Journal of Education and Learning (EduLearn)
Vol. 15, No. 3, August 2021, pp. 397~405
ISSN: 2089-9823 DOI: 10.11591/edulearn.v15i3.20018

Preservice biology teachers' knowledge and usage level regarding lab equipment and materials

Ahmet Gökmen, Burak Gürkan, Hikmet Türk Katırcıoğlu
Department of Biology Education, Gazi Education Faculty, Gazi University, Turkey

Article Info

Article history:

Received Feb 14, 2021
Revised Jun 12, 2021
Accepted Jun 24, 2021

Keywords:

Biology
Preservice teachers
Equipment and materials
Laboratories

ABSTRACT

Laboratories are an indispensable part of the fundamental sciences. Laboratories are important learning environments that enable students to relate events to daily life as well as being places where theoretical knowledge is implemented. The present study investigated the knowledge and usage level of preservice biology teachers regarding lab equipment and materials. The study utilized a descriptive survey. A total of 61 preservice biology teachers from the Biology Education Department of a public university in Turkey constituted the participants. Lab Equipment and Materials Recognition Form that is developed by the researcher of the present study was used to collect data. In the design of this form, the 9–12 grade biology curriculum was first analyzed, and a list of frequently-used equipment and materials of biology laboratories was created in line with the opinions of field experts. The form included 40 laboratories equipment and materials and questions regarding the recognition of these items, their functions, and their application processes. The preservice teachers' answers to these questions were graded as: zero points for each incorrect answer, one point for each partially correct answer, and two points for each correct answer. The data obtained were analyzed using cluster analysis, descriptive analysis, one-way analysis of variance, and independent samples T-test in SPSS27 software, and the Polycoric correlation coefficient in Factor Analysis software. The results revealed that the preservice teachers mainly recognize the biology laboratories equipment and materials but generally lack information regarding the application process of laboratories equipment and materials.

Corresponding Author:

Ahmet Gökmen
Department of Biology Education
Gazi Education Faculty, Gazi University
06500, Teknikokullar/Ankara, Turkey
Email: agokmen@gazi.edu.tr

1. INTRODUCTION

The 21st century contemporary educational systems prioritize individuals' ability to use knowledge learned in solving new problems [1], [2]. To create an appropriate climate in science education, it becomes a necessity to increase the quality of education [3]. There is, therefore, a need for methods and techniques in science education that embody science topics, help to teach them through experiences and realize permanent learning, and provide the active use of all cognitive, affective, and psychomotor skills [4], [5]. Laboratories are the learning environments that enable students to relate events to daily life as well as being places where theoretical knowledge is implemented [6], [7] and therefore considered important and indispensable learning environments of science education [8]-[10].

Laboratories play a key role to attain the objectives specified by the curriculum and make the retention of these objectives for learners [11]-[13]. Furthermore, laboratories do not only contribute to students' knowledge of science but also develop their skills of scientific researching, discussion, and scientific thinking and behavior [14]-[16].

Studies in the related literature reported that lab applications increase the achievement in science education [17]-[21]; positively affected students' attitudes towards science and science experiments [22]-[25] boosted students' motivation in science [15], [23], [26]; and provided the retention of knowledge [27]-[29].

To realize the objectives in biology education, laboratories and course materials must be used in an efficient way [30]. However, the efficient way here cannot be achieved only with the physical existence of laboratories. Beyond the access to the laboratories and their physical properties, the use of equipment and devices and the application with those devices supported by the suitable teaching methods with students directly affects the benefits of laboratories. By the nature of the constructivist approach, the more the student is engaged in learning activities, the more efficient and permanent learning will be achieved [31]. An effective lab use needs students being active learners in open-ended experiments. Open-ended experiments in which students reach their results using equipment and materials will produce more successful educational outcomes. Meaningful learning in laboratories will be possible if students are allowed to alter their knowledge.

Meaningful learning in laboratories will be possible if students are given the option to change their knowledge by selecting, adding, and removing equipment and materials to build their knowledge of scientific concepts and phenomena [32]-[34]. Therefore, it is of critical importance to be knowledgeable about the equipment and materials used in laboratories and, thus, to use them in line with their functions.

