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A TEACHING STRATEGY FOR DEVELOPING THE POWER OF OBSERVATION IN SCIENCE EDUCATION

BİLİM EĞİTİMİNDE GÖZLEMİN GÜCÜNÜ GELİŞTİRMEK İÇİN BİR ÖĞRETİM STRATEJİSİ

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ABSTRACT: *Despite the importance of observation in knowledge building, it has received less attention than experimental forms of inquiry in science education. Therefore, the aims of this study are to use observation strategies for developing the power of observation in science education and to develop student teachers' skills of observation process. The data of the qualitative study have been collected sequentially through two different activity steps.*

The study enabled students (n:33) to make a scientific observation, to follow scientific inquiry processes that starts with formulating questions, and then continues with gathering evidence, organizing, and proposing explanations. It has been observed that during the study students tend to use all their five senses in terms of the quantity of the objects that can be perceived. On the other hand, inquiry based scientific observation not only led students to focus on certain areas but also facilitated a more detailed, systematic and rich outcome observation.

Key Words: *observation, scientific inquiry, observing with senses, indoor and outdoor classroom activities.*

ÖZET: *Bilginin oluşumunda gözlem önemli bir yer tutmasına rağmen, bilim eğitiminde gözlem temelli bilgiye, deneysel temelli bilgiye göre daha az yer verilmiştir. Bu nedenle, bu çalışmanın amacı bilim eğitiminde gözlemin gücünü geliştirmek için gözlem stratejileri kullanmak ve öğretmen adaylarının gözlem süreç becerilerini geliştirmektir. Nitel veriler, ardışık iki farklı etkinlik sürecinde toplanmıştır. Çalışma, sorgulama temelli bilimsel gözlem yapma, öğrencilere (n:33) sorunun oluşturulmasıyla başlayan ve ardından kanıtların toplanması, organizasyonu ve açıklama önerileri ile devam eden bilimsel sorgulama süreçlerinin takibini sağlar. Çalışma sonucunda öğrencilerin nesnenin algılanabilir niteliklerine göre birden çok duyu organını kullanmaya eğilimli oldukları gözlemlenmiştir. Diğer taraftan sorgulama temelli yürütülen gözlem süreçlerinin, gözlemi belli alanlara yoğunlaştırdığı gibi daha detaylı, sistemli ve zengin verilerin elde edilmesini sağlamıştır.*

Anahtar Kelimeler: *gözlem, bilimsel sorgulama, duyular ile gözlem, sınıf içi ve sınıf dışı etkinlikler*

INTRODUCTION

Since Descartes, the core of the scientific method has been based on the synthesis of data from sensorial experiences (obtained by observation and experiment) and an intuitional and deductional (obtained by intelligence and thought) approach (Cushing, 2000). Millar (1990) described that within this approach, observation is one of the processes that cannot be excluded from science. Haury (2002) indicated that, even though observations can be unreliable because of limited human senses, it remains at the heart of science, and is the final arbiter in constructing and testing ideas. For Haury, observation in science is more than seeing; it refers to skills associated with collecting data using all the senses, as well as instruments that extend beyond

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the reach of our senses, and it is influenced by the assumptions and theoretical knowledge of the observer. Malcolm (1987) summarized it in the following way: "Observation and direct experience are crucial in concept development and challenging existing beliefs and understanding" (p.72).

Consequently, observation is not simply the activity of 'looking at' an image and recording it like a photograph being reproduced by a camera (Driver, 1983). Observation is used at all stages of scientific inquiry: as a stimulus for raising questions, in linking earlier experience to new encounters, in gathering information, and in finding patterns and relationships between events and objects. Accordingly, observation is transferring stimuli into knowledge by using all stages of scientific methods (Kosso, 1992).

Russell *et al*. (1993, as cited in Haslam & Gunstone, 1996) outlined the aspects of scientific observation as follow:

- Scientific observation is a part of whole investigation, not a process to be carried out in isolation.
- Scientific observation is one of the inevitable processes of scientific inquiry.
- Scientific observation is a complex activity that one cannot explain as a straightforward process.
- Scientific observation is based on the observer's perception, experiences and conceptual knowledge, which serve as a guide in the selection and interpretation of the observation made.

