Biology student teachers' ideas about purpose of laboratory work

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Contents

Abstract

The aim of this study is to investigate biology student teachers' ideas about the purpose of laboratory work in teaching biology. Data has been collected from 82 participating students using an open-ended questionnaire and analyzed using content analysis techniques. The results show that almost all of the student teachers considered laboratory work an integral part of teaching biology. However, participating students focused on the verification of theoretical knowledge and laboratory techniques as the main purpose of laboratory work. Furthermore, most of the participating students ignored the purposes relating to scientific process skills and the nature of science. These results are compared with related literature and recommendations are provided.

Keywords: Laboratory work, biology teaching, student teachers

Introduction

To date, many studies have been conducted on the importance of laboratory work while teaching science. Currently, science educators and teachers agree that laboratory work is indispensable to the understanding of science (Cardak et al., 2007; Ottander & Grelsson, 2006; Tan, 2008). The role of laboratory work in science education has been detailed by some researchers (Lazarowitz & Tamir, 1994; Lunetta, 1998). The main purpose of laboratory work in science education is to provide students with conceptual and theoretical knowledge to help them learn scientific concepts, and through scientific methods, to understand the nature of science. Laboratory work also gives the students the opportunity to experience science by using scientific research procedures. In order to achieve meaningful learning, scientific theories and their application methods should be experienced by students. Moreover, laboratory work should encourage the development of analytical and critical thinking skills and encorage interest in science (Ottander & Grelsson, 2006).

There are concerns about the effectiveness of laboratory work in helping the students understand the various aspects of scientific investigation (Lazarowitz & Tamir, 1994; Schwartz et al., 2004). Teachers usually want to develop students higher order thinking skills, like critical thinking, through laboratory work; but to what extent they can achieve this is controversial (Bol & Strage, 1996; Ottander & Grelsson, 2006). Therefore, it is important to analyze the purposes related to laboratory work, as the purposes need to be well understood and defined by teachers and students alike for the practical work in the laboratory to be effective.

In spite of efforts to better define the purposes and role of laboratory work in science education, research has shown that teachers see laboratory activities as contrived (Tan, 2008; Tobin, 1986). In general, teachers cannot see laboratory activities as conceptually integrated with theoretical science lessons. In addition, teachers fail to understand that laboratory activities may provide opportunities for students to produce new knowledge through scientific investigations. According to a research conducted by Kang and Wallace (2005), teachers perceive laboratory work solely as an activity for the purpose of verification. Researchers have also uncovered that teachers do not think of the laboratory as an environment where scientific knowledge claims are discussed.

Different reasons have been shown for the problems relating to laboratory work (Tan, 2008). According to Bencze and Hodson (1999), problems in laboratory work arise when students blindly follow the instructions of the teachers. Some researchers, on the other hand, claim that the laboratory, instead of being a place for science and experiments, has become a place where tasks set by the teacher are carried out. No attention is given to the methods or purposes during laboratory work, only the set tasks are carried out (Hart et al., 2000; Jimenez-Aleixandre et al., 2000). Wilkinson and Ward (1997a; b) have connected the problems with laboratory work to a poor evaluation of the purposes of the tasks undertaken in the laboratory.

The multiple purposes of laboratory work has been the subject of discussion worldwide for many years. Multiple lists of these purposes have been prepared for different levels of education. Many of these lists focus on carrying out experiments through scientific methods and technical skills. While some strongly emphasize effective objectives, others have dwelled on other purposes (Johnstone & Al-Shuaili, 2001; Reid & Shah, 2007). When university biology laboratories are considered, the general purposes of laboratory work may be:

- Supporting or strengthening theoretical knowledge,
- Experiencing the pleasure of discovery and development of their psycho-motor skills,
- Teaching how scientific knowledge may be used in daily life,
- Increasing creative thinking skills,
- Gains in scientific working methods and higher order thinking skills,
- Developing communication skills,
- Developing manual dexterity by using tools and equipment;
- and allowing students to apply skills instead of memorizing (Bayraktar et al., 2006).

