THE OPINIONS OF TURKISH HIGHSCHOOL PUPILS ON INQUIRY BASED LABORATORY ACTIVITIES

Ahmet KILINÇ
Gazi University Gazi Education Faculty
Department of Biology Education
ahmet_tr@yahoo.com

ABSTRACT
The purpose of this study is to prepare inquiry based experimental activities on the photosynthesis, thought to be a very difficult subject by pupils, and to determine the pupil's ideas towards this method. This study was made with 24 pupils from Grade 3 at Atatürk Anatolian High school in Turkey. As data gathering material; seven inquiry experimental study sheets, the pupils' opinions survey consisting of six open-ended question, and two-lesson-hour video records were used. According to the result of study, the pupils declared that the inquiry based laboratory activities were more permanent, more enjoyable, and more pupil centered than the traditional methods, that thanks to this method, they studied cooperatively and benefit from different aspects by discussing, that they were be satisfied with the teacher's guide position in the implementations, and that their attitudes related to biology increased positively.

Key words: Inquiry, laboratory, experiment, opinion, photosynthesis

INTRODUCTION

Inquiry Based Learning

The idea of teaching science by inquiry methods is not a new one. In Dewey's Democracy and Education (1916), he states that is not advisable to present the learner with just the conclusions from scientific experimentation. Instead he proposed that students be allowed / encouraged to explore and experiment to come up with their own conclusions about science concepts, as well as the process and nature of science. If students are to learn by more expository instruction, then the students tend to see science as just another content area instead of learning that science is a process that can be applied to ordinary experiences. In addition, Dewey proposes that if the learner applies more discovery methods of learning, he will "…gain independent power to deal with material within his range, and avoid mental confusion and distaste" (Dewey, 1916; Thomas, 2005)

Dewey's philosophy on education was widely accepted, and was used as an integral concept during the curricular reform the 60's and 70's. Inquiry based learning installed by Dewey is a type of problem solving approach and based on the students' research and analysis.

Scientific inquiry refers to diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to the activities of students in which the develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NRC, 1996).

However, inquiry does not consist of a single facet, in fact, there are varying degrees ranging from a more traditional approach, to a more open inductive approach where students are generating their own experiments. The National Science Standards (1996) determined that inquiry contains five essential characteristics:

- Learners are engaged by scientifically oriented questions
- Learners have the ability to determine what data allows them to develop and evaluate scientific explanations
- The students will have the ability to formulate their own explanations from the evidence they have obtained
- Students can expand upon their findings and relate those findings to similar situations
- The learner will then be able to communicate their experimental findings to others in class via small group work, presentations to the entire class, or written laboratory reports.

The studies showed that this strategy which was used in natural sciences such as mathematics and science may also be used in all areas. This is an effective strategy when the subject comprises of a problem to be solved (Ornstein & Thomas, 2004).

The inquiry process starts with presentation of a complicated event to the students. Suchman suggested that individuals encountered with such a condition would desire to solve this problem naturally (Joyce et al., 1992).

- The students when encounter with a problem/ a complicated condition they naturally question and analysis.

- They might become curious to learn about their own idea strategies and analysis them
- New strategies can be learned directly and added to the others
- The inquiry based on cooperation enriches the way of thinking and helps the students to learn that knowledge has a transient and developing nature. In addition it helps them to evaluate alternative explanations (Joyce et al., 1992).

Inquiry-based learning is a process where students are involved in their learning, formulate questions, investigate widely and then build new understandings, meanings and knowledge. That knowledge is new to the students and may be used to answer a question, to develop a solution or to support a position or point of view. The knowledge is usually presented to others and may result in some sort of action.

Research suggests that using inquiry-based learning with students can help them become more creative, more positive and more independent (Kühne, 1995). This is true for all students, including those with special needs who require more individual attention during the process.

Building a culture of inquiry also means recognizing, supporting and teaching the role of metacognition. Metacognitive skills are part of the "learning to learn" skills that are transferable to new learning situations, in school and out of school. Through reflecting on the process during inquiry-based learning activities, students are given opportunities to explore and understand both the cognitive and affective domains of "learning to learn" (Hacker, 1999; Kuhlthau, 1988). Understanding and dealing with thoughts and feelings makes inquiry-based learning a powerful learning experience for students and teachers.

Inquiry-based learning provides opportunities for students to:

- develop skills they will need all their lives
- learn to cope with problems that may not have clear solutions
- deal with changes and challenges to understandings
- shape their search for solutions, now and in the future.

A systematic approach to the development of these skills is essential to prepare students for problem solving and lifelong learning. A systematic approach ensures that students have the opportunity to engage in inquiry, to learn an overall process and to understand that this general inquiry process can be transferred to other inquiry situations.

Using these same process skills as they proceed from primary grades through senior high school will enable students to:

- become familiar with the inquiry process
- understand a framework that supports searching for and using information
- internalize a variety of inquiry skills and strategies for independent and group use
- adapt procedures to various inquiry situations (Alberta Education, 1990).

