inquiry skills for the inquiries that they will make independently in the future. In the guided inquiry process, the activity of asking questions is done by the teacher and the activities of planning the process and acquiring results are done by students (Colburn, 2000; Colburn, 2004; Gormally, Brickman, Hallar, & Armstrong, 2011; Lim, 2001; Llewellyn, 2002; Martin-Hansen, 2002; Olson & Loucks-Horsley, 2000; Spaulding, 2001; Tatar, 2006).

Open Inquiry

It is the highest level of inquiry where students decide what is important in the subject that they are learning and determine the activities and the research by themselves. It is accepted as completely student-centered. Here, since the students even determine the subjects that they will learn, a true process of working like a scientist is observed. Therefore, in the process of open inquiry, the activities of asking questions, planning the process and reaching conclusions are done by the students, and they are directly responsible for their own learning (Blanchard et al., 2010; Keller, 2001; Llewellyn, 2002; Tatar, 2006). Thus, the teacher has a smaller role in this type of inquiry.

Table 1: Roles of the Students and Teachers According to Types of Inquiry

	Structured Inquiry	Guided Inquiry	Open Inquiry
Asking Questions	Teacher	Teacher	Student
Planning the Process	Teacher	Student	Student
Obtaining Results	Student	Student	Student

Models That are Used in the Process of Inquiry-Based Learning

Inquiry models are presentations that are created in order to understand how events that cannot be directly observed occur (Branch & Oberg, 2004). Inquiry models support the roles of teachers and students and can be used for many purposes in education (Donham, 2001). Various educational models were designed to be used in inquiry-based learning approach. Educational model means an organized application that includes the organization of some steps, movements and decisions for education. Educational models are created considering the nature of research, scientific information, process of science and the purpose of learning (Carin & Bass, 2001).

Even though there are differences in the application of these models, the main focus of them all is to guide students in understanding the nature of science. When these models are investigated, it is seen that they are based on the constructivist theory (Bybee, 1997; Carin & Bass, 2001; Eisenkraft, 2003; Lawson, 1995; Llewellyn, 2002). Some of these models are as follows:

John Dewey's Inquiry-Based Learning Model

In Dewey's model, in the first "asking questions" stage, students' enthusiasm is raised by questions that would make them think and their sense of curiosity is increased for the purpose of discovery. In the second stage, they collect raw information by starting to do research. In the third stage, the configuration of the knowledge is realized by combining and relating the collected information and preliminary knowledge through new thoughts, ideas and experiences. In the third "discussion" stage, the knowledge is shared with other individuals, and the results are compared. Projection, which is the final stage, is the remembering of the whole process (Çepni, 2005).

Guided Discovery Model

Students who are newly starting to learn through research can feel constrained and may need a guide until they achieve inquiry skills. Also, from the perspective of the teacher, they can feel constrained by the freedom that the students are given until they gain the necessary research skills since they are used to receiving the information passively. It is very convenient to use the guided discovery model in order to avoid these situations. With this model, by learning the ways of thinking, the students gain the ability to do research independently in the future (Howe & Jones, 1993).

Throughout the process of discovery, students think about the potential ideas and create their own ideas. Students are given freedom by the teacher to solve problems. However, they are also guided during the process. Instead of directly telling them what to do during the research, they are guided to create their own discoveries through questions or clues (Şensoy, 2009).

3E Model

Stages of the 3E Model developed by Lawson (2010):

1. Exploration: In this stage, students learn to do research and make discoveries through their studies. The teacher does very little guiding at this stage. Students try to solve the problems by trying to develop different perspectives.

2. Explanation: It is the stage where the concepts that were used in the exploration stage are explained. The explanations can also be done by the teacher.

3. Expansion: It is the stage where the information learned is applied to other situations. By using what they have learned properly, students make their learnings meaningful and permanent (Kanlı, 2007).

4D Model

One of the models that is proper for an effective research is the 4D Model (Coghlan, Preskill, & Tzavaras Catsambas, 2003). The steps of the model are as follows:

1. *Discovery:* In this stage, the participators have conversations and share their experiences with each other.

2. *Dream:* Based on the information obtained from conversations, participators engage in imaginations. A wide and whole thinking activity is done with various visualizations and creative exercises.