There are many factors affecting the attainment of the above targets. These factors are: the attitudes of the teacher and the students towards the laboratory, student communications, laboratory manuals and the approaches used in laboratory instructions. Many studies have shown that teachers are not aware that the different practical activities in the laboratory have different objectives (Nott & Wellington, 1997; Wilkinson & Ward, 1997a). The teachers agree that carrying out a traditional laboratory work is a good thing without fully considering what the real purpose of the practical activity (Ergin et al., 2005).

Hirvonen and Viiri (2002) have reported that as a result of learning practical skills and scientific learning methods, students experience an increase in motivation and teachers gain the opportunity to evaluate the knowledge of their students. When this occurs, the theory-practice connection in student teachers was measured at the highest level. In addition, the researchers suggested that the nature of science and scientific knowledge requires a different approach to learning. Although it offers a biased view of the nature of science, laboratory work gives the impression that research is the core domain of science.

Sahin-Pekmez et al. (2005) examined science teachers' thinking on the nature and purpose of practical work in the context of the National Curriculum for Science in England. Data was collected through individual interviews with science teachers about their classroom practice. The findings suggest that little attention is being given to procedural understanding in terms of ideas relating to the quality of data. It is argued that this is a key limiting factor in the development of pupils' ability to engage in genuine investigative work.

Ottander and Grelsson (2006) investigated the ideas of biology teachers on the role of laboratory work. According to the results of this study, teachers agree that laboratory work is an important part of biology and science lessons. However, teachers focus on the most common purposes of laboratory work, such as building the connection between theory and practice and increasing motivation. Furthermore, teachers do not consider the purposes of laboratory work as being concerned with scientific process skills. Moreover, the interpretation of the learning outcomes of experimental activities differs between students and teachers.

The importance of laboratory work in science education is well known. However, there is a lack of clarity regarding the purposes of laboratory work and the perceptions and experiences of the students do not conform to known purposes (Reid & Shah, 2007). It is important that biology student teachers ideas about the purposes of laboratory work is understood in order for the expected outcomes to be acquired from laboratory work and for the proper planning of lessons.

Purpose

The aim of this study is to investigate biology student teachers' ideas about the purpose of laboratory work in teaching biology. This study focuses on the following questions: What purpose do biology student teachers ascribe to laboratory work? What categories can be derived from these purposes in terms of common features?

Methodology

Participants

A total of 82 biology students from the Ahmet Kelesoglu Education Faculty of Selcuk University in Turkey, who were studying to become secondary school biology teachers, participated in this study. The average age of the students was 22.1 years old (range 19–26). The majority of the students were female (53 of 82). However, this study did not focus on gender differences. The participants are graduate students who have carried out the application of many theoretical biology lessons in the laboratory. The study was conducted in October 2009.

Data Collection

In order to establish the ideas of the student teachers regarding the purposes of laboratory work in biology teaching, each individual was asked to respond to the following open-ended question: "Each day, the importance of laboratory work in secondary school biology teaching is understood better. However, whether teachers understand the importance and purposes of laboratory work is a subject for discussion. In your opinion, what are the purposes of laboratory work in biology teaching? Please explain." The participants were given approximately 15 minutes to write down the purposes of laboratory work. As the intent was to understand the first purposes to come to the minds of the student teachers, this timeframe was considered sufficient. The open-ended question above is the basic data source for this study.

Data Analysis

During the first stage, the 82 student teachers were asked to write down the purposes of laboratory work. However, only 79 of these participants wrote down valid purposes. The responses of the remaining three participants were not included, because these participants focused on the general purposes of biology teaching rather than the purposes of laboratory work. Therefore, data analysis was done on the 79 papers. The analysis and interpretation of the answers given by the student teachers to the open-ended question were conducted in four stages. First, the written responses were read in detail to establish the general level, and it was seen that there was a very wide spectrum of purposes for laboratory work. Second, the "content analysis technique" (Yildirim & Simsek, 2005) was used to separate each purpose into its components and analyzed for similarities or common factors with other purposes. The purposes defined by the student biology teachers were investigated, and the 79 papers were culled. Based on the written responses of the student biology teachers, the main purpose categories for laboratory work were established. Third, each purpose was placed in an appropriate category. Lastly, the number of participants (n) and the percentage (%) representing each of the 12 main categories made up of 235 purposes were calculated. Many studies have shown this type of data analysis technique provides reliable results (Hirvonen & Viiri, 2002; Sahin-Pekmez et al., 2005)