In their study, Haslam and Gunstone (1996), described how students saw observation as a separate process in each of the different areas of science – Physics, Chemistry, and Biology. In short, they did not see the process of observation as being particularly relevant to the science learning process. The study also showed that no students used the word "inferences"; words that were volunteered included "guesses", "knowledge", "facts", "acknowledge" and "thoughts". What the authors conclude is that there is a need to teach students about inference and its relationship with scientific observation. However, it is not only students, but also the teachers involved in this study who have an inadequate understanding about scientific observation. In their further study about teachers' views on observation, Haslam and Gunstone (1998) observed that, even though teachers saw the importance of "student self questioning" during experiments, they did not show any desire to encourage self-questioning during observation. Moreover, teachers did not see the difference between looking and observation.

The Importance of Theoretical Background in Observation

The theoretical background or the previous knowledge of learners' influences their observations. In other words, existing cognitive knowledge and beliefs held by an observing student influence both the nature and interpretation of their observation (e.g., Martin, 1972; Driver & Bell, 1986; Chalmers, 1987; Appleton, 1990; Haslam & Gunstone, 1996, 1998). Smith and Reiser (2005) stated that scientists' observations are directed by their domain specific knowledge. Therefore, they concluded that students require some familiarity with the domains that they are working in and the types of questions that drive observations in those domains.

Several classroom instructions concerning observation were created by establishing a reference point based on the learners' theoretical background (e.g., Checkovich & Sterling, 2001; Gostev & Weiss, 2007; Linnell, 2007). The instructions were intended to encourage learners to think about what they are observing and were compared with the commonalities and differences of the observed objects. Differently, Topinka and Sands (2005) tried to develop the habit of skillful observation as a way to enhance students' understanding of science. The researchers used sketching as an observational tool since it required many sequential observations of the same objects. The authors used sketching not only to enhance observation, but also to develop the questioning mindset that is a part of scientific inquiry.

Relationship between Observation and Scientific Inquiry Processes

Observation is a form of inquiry in scientific discipline that is for building and generalizing explanations and theories when experimental methods of controlling and manipulating variables are difficult (Smith & Reiser, 2005). Examples are the observational techniques used for examining animals in the wild, or those for observing the universe to understand how things like planetary behavior fit or deviate from existing theories and models. In their classroom-based study, the authors encouraged students to understand observation as a scientific method that can be used to generate new hypotheses and articulate existing theories to develop comprehensive understandings of scientific practice.

Following scientific methods in observation is essential if students are to acquire complex thought processes in order to correct their misconceptions (Park & Kim, 1998). Because students are not passive devices that directly record all the information in classroom activities, activities that only included demonstration and passive observation cause students to neglect, distort, or reject the observed results. Students are active subjects, who select, organize and interpret information based on their own prior knowledge and expectations. Similarly, Tomkins and Tunnicliffe (2001) described how the drawing of biological specimens is not an observation that leads to creative thinking about either the organism or indeed its biology.

Bachelard (1938) notes that scientific activities always start with asking questions, and continue with observation. In short, he stated that, "for a scientific mind, knowledge is always an answer to a question" (p.287), while Popper (1972) asserted that science begins with a problem; both philosophers stated that this is the origin of investigation. Driver (1983) observed that students cannot do scientific observations unless they are provided with clear initial questions to guide their investigation. Therefore, developing the process skill of observing will enable learners to seek consciously for information that will extend their ideas.

Macdonald (1977, as cited in Gunstone, Loughran, Berry, & Mulhall, 1996) defined 'inquiry' as the "search for knowledge, investigation, a question" (p. 677). Gunstone *et al.* (1996) then described 'inquiry learning' as "…learning/teaching approaches that are consistent with students 'searching' for knowledge, 'investigation' … and 'questioning'…" (p. 3). Even though 'question' and 'questioning' are inevitable parts of scientific methods, the earlier studies did not give enough importance to starting observation by formulating research questions as much as is emphasized in experimental studies.