3. *Design:* A decision is made concerning strategy, process and system regarding what was imagined.

4. *Evaluation:* The participators begin to apply the visions and private propositions that were discussed in the previous stages. This stage continues with first the participants' application of changes, then their follow-up of the process and discussions held for the new research.

5E Education Model

This model is based on Piaget's cognitive development model. It was shaped by constructivist learning and consists of 5 stages (Şensoy, 2009):

1. *Enter/Engage:* This stage includes the efforts that are made in order to attract the students' attention and invoke their enthusiasm for learning.

2. *Explore:* The aim here is to make students gain a general experience. In this stage, students who are quite active in the process make observations about the solution of a determined problem, generate hypotheses, collect data, analyze data, check the validity of the hypotheses that they have generated, put forth their ideas by working collaboratively, broaden their perspectives by listening to others and move towards creative thinking.

3. *Explain:* In this stage, the teacher asks questions and makes scientific explanations to students to make sure they have fully understood the study, explanations and commentaries that were made towards the solution of the problem.

4. *Elaborate:* This stage entails doing exercises, revising and applying what they have found out to other situations. Making what is learned more meaningful, developing knowledge and skills and deeper learning are the goals of the activities in this stage.

5. *Evaluate:* In the evaluation stage, the learned information, skills and the products made by students are examined. Students' skills of using what they have learned on different situations are evaluated. In other words, not the memorized but the absorbed is evaluated.

7E Education Model

5E Model was developed by Bybee (2003) and Eisenkraft (2003) and re-interpreted as the 7E model.

Stages of the 7E model according to Eisenkraft (2003) are explained as follows:

1. *Elicit:* This stage includes the determination and execution of the preliminary knowledge that are very effective in the learning process.

2. *Engage:* Activities that interest the students are done in the engagement stage.

3. *Explore:* In this stage, students notice the simple relations by making observations, test hypotheses, generate new hypotheses and record the ideas that were achieved by discussion.

4. *Explain:* In this stage, the questions "What, Why and How" are tried to be answered.

5. *Elaborate:* In this stage, students are asked to create alternate solutions to the problem. In this process, by transferring what they have learned to new situations, problems and hypotheses, students can review some or all of the activities.

6. *Evaluate:* It is the stage where students' knowledge and skills are evaluated.

7. *Extend:* This stage includes the application of learned information to new situations and consolidation of the knowledge.

Conceptual Change Model

When creating their new knowledge, students make changes in their already existent knowledge. The configuration of the new knowledge happens in two ways: changing the old knowledge with the new ones or re-organizing them. This process is called "conceptual change" (Goossen, 2002). Four conditions were determined by Posner and others (1982) in order for the individuals to absorb what they have learned and a conceptual change to occur:

1) The individual feels that what is already known is not adequate for them.

2) Understanding the newly learned knowledge, even at a minimum level, at the beginning.

3) The individual sees information as plausible, and the new information is used to solve problems.

4) It is necessary for new information to direct the student to new research areas.

Daniel Neale approached the conceptual change model in 7 stages (Şensoy, 2009). The steps are as follows:

1. *Introduction:* In this stage, the content and the activities of the course are told in order to motivate the students.

2. *Review:* In this stage, a discussion environment is created in the class for determining students' readiness and activating students' preliminary knowledge.

3. *Development:* The problem is determined by the teacher, conversations and discussions are held about the problem. They try to determine whether the subject was understood by the students by evaluating the explanations made by students.

4. *Research and Activities:* In this stage, students work to solve the problem.

5. *Presentation*: In this stage, students share the conclusions they acquired with the class.

6. *Discussion*: The teacher tries to detect whether wrong or incomplete learnings took place.

7. *Summary:* In this stage, the conclusions are summarized by making associations with other subjects.

The teacher who uses this model creates class activities that motivate the students by using the schemes they use to describe, explain and guess the world surrounding them. Conceptual understanding is required in complex activities such as making explanations. The main aim of science education should be developing conceptual understanding in students, rather than making them memorize and remember the explanations (Smith, Blakeslee, & Anderson, 1993).