Results

All of the student biology teachers have defined more than one purpose for laboratory work in biology teaching. As a result of the analysis of the written responses, a total of 235 valid purposes were identified. Each has been further examined independently by the researcher and two lecturers in biology education, with an original agreement of 227 for the 235 purposes. The remaining 8 purposes were agreed upon during following consensus discussions. Nearly all participants have noted that laboratory work in biology teaching is beneficial and necessary. The purposes ascribed to laboratory work by the participants vary. These purposes have been gathered under 12 main categories. The distribution of these purposes according to categories is shown in Table 1. It should be noted that the responses of many participants fell into more than one category.

Table 1. Biology student teachers' responses relating to the purpose of laboratory work

	Category	n	%
1	Purposes related to verifying facts and principles already taught	51	64.6
2	Purposes related to laboratory techniques	43	54.4
3	Purposes related to meaningful learning	36	45.6
4	Purposes related to concrete abstract concepts	27	34.2
5	Purposes related to motivation	22	27.8

6	Purposes related to scientific process skills	15	18.1
7	Purposes related to problem solving skills	10	12.7
8	Purposes related to establishing a connection between science and daily life	10	12.7
9	Purposes related to understanding the nature of science	8	10.1
10	Purposes related to developing positive attitudes towards science and scientists	7	8.9
11	Purposes related to critical thinking skills	4	5.1
12	Purposes related to science, technology and society (STS)	2	2.5

According to the results, the first category encompasses purposes related to verifying theories and principles already known (64.6% of responses). In this category, participating students have mentioned the purpose of laboratory work as verifying theoretical knowledge taught in biology classes in the laboratory environment. For example, "The primary purpose of laboratory work is to strengthen theoretical knowledge. The students prove and try out the theoretical knowledge they obtain in the classroom, in the laboratory environment" (Student 12).

The second category covers purposes related to laboratory techniques (54.4% of responses). In this category, participating students have mentioned purposes related to the recognition and use of laboratory equipment such as the microscope and pH meter. For example, "Laboratory work enables students to recognize the tools and equipment they will use in experiments, learn what purpose [they serve] and how to use them. A student who doesn't know how to use tools, such as the pH meter and microscope, cannot run most of the biological experiments. Therefore, laboratory tools and equipment need to be introduced to the students. For example, students learn the dissection process in the laboratory " (Student 3).

The third category involves purposes related to meaningful learning (45.6% of responses). In this category, participating students have mentioned the role of laboratory work in meaningful learning. For example, "One of the most important methods we can use for meaningful learning is laboratory work. Students gain new knowledge during laboratory work, and they associate this new knowledge with knowledge they have learned before. Laboratory work aids students in acquiring application skills instead of memorizing" (Student 72).

The fourth category includes purposes related to concretization (34.2% of responses). In this category, participating students have pointed out that laboratory work plays an important role in concretizing abstract concepts. For example: "Biology lessons comprise many abstract concepts such as enzymes, DNA, chromosomes. . . These concepts are concretized in laboratory work. Students experience these abstract concepts in the laboratory environment." (Student 54).

In the fifth category, the participating students are focused on the purposes of laboratory work related to motivation (27.8% of responses). For example: "Laboratory work helps to motivate students in a new subject. One of the most important factors affecting learning is motivation. An interesting laboratory work applied before starting a new subject will motivate the students in that subject, because students usually enjoy experimenting in the laboratory" (Student 35).

The sixth category covers purposes related to scientific process skills (18.1% of responses). In this category, participating students are focused on scientific process skills such as experimenting, establishing hypotheses and communicating. For example: "During laboratory work students learn both how to run experiments and how to function as a team and work in collaboration. Students share the work and the information during an experiment and learn how to work together" (Student 18).