Success with inquiry-based learning often requires a change in school culture. Some schools, individually or as part of a district-wide initiative, have made inquiry-based learning their instructional priority. Studies investigating the implementation of inquiry-based science education, inquiry-based information literacy programs and other inquiry-based educational innovations have resulted in guidelines for building a culture of inquiry (Falk & Drayton, 2001; Fullan, 1991; Kuhlthau, 2001):

- Administrators in the school or district have a clearly articulated vision for inquiry.
- The vision for inquiry is carried forward despite competing pressures.
- Two or more champions promote the vision for inquiry.
- Resources and space for inquiry are readily accessible.
- Teachers collaborate and support each other.
- Teachers, students and parents trust each other.
- Small, interdisciplinary teams of teachers work together.
- Problem-solving and investigative skills are valued throughout the school/school system.

For the last several years, there has again been a call for curriculum reform in science classes and laboratories in particular. The National Science Foundation (NSF) has put out a call for instructors to educate students in the ability to formulate useable questions, plans, appropriate experiments, conduct observations, interpret, and analyze data, draw conclusions, communicate their results, as well as being able to coordinate and implement a full investigation (NRC, 2000; Thomas, 2005). Toward this end, there has been a resurgence of interest and research in the inquiry approach to science. Inquiry in general obtaining and constructing his or her own knowledge rather than receiving the information from a didactic lecture or a "cookbook" laboratory (Thomas, 2005).

Teachers play varied roles in supporting students' development of inquiry skills. These roles include modeler, guide, diagnostician, facilitator, mentor, and collaborator, which indicate a varied amount of structure and scaffolding teachers build into an activity (Wu & Hsieh, 2006; Crawford, 2000). For example, as a guide, a teacher provides specific directions for developing students' skills and strategies. When a teacher plays a role of collaborator, he or she does not provide scaffold but allows students to take a role of teacher.
Classrooms where teachers emphasize inquiry-based learning have the following characteristics (Drayton & Falk, 2001):

- Inquiry is in the form of authentic (real-life) problems within the context of the curriculum and/or community.
- The inquiry capitalizes on student curiosity.
- Data and information are actively used, interpreted, refined, digested and discussed.
- Teachers, students and teacher-librarian collaborate.
- Community and society are connected with the inquiry.
- The teacher models the behaviors of inquirer.
- The teacher uses the language of inquiry on an ongoing basis.
- Students take ownership of their learning.
- The teacher facilitates the process of gathering and presenting information.
- The teacher and students use technology to advance inquiry.
- The teacher embraces inquiry as both content and pedagogy.
- The teacher and students interact more frequently and more actively than during traditional teaching.
- There is an identifiable time for inquiry-based learning.

Scientific inquiry is a "multifaceted" activity (NRC, 1996) and can take many forms. Inquiry learning moving away from the traditional approach of a universal and procedural scientific method is to encourage students to participate in a range of activities in which students construct and evaluate scientific knowledge (McGinn & Roth, 1999). What types of activities might be involved in inquiry learning? What are the important aspects of inquiry that ought to be supported in a learning environment? Following NRC (2000) and Krajcik et al. (1998), it can be identified seven phases in an inquiry process: asking and deciding questions, searching for information, designing investigations, carrying out investigations, analyzing data and making conclusions, creating artifacts, and sharing and communicating findings. These phases are not steps to take in a linear fashion and students can go through the phases in complex ways. For example, students can reframe their research question and redesign their investigation after recognizing that their data can not answer their questions. Additionally, due to the nature of inquiry some scientific investigations do not involve all seven phases. For example, analyzing data from a weather database and constructing explanations of phenomena such global warming and climate change could be an interesting project for inquiry, although students do not collect empirical data by themselves nor do they carry out hands-on experiments. Students should be provided with opportunities to appreciate and understand various forms of scientific inquiry (Wu & Hsieh, 2006).
From the constructivist point of view, inquiry-based science learning charges students to take the responsibility of their own learning and "doing" science to perceive 'science as a process of seeking knowledge' that requires students to possess process skills. Contemporary cognitive learning theories and information processing strategies discussed and reviewed above recognize that meaningful learning of science is reflective, constructive, and self regulated (Saha C.G., 2001).
Recognizing constructivism as the basis of current reforms in science education, NSTA (1992) called for "hands-on" experimentation and learner-generated questions, investigations, hypotheses, and models. Students need to have opportunity to learn process-based science in the schools to construct a robust backround of previous knowledge so that they can pose testable question, design and conduct an experiment to answer their research question, collect, analyze, infer communicate their findings. (Saha C.G., 2001).

In response to the 1957 launch of the Soviet satellite "sputnik" concerns in quality of math and science education. As a result, organizations such as National Science Teacher's Association put together organizations whose purpose was to investigate scientific literacy and reiterated the need for less memorization and more hands-on learning. During this "progressive movement" organizations such as the biological sciences curriculum study were formed to implement more inquiry based learning into the classroom (Thomas, 2005)

Inquiry Based Laboratory

Interest in using inquiry-based teaching strategies has increased in recent years as science teachers have become more critical about the efficacy of cookbook-type laboratory activities and indeed the purposes, practices, and learning outcomes of laboratory in general.

It is gradually being recognized that whereas cookbook labs can teach some laboratory technique sand skills (Wu & Hsieh, 2006) or serve as visual aids for concepts already studied, they are largely ineffective as a tool for teaching science concepts. As stated by one teacher-researcher, ''In the same way as any scientist, students will see what their prior theories lead them to expect. More significantly, they will not make the meaning that we as teachers expect them to make of experimental evidence until they have already grasped the theoretical framework that allows them to 'see' the evidence.'' (Wu & Hsieh, 2006) Therefore, cookbook laboratories may work well as illustrations of concepts already studied and understood but it is unlikely they will lead to new conceptual learning.