A summary of the findings from the review of articles on observation is presented in Table 1. The first column refers to the outcomes of the articles, and the second column refers to the authors.

Table 1. Summary of Previous Studies on Observation.

Research themes	Reference
Importance of observation in science and in science education	Haury, 2002; Malcolm 1987; Millar,1990
Importance of all the senses in observation	Driver, 1983
Relationship between observation and scientific inquiry processes	Bachelard, 1938; Park & Kim, 1998; Popper,1972; Russell, Black, Bell & Daniels, 1993
Students' and teachers' perceptions of observation	Haslam & Gunstone, 1996, 1998
Previous knowledge in observation	Appleton, 1990; Chalmers, 1987; Driver & Bell, 1986; Haslam & Gunstone, 1996, 1998; Martin, 1972; Smith and Reiser, 2005.
Classroom-based studies on observation	Checkovich & Sterling, 2001; Gostev & Weiss, 2007; Linnell, 2007; Smith & Reiser, 2005; Tomkins and Tunnicliffe, 2001; Topinka and Sands (2005)

The Purpose and Significance of the Study

Despite the importance of observation for knowledge building, it has received less attention than experimental forms of inquiry in science education, especially in helping students learn the goals and strategies of observation in classroom science. The authors will not spend time, here, making the case for the importance of observation. What they are more concerned with is examining and developing methods for observation, which has been somewhat neglected in science education. Even though there is a widespread acceptance of the importance of observation in every level of education, little is known about the following aspects:

- How students perceive the nature and value of observation in their science learning.
- What educators can do to promote effective observation in their science classes.
- How observation is seen to be conducted in science.
- How learners' process skills of observation can be developed.

In science classes, teachers can teach their students the meaning of 'observation', but that does not mean students learn how to 'do observation'. Previous studies have described the problems and the participants' views of observation and the importance of observation. However, studies on the process skills of observation and how to construct an observation activity in science classrooms are limited. Above all, even though the previous studies described observation as a part of scientific inquiry processes in science education, the application and the learning environment for facilitating student-direct observation was neglected.

The teachers' role in developing learners' process skills of observation is to provide opportunities for using the different aspects of observation, often through discussion or through providing problems whose solutions require a wide range of observations to be made and brought together. What this means is that observation is a complex activity; teachers of science should know how to make observations, how to apply them at all grade levels and, finally, in the role of guide, how to monitor and evaluate their students. Therefore, the aims of this study were to create observation strategies for developing the power of observation in science education and to develop student teachers' process skill of observation.

METHOD

Participants

The study was conducted at a four-year public university located in the Mediterranean region of Turkey with thirty three student teachers (n=33) enrolled in the department of Science Education in Primary School Teaching. The students were admitted to the college based on their scores on the nationwide, centralized university entrance exam and their preferences. Generally coming from middle class working families, students come to the college from different parts of the nation. Students of this department had already completed the basic physics, chemistry, biology and educational courses before the study was conducted.

Strategies for Data Collection

The data were collected sequentially using two different activity steps. Both steps proposed different strategies for developing the power of observation.

Data collection strategy for activity step 1

First, researchers instructed students in understanding observation made empirically (through the use of our senses). After emphasizing that "good" observations are detailed and involve the use of our senses (sight, touch, taste, hearing, smell), the materials to be observed (see Figure 1) and the observation sheets were given to each student.

Figure 1: The materials to be observed.

The materials to be observed were everyday items, including vegetables such as a cauliflower, fruit such as a lemon, a flower such as a daisy, and plants such as *rosaceae*, pine cone, *euphorbia helioscopia*, and *pistacia lentiscus*. Even though many students were familiar with the vegetables, fruit and flowers, they were not familiar with some of the herbs. However, unfamiliarity was not the point here, because the main goal was to investigate whether students would note the fragmental structure (that is, the fragmented geometric shape of the materials that can be subdivided into parts, each of which is (at least approximately) a reduced-size copy of the whole). Additional goals for the first step were to encourage students to use their senses actively and to support them in evaluating what they observed.