The seventh category covers purposes relating to problem-solving skills. In this category, the participating students have focused on the solution of a scientific problem regarding the purposes of laboratory work (12.7% of responses). For example: "Practical work provides students with the skill to solve a scientific problem they encounter. To this end, open-ended experiments must be designed in the laboratory. During these experiments, students learn by doing and experiencing " (Student 59).

In the eighth category, participating students have emphasized the necessity of laboratory work in creating associations between scientific knowledge and daily life (12.7% of responses). For example: "Students establish associations between scientific knowledge and daily life through experiments conducted in the laboratory. Thus, they learn to use scientific knowledge in daily life" (Student 42).

The ninth category covers purposes related to the nature of science (10.1% of responses). For example: "In my opinion, laboratory work may provide students with the idea that known theories and models may change through time. Furthermore, through laboratory work the students will realize that scientific knowledge can be tried out" (Student 30).

The tenth category involves purposes related to developing a positive attitude towards science and scientists (8.9% of responses). For example: "Laboratory work causes students to admire scientists and what they do. Through practical activities students may develop positive attitudes towards science" (Student 44).

The eleventh category covers purposes related to critical thinking skills (5.1% of responses). For example: "Through the activities they carry out in the laboratory environment, students learn how to judge, think logically and think creatively. Particularly open-ended experiments in particular require higher level thinking skills. Such experiments develop the critical thinking skills of the students" (Student 67).

The last category covers purposes concerned with creating associations between science, technology and society (2.5% of responses). For example: "Laboratory work helps the students to establish associations between science, technology and society" (Student 23).

Discussion

The aim of this study is to establish biology student teachers ideas about the purpose of laboratory work. Nearly all the participants think that laboratory work is an important part of biology teaching. However, the analysis of the written answers shows that student teachers are generally focused on purposes relating to the verification of theoretical knowledge (64.6% of responses) and laboratory techniques (54.4% of responses). Furthermore, most of the student teachers ignore purposes related to scientific process skills. This is clearly shown by the fact that only 18.1% of the participants have mentioned purposes related to scientific process skills. These results confirm the results of previous studies on the subject (Kang & Wallace, 2005; Ottander & Grelsson, 2006). Purposes concerned with the verification of theoretical knowledge and laboratory techniques generally reflect the purposes of traditional laboratory instruction. This type of instruction is usually referred to as expository, deductive, or cook-book. This method is based on students following a recipe procedure in order to try out a pre-determined outcome in the laboratory (Cepni & Ayvaci, 2006; Domin, 2007). Although the process of scientific inquiry has been put forth as an important outcome of laboratory work (Lazarowitz & Tamir, 1994), it has been observed that student teachers do not regard this as an important goal. According to the ideas of the student teachers, the main goals of laboratory work cover purposes such as the verification of theoretical knowledge and laboratory techniques. According to most of the student teachers, the main outcome of laboratory work is the verification of theoretical knowledge and helping students carry out the experimental procedures defined in laboratory manuals. In order to eliminate these problems, it is necessary to place more emphasis on an inquiry-based laboratory approach in biology laboratory applications at the university level. According to Wyatt (2005), students acquire the necessary skills to conduct experiments, to measure practical parameters more accurately and to better evaluate the information on the experiment report through an inquiry-based laboratory approach. Research literature suggests that the primary source of failure in laboratory work is the instructional approach that shows up in higher education, namely didactic lectures and verification "cookbook" or "recipe" style laboratory experiences (Lawson et al., 2000). Inquiry-based instruction approaches are more powerful (Lord & Orkwiszewski, 2006).

The results of this study show that student teachers are not aware of the benefits of laboratory work on the students facing their own misconceptions. These results support the results of Ottander and Grelsson (2006). The scientific discussions held during the laboratory work help to define the misconceptions entertained by the students. Furthermore, laboratory work provides concrete experiences and opportunities for students to face their own misconceptions (Lazarowitz & Tamir, 1994).