In science instruction, laboratory practicals have been a popular vehicle for activity/performance-based science tasks for a long time. However, in many school science programs these laboratories are used in a cookbook fashion to verify scientific facts and not promote laboratory or science process skills to investigate the natural phenomena. On the other hand, inquiry based (requiring students to explore in order to figure out how the world works) laboratory practicals that incorporate direct, holistic and complex performances are potent IPAs alternative to traditional paper-and-pencil multiple-choice test (Saha C.G., 2001).

Many definitions of inquiry-based laboratories and inquiry pedagogical models may be adapted to fit the local context. The authors of this report consider inquiry to be any combination of the following activities described as inquiry by the National Science Education Standards (National Research Council, 1996): observing objects and events, posing questions, designing investigations, proposing explanations, collecting data, analyzing data, and comparing proposed explanations with new data. As inquiry-based laboratories gain popularity, one important question facing science education researchers is whether inquiry-based laboratories have the potential to teach science concepts. Do the problem-solving components of inquiry promote conceptual growth in science? The purposes of this study were to explore, using interpretive research methodology, potential change in the conceptual ecologies of college students enrolled in an inquiry-based laboratory for non majors and to relate this change to the students' learning beliefs and science epistemologies.

The National Research Council (1996) recommended that students learn science through scientific inquiry. Inquiry-based classes are preferred over traditional classes because students are engaged in learning science through an active process (NSTA, 1996). While there are many variations, in an open-ended inquiry-based laboratory, students formulate their own hypotheses, design a unique experiment, and conduct an investigation. Courses that include open-ended scientific investigations enhance students' skills of observation and discovery, hypothesis formation, testing, and evaluating (Division of Undergraduate Science, Engineering, and Mathematics Education, 1990). To optimize learning, students must have the opportunity to design their own experiments and test their own hypotheses, especially in the laboratory (Lunsford, 2002).

National Based Education Standards (NRC, 1996) considers science by "doing" as a valid way to attain scientific literacy. Inquiry-oriented performance–based science learning process (where students require to conduct some activities in order to investigate a question on a natural event) means learning by experience in which students encounter science via a process of inquiry and problem solving. Thus doing science rather than just learning about science provides students an opportunity for viewing scientific evidence objectively and help make sense of the natural events meaningfully. "Even Aristotle once said that what we have to learn to do, we learn by doing."(School of Ocean and Earth Science&Technology-SOEST, 2000)

In other words, inquiry-based laboratory tasks have the promise to help understand the processes that underlie student performances-not only in diagnosis but also in suggesting remediation (Siegler, 1989). Tamir and Frankl (1991) observed inquiry based biology courses help students achieve high standard of functional knowledge, process skills, cognitive and intellectual development. Lawson and Wornsnop (1992) recommended that biology lessons be planned to promote hypothetico-deductive reasoning that itself calls for hands-on activities requiring students to explore in much the same way as scientists do. In addition, constructed response formats encourage deeper understanding and higher-order, critical-thinking process and thus promote learning and instruction aimed at achieving scientific literacy for all. Realizing the potentials of IPA in implementing standards-based reform, science educators are seeking ways to use these assessments to measure student science learning outcomes (Saha C.G., 2001).

PURPOSE

When the studies (Crawford,2000, Deckert et al.,1998, Drayton & Falk,2000, Gentry, 2002, Herron, 1971, Howard & Boone, 1997, Krajcik et al, 1998, Lawson et al.,1990, Laipply, 2004, Lunsford, 2002, Mcginn & Roth,1999, Russell & Donald, 2001, Saha, 2001, Staer et al., 1998, Thomas, 2005, Wu & Hsieh, 2006, Wu & Krajcik,2006) related to inquiry based laboratory activities examined, It was determined that there was no study is based on pupils' opinions. Besides, in this study, photosynthesis subject was chosen to be able to implement inquiry based laboratories activities. Photosynthesis is an important biochemical process by which energy-rich organic nutrients, for both the photosynthetic organisms and the heterotrophs, are produced from simple inorganic molecules found in the environment. According to Arnon, "Photosynthesis eminently merits its distinction as the most important biochemical process on earth" (Barker & Carr, 1989). As a consequence of its scientific importance, photosynthesis is considered one of the main topics in school biology and it is included in almost every middle school syllabus. This is based on its importance for a basic understanding of how the world functions as an ecosystem (Eisen & Stavy, 1988) and of how it acts as a bridge between the non-living and the living world (Waheed & Lucas, 1992). Photosynthesis has been rated as one of the most difficult topics for students (Waheed & Lucas, 1992). Its difficulty lies mainly in the fact that it is a complex biological topic, with a number of conceptual aspects (ecological, physiological, biochemical, energetic, autotrophic feeding) whose connection cannot be easily understood by the students (Waheed & Lucas,1992).

The purpose of this study to determine the effect of inquiry based laboratory activities on photosynthesis subject which was rated as one of the most difficult topics for students by using pupils' opinions.