Methods and Techniques Used in Inquiry-Based Learning

When the features of inquiry-based learning are examined, it is seen that they are intermingled with and supported by some learning experiences and approaches. These learning experiences and approaches are the following:

Problem Solving: It is the scientific approach an individual uses to solve problems that seem inextricable (Owens, Hester, & Teale, 2002). Inquiry-based learning usually starts with problems, and the inquiry process is completed by using the scientific research steps (determining the problem, defining the problem, generating hypotheses, testing hypotheses, interpreting conclusions) that are used in solving the problems (Fansa, 2012; Owens et al., 2002).

Experiment: Experiment in science education is students' discovery process of the knowledge by using instruments, doing and observing. Students use problem solving steps and learn how to do a scientific research while making experiments (Fansa, 2012).

Sightseeing-Observation: Through the observation technique, students gain the opportunity to examine the assets and events in their natural environment in a planned and objective way (Çepni et al., 2006). In inquiry-based learning, sightseeing-observation is also a method used in testing hypotheses.

Brainstorming: It is the process of producing original and creative ideas in order to find a solution to the problems. Since it is important to put as many different ideas as possible in the brainstorming technique and not to intervene in the formation of ideas, it is often used in inquiry-based teaching (Sönmez, 2008).

Example Case: In this method, problems that are encountered in real life are brought to class and learning experiences are enabled by finding solutions to these problems. In inquiry-based learning, example case method is used in the first step of the loop, which is drawing attention (Çepni et al., 2006).

Discussion: This method is used in order to encourage students to think about a subject and explain the points that are not clearly understood (Demirel, 2004). Discussion method is often used by students in inquiry-based learning in the stages of revealing the already existent knowledge, making guesses and interpreting.

Question-Answer: It is a technique that enables the students to gain the habits of talking and speaking. The question-answer method in inquiry-based learning is a method that is used both between teachers and students and among students when they are making inquiries (Çepni et al., 2006).

Simulation: It is a teaching technique that enables the students to make educative works in class by approaching an event as if it is real (Demirel, 2004). In inquiry-based learning, since students are interested in working on an artificial situation that is similar to a real-life one, it is beneficial to use this technique in making the students learn contradictory and difficult concepts.

Role Play: In this technique, the individual puts him/herself in someone else's place by leaving his/her own true role and feelings aside. The individual may also show what he/she would do and feel in a certain circumstance as a result of his/her actions. In a sense, role playing is the demonstration and discussion of a problem by using actions (Açıkgöz, 2009).

Group Work: Students who are aiming to learn come together in groups. The individuals who participate in group work during the inquiry process gain the skills of discussion, responsibility taking, critical and creative thinking.

Presentation: It is defined as a verbal way of communication that is used to give information about various subjects (Sönmez, 2008). Presentation method is used in the last phase of the inquiry-based learning loop.

Evaluation in Inquiry-Based Learning

Evaluation in inquiry-based learning approach is implemented with a focus on enriched learning in order to determine what each student has learned and understood, whether there are missing or unclear information and what students can do with what they have learned, and it may pursue different goals. In this regard, evaluation may be on a scale varying from the questions the teacher asks during lessons, to exams given at end of units and to exams that are administered at province or country level. In inquiry-based learning, there are two types of evaluations: *formative evaluation* and *performance evaluation.* Formative evaluation is a type of evaluation that can be conducted at any time and enables the teacher to meet students' needs in the best way possible. Performance evaluation is another type of evaluation which is conducted at the end of learning activities to determine activities' effect on students' learning (NRC, 2000, 2007). Even though formative evaluation is particularly significant for planning and guidance, it is not effective enough to assist in making great decisions with regards to teaching policies or vocational development planning. Concerning all these, the importance of performance evaluation can easily be observed (Alvarado & Herr, 2003; NRC, 2000).

A variety of evaluation tools can be utilized in inquiry-based learning. The most preferred of these exclusive (process-oriented / authentic) tools are student portfolios, rubrics, concept maps, monitoring charts and self-evaluation forms (Bass, Contant, & Carin, 2009; Nartgün, 2006; NRC, 2000).

Authentic Assessments: Authentic (process-oriented) evaluations are defined as evaluation strategies which are unconventional, student-oriented, substantive, interesting and appropriate for students. Multiple choice and true-false questions serve as a tool to evaluate the information memorized by students (Llewellyn, 2002).