The observation sheet was developed by the authors. The sheet consisted of four requirements: writing about and drawing the main properties of the materials, a comparison of the similarities and differences of the materials, the iterative properties of the materials and, finally, the particular properties of the materials.

As a result, the first step of the study was framed by the following research questions:

1- Which senses do student teachers use during the observation activity?
2- What do student teachers know about comparison?
3- What do student teachers tend to observe?
4- Do student teachers notice any patterns in observation?

Data collection strategy for activity step 2

The second step of the study was framed around assessing the relationship between observation and scientific inquiry processes. Students were asked to make field observation. The observation sheets, developed by the authors, consisted of four main parts: preparation, process I, process II, and interpretation. During the preparation part, students were asked to decide their research question(s) and to limit their observation domain. Then, students were asked to make quantitative and qualitative observations during processes one and two, respectively. Finally, students were asked to write their inferences. Each part of the observation sheet included sub-questions.

In both steps, students were given whatever materials they needed for their observation such as a camera, lenses, or measurement apparatus, and they were asked to record as many details as possible about their observation domain. During this time, the role of the authors was to guide, facilitate, and continually assess student work. Students had approximately one hour for observations.

In this study, the authors were also attempting to gather more comprehensive data. Thus, in addition to the observation sheets, the authors interviewed with the students and recorded them at the beginning, during and after the activity. The qualitative data (in the form of paper and pencil output and transcripts of recordings) was analyzed using an iterative process of open coding (Strauss & Corbin, 1998). Iterative process of open coding is the process of identifying, naming and categorizing the essential ideas found in the data. Two researchers constructed the coding schemes of the qualitative data to establish the reliability.

RESULTS AND DISCUSSION

Since the data obtained in this study were rich and extensive, the authors only give some of the most significant findings for each step and give examples from data to support the findings.

Results and Discussion for Activity Step 1

Which senses do student teachers use during the observation activity?

Figure 2 indicates the senses student teachers used during the observation. The figure shows the plants names on the horizontal axes and the percentage of the students in terms of which senses they use on the vertical axis.

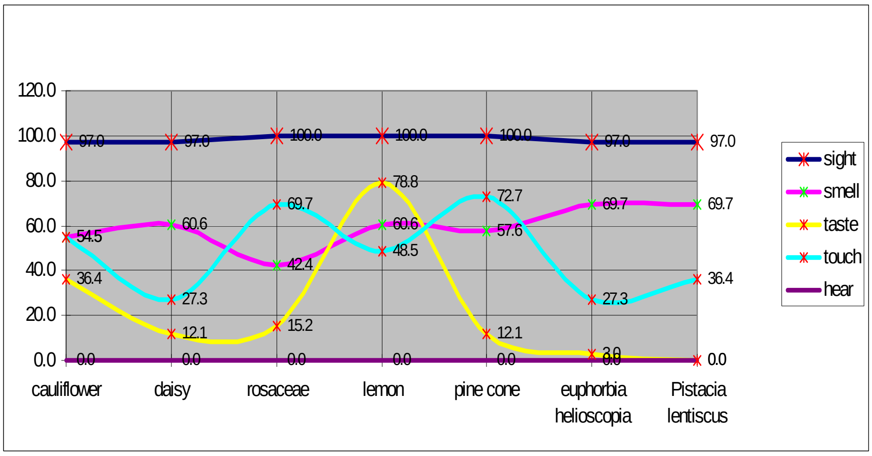

Figure 2. The results of senses student teachers used during the observation.

Students tended to use all their senses during the observation except the sense of hearing (because they did not need it in this activity). Even though that would seem to be a limitation of the study, the authors recorded that the students did use the sense of hearing during the field observation (second step). The dominant characteristics of the plants were determinative during the observation (for example, the pleasant smell of the daisies, or the unpleasant smell of the *euphorbia helioscopia*), and a majority of students (60.6% and 69.7%, respectively) paid attention to this olfactory sense. However, ‘sight’ was always the primary sense during the observations.

What do student teachers know about comparison?