METHODOLOGY

This study was made with 24 pupils at Atatürk Anatolian High school in 2006-2007 academic period. As data gathering material; seven inquiry experimental study sheets, the pupils' opinions survey consisting of six open-ended question, and two-lesson-hour video records were used.

The process steps followed in the study are below:

1. Preparing the lesson plan: In this step, the lesson books on the photosynthesis were examined, the concept misunderstandings about this subject were determined, the lesson plan including purposes and timing of study was prepared by making a literature research.
2. Preparing the laboratory hand-outs: The experiment mechanisms about photosynthesis, prepared before, were adapted to inquiry based learning, and six experiment hand-outs were prepared. There are the general information, blanks to draw the mechanism, and the questions about the experiment in the hand-outs (Figure 1). The information about the materials in the experiment wasn't given intentionally, and the pupils were asked to find it in "general information" part by themselves.

Hand-out
General information:
Mechanism:
Questions:

Figure 1. A simple inquiry based hand-out

3. Preparing groups: The pupils were divided in to six groups of four before the experiments, and the information about all the experiments was given to each pupil by copying the hand-outs. Then, six experiments were distributed as one to each group. Meanwhile, after the groups read the general information about the experiments, they chose the experiment they would do.

4. Answering the introduction questions: The introduction questions about photosynthesis prepared before were answered by pupils before the mechanisms were set up. Introduction questions were given below;

1. What is the aim of photosynthesis?
2. Were photosynthesis observed on only plants?
3. Why couldn't the colors seen in darkness?
4. What are the differences which may happen on the matter when a matter is illuminated?
5. Why is the leaf of plant green?
6. Why aren't the roots of plant green?
7. Why can't a green penny perform photosynthesis under the sunshine?
8. There are 7 colors in the sunshine. How can we understand whether these colors exist or not.
9. Were photosynthesis observed on aquatic plants?
10. Why is the lime juice used in the experiments of photosynthesis or respiration?
11. Sleeping in the same room with house plants at night is said to be harmful. What is the reason of this situation?
12. Why is the frothing observed when a bottle of soda shakes?
13. The plants don't take oxygen from atmosphere in the afternoon. What is the reason of this situation?

5. Preparing mechanisms: After the pupils read the part of "general information", they discussed the mechanisms they will prepare. After they decided essential materials, they took materials from laboratory boards. In this step, the teacher didn't participate in study, he only answered the pupil's questions related to materials. Besides, the pupils interested not only in their experiment but also in the different group's experiments, and they took information from their friends.

6. Demonstrating experiments: The group members recorded the data related to experiment, and discussed the results of experiment. When the experiments completed, one of the group members demonstrated their mechanisms, aims of the experiment, what hypothesis was used in the experiment, and also the answers of the questions related to the experiment. Meanwhile, the other group members asked the part they couldn't understand and an discussion atmosphere occurred. During each demonstration, the other group members filled in the blanks in the hand-outs.

7. Repeating information: The data obtained from mechanisms and scientific information was repeated by the teacher.

8. Implementing Pupils' Opinions Survey: Pupils' opinions survey, consists of six open-ended questions, developed by researcher implemented final of study and pupils' opinions related to inquiry based laboratory were tried to determine.

FINDINGS

The questions in the pupils' opinions survey and some of the pupils' answers are given below:

a) How do you like the experiments? Were you able to understand all the experiments?

Pupil A: *We were. They were selective and nice. I have taken biology lessons for 8 years in my twelve-year educational background, and I have done an experiment for the first time.*
Pupil B*: Yes, I was. The experiments were quite nice. We have done a biology experiment for the first time for a long time. The application of the experiments was easy and teaching. Also, It was very useful that we did the experiments.*
Pupil C: *The experiments were applicable. We justified the information which we learned. We understood all the experiments.*
Pupil D: *Our own experiment was easier to understand. Because we watched only the presentations of the others, they weren't very useful. The one we did was quite better.*

Almost all of the pupils determined that the experiments to be teaching, applicable and easy. Two of the pupils expressed that they couldn't understand all the experiments, but that they comprehended at least some of the information in the experiments they couldn't understand.

b) Thanks to the inquiry based laboratory activities, did your negative attitudes towards biology lesson change? Could you explain your answer?

Pupil E: *There was not my any negative attitude. But I can say that the teaching was better.*
Pupil F: *There was not my any negative attitude. Thanks to these experiments, we learned about new things in the mysterious world of biology, and the lesson was more enjoyable.*
Pupil G: *I have already liked biology. These experiments increased my interest towards lesson, and made the lesson unforgettable easily.*
Pupil H*: No, there was no change. There is no thing I can explain, I didn't like it before and don't like it now.*

Most of the pupils (87,5 %) expressed that they had no negative attitudes towards biology and they liked this lesson before. Also, they point out that their positive attitudes about biology increased thanks to this study. Remaining three pupils (12,5 %) expressed that they had negative attitudes related to biology, and that they didn't like this lesson because It was based on memorization, but two of these pupils expressed that their attitudes changed a bit positively, and the other pupil expressed that his negative attitudes continued.

c. Were the discussions in the lesson useful? Could you explain your answer?