Most of the student teachers ignored the relationship between laboratory work and the nature of science or developing positive attitudes towards science. As a matter of fact, it has been shown that students positive attitude towards science increases with laboratory work (Freedman, 1997). According to Kang and Wallace (2005), it is likely that teachers with naive epistemological beliefs will prefer the delivery of information as the prime teaching goal.

In order for practical work in the laboratory to be effective, the purposes need to be known well. Ottander and Grelsson (2006) have emphasized that when certain laboratory work is being planned, the goals, instructions and the assessment criteria should be considered holistically. Laboratory work at the post-graduate level must comprise scientific inquiry skills such as identifying problems, generating research questions, planning and conducting investigations, formulating and communicating (Hofstein & Lunetta, 2003).

Conclusions and implications

It is expected that students taking biology classes should be interested in science and should know the methods used by scientists in scientific research. However, many studies conducted on biology teaching since the 1980's show that no matter how the curriculum programs are changed, most of the students develop incorrect purposes regarding biology subjects and graduate with misconceptions about biological phenomena (Wandersee et al., 1994). Currently, new research is constantly being conducted to enable students to learn more efficiently. The importance of laboratory work in the learning biology and increasing students' interest in biology cannot be denied. It is for this reason that laboratory work is conducted in most university level biology classes. However, in order to reach the expected outcomes from laboratory work, a suitable laboratory instruction approach must be selected and implemented. There are many approaches related to laboratory instruction. The results of the present study show that the purposes identified by the biology student teachers reflect the traditional, deductive or cook-book approaches. Therefore, alternative approaches such as inquiry-based laboratory must be brought to the foreground. For example, Domin (2007), in addition to the traditional expository instructional method, touches on the three instruction styles in common use: discovery (guided-inquiry), inquiry (open-inquiry) and problem-based. Although these alternative styles are generally gathered under the single rule of non-traditional instruction, each one is different and places the student in a unique learning environment. Students' efforts must be given a definite direction with closed- and open-ended experiments. However, in teaching biology, studies with open-ended experiments (Bayraktar et al., 2006; Cepni & Ayvaci, 2006) are observed to be more useful, as in these experiments the carrying out of the operations, the interpretation, the gleaning of results, the presentation of factual hypotheses and generalizations are entirely up to the student. In addition, learning environments that make it necessary for students to take an active role in laboratory work and to make discoveries must be established. In such environments, the role of the teacher is not just to transfer packaged knowledge directly to the students; the teacher's role is to encourage students in problem solving. During this process, realized under the supervision of the teacher, new knowledge is discovered in the laboratory. This knowledge can later be used in other lessons as a basic concept.

Time must be set aside for discussions, both before and after the experimentations in laboratory implementations, as discussions aid in adding to incomplete knowledge and in discovering new knowledge.

References

Bayraktar, S., Erten, S. & Aydogdu, C. (2006). Fen ve teknoloji ogretiminde laboratuvarin onemi ve deneyler. M. Bahar (Ed.), *Fen ve teknoloji ogretimi (Science and Technology Instruction)* (pp. 219-248). Ankara, PegemA Yayincilik. [in Turkish].

Bencze, L. & Hodson, D. (1999). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching*, *36*(5), 521–539.

Bol, L. & Strage, A. (1996). The contradiction between teachers' instructional goals and their assessment practices in high school biology courses. *Science Education, 80*(2), 145–163.

Cardak, O., Onder, K. & Dikmenli, M. (2007). Effect of the usage of laboratory method in primary school education for the achievement of the students' learning. *Asia-Pacific Forum on Science Learning and Teaching*, *8*(2), Article 3. [Online] http://www.ied.edu.hk/apfslt/v8_issue2/cardak/.

Cepni, S. & Ayvaci, H.S. (2006). Laboratuar destekli fen ogretimi yaklasimlari. S. Cepni (Ed.), *Fen ve teknoloji ogretimi (Science and technology instruction)* (pp. 167–195). Ankara, PegemA Yayincilik. [in Turkish].