Student Portfolios: Student portfolios are files or envelopes including and proving students' achievements, studies, performances they have kept or performed. Student portfolios facilitate students' study reviews according to particular criteria and make it easier to judge and evaluate any progress shown by students (Trowbridge, Bybee, & Powell, 2000).

Rubrics: Rubrics are guides that enable marking student performance criteria and performance at different levels. It is a set of pre-defined criteria to grade student exams, portfolios or performances. When rubrics are used in science and technology classes, students can clearly understand what is expected from them, and it makes the learning process much more meaningful (Korkmaz, 2004).

Concept Maps: A concept map is the graphical representation of concepts and inter-relationships between different concepts (Novak & Gowin, 1984). In an evaluation with concept maps, the grade system for a concept map could be used in different ways as an evaluation criterion. For instance, all concept map grades in class can be averaged and maps can be evaluated as "good", "average", "bad" (Duban & Yaşar, 2007).

Monitoring Charts: Monitoring charts are charts which include observation records of what is expected from a student during inquiries (Llewellyn, 2002).

Self-evaluation: Self-evaluation implies getting feedback from the students about how they see their individual and group performances. Self-evaluation can vary from a form of a control list and questionnaire to a format which

includes the reflections that students have produced in their essays. However, all self-evaluations have one common point: students review what they have learned and identify the areas where they have problems and become aware of their progress and become aware of their responsibilities (Trowbridge et al., 2000).

Evaluation and learning are two inseparable processes, and they are in a cyclical relationship. In this way, the evaluation conducted after each and every teaching process lays the foundation for the first steps of the new learning process. When students participate in the evaluation process, they realize what is expected of them and how much they have achieved as a result of their own effort, which motivates them to learn and achieve. Inquiry-based learning is a method which aims to improve students' cognitive, affective and motor skills.

In this context, inquiry-based learning is an appropriate method in terms of effective teaching and evaluation by making both the teacher and the students engaged, evaluating their achievements gained in cognitive, affective and motor fields, being as open-ended as possible and thus revealing dimensions that are missing as well as gains.

The Importance of Inquiry-Based Learning in Science Education

The basic benefits provided by Inquiry-Based Learning are listed below:

- Increases the performance of students and data interpretation (Mattheis & Nakayama, 1988).
- It gives students various opportunities such as collecting, sorting, questioning and classifying knowledge (Hinrichsen, Jarrett, & Peixotto, 1999; Rutherford & Ahlgren, 1991; Wilder & Shuttleworth, 2005).
- Ensures permanent learning (White, Shimoda, & Frederiksen, 1999).
- Ensures the understanding of the nature of scientific knowledge (Quintana, Zhang, & Krajcik, 2005).
- It is effective in increasing students' motivation (Bayram, Oskay, Erdem, Özgür, & Şen, 2013).
- Students learn to share the resources they collected to solve a problem (Wenk, 2000; Wood, 2003).
- Enables the individual to engage in habitual life-long learning (Arthur, 1993).
- It is important in using creative thinking in the aspects of examining the information and developing the skills of analyzing and producing (Vural, 2004).
- Enables students to be in social interaction and gives them the opportunity to get to the better levels in reasoning skills (Shih, Chuang, & Hwang, 2010).
- Students learn how they are supposed to learn. Therefore, it helps to develop the students' epistemological beliefs (Shih, Chuang, & Hwang, 2010; Wilke & Straits, 2005).
- It enables the students to develop their critical thinking, scientific processing and problem-solving skills (Bell, Smetana, & Binns, 2005; Bybee, 2006; Chung & Behan, 2010).
- Gives students the opportunity to explain their ideas, research the questions and try new approaches (Hamm & Adams, 1992).
- Contributes to students' social and mental development (Dyasi, 1999).
- Contributes to the development of high-level learning skills (Wilke & Straits, 2005).