Pupil I: *Yes, for example, I didn't used to know what acetone is used for .We discussed this with my friend, and realized that neither of us know it.*
Pupil J*: Yes, my interactions with my friends improved. The coordination and getting along with my friends supported our friendship and connection.*
Pupil K*: It was useful. We helped each other with understanding the experiments.*
Pupil L: *It was not very useful. It was a little noisy.*

Most of the pupils (91,7 %) pointed out that these discussions were more useful. Also, they expressed that they benefit from different aspects, that their communication skills improved, and that they corrected their mistakes thanks to this method. Remaining two pupils (8,3 %) expressed that there was noise in the classroom.

d. Has learning with your own thoughts been useful in this pupil based study? Have you been satisfied with the guide position of the teacher?

Pupil M: *Yes, It has. My self-confidence has improved, also, our teacher was very good.*
Pupil N: *It has. Our teacher has made a quality and highly successful study.*
Pupil O: *The guide position of the teacher was good.*
Pupil P: *It was useful that learning with our own thoughts, and that the pupil was responsible for and interest in the experiments at first level.*

All the pupils expressed that learning with their own thoughts was very useful, that they were satisfied with the guide position of the teacher, and that the guidance of the teacher was necessary. Also, some of the pupils expressed that the experimental studies in which the teacher makes alone and the pupils do nothing except for watching him are not educational and enjoyable.

e. Could you compare this study with traditional learning

Pupil R: *It was more effective than traditional learning. Because the visual materials were used more effectively. The concrete results of the things told in theory were observed.*
Pupil S: *I realized that the didactic method was infertile and I was more active in the inquiry based activities. I found out that the learning by seeing and thinking was more permanent.*
Pupil T*: The laboratory was very cold. We were cold but had fun. We had been cold and hadn't had fun during the traditional method.*
Pupil U: *I think that answering the questions in a test book is the best teaching method. We could have had more information in the same period of time. But It was very useful in that It made the information permanent.*

The pupils expressed that the inquiry based laboratory activities were more enjoyable, educational, permanent, scientific, and pupil centered than the traditional methods.

f. What are the missing parts in the study and your negative critics?

Pupil V: *Because the laboratory was insufficient, there were a few missing parts. We had trouble providing the plant with darkness. But this situation didn't prevent us from performing the experiment.*

Pupil W: *We couldn't observe the expected results in some of the experiments. One or two-day-waiting period was necessary in these experiments. We couldn't observe some of the results because we were in the laboratory only two hours. The lack of material in the laboratory was a bit problem.*
Pupil X: *There was a serious timing problem. We had to complete the experiment in a shorter time than necessary time. Moreover, there was a serious heating problem in the laboratory.*
Pupil Z: *There is no missing part I saw. I think that this kind of experiments are useful after every subject. The lack of material may cause trouble. But finding solutions to this problems increases creativity (For example, using water instead of prism).*

The pupils generally criticised the lack of materials and finding some experiments whose results could be observed in a longer time.

RESULTS

The laboratory activities are very important in the subjects in which metabolic events, such as photosynthesis, could be explained experimentally. But the laboratory lessons should be done more inquiry based, not with the guidences in which all the process is given one by one. Only in this way could the traditionality in this lesson be through taken over.

According to the results of this study, the pupils expressed that the inquiry based laboratory activities are more permanent, enjoyable, and pupil centered than the traditional methods, that they studied cooperatively thanks to this study, that they utilized different aspects, that they were satisfied the guide position of the teacher during the application, and that attitudes towards biology lesson increased positively.

DISCUSSION

Wu and Hsieh (2006) identified four inquiry skills that are critical for students to develop scientific explanations in their study: to identify causal relationships, to describe the reasoning process, to use data as evidence, and to evaluate explanations. The purpose of this study was to understand how sixth graders develop inquiry skills to construct scientific explanations throughout a series of inquiry-based learning activities. Inquiry has been viewed as an approach to learning science that involves a process of exploring the natural or material world (NRC, 1996; Tamir, 1989). This study defined inquiry as a question-driven learning process involving conducting scientific investigations, documenting and interpreting narrative or numerical data, and summarizing and communicating findings. To help students learn science through inquiry, they developed a framework for inquiry learning that involves three dimensions: phases in an inquiry process, features of inquiry learning, and intellectual skills required for inquiry learning. Explanatory activities play a particular important role in the latter two dimensions. The results of my study get along with Wu and Hsieh's results. The pupils constructed causal correlations with introduction questions, then collected data by using their mechanisms, shared their data with their friends, and evaluated the results of the experiment. Therefore, the four inquiry skills, defined by Wu and Hsieh, were observed in this study.
David Ausubel developed the meaningful learning model as an alternative to the memorizational learning. In the theory of Ausubel, an "advanced organizer" is needed to get the pupil to construct a connection between pupil's previous information and new ones. In the meaningful learning, the new concepts can be learned by collecting more detailed concepts. The advanced organizers can be a caricature, a graphic, an audial material or questions. In each condition, the advanced organizers should be designed to set a mental model iin the pupil's mind to learn the new information. In my study, the introduction questions were used as the advanced organizer. Thanks to these questions, the pupils interests were attracted and they were made to discover the information which they will use in the mechanisms.
The seminal work of Ausubel, interpreted for science education by Novak (Novak & Gowin, 1984), on the construction of conceptual knowledge networks through meaningful learning has provided a foundation for many contemporary studies, including this one. Ausubel's theory of meaningful learning posits that learners increase their conceptual knowledge bases when they choose to relate new information to prior knowledge. Ausubel named three cognitive functions involved in meaningful learning: (a) subsumption—the attachment of the concept to a network of other meaningful concepts; (b) progressive differentiation—categories for concepts become increasingly branched; and (c) integrative reconciliation—two or more concepts are seen as related in new ways. Thus, science learning consists of increasing levels of classification, clarifying hierarchical relationships, adding exemplars, and forming new links between concepts. In my study, the pupils were observed to make use of their information about light and reflect which they learned in Physics lessons, their information about catalyst and chemical reactions which they learned in Chemistry lessons, and also the pre-information about the plant metabolism and the general structure of a plant cell.

