PRIMARY SCIENCE STUDENTS’ APPROACHES TO INQUIRY-BASED LEARNING

Ayse Oguz-Unver\textsuperscript{1}, Kemal Yurumezoglu\textsuperscript{2}
(Project Pri-Sci-Net Partners)

\textsuperscript{1}Assoc. Prof. Dr., Mugla Sitki Kocman University, Faculty of Education, Department of Science Education, 48000, Mugla-Turkey
ayseoguz@mu.edu.tr

\textsuperscript{2}Assoc. Prof. Dr., Dokuz Eylul University, Faculty of Education, Department of Physics Education, 35000 Izmir-Turkey
kemal.yurumezoglu@deu.edu.tr

ABSTRACT
Pri-Sci-Net, an EU funded FP7, is a project that promotes inquiry-based learning in science at the primary education level through developing activities for teachers to use as well as setting up a Europe-wide network for professionals and academics in the area of Primary Science Education. In this context, two science activities, ‘The secret of the human body’ and ‘Pigment research’, were developed for the 9-11 age group and were applied to the students in this study. An observation protocol and semi-structured interviews with students were used for collecting data. The results of the study showed that students were convinced about, and realized the importance of, doing inquiry-based activities in learning science. Activities were mediated to create an inquiry-based social science environment. Even poor academic performance students were very active during the activities since all thoughts were considered valuable.

Keywords: Inquiry-based learning, primary level students, inquiry-based science activities.

INTRODUCTION
As a learning activity, inquiry-based learning (IBL) refers to the activities of students in which they develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world (Anderson, 2002). Inquiry is based on scientific investigation through classroom practices such as posing questions, and it is concerned with knowledge acquisition and development (Blanchard, Southerland, & Granger, 2008). The main reason for its widespread acceptance and usefulness in science teaching is that it is compatible with human nature. From the moment we open our eyes to nature, all of our learning, except our instinctive behaviors, is based on our observations and inquiries. Therefore, all of our observations, learning needs, and inquiries require asking the right questions. IBL begins with questions based on real observations, and then proceeds through discussions and explanations based on evidence (Cuevas, Lee, Hart, &Deaktor, 2005). Consequently, it can be said that inquiry is the art of questioning and the art of raising questions.

Most instructors match IBL with hands on activities. This is a correct approach to some extent, but IBL learners are not just active learners; the activation is also in the learners’ minds. IBL is in the learner’s mind because the main knowledge construction is part of the learner’s thinking. In this method, the learner is asking and refining questions, planning and designing how to answer their ideas, sharing ideas, making sense of data and designing and conducting experimental work. All these activities are mental processes and engage learners to become active learners.

The research on IBL in terms of implementing this theory in education varies according to different topics. It includes work on conceptual understanding (e.g., Anderson, 2002;Dalton and Morocco, 1997), attitudes and perceptions toward science (e.g., Anderson, 2002; Shymansky, Kyle, &Alport, 1983; Spronken-Smith,2012), critical thinking (e.g., Anderson, 2002; Panasan&Nuangchalerm, 2010), academic achievements (e.g., Marx et. al., 2004; Wolf and Fraser, 2008) scientific processing skills, cognitive achievement (e.g., Anderson, 2002;Kraijcik, et. al., 1998; Panasan&Nuangchalerm, 2010;
Shymansky et. al., 1983, Lawson, 2010; Wu, et. al., 2006) and learning content as well as discipline-specific reasoning skills and practices (e.g., Hmelo-Silver et. al., 2007; Khishfe and Abd-El-Khalick, 2002). In addition, to address the impact of inquiry-based science instruction on K–12 students, Minner et al. (2010) synthesized the findings from research conducted between 1984 and 2002. Overall, research suggests that using IBL with students can help them become more creative, more positive and more independent. A systematic approach to the development of IBL skills is essential to prepare students both for problem solving and lifelong learning.

The Pri-Sci-NetVision of IBL for Children

Pri-Sci-Net is an EU funded FP7 supporting and coordinating action (Call SiS-2010-2.2.1.1) on innovative methods in science education: teacher training on inquiry-based teaching methods on a large scale in Europe. The project is coordinated by the Malta Council for Science and Technology (MCST) and has 17 partners from 14 countries.