Domin, D.S. (2007). Students' perceptions of when conceptual development occurs during laboratory instruction. *Chemistry Education Research and Practice*, *8*(2), 140–152.

Ergin, O., Sahin-Pekmez, E. & Ongel-Erdal, S. (2005). *Kuramdan uygulamaya deney yoluyla fen ogretimi*. Izmir, Dinazor Kitabevi. [in Turkish].

Freedman, P.M. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching*, *34*(4), 343–357.

Hart, C., Mulhall, P., Berry, A., Loughran, J., & Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of Research in Science Teaching*, *37*(7), 655–675.

Hirvonen, P.E. & Viiri, J. (2002). Physics student teachers' ideas about the objectives of practical work. *Science & Education*, *11*, 305–316.

Hofstein, A. & Lunetta, V.N. (2003). The laboratory in science education: foundations for the twenty-first century. *Science Education*, *88*(1), 28–54.

Jimenez-Aleixandre, M.P., Rodriguez, A.B. & Duschl, R.A. (2000). 'Doing the lesson' or 'Doing science': Argument in high school genetics. *Science Education*, *84*(6), 757–792.

Johnstone, A.H. & Al-Shuaili, A. (2001). Learning in the laboratory: some thoughts from the literature. *University Chemistry Education*, *5*, 42–51.

Kang, N.H. & Wallace, C.S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education*, *89*(1), 140–165.

Lawson, A.E., Clark, B., Cramer-Meldrum, E., Falconer, K.A., Sequist, J.M. & Kwon, Y.-J. (2000). Development of scientific reasoning in college biology: Do two levels of general hypothesis-testing skills exist? *Journal of Research in Science Teaching*, *37*(1), 81–101.

Lazarowitz, R. & Tamir, P. (1994). Research on using laboratory instruction in science. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 94–128). New York: Macmillan.

Lord, T. & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *The American Biology Teacher*, *68*(6), 342–345.

Lunetta, V.N. (1998). The school science laboratory: Historical perspectives and centers for contemporary teaching. In: B.J. Fraser & K.G. Tobin (Eds), *International handbook of science education*. Dordrecht. Kluwer Academic Publishers.

Nott, M. & Wellington, J. (1997). Producing the evidence: Science teachers' initiations into practical work. *Research in Science Education*, *27*(3), 395–409.

Ottander, C. & Grelsson, G. (2006). Laboratory work: the teachers' perspective. *Journal of Biological Education*, *40*(3), 113–118.

Reid, N. & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice*, *8*(2), 172–185.

Sahin-Pekmez, E., Johnson, P. & Gott, R. (2005). Teachers' understanding of the nature and purpose of practical work. *Research in Science & Technological Education*, *23*(1), 3–23.

Schwartz, R.S., Lederman, N.G. & Crawford, B.A. (2004). Developing views of nature of science in an authentic context: an explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610–645.

Tan, A-L. (2008). Tensions in the biology laboratory: What are they? *International Journal of Science Education*, *30*(12), 1661–1676.

Tobin, K. (1986). Secondary school laboratory activities. *International Journal of Science Education*, *8*(2), 199–211.

Wandersee, J.H., Mintzes, J.J., & Novak, J.D. (1994). Research on alternative conceptions in science. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 177–210). New York: Macmillan.

Wilkinson, J. & Ward, M. (1997a). A comparative study of students' and their teachers' perceptions of laboratory work in secondary schools. *Research in Science Education*, *27* (4), 599–610.

Wilkinson, J.W. & Ward, M. (1997b). The purpose and perceived effectiveness of laboratory work in secondary schools. *Australian Science Teachers' Journal*, *42*(2), 49–55.

Wyatt, S. (2005). Extending inquiry-based learning to include original experimentation. *The Journal of General Education*, *54*(2), 83–89.

Yildirim, A. & Simsek, H. (2005). *Sosyal bilimlerde nitel araştırma yöntemleri (Qualitative research methods in social sciences)*. Ankara: Seckin Yayıncılık. [in Turkish].