Garnett, Garnett and Hackling (1995) have suggested that the aims of laboratory work can be grouped into four main categories: conceptual learning; techniques and manipulative skills; investigation and problem solving skills; and affective outcomes. The Mayer Report (Mayer, 1992), the National Statement on Science for Australian Schools and the Science Profile have placed a particular emphasis on the development of inquiry and problem solving skills, as have similar national curriculum frameworks in North America, Canada, the United Kingdom and New Zealand. For example, the National Science Education Standards of the United States of America (National Academy of Sciences & National Research Council, 1996) outlines a national goal that all students should become scientifically literate, which means that a person can "ask, find or determine answers to questions derived from curiosity about everyday experiences" and can "evaluate the quality of scientific information on the basis of its sources and the methods used to generate it." Similarly the UK Science National Curriculum Orders include Experimental and Investigative Science as one of four attainment targets (School Curriculum and Assessment Authority, 1994). Tamir and Lunetta (1978) have argued that to achieve such aims there is a need for teachers to match appropriate types of laboratory work to those aims (Staer et all., 1998)

The Working Scientifically strand of the Australian Science Profile describes the development of science investigation skills through eight levels. The Western Australian Monitoring Standards in Education project revealed that typical Year 10 students have only attained Level 3 and some of the simpler Level 4 science investigation skills (Education Department of Western Australia, 1994). Hackling and Garnett's research (1991) indicates that Western Australian secondary students "had poorly developed skills of problem analysis, planning and carrying out controlled experiments, basing conclusions only on obtained data, and recognizing limitations in the methodology of their investigations". The low levels of investigation skills reported for Western Australian secondary students are likely to be related to the opportunity given through laboratory work to practice these skills; that is, the extent to which laboratory work is open to inquiry (Staer et al., 1998).

Laboratory activities can be classified by level of openness to inquiry according to whether the teacher prescribes the problem, the apparatus to be used, the procedure to be followed and the expected answer, or the students are required to make these decisions for themselves. A scale of openness to inquiry has been developed (Hegarty-Hazel, 1986; Tamir, 1989) to classify laboratory activities (Table 1). A scale was first devised by Schwab in 1962 and elaborated to include level zero, the lowest level of inquiry, by Herron in 1971 (Tamir, 1989). Hegarty-Hazel (1986) further elaborated the scale to divide level 2 into levels 2a and 2b to increase discrimination between levels of openness.

Table 1. ***Levels of Openness of Inquiry in Laboratory Activities (after Hegarty-Hazel, 1986)***

Level	**Problem**	**Apparatus**	**Procedure**	**Answer**	**Common name**
0	*Given*	*Given*	*Given*	*Given*	*Verification*
1	*Given*	*Given*	*Given*	*Open*	*Guided inquiry*
2a	*Given*	*Given*	*Open*	*Open*	*Open guided inquiry*
2b	*Given*	*Open*	*Open*	*Open*	*Open guided inquiry*
3	*Open*	*Open*	*Open*	*Open*	*Open inquiry*

At the lowest level of inquiry (level 0), the problem to be investigated, the apparatus to be used, the procedure and the answer to the problem are all given to the students by the teacher or by a worksheet. At the highest level of inquiry (level 3), the students are required to determine all of these for themselves (Staer et al., 1998).

Analysis of laboratory manuals from North American inquiry based curricula such as BSCS and PSSC by Herron (1971) and Tamir and Lunetta (1978) revealed limited opportunities for open investigation work. Similarly, Friedler and Tamir's (1986) analysis of Israeli high school science laboratory manuals and classroom observations revealed that one third of activities were at level 0 and one half were at level 1 on Herron's (197I) scale, and "only rarely were students required to identify and formulate problems, to formulate hypotheses, to design experiments, and to work according to their own design". In my study, the prepared inquiry based laboratory activities could be said to be “2b” level in the classification which is described by Tamir. Because the problem was given in the experiments, the pupils were made to determine the materials and to use the mechanisms, the details were not given in the general information part, the process ranking in the experiment was determined by the pupil, they were asked to answer the questions at the end of the experiment and also to discuss among themselves.

Russell et all (2001) found that students in these labs spent more time on task and had higher levels of active participation than students in more traditional, or "cookbook", laboratories. In my study, the cook book based on the laboratory implementation was not used, instead a more creative atmosphere was prepared. Most of the pupils expressed that they designed many mechanisms themselves and dealed with the questions individually were highly useful and interesting.