Students made comparisons during the activity step 1 in three ways: one with the others, matching one by one, and holistic comparison. Students who had limited knowledge about the observed plant tended to compare plants one with another. For instance, student 31 compared the similarities of the plants by giving numbers to unknown plants and compared all of these with the daisy.

…Daisy and the plant 5 both have flowers and their stems are green and thin… And also both flowers seeds are visible…

Student 1 compared the similarities and the differences of the plants in terms of matching coding. For instance, the student wrote:

…The cauliflower and the daisy both have fresh smell…

…Lemon’s taste was sour whereas cauliflower was sweet.

Student 2 observed the plants as a whole. The authors coded these kind of phrases under the concept “holistic”. For example, one student wrote the following:

...All the plants that I am observing now grown up on the ground...

Figure 3 and Figure 4 shows students' comparison of plants in terms of their similarities and differences, respectively. More than half of the students (52%) compared the similarities of the materials in terms of one by one matching, whereas approximately a quarter of the students (23%) observed by making a comparison of the differences. The students tended to observe the differences of the materials by comparing them one with the others (47%). In both comparisons, less than half of the students paid attention to all the plants.

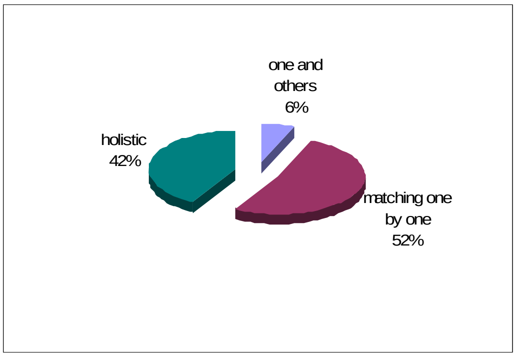

Figure 3. Comparison of the similarities.

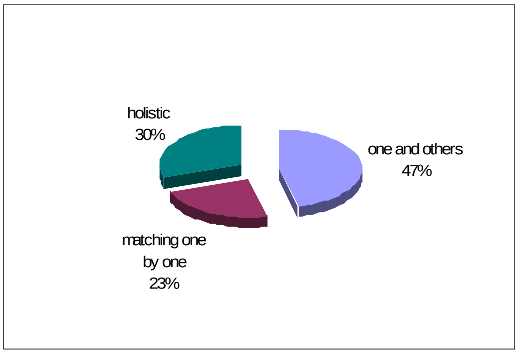

Figure 4. Comparison of the differences.

What do student teachers tend to observe?

The last two questions on the observation sheet for the first step included questions as to whether the plants have any specific properties and whether the students could determine any patterns between the plants.

For the first question, the majority of students' (83%) observations were based on their previous knowledge. In short, they observe what they know. For instance, student 30 wrote that,

...Lemon is a plant with white flower. It taste sour and some grow up every season...

Even though the student could not actually observe the white flower or the crop season of the lemon, s/he made note of it. Figure 5 illustrated the results.

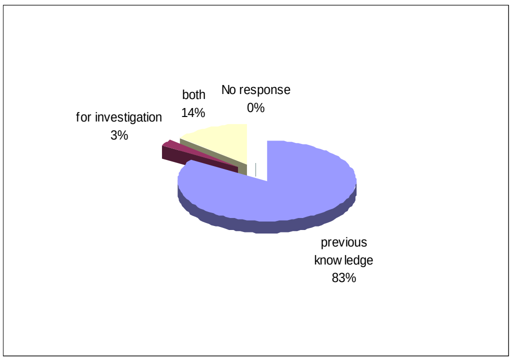

Figure 5. What students' observations were based on while observing the specific properties of the plants.

Do student teachers notice any patterns in observation?

For the last question, the authors asked a more specific question. The question was whether there is a pattern between the plants. Thus, students observed in order to find the pattern. However, half of the students (51%) still examined the plants based on their previous knowledge. Again, they could only observe what they know. For instance, student 26 wrote that,

The small pieces that formed pine cone shaped the whole. The petal of the daisy formed the whole. The small pieces of cauliflower formed the whole…

Since the student did not know about fractal structure, s/he could not observe the patterns in the cauliflower, daisy, pine cone and rosaceae; the student did not observe for investigation. On the other hand, 37% of students were able to find the patterns even though they had no prior knowledge of the concept of fractal structure. For instance, student 24 wrote that,

If you picked a small piece of cauliflower, it is the same as the whole.

