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Evaluation of Laboratory Practices by Science Teachers

Ulas Kubat

Mugla Sitki Kocman University

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***Corresponding author:** Ulas Kubat

Mugla Sitki Kocman University

Abstract

The laboratory environment plays a vital role in concretizing this abstract knowledge. Consequently, one of the most effective methods in science education is learning by doing and experiencing. In science education, a laboratory is a workspace or specialized classroom equipped with specific tools, instruments, and equipment for conducting scientific research and applications such as demonstrations and experiments. The science laboratory provides students with highly significant qualities, such as reasoning, critical thinking, gaining a scientific perspective, and developing problem-solving abilities. This study, aiming to reveal the views of Science teachers regarding the use of laboratories in science teaching. At the conclusion of the research, teachers stated that laboratories hold a very important place in science education for the application of theoretical knowledge to practice. In addition, they emphasized the lack of equipment and the importance of laboratory safety. Furthermore, they recommended reducing class sizes and increasing safety measures as suggestions.

Keywords: *Science, Science teaching, Laboratory*

1. INTRODUCTION

Laboratories occupy a crucial position in science education. A significant portion of the topics in the curriculum are highly abstract for students. The laboratory environment plays a vital role in concretizing this abstract knowledge. Consequently, one of the most effective methods in science education is learning by doing and experiencing. In this context, laboratories provide a natural learning environment for students to learn through experience the theoretical knowledge taught in lessons.

The primary objective of the Science Curriculum is to equip students with scientific knowledge, skills, attitudes, understanding, and values, enabling them to grow into individuals who engage in research and inquiry, think critically, possess problem-solving skills, and embrace lifelong learning. To achieve these goals, the curriculum is designed in accordance with the constructivist

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learning theory, and during implementation, learning environments and teaching strategies must reflect this theory.

Students need to move away from rote learning approaches and acquire the habit of conducting experiments to comprehend curriculum topics, participate actively in learning processes, and develop problem-solving skills (Aydoğdu & Kesercioğlu, 2005: 86). In this regard, laboratories, which are specially equipped spaces in schools, are used as the primary setting for experiments. Thus, it is well-established that the laboratory environment has numerous positive effects on students, such as developing reasoning, critical thinking, acquiring a scientific perspective, and enhancing problem-solving skills. In science education, a laboratory is a workspace or specialized classroom equipped with specific tools, instruments, and equipment for conducting scientific research and applications such as demonstrations and experiments.

Topics in the field of science are often complex and abstract. For students at the primary and secondary education levels, grasping these abstract subjects implies that the topics should be taught through activities in a laboratory setting. This is because the laboratory, with its concrete materials, will facilitate gaining experience in this context. Simultaneously, teachers have significant responsibilities in creating an effective science teaching environment. In the laboratory setting, teachers should undertake a role that prepares the ground for student-teacher and student-student interactions, enabling students to take responsibility for their own learning.

The high quality of science education provided at the primary and middle school levels will allow the knowledge and skills acquired at these ages to form a foundation for subsequent learning, thereby enabling the attainment of advanced knowledge and skills in the field of science. In science education, the critical role played by laboratory applications in concretizing theoretical knowledge, acquiring scientific process skills, and establishing permanent learning is indisputable. The constructivist approach, where learning occurs through doing, experiencing (experimentally), and observing, forms the basis of effective science education. In this context, laboratories are indispensable learning environments that provide students with direct experience, opportunities for hypothesis formation, and inquiry-discussion-based research, laying the foundation for the development of scientific literacy skills.

While the use of laboratories in science teaching is essential for all educational levels, it holds a particularly decisive and critical function at the primary and middle school levels in terms of imparting fundamental skills. This is because achieving the high-level outcomes targeted by science education depends on grounding the instructional process in practical applications. The most central and effective environments where this practical learning process can occur are science laboratories.