- It is effective in increasing students' scientific literacy, conceptual understanding and positive attitudes towards science (Haury, 1993; Lloyd & Contreras, 1987; Rakow, 1986).
- Gives the opportunity to learn by doing and living (Tatar & Kuru, 2006).
- Raises individuals who are more confident in science (Tatar & Kuru, 2006).
- Makes them learn science effectively (Brooks & Brooks, 1993; Eick & Reed, 2002; Mintzes, Wandersee, & Novak, 1997).
- Helps the students who are slow-learners (Kyle, 1980).
- Helps the students who are fast-learners to develop their thinking skills (Davis, 1993).
- It is effective in making students develop a positive attitude towards science (Tsai & Tuan, 2006).

Different Roles of Teachers in Inquiry-Based Learning

Upon examining literature, it becomes evident that a great number of research teachers play an important role in inquiry-based teaching (Crawford, 2000; Keys & Bryan 2001; Llewellyn, 2005; Sandoval, Deneroff, & Franke, 2002; Wallace & Kang 2004). However, teachers' role in inquiry-based teaching has been expressed by researchers in various ways, some of which are as follows:

- In inquiry-based learning, the teacher does not introduce the information directly to students, but rather provides guidance for them in the information generation process (Battista, 1999; Bolton, Brennan, & Terry, 2009; Crawford, 2000; Duban, 2008; Hogan & Berkowitz, 2000; Keller, 2001; Lawson, 2010; Lechtanski, 2000; Lim, 2001; Sever, 2012; Sönmez, 2008; Tseng, et.al., 2013; Wu & Hsieh, 2006).
- The teacher activates students so that they can develop a thorough understanding of science (Flick, 2000; Hogan & Berkowitz, 2000; Tseng, et.al., 2013).
- The teacher channels students' textbook-oriented learning habits into student-oriented research questions (Keys & Kennedy, 1999).
- The teacher takes up the role of a facilitator in inquiry-based learning environment (Battista, 1999; Keller, 2001).
- The teacher shows respect to different students and different types of learning styles (Battista, 1999; Keller, 2001; Duban, 2008).
- The teacher contributes to increasing scientific literacy among students (Zion & Slezak, 2005).
- The teacher increases students' motivation regarding their performance and responsibilities (Crawford, 2000; Tseng, et.al., 2013; Zion & Slezak, 2005).
- The teacher helps students develop similar thinking strategies that can be utilized during their learning experience (Duban, 2008; Sönmez, 2008).
- The teacher creates various learning environments for students of different levels (Keller, 2001; Tseng, et.al, 2013; Windschitl, 2003).

- Teacher develops different multi-strategies and skills to implement inquiry-based learning (Keller, 2001; Tseng, et.al, 2013; Windschitl, 2003).
- The teacher is a very good observer in following students' every step during their research process (Llewellyn, 2002).
- The teacher continuously supports research or studies undertaken by students (Lim, 2001).
- The teacher contributes to students' existing knowledge and examines the changes in their understanding (Eick & Reed, 2002; NRC, 1996).
- The teacher is a role model and sets an example for students in using the learning method expected from them (Keller, 2001; Lechtanski, 2000; Wu & Hsieh, 2006).
- In inquiry-based teaching, the teacher is the organizer of the environment where the students gain experiences through certain activities (Dickson, 2002; Wadsworth, 1978).
- The teacher helps students uncover their thoughts (Dickson, 2002; Wadsworth, 1978).
- The teacher initiates group activities (Bolton, Brennan, & Terry, 2009; Dickson, 2002; Wadsworth, 1978).
- The teacher is innovative (Crawford, 2000).
- The teacher is investigative and encourages students to investigate (Crawford, 2000; Joyce & Calhoun, 1996; Lechtanski, 2000; Wu & Hsieh, 2006).
- The teacher is collaborative (Crawford, 2000; Lechtanski, 2000; Wu & Hsieh, 2006).
- The teacher identifies students' prior knowledge and integrates it with the new one before the course starts (Crawford, 2000).
- The teacher develops him/herself by following recent developments in their own field (Crawford, 2000).
- The teacher seeks ways to try new teaching and assessment methods (Crawford, 2000).
- The teacher has the ability to find different techniques of asking questions (Llewellyn, 2002).
- The teacher is careful to ensure that the research conducted during the process is not limited to the classroom and leads students to pursue their research outside the classroom (Llewellyn, 2002).
- The teacher provides opportunities for students to conduct research in a laboratory, in the school yard or outside the school (Llewellyn, 2002).
- The teacher ensures that the students think further (Bolton, Brennan, & Terry, 2009).
- The teacher contributes to the students' development of critical thinking, scientific processing, problem solving and high-level thinking skills (Tseng, et.al., 2013).