Within the vision offered by the Pri-Sci-Net Project, inquiry-based science at the elementary school level involves a framework of teaching and learning that comprises applications for learning science, learning to do science, and learning about science (National Research Council, 2000).

In this framework:

Children:
- engage actively in the learning process with an emphasis on observations and experiences as sources of evidence;
- tackle authentic and problem-based learning activities, where the correctness of an answer is evaluated only with respect to the available evidence and getting to a correct answer may not be the main priority;
- practice and develop the skills of systematic observation, questioning, planning and recording to obtain evidence;
- participate in collaborative group work, interact in a social context, construct discursive argumentation and communicate with others as the main process of learning;
- develop autonomy and self-regulation through experience.

Purpose of the research

Since the school programs are promoting IBL in science at the primary level, it is important to provide professional support to both students and teachers to help them use inquiry-based learning in their teaching and learning. Pri-Sci-Net is one of the projects that promotes inquiry-based learning in science at the primary level of education, both through developing activities for teachers to use with students, and through the setting up of a Europe-wide network for professionals and academics in the area of Primary Science Education. In this context, two science activities were developed for the 9-11 year old age group and were applied to the students in this study. Since many studies on the impact of IBL activities on students’ thoughts are purely descriptive, the main aim of this study was to gain an understanding of students’ approaches to IBL.
MATERIALS AND METHODS

Participants

This study was restricted to two urban public elementary schools located in the Mediterranean region of Turkey. The study used purposeful and convenience sampling procedures (Johnson & Christensen 2004), which offer a non-random method of sampling where the researcher selects information-rich cases for study in depth. The study was conducted with sixty fifth grade elementary school students (32 male and 28 female, mean-age 11), and the interviews were held with eight volunteer students (5 female and 3 male) from among these participants.

Data collection instruments

An observation protocol and semi-structured interviews with students were used for collecting data. The observation protocol consists of three main parts and sub-divisions. These three main parts were also coding schemes for qualitative data analyses which were conducted by two researchers. The level of students’ engagement in scientific thinking and discourse, the level of students’ work with evidence and formulation of explanations, and the level of students’ reflection on the process of their inquiry were observed and noted. Semi-structured interviews were framed around three questions: whether the students enjoy the activity, what did they like or not like; whether they had previously done science activities in this way and whether they like to work with their friends.

Activities used in this research

Teachers generally claim that science classes associated with the use of inquiry is time consuming since the activities span several class sessions, which conflicts with the complete core curriculum. Therefore, this study used two small-scale inquiry activities that only required 2 or 3 class sessions for completion, and which utilized only the key aspects of inquiry that challenge students. Both activities were applied to two different classes from two different schools that participated in this study.

The first activity, ‘The secret of the human body’ (Author: Mgr. Dagmar Kubátová, PhD), encourages students to formulate a hypothesis about changes in heart rate intensity during various activities and to verify it experimentally. Students were then asked to compare the established results among themselves and explain the differences between individuals in the group. The second activity, ‘Pigment research’ (Authors: Jiří Škoda, Pavel Doudík), stimulated the students to observe the separation of colors and to reason based on their evidence. The activities used in this study were developed for the Pri-Sci-Net project.

RESULTS AND DISCUSSION

The results of classroom observation

Before doing the activities, questions that enable students to discover answers through their own hands-on experiments or through their own observation were asked. The goal was to encourage students to go beyond the idea of just memorizing facts and move them toward taking the initiative and responsibility for their own learning. The classroom observation is reported in terms of the observation protocol.

The level of students’ engagement in scientific thinking and discourse

Before starting the pigment activity, the instructor asked the children whether the color of black ink in the pen contains different colors. The students started questioning and came up with several ideas. The
instructor wrote all the ideas on the board without judging. This encourages students to talk more. The ideas of the students were as follows:

- **black consist of only primary colors (yellow, red, blue),**
- **there are no primary colors in black (dark blue, brown, gray),**
- **One cannot say whether there are primary colors in black since black is the combination of all colors,**
- **black contains only dark colors,**
- **black contains only light colors,**
- **There may be some dark and some light colors in black, since dark and light colors complement each other,**
- **black has only its own color.**

At this point, the students were ready to hear the teacher’s answer since they thought that, after this brainstorming, their job was finished; now, they thought, it was time to get answer.