Laboratories offer multifaceted benefits, such as ensuring active and permanent learning in students, developing habits of scientific thinking, acquiring basic skills for using the laboratory efficiently as a research environment, internalizing the importance of using scientific tools and equipment, and fostering a positive attitude toward laboratory work. With all these functions, laboratory applications constitute a fundamental component that directly determines the pedagogical effectiveness and quality of science education. The science laboratory provides students with highly significant qualities, such as reasoning, critical thinking, gaining a scientific perspective, and developing problem-solving abilities.

1.1. Factors Limiting Teachers' Use of Laboratories

Although teachers are aware of the pedagogical importance of the laboratory and experimental method, it is observed that they encounter various limitations in applying this method. These limiting factors can be summarized as follows:

The absence of a dedicated physical space for laboratory work in educational institutions,

Lack of necessary tools, equipment, and resources,

Class sizes exceeding the ideal number,

Teachers and students perceiving laboratory work as a time-inefficient process,

Teachers viewing the necessary preparation process before experiments as an additional burden,

The difficulty of classroom management in a laboratory environment are among the factors limiting laboratory use.

Despite the aforementioned pedagogical contributions of laboratory applications, various structural and functional limitations are observed during the implementation process. Examples of these limitations include: large class sizes restricting opportunities for individual experimentation and reducing applications to group work or demonstration formats; the absence of laboratory infrastructure in some educational institutions or the inadequacy of tools and equipment in existing laboratories. Furthermore, factors such as experiments becoming time-consuming and costly due to planning deficiencies encountered during curriculum implementation, and teachers' lack of pedagogical knowledge and technical skills related to laboratory use can also hinder the achievement of expected learning outcomes from laboratory activities.

This study, aiming to reveal the views of Science teachers regarding the use of laboratories in science teaching, sought answers to the following questions posed to teachers:

What is the importance of using laboratories in science teaching?

What are the challenges and limitations of using laboratories in science teaching?

What are your recommendations and suggestions for overcoming the challenges and limitations of using laboratories in science teaching?

2. METHOD

2.1. Research Design and Methodology

This study adopted a phenomenological design within the qualitative research paradigm. Phenomenological research aims to explore the deep meanings inherent in individuals' daily life experiences and to describe these meanings systematically (Robson, 2002). This method provides a suitable foundation for in-depth examination of phenomena that are familiar but not fully grasped in terms of their meaning. In such research, the primary data source consists of individuals or groups who have personally experienced the phenomenon on which the research focuses and are capable of articulating that experience (Yıldırım & Şimşek, 2013).

2.2. Study Group

The study group of the research consists of 20 Science Teachers

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working in Muğla during the 2023-2024 academic year. In selecting the sample, the convenient sampling method was preferred. This method provides practicality, time efficiency, and cost-effectiveness to the research (Yıldırım & Şimşek, 2013). According to this sampling technique, the participants from whom data will be collected are determined from among the individuals closest and most accessible to the researcher (Robson, 2002).

Table 1:Study Group

	Total	Frequency
Gender		
Woman	10	50
Man	10	50
Ages		
21-25	2	10
26-30	4	20
31-35	4	20
36-40	5	25
41-45	5	25
Years of Service		
1-5	0	0
6-10	2	10
11-15	5	25
16-20	5	25
20-25	8	40

2.3. Data Collection Process and Tools

A semi-structured interview form developed by the researcher based on a review of the relevant literature was used as the data collection tool in the study. The preparation process of this form consisted of the following stages: First, national and international literature on the subject was reviewed (Wellington, 1990; Ouvry, 2003; Strauss & Terenzini, 2007; Uğraş, Uğraş & Çil, 2013; Bodur, 2015). Subsequently, to ensure the content validity of the form, opinions were sought from four science educators and four measurement and evaluation experts. In the next stage, a pilot interview was conducted with two pre-service science teachers to test the comprehensibility of the interview questions and their suitability for the research questions. Finally, necessary revisions were made to the form based on expert opinions and pilot application results, finalizing it. The prepared interview form consists of a total of four open-ended questions aimed at determining the views of pre-service science teachers regarding out-of-school learning environments.