Only 9% of students answered the question in both ways. They observed not only based on their previous knowledge, but also based on investigation. Figure 6 illustrates the results.

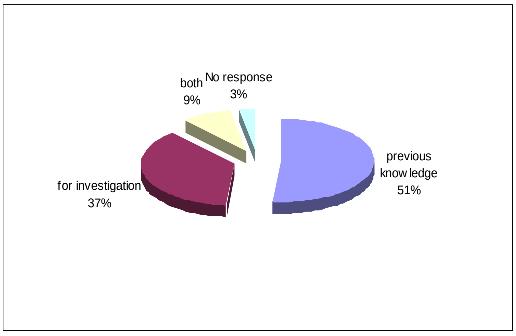

Figure 6. What students' observations were based on while observing the patterns of plants.

The outcomes and discussion of the activity step 1

The outcomes of the activity step 1 are summarized below:

1- The observations were based on students' previous knowledge.
2- The observations were descriptive.
3- Students tended to use all their senses during the observation but the sense of sight was always the primary sense.
4- Students were likely to observe what they already knew. They did not pay attention to the patterns between the materials. The students were not observing for investigation.
5- Students tended to observe the similarities of materials by matching them one by one and tended to observe the differences by comparison one with the others.

Even though studies stated that students tended to use only the sense of sight while observing (e.g., Checkovich & Sterling, 2001; Gostev & Weiss, 2007), the present study showed that student teachers tended to use all their senses. However, they made their interpretations in terms of senses that had a preference for the characteristic of the objects. The result is consistent with Tomkins and Tunnicliffe (2001) study showing that, when the students in that study are challenged with a specific observation task with a novel animal to study, they will notice, without guidance, the salient features of that animal's anatomy and behavior.

Results and Discussion for Activity Step 2

Analysis of student teachers research questions during observation

The second activity step was framed around assessing the relationship between observation and scientific inquiry processes. The authors analyzed the observation sheets by looking at the relationship between students' research questions and their results.

Even though students had difficulties in formulating research questions, they all tried to define one. The problems with the research questions were:

1- Some were not limited.
2- Some were not defined.
3- Some were impossible to find an answer to at a certain time.
4- Some were simply questions, not research questions.

Examples for the above statements are presented below, pointing out the consistency between the students' research questions and the results of their observations.

Student 6's research question: *Why flowering plants' structures and number of their flowers are different?*

Result: *I have observed that stamen in plants with multiple flowers were adapted in terms of leaving the pollens on stigma while those pollens were moving by wind in plants with single flowers (con-poppy)… The number of flower might be a factor caused by pollination.*

Student 6's data is an example of an undefined and unrestricted research question. The observation included some conjectures without data. On the other hand, student 25's data could be an example of a good research question:

Student 25's research question: *How do antirrhinums pollinate even though their petals cover the stamen and pistil?*

Result: *I observed it! …My research question was in terms of the observation that I am doing right now. Antirrhinum's petals cover its stamen and pistil. Therefore, it does not pollinate by wind. The pollination happens when the insect go into the flower to have its nectar. But I have to do more observation to prove it.*

Student 25 limited the research question to one task and focused on finding an answer. Even though not all the statements made were true, there was a consistency between the research question and the results. Conversely, student 18's research question was good, but the result was not related to the research question:

Student 18's research question: *In selected area how many different tree are there and how their leaves different from each other? Can there be a reason for that?*

Result: *If the tree species are different, then the leaves are different.*

Student 18 wrote a conclusion without observing either the number of tree species or their leaves. Although the research question was good, some problems were detected in the procedure used. In contrast again, student 9's data was a good example for both the research question and the result:

Student 9's research question: *Why some pine cones' scale clasped together and some are separated?* (see Figure 7).