Gentry (2002) found that most students enjoyed working in groups and agreed that their group members explained lab procedures if they did not understand. Some studies have also found that students enjoy working in groups in the laboratory (Pratt, 2003, Travis and Thomas, 2004). Other research has studied the benefits of group work in the science laboratory. Howard and Boone (1997) reported that students rated working in groups as the most enjoyable aspect of their laboratory course. Because their students were assigned seats alphabetically (similar to our seating arrangements), they concluded the positive response was not a reflection of friends helping each other. Instead, working in groups provides the opportunity for cooperative learning. Travis and Thomas (2004) demonstrated that group interaction increased the level of student involvement in the laboratory. They showed that students working in groups were able to recall and apply the information learned in laboratory better than students that did not participate in a group. In my study, the pupils were divided the groups of four people randomly. The pupils expressed that small groups were useful, that a task was given to every member, and also that there was a constant information exchange among members.

Inquiry based laboratories include open-ended scientific investigations that require students to observe, form hypotheses, test, and evaluate (Division of Undergraduate Science, Engineering, and Mathematics Education, 1990). In my study, the pupils determined the hypothesis of every experiment, recorded the data during experiment, and evaluated the results with their friends.

Much of the research looking at inquiry in a college setting, is implemented in non-majors biology courses. In 1990, Lawson, Rissing and Faeth created a Biology 100 course for the explicit purpose of teaching non-majors how to do science. They propose that through inquiry based laboratories, students gained an understanding of modern biological theories and concepts and were able to use them in application in their everyday lives (Lawson, Rissing and Faeth, 1990). Sundberg & Moncada (1984) also implemented an investigative laboratory approach in non-majors biology class. They presented their investigative laboratory approach as one with a level of inquiry similar to that found in an open inductive inquiry approach rather than a open-ended more traditional approach. When comparing their students with those registered in a concurrent major biology class, they found some interesting things. Although the non-majors received less course content (though more inquiry), the non-majors consistently demonstrated more in depth understanding of major biological concepts than the majors did. A group of twenty-four-pupils attended to my study. Some of them expressed that the reason why the experiments were more enjoyable and effective was the number of pupils in the classroom was few.

Little to no research has investigated relationships attitude towards science and biology self-efficacy. The most recent, and the most applicable research to date was published as a case study investigating relationships between self-efficacy and attitudes toward science in an inquiry based biology laboratory. Research showed that inquiry based instruction had a positive effect on both student's attitudes toward science and their biology self-efficacy (Laipply, 2004).The result of this study get along with my study. In my study, thanks to inquiry based laboratory activities, some of the pupils expressed that their interests in science increased and that their negative attitudes about biology changed positively.

Recent studies has looked into implementing and designing inquiry laboratories that are effective in promoting students' development of formulating and implementing their own investigations (Deckert, Nestor, Dilullo,1998; Sundberg&Moncada,1984) In my study, the pupils expressed that self-directed learning and the mechanisms which were designed by themselves were very useful, and that their self-confidence increased.

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TABLES

Table 1. ***Levels of Openness of Inquiry in Laboratory Activities (after Hegarty-Hazel, 1986) (PAGE 11)***

Level	Problem	Apparatus	Procedure	Answer	Common name
0	*Given*	*Given*	*Given*	*Given*	*Verification*
1	*Given*	*Given*	*Given*	*Open*	*Guided inquiry*
2a	*Given*	*Given*	*Open*	*Open*	*Open guided inquiry*
2b	*Given*	*Open*	*Open*	*Open*	*Open guided inquiry*
3	*Open*	*Open*	*Open*	*Open*	*Open inquiry*

FIGURES

Hand-out

General information:

Mechanism:

Questions:

Figure 1. A simple inquiry based hand-out (PAGE7)

APPENDIX

Some Inquiry Based Laboratory Hand-outs (The mechanisms were drawn by pupils)

Experiment 1

An Elodea (aquatic plant) and a little tap water are put in a per. The light source is placed on 4x distance to the per, and after waiting for “t” time, the number of the bubbles released by Elodea is counted. Then, the same process is done again for 3x, 2x, and x distance.