After obtaining the necessary ethical and institutional permissions for the research, the participating pre-service teachers were informed about the purpose of the study, and their participation was ensured on a voluntary basis. All conducted interviews were audio-recorded with the consent of the participants. Each interview lasted an average of twenty minutes, and the data were collected in May 2024 and June 2024.

2.4. Data Analysis

Descriptive analysis technique was used to analyze the collected qualitative data. To increase the reliability of the analysis process, the data were coded and thematized independently by the researcher and another science educator working in the same field. The analyses of the two coders were compared to establish a common consensus, and points of disagreement were discussed to reach a consensus. The inter-coder agreement (reliability) was calculated using the formula "Agreement / (Agreement + Disagreement) x 100" proposed by Miles and Huberman (1994) and was found to be 86.14%. In the literature, agreement rates of 70% and above are considered to provide acceptable reliability (Miles & Huberman, 1994).

During the analysis process, each participating teacher was coded as ST1, ST2, ..., ST16... while keeping their identity confidential. For example, ST1 represents the first pre-service teacher, ST8 the eighth teacher, and ST20 the twentieth teacher.

3. FINDINGS

The codes obtained for the question "What is the importance of using laboratories in science teaching?" posed to the teachers are presented in Table 2.

Table 2

The Importance of Using Laboratories in Science Teaching

Codes	Frequency	Teachers
Application of Theoretical Knowledge	12	ST1,ST2,ST3,ST5,ST6,ST9,ST11,ST13, ST16,ST17,ST18,ST20
Scientific Thinking and Inquiry	8	ST2,ST3,ST5,ST7,ST9,ST10, ST16,ST17
Understanding the Nature of Science	6	ST4,ST6,ST9,ST13, ST19,ST20
Psychomotor Development	4	ST4,ST8,ST12,ST13
Learning by Doing and Experiencing	4	ST5,ST9,ST14,ST17
Increasing Interest and Motivation	3	ST8,ST11,ST15
Contribution to Problem-Solving Skills	2	ST7,ST16
Permanent Learning	2	ST2,ST13

An examination of Table 2 reveals that science teachers most frequently emphasize the importance of applying theoretical knowledge to practice as a key benefit of using laboratories in science teaching. Additionally, teachers highlighted the importance of laboratory use for fostering scientific thinking and inquiry, and for understanding the nature of science. Teachers expressed their views as follows:

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"Laboratory use is very important as it helps students understand difficult abstract concepts by concretizing them through practical application."(ST3)

"I have observed that my students show very high interest and motivation, especially in experiments they conduct themselves."(ST8)

An examination of Table 3 reveals the codes obtained for the question "What are the challenges and limitations of using laboratories in science teaching?" posed to the teachers, which are presented in Table 3.

Table 3

Challenges and limitations of using laboratories in science teaching

Codes	Frequency	Teachers
Laboratory Accidents	9	ST4,ST5,ST9,ST11,ST13, ST15,ST17,ST18,ST20
Lack of Equipment / Materials	8	ST1,ST3,ST5,ST7,ST9,ST12, ST15,ST17
Laboratory Safety	6	ST7,ST9,ST12,ST13, ST16,ST20
Physical Conditions of the Laboratory	6	ST6,ST9,ST10,ST12,ST16,S20
Non-compliance with Rules	4	ST9,ST10,ST13, ST14
Classroom Management and Control	4	ST2,ST11,ST15,ST19
High Number of Students	2	ST6,ST14

An examination of Table 3 reveals that regarding the challenges and limitations of using laboratories in science teaching, teachers most frequently emphasized laboratory accidents. In addition to this, they highlighted the lack of laboratory equipment and materials, as well as laboratory safety. Teachers expressed their views as follows:

"If not handled with great care, very dangerous laboratory accidents such as cuts, burns, or even explosions can occur."(ST5)

"Although we try to conduct our experiments with simple and easily obtainable materials, we still face deficiencies in terms of equipment." (ST17)

An examination of Table 4 reveals the codes obtained for the question "What are your recommendations and suggestions for overcoming the challenges and limitations of using laboratories in science teaching?" posed to the teachers, which are presented in Table 4

Table 4: Recommendations for Overcoming Challenges in Laboratory Use

Codes	Frequency	Teachers
Enhancing Safety Measures	8	ST4,ST6,ST8,ST9,ST11,ST12,ST14,ST17
Addressing Equipment/Material Shortage	6	ST7,ST9,ST10,ST12,ST18,ST20
Sourcing Easy and Low-Cost Materials	6	ST1,ST5,ST10,ST17,ST18,ST20
Reducing Class Size	6	ST2,ST8, ST10,ST14,ST15,ST18
Conducting Inquiry-Based Experiments	3	ST6,ST15,ST19
Student-Conducted, Open-Ended Experiments	2	ST7,ST13

An examination of Table 4 reveals that regarding recommendations for overcoming the challenges and limitations of using laboratories in science teaching, teachers most frequently mentioned enhancing safety measures and addressing the shortage of equipment and materials. Teachers expressed their views as follows:

"The laboratory environment—from the preparation stage, through conducting the experiments, to the cleanup—is quite a difficult process. Since very dangerous accidents can occur if necessary precautions are not taken, great attention must be paid to safety measures."(ST9)

"Of course, it is best for students to perform the experiments themselves under the teacher's supervision, but due to safety concerns, as a teacher, I usually conduct demonstration experiments. Especially for 6th-grade students, since some materials in the laboratory are sharp and flammable, I, as the teacher, perform the demonstration, and the students observe."(ST14)

4. DISCUSSION AND CONCLUSION

A laboratory can be defined as a controlled learning environment where students construct specific scientific concepts and processes through direct experience, observation, and application. These environments are centers where knowledge is transformed into practice, problems are defined and solved, and manual skills as well as procedural competencies are developed. The positive contributions of laboratories to the teaching-learning process in science education can be listed as follows: They allow the direct,

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first-hand examination of facts and phenomena. Students' active use of multiple senses during the experimental process enhances the quality and permanence of the learning experience. They develop students' creative and critical thinking capacity. They facilitate the acquisition of scientific process skills (observation, hypothesizing, data collection, inference, etc.). They ease the transfer of learned knowledge to real-life contexts. They provide opportunities for repeated observation and examination of cause-effect relationships by manipulating experimental variables. They allow for the creation of a learning environment suitable to the student's own learning pace and prior knowledge. The research findings indicate that teachers also highlighted these positive aspects of laboratory use. Furthermore, teachers noted that it contributes to understanding the nature of science and supports students' psychomotor development. According to Beichner (2014), these environments offer opportunities for skills that students not only learn by actively participating in experiments but also apply in daily life.

Despite the indispensable role of laboratory applications in reinforcing theoretical knowledge and imparting scientific process skills in science education, there are significant obstacles in practice to realizing this potential. Factors such as overcrowded classrooms, insufficient equipment, unsuitable physical conditions (electricity, water, heating, space constraints), limited class time, and teachers' lack of practical training in laboratory use lead to a reliance on demonstration experiments over individual experiments and restrict student participation. Alongside the positive aspects, laboratory use has certain limitations. Its use is difficult and time-consuming in classes with a high number of students. The research findings also show that teachers stated the high number of students negatively affects laboratory use. Especially in laboratory environments without adequate equipment, it takes a very long time for all students in crowded classes to conduct experiments. This increases the likelihood of students' experiments being unsuccessful. Particularly in crowded classes, it is challenging to provide experimental equipment for every student for all topics. Classroom management and control are difficult in laboratories with high student numbers. Similar to this study, the literature indicates that lack of equipment or its absence, and crowded classrooms constitute major problems (Monk, Fairbrother & Dillon, 1993). Students can easily get out of control, which can jeopardize laboratory safety.