Figure 7. Pine cone closed and open

Result: **…***Even though I could not reach the exact result such a short time, I am sure intact pine cone is the primary phase of separated one. Wind, heat, or irrigation are some independent variables that I could not control during my observation…*

The student organized a well-defined research question. With the help of the observation sheet, s/he followed the scientific thinking processes and reached scientific outcomes.

Finally, the authors looked at whether the student with an undefined research question reached a scientific conclusion. The authors found no evidence for this. In the examples below, the students do not know the differences between a question and a research question, nor what a scientific result is:

Student 3's research question: *What insects (any kind of insect) do?*

Result: **…***In fact I could not find an answer…*

Student 14's research question: *What does an ant do during a day and what kind of difficulties they encounter?*

Result: *Ants tried to find food and stay alive whole their life…In short the only thing ants do is working and working…*

Both students tried to observe the insects, but they could not formulate the research question. Consequently, they could not follow their observation sheet and could not find any answer.

However, a student with a well-structured research question about insects reached a scientific result and some sub-questions based on the observations made:

Student 30's research question: *Ants line up in a certain path. If a similar path forms, do they change their direction into that route?*

Result: *…I formed a similar path and a burrow by the end of path…Some time later, a number of ants changes their route into the new one and even some of them reached the burrow…I should continue my observation whether all the ants will change their route. Then I should* *observe the ants changed their route will back into their old path. By the end of those observations, I could only reach the answers of my research question…*

Students' observations were not only about living things, but also about phenomena, as in the following example:

Student 9's research question: *How could be the sun rays' coming angles measured with a stick that stands on a plane?*

The overall results showed that research questions enable students to carry out systematic observation. However, even though well structured research questions helped students reach scientific conclusions, some students could not achieve the same success as others because of their lack of knowledge about scientific methods. However, the data also showed that students' with poor research question could not reach any results.

What made students to choose particular research question

One of the sub-questions on the observation sheet was, "what made you choose that particular research question?" Figure 8 categorizes the results from most to least. The choices are presented on the horizontal axes, and the percentages of the students are indicated on the vertical axis. Nearly half of the students (44.19%) wrote that the reason they chose their particular research question was their curiosity.

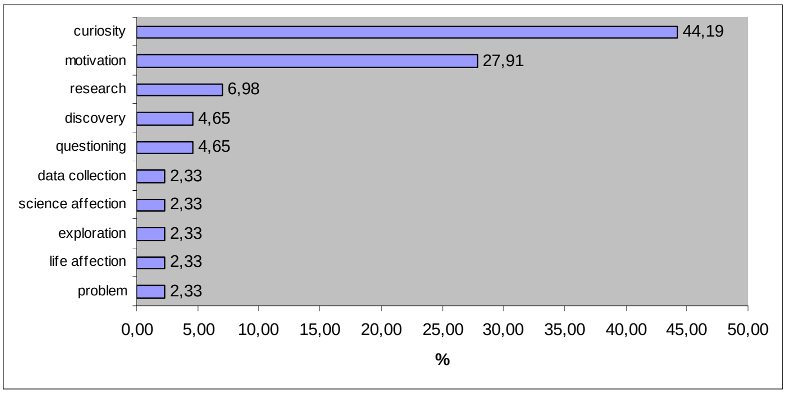

Figure 8. What makes students choose their research question?

Comparison the relationships between the student teachers' research questions and their results

The last question on the observation sheet concerned whether or not the student had found an answer to the research question. The aim was to compare the relationships between the research question and the result. Moreover, students had opportunities to self-test themselves. Even though 64% of the students wrote that they found an answer for their research question, the data analyses showed that only 34% of students' research questions and their results were complementary. The results from both students' perspective and the researchers' perspective are represented in Figures 9 and 10, respectively.