As a result, in inquiry-based learning approach, the teacher is expected to observe students and, if necessary, mentor them with guiding actions to enable them to form their own learning at every stage of their teaching-learning process.

Different Roles of Students in Inquiry-Based Learning

In inquiry-based learning, students have the most significant role. This process involves students to be active throughout the implementation. Students' roles in inquiry-based learning are listed below:

- In inquiry-based learning, students primarily hold a view about a problem after analyzing the problematic issue which has been introduced to them. By taking advantage of the information obtained while researching, they produce ideas towards solving the problem (Carin & Bass, 2001; Lim, 2001; Şenocak & Taşkesenligil, 2005).
- Students exhibit curiosity and make observations (Budak-Bayır, 2008).
- Students undertake certain duties and responsibilities within a group (Alvarado & Herr, 2003; Çalışkan, 2008; Gallagher-Bolos, & Smithenry, 2004; Şenocak & Taşkesenligil, 2005).
- Students find opportunities to express themselves (Budak-Bayır, 2008).
- Besides gaining basic knowledge and skills, students are responsible for their own learning and in the position of making the information meaningful for themselves (Keselman, 2003; Lawson, 2010).
- Students distinguish the strong and weak sides of their studies (Budak-Bayır, 2008; Correiro, Griffin, & Hart, 2008; Gallagher-Bolos & Smithenry, 2004).
- Students classify the knowledge and decide what is right (Budak-Bayır, 2008).
- Students support group interaction and collaborate with their friends as a team (Budak-Bayır, 2008; Gallagher-Bolos & Smithenry, 2004; Lim, 2001).
- Students start to think in a more metacognitive way, plan more carefully, reflect their own studies and evaluate their own progress (Krajcik, et.al, 1998).
- Students can make observations like a scientist using the research methods they have designed and learn while practicing and experiencing (Llewellyn, 2002).
- In inquiry-based learning, students feel more confident when it comes to risk taking, knowing that their ideas are appreciated (Olson & Loucks-Horsley, 2000).
- Students express their ideas by making use of reports, drawings, graphics and tables (Şenocak & Taşkesenligil, 2005).
- Students who learn with their own effort and experience the feeling of success are motivated towards learning, and in time, the tasks assigned to them are acquired as personality traits and skills as affective and motor achievements (Llewellyn, 2002).
- Students have the ability to choose and use the materials they need (Martin-Hansen, 2005).
- Students examine situations, capture details and recognize similarities and differences of situations (Budak-Bayır, 2008).
- Students organize research and, by this means, collect data through observation, develop theories and then test these theories (Gallagher-Bolos & Smithenry, 2004).

- Students compare the outcome of their tested theories with the questions they have been asked and try to explain the results (Gallagher-Bolos & Smithenry, 2004).
- Students come up with and ask questions that require further research (Budak-Bayır, 2008; Gallagher-Bolos & Smithenry, 2004; Lim, 2001).
- Students tend to make deductions from specific observations and generalize them (Lindquist, 2001).
- Students plan ways to prove the accuracy of their ideas and further expand them by testing them (Budak-Bayır, 2008; Correiro, Griffin, & Hart, 2008; Martin-Hansen, 2005).
- Students use high-level thinking skills (Gallagher-Bolos & Smithenry, 2004).

In conclusion, in inquiry-based learning approach students undertake important roles and they are expected to plan, conduct and evaluate their own learning processes. Furthermore, they own roles such as behaving like a researcher, identifying a problem within a group by collaboration, developing theories in order to solve the problem, collecting data to test the theories, obtaining results by evaluating the data and sharing with others what they have concluded.

Inquiry-Based Learning Environment and Its Characteristics

In order for the inquiry-based learning to be realized, it is imperative that students are provided with a learning environment which enables them to generate new ideas, deepen their understandings, learn to think critically and gain various experiences (NRC, 2000).