It can be argued that the primary objectives of laboratory work in science education are to reinforce theoretically acquired knowledge through application and to translate knowledge related to daily life into practice. Additionally, supporting permanent and meaningful learning, and developing the habit of scientific thinking and inquiry are among other objectives of laboratory work. In other words, integrating theory and practice is of great importance for learning in the educational process. In science teaching, laboratory applications are utilized as a fundamental tool to achieve this integration. The research findings also show that teachers emphasized the importance of integrating theory and practice.

Teachers emphasized laboratory safety due to concerns about accidents. As a safety measure, laboratory floors should have plastic flooring. A well-equipped first aid cabinet must be available. There should be gas and heat masks for the number of individuals. Firefighting equipment; sand blankets, CO2 foam-filled extinguishers should be present (Ergin, Pekmez & Erdal, 2005, p.136). Although teachers drew attention to laboratory accidents, none of them mentioned such necessary precautions. In their study titled "An investigation of science and technology teachers' competency perceptions regarding laboratory work according to different variables," Böyük, Demir, and Erol (2010) concluded that the perceived competency levels of teachers who participated in in-service training showed a statistically significant difference compared to their colleagues who did not receive such training. Therefore, providing regular in-service training for science teachers on laboratory safety is extremely important.

Laboratory applications play a critical role in concretizing abstract concepts of science and relating them to daily life. Kenneth Tobin (1990) posited that laboratory activities offer an effective means for students to achieve meaningful understanding while simultaneously engaging in the constructive process of knowledge building through hands-on scientific inquiry.Teachers also indicated in the research findings the application of theoretical knowledge to practice. Furthermore, they stated that it provides opportunities for learning by doing and experiencing, as well as for permanent learning. Similarly, the most effective science teaching occurs through doing, experiencing (experimentally), and observing. Brown and Atkins (1997) state that laboratory-based research contributes to students acquiring research and observation skills and methods, developing their scientific research processes and problem-solving competencies, and adopting a positive attitude towards such activities. Research shows that without laboratory experience, effectively conveying these inherently abstract concepts to students and ensuring permanent learning is quite difficult (Belhan & Şimşek-Laçin, 2012). Laboratories also provide a fundamental environment for students to experience scientific processes firsthand, develop hypotheses for problems they encounter, and conduct research based on discussion and inquiry (Çetinkaya, 2016).

Experiment activities conducted in science classes offer a fundamental opportunity for the development of students' scientific process skills. The research findings support this conclusion. Similarly, the research findings indicate that laboratory use contributes to students' scientific thinking and inquiry skills. Experiments conducted with simple materials are highly effective, and students design controlled experiments during this process. Such low-cost and easily accessible activities increase student participation and positively affect their attitudes towards science. In line with the research findings, teachers recommended using easily accessible and inexpensive materials for experiments. Based on the research results, it can be said that the insufficiency of laboratory use stems primarily from the following reasons: Inadequate material and equipment, unsuitable physical environment and lack of tools/equipment, overcrowded class sizes, lack of classroom management, and teachers' insufficient laboratory knowledge and practice. Overcoming these obstacles is a prerequisite for enhancing the quality of ideal science education. This result is consistent with views expressed by various researchers in the literature (Landolfi, 2002; Tsai, 2003).

It is very important for an ideal science teacher to be in a position where, alongside subject knowledge, they can effectively use laboratory tools and equipment, relate science in an interdisciplinary context, and guide their students. It is essential that laboratories are fully equipped, of a size proportional to the number of students, safe, and allow students to conduct individual or group work with ease and in compliance with safety rules. Furthermore, it is critically important for the teacher to prepare

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experiments in advance, clearly state objectives and safety rules, and assume a guiding role for the students.

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