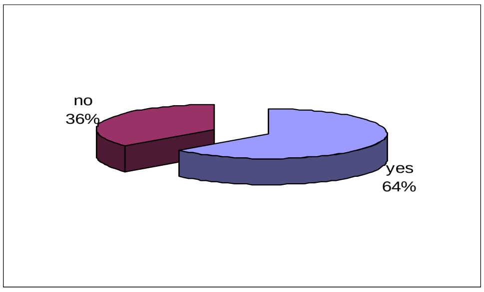

Figure 9. Student perspective

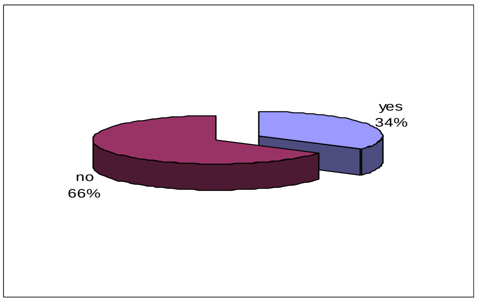

Figure 10. Researcher perspective

The outcomes and discussion of the activity step 2

The results of the study suggest that following the process of using inquiry skills during the observation leads students to reach scientific conclusions. Even though not every well-structured research question enabled students to reach a scientific conclusion, the data suggest that students were cognizant of the importance of following the scientific inquiry process during the observation. Furthermore, Park and Kim (1998) showed that differences in inquiry skills caused difference in the students' responses in that students who had done simple observation had difficulties in correcting their misconceptions compared with those students utilizing more complex forms of the observation process.

CONCLUSION AND FURTHER IMPLICATIONS

The study sought to understand student teachers' approach to the task of observing during science classes when conducting investigations that involve scientific observation and inference. The main goal of the study was to show students that observation is a method of inquiry that provides data for investigation. The results of the study showed that making a scientific observation enabled students to learn about gathering evidence, organizing their ideas, and about proposing explanations about the world around them. By challenging the students to use their five senses to make detailed observations, researchers were encouraging students to collect and organize information about natural phenomena that they naturally find compelling.

Enabling children to touch in science at early ages can only be achieved by reducing science to the level of the perceptional and sensational world. The interactions between the sense organs and the attributes of objects bring us data from the external world that are processed under the control of our mental activities and placed in our consciousness. Observations not only connect us to the world that we live in, but they also open doors for scientific methods. Thus, scientific observation in science education is as crucial as are experimental methods. Learning observation under the guidance of systematic teacher is essential not only for gaining scientific thinking processes, but also for the quality of learning outcomes.

The authors stated that, if one approaches the observation from scientific perspectives with processes that originate with a research question and hypothesis, the notion that observations hold biases diminishes in value. Giving only simple tools like thermometers, rulers, camera or magnifiers to the students is insufficient for designing and conducting observation that involve the use of equipment. Strategies for guiding students and teaching the procedures of scientific processes should also be included in the activity. The observation sheets were one of the significant tools for giving guidance. Even though there was no teaching done, scientific observation with guidance sheets encouraged students to think about nature, build up research questions, and to reflect based on the evidence. In short, the observation sheets acted as a reflective and interpretative discussion tool for students themselves.

Observation is the cornerstone of the inquiry process. It is a significant tool for investigation. If educators or researchers persuade teachers to understand the primacy of observation in science education, their students might directly benefit from this. Therefore, scientific observation for participants would be a step not only for true understanding of the world we are living in, but also for starting to do science. Human beings who tend to reach external world with synergy of sensation and processed mental data will not only analyze nature better, but also find answers to their problems more easily.

The number of participants might be considered as a limitation for the study. However, the study was designed to create observation methods and to develop the student teachers' process skill of observation rather than generalizing it. Overall, the study provided promising insight and evidence for the proposition that inquiry-based science teaching depends partly on the quality of observation. The evidence showed that only teachers who encourage their students to follow scientific methods could succeed in this. Moreover, providing opportunities and invitations to observe, asking appropriate questions to focus observations, and discussing what students observe are some other methods that teachers can follow in order to improve the quality of observation.

The results of this study raise two issues for further exploration. First, the need to conduct the study with a larger group of participants and with different age groups and, second, the requirement to apply and create observation strategies for different subject matters and concepts. All these variables remain for future studies. In short, the further goal is to establish a culture of knowledge building around observational investigations in classrooms.

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