One student asked: “**Teacher, what is the answer**”

Instructor: “**I am not sure. We should find a way to discover that**”

Students were surprised since this was not the teaching approach they were used to. Many of them were extremely curious about which answer on the board was right. Consequently, they were already engaging in scientific thinking and discourse even despite some of the students claiming that science is boring.

During the other activity, ‘The secret of the human body’, the students decided to measure their heartbeat not only after the activities, but also before the activities since this meant they could make a comparison. This was a significant decision in terms of IBL since the students found the activity interesting (engaging) and dynamic. They formed predictions, collected data, worked together, recorded the data and drew conclusions through discussion.

**The level of students’ working with evidence and formulating explanations**

In terms of developing explanations (e.g. **How changes in heart rate intensity during various activities?**), it is the instructor who leads the discourse and stimulates the students to formulate predictions and explanations. In addition, the instructor took the lead in creating a challenging situation such as by creating the bar graphs and guiding children to reason based on their evidence. At the end of the activity, the instructor told the students that they had worked as scientists and gathered scientific explanations based on their evidence. Students did their observation in terms of their hypothesis and decided whether it was correct or not, and they also discussed contradictory situations with their friends.

*Student e.g. “We shared our observation results, and different stuff. We looked at the results of the other groups”*

In ‘the secret of the human body’ activities, students worked as a group (See picture 1). In each group there were five students. One student was counting the sounds of a heartbeat per minute using a stethoscope, one was responsible for the timing, and the others were doing the activities. Having a real stethoscope to use made the children very excited. They immediately became engaged with the activity. It should be noted, however, that in some cases some students missed counting the heartbeat because of the crowded environment and the noise. The classroom was not big enough for 5 groups which had 5 students in each. Therefore, by the end of the activity the instructor had to explain that some data should be ignored because of observer error. Nevertheless, the students were having the
chance to do real science, and their interest and excitement contributed to the noise level in the room. During the pigment research activity, there were also problems because students became tired or lost interested while waiting for the separation of the pigment (which takes approximately 15 minutes. See picture 2). However, the instructor immediately found a solution by motivating students throughout the experiment by asking questions and encouraging the students to do observations and take notes. To sum up, during the activities the teacher wrote all the results on the board and had students communicate procedures, evidence and explanations. The instructor guided the students through questioning. The activity’s data allowed students to make actual comparisons (See picture 3).

![Picture 1. Students are working together](image)

![Picture 2. Students are observing pigment separation](image)

![Picture 3. The activity’s data allowed students to make actual comparisons](image)
The level of students’ reflection on the process of their inquiry

The students had a chance to behave as real researchers and do hands on experiments. Using real tools like a stethoscope, chromatography paper, a chronometer etc. excited and motivated them as the comment of one student shows:

“This experiment was quite different. It was like a real experiment, I mean, I felt like I was an proper researcher. We collected information through research in that experiment”

The results of the observation suggest that, that since the students are used to taking more traditional courses, they are much closer to structured inquiry (Staver and Bay, 1987), where teachers provide an issue or problem and an outline for addressing it. However, an assumption can be made that students would like to move to guided inquiry (Staver and Bay, 1987), where teachers provide questions to stimulate inquiry, but students are self-directed in terms of exploring these questions. Finally, very structured curriculums and exam systems (like those in Turkey, for example) make it difficult to apply open inquiry (Justice et al., 2002) where students formulate the questions themselves as well as going through the full inquiry cycle.