Mechanism

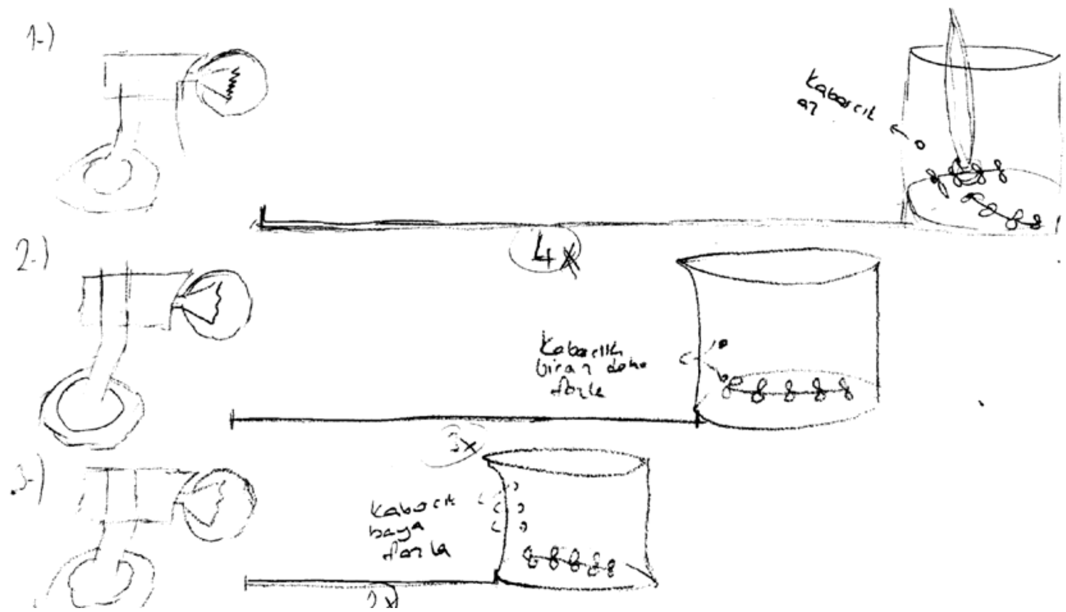

Figure 2. Mechanism 1

Questions:

1. **What gas the reason of the bubbles released by Elodea?**
2. **What factor plays a role in the photosynthesis velocity in this experiment?**
3. **What are the results of the experiment?**

Experiment 2

Three pers are used in this experiment. Only tap water is put in one of them, the tap water and a little lime water are put in the second, and the tap water and soda are put in the third. After the same length Elodea plants are added in each of the pers, the mechanisms are placed in front of the light source. The number of bubbles in each of the pers is counted.

Mechanism

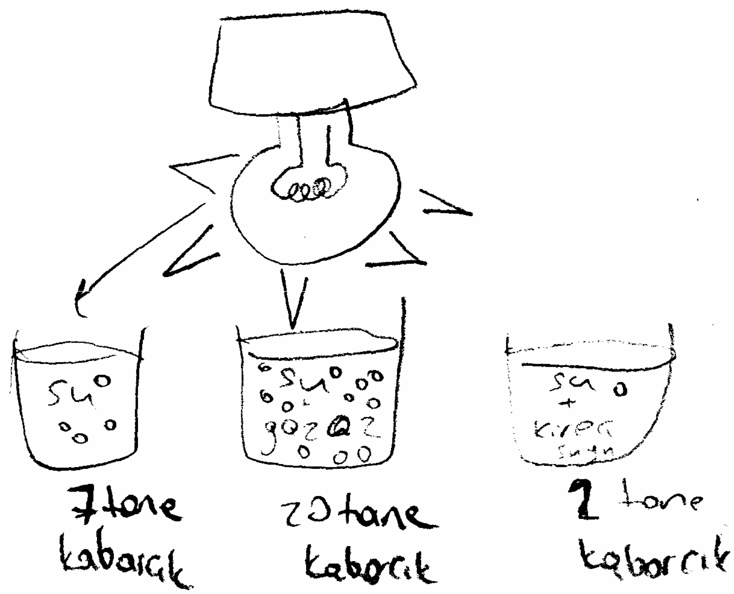

Figure 3. Mechanism 2

Questions:

1. **What is the reason of adding the lime water and soda?**
2. **What factor plays a role in the photosynthesis velocity in this experiment?**
3. **Which per is the control group?**
4. **What are the results of the experiment?**

Experiment 3

The geranium plant and lime water are put in a per. The per is attached to glass pipe including an oil drop by using a plastic pipe. The prepared mechanism is kept in darkness and the movement of the oil drop is observed with a meter.

Mechanism

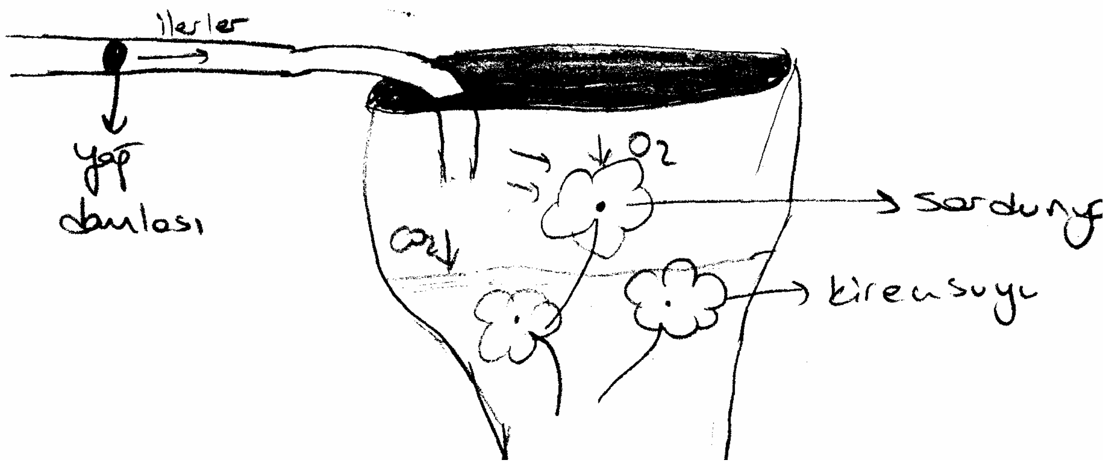

Figure 4. Mechanism 3

Questions:

1. **What is the reason of adding the lime water?**
2. **What is the role of the oil drop in the experiment?**
3. **If the experiment performed under sunshine, how do the results change?**
4. **What are the results of the experiment?**