The characteristics of the inquiry-based learning environment are as follows (Llwellyn, 2002, p. 60-61):

- The questions “What if?” and “I wonder…” are commonly used in class.
- There are concept maps on the walls.
- There is evidence of students studying outside the classroom as well.
- Students’ desks are arranged in pairs, in triple or quadruple groups.
- These classes are learning centers for individual and group studies.
- Bookshelves in classrooms contain novels, other books, magazines and other resources.
- The teacher’s desk is not located in the center or in front of the classroom; it is rather located on one side or at the back of classroom.
- There is a chest or box in the classroom to keep the portfolios and magazines for students.
- All the materials are placed in boxes or chests in a way that they can be easily reached.
- A video system is in place so as to record students’ presentations and watch them later to evaluate their performance.
- Computers are accessible for students to reach information outside the school building as well.

These kinds of inquiry-based learning environments with the above characteristics are effective learning environments where students are able to find answers to their questions on their own, since inquiry-based learning

is an efficient approach that focuses on question asking, critical thinking and problem solving. The last part of the quote “If you tell me, I will forget. If you show me, I will remember. If you make me do it, I will learn.” sums up the core of inquiry-based learning (Macy, 2003).

In an environment where students are responsible for and supportive of their own self-learning, they will be able to interpret the data they have collected, explain their observations, cases and facts and have confidence to state the relations among different variables (Al-Naqbi, 2010).

Students should have the right to speak during the process of inquiry-based learning which is also considered as a student-centered approach. Although there is a pre-determined learning environment in the first days of school, students’ opinions have to be taken into consideration and new regulations should be set based on their opinions later on (Llewellyn, 2002). It will also be a step forward in effectively establishing a learning-teacher process, preparing a learning environment in line with the requirements of inquiry-based learning approach.

Misconceptions Concerning Inquiry-Based Learning

The studies which investigate the reasons why inquiry-based learning is not used in class reveal that teachers have misconceptions about this method (Costenson & Lawson, 1986; Trowbridge & Bybee, 1996). Llewellyn (2002) lists these misconceptions as the following:

- Having students do hands-on experiments means that they are using inquiry-based learning.
- In inquiry-based learning, what the students need to do is not clear, which creates a chaos in class.
- Inquiry-based learning can be taught without paying attention to knowledge on a particular subject.
- Real inquiry occurs when students form their own questions and pursue them on their own.
- Inquiry-based learning means making students follow the exact steps given as the "scientific method".
- Inquiry-based learning is only appropriate for primary education students.
- Inquiry-based learning means constantly asking questions to the students.
- All science subjects should be taught with inquiry-based teaching method.
- In inquiry-based teaching method, the teacher is prepared to answer any kind of questions.
- Learning cannot be evaluated in inquiry-based education.
- Inquiry-based learning is applicable for only successful students.
- Inquiry is softened science-making, and it does not relate to scientific context.
- Inquiry-based learning can be implemented easily, since experiment kits are used.

Challenges Encountered in Inquiry-Based Environment

Some challenges encountered in science teaching in an inquiry-based environment are given below:

- It remains unclear what inquiry helps to structure (Campbell, Zhang, & Neilson, 2011).

- There are not enough examples which demonstrate how inquiry as a teaching strategy paves the way for classrooms (Campbell et al., 2011).
- There is a lack of clear collaboration between inquiry-based learning and scientific contents (Windschitl, Thompson, & Braaten, 2008).
- The curriculum is content-heavy and inquiry-based teaching takes so much time (Cheung, 2008; Hackling, 2005; Campbell et al., 2011).
- The high number of students, materials and experiments make it harder to manage the classrooms (Cheung, 2008; Hackling, 2005).
- Teachers fail to manage and control the student inquiry processes (Campbell et al., 2011; Keller, 2001).
- Students are unable to propose research questions regarding the subject being issued (Harlen, 1997).
- Teachers are reluctant to answer students' questions in inquiry-based learning (Harlen, 1997).
- Teachers have insufficient knowledge on their own area, and therefore feel unprepared to answer difficult questions asked by students (Deters, 2005; Pierce, 2001).

The reasons indicated above account for why teachers do not prefer inquiry-based learning while choosing their teaching methods.

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