The results of semi-structured interviews

Semi-structured individual interviews were used to establish the validity of the observation by ensuring that the researchers’ interpretations corresponded to those of the participants. During the interviews, follow-up questions were used to probe students’ ideas in-depth, and to explore the relationships between these ideas. The interviewer avoided directives, and limited her discourse to encouraging participants to elaborate and clarify their ideas. All interviews, which typically lasted for about 15 minutes, were videotaped and transcribed verbatim for analysis. The categories and examples drawn from the interview data are reported as follows:

Students expressed their thoughts on how they faced questions with more than one possible answer.

Student 7: During the pigment research, I assumed that there was only one answer. But the teacher wrote all the answers on the blackboard.

Student 4: ... We could not count the heartbeat properly because of the noise in the classroom. Yet the teacher still wrote our result on the board. We discussed why our result is different from the others. The teacher thanked our group for bringing ‘observer error’ to our friends’ attention. I learned that it is very important to minimize observer error while doing experiments...

Students stated that they learned how to solve problems and answer questions. They reflected on how they feel like real researchers. In addition, many of the students in the classrooms were from different schools. Thus, the researchers had an opportunity to learn more about the profile of science classes in the town generally. The results showed that students have little experience of doing experiments. What is more, many of them were of the opinion that science means rote learning without asking questions:

Student 2: Teacher! This experiment was different. It was like a real experiment, I was like a real researcher...

Interviewer: ... I would like to ask you whether you used to do experiments like this.
Student 1: When I was in 3rd grade we did experiments.
Interviewer: Do you remember how you did the experiments?
Student 1: For example, we measured the temperature with a thermometer or something, but didn’t do anything like this.
Interviewer: ... The teacher was measuring or each one of you had a thermometer?
Student 1: The teacher was measuring, and we were watching. He did not allow us to touch anything.
Interviewer: Well where do you feel you are a scientist? In the activity you did in 3rd grade or here?
Student 1: Absolutely here.
Interviewer: Why?
Student 1: Because we were not doing research there. Our teacher was doing most of the things, and we were watching. But here, we are doing all the things by ourselves, even the experiments. We did everything by ourselves. That feels good!

Interviewer: What were you doing in science classes last year?
Student 8: Our teacher was very authoritarian, he was reading from the book and we were writing what he says. Then...he never ever made us do experiments. He always talked like that. You know, without doing anything visually.

Students expressed their thoughts on how they discussed things with others and learned more than they had expected.

Student 3: ...let’s say I talked with some friends from other groups. For instance they were thinking there is only black in black color. Then I said there are other colors in black. After the experiment they said I was right...And then I also learned from the experiments about drawing graphs, measuring, using different tools, how to do experiments at home and how to do research.

Student 5: ...I learned about working as a group since everyone has their own responsibility.

Overall, the results of the study showed that students were convinced about, and realized the importance of, doing inquiry-based activities when learning science. Activities were mediated to create an inquiry-based social science environment. Even poor academic performance students were very active during the activities since all of the students’ thoughts were valued.

CONCLUSION AND FURTHER IMPLICATIONS

The aim of this research was to understand students’ approaches to inquiry-based learning. The research showed that students feel as if they are real researchers while doing the activities. Moreover, they were more creative, more positive and more independent through using IBL. In addition, students were involved in their learning and developed solutions. However, students were in need of more inquiry-based style classes for further, higher-order learning. IBL was a new approach for many of the students in this research. Therefore, they had difficulties in synthesizing findings, relating to new questions, and going through the full inquiry cycle.

Each stage of the activities done in this research contributes to the creation of scientific knowledge. The skills acquired during the execution of the activities will lead to learning to do science; the students who find answers to their questions at the end of the activity will gain knowledge learning about science, and those who make use of the process to solve ordinary everyday problems internalize the experience of learning science and benefiting from what they have learned. Choosing activities from everyday life that have been designed within this basic framework provides motivation for both students and teachers. Moreover, when knowledge acquired in school can be used in solving problems encountered in everyday life, that knowledge becomes all the more meaningful for the individual learner. Our research involved only two classrooms and eight cases, which meant small sample sizes. Thus, further research should be conducted using a bigger sample with demographic subgroups. Furthermore, research should be undertaken regarding what kinds of design needs exist for learning environments in order to foster science inquiry among all elementary students.
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REFERENCES