Science lessons involve experiences through experiments in order to use equipment and equipment, and the retention of learning is realized with the experiments carried out [35]. Lack of equipment and materials that are necessary for experiments reduces the efficiency of laboratories [36]. It was highlighted centuries ago that certain tools were needed to carry out an experiment. Abu Bakr Razi (854-935), an Iranian alchemist known as Rhazes in medieval Europe, made a list of tools and made suggestions on equipping laboratories [37]. Considering all these, recognizing equipment and materials in laboratories is seen as a prerequisite for reliable experimental outcomes.

Certain studies in the related literature reported that laboratories, despite their importance in science education, are not efficiently used due to some limitations, which are mostly time, cost, and curriculum-related [38]. Besides, some studies put forward that laboratories are not fully used even in cases where laboratories are equipped with necessary materials. Güneş, *et al.* conducted a study on the use of laboratories in the science and technology course [39]. They found that lab activities or experimental implementations are sufficiently included in the course design even though the participating schools have laboratories and that experiments that can even be performed with daily life equipment were ignored.

Bardak and Karamustafaoğlu in their study stated that teachers carried out the experiments as a demonstration due to concerns such as waste of time and failure to provide classroom management, which prevents students from recognizing lab equipment [40]. This situation inevitably reduces the educational efficiency of laboratories. For example, Coştu, *et al.* conducted a study with preservice science teachers and found that they use lab equipment outside of the intended use while preparing solutions and took chemicals to be prepared from the container using inappropriate equipment [41].

Among the studies in the literature on the use of equipment and materials, Kızılcık, *et al.* reported that secondary school students largely do not know the names and functions of materials that are used in physics experiments [42]. Studies with preservice teachers mostly corroborate these results. Coştu, *et al.* in their study with preservice teachers determined that preservice teachers' skills to use lab materials are insufficient [41]. Similarly, Böyük, *et al.* found that teachers do not sufficiently recognize lab equipment [43].

This study aimed to investigate preservice biology teachers' knowledge level regarding recognizing lab equipment and materials, identifying their functions, and their implementation processes. Novice teachers, who are sufficiently knowledgeable and experienced in lab use from their preservice education, are expected to act courageously in solving lab-related issues and to maximize the efficiency of lab use in any case. Therefore, it is of critical importance to reveal preservice teachers' knowledge and application level of lab equipment and materials and to determine existing deficiencies in this regard.

The present study sought an answer to these questions:

1. What are the preservice teachers' scores on recognizing lab equipment and materials, identifying their functions, and implementing them?
2. Does the preservice teachers' scores on recognizing lab equipment and materials, identifying their functions, and implementing them differ by gender?

3. Does the preservice teachers' scores on recognizing lab equipment and materials, identifying their functions, and implementing them differ by grade level?
4. What is the relationship between the preservice teachers' scores on recognizing lab equipment and materials and identifying their functions, and their scores on implementing them?

2. RESEARCH METHOD

In this part of the study, the design of the study, participants, data collection tools, and data analysis procedure were presented.

2.1. Design of the study

The present study determined preservice biology teachers' knowledge level regarding recognizing lab equipment and materials, identifying their functions, and their implementation processes. The study utilized a descriptive survey study to picture preservice teachers' current situation regarding lab equipment and materials in the existing conditions [44], [45], to enlighten the relationship between the dimensions that are examined within the scope of the study, and to reveal the links between events [46].

2.2. Participants

A total of 61 preservice biology teachers from the Biology Education Department of a public university in Turkey constituted the participants. These participants were determined using the convenience sampling technique considering the factors of speed, practicality, and time and cost factors [47]. Information about the participants is presented in Table 1.

Table 1. Information about the participants

Grade			Gender		
	f	%		f	%
1	17	27.8	Female	14	22.9
			Male	3	4.9
2	19	31.1	Female	14	22,9
			Male	5	8.1
3	15	24.5	Female	12	19.6
			Male	3	4.9
4	10	16.3	Female	9	14.7
			Male	1	1.6
Total	61	100	Female	49	88.3
			Male	12	19.6

Table 1 shows the distribution of the participants by gender and grade level. Of the participants, 49 were female (83.3%) and 12 were male (19.6%). The participants were distributed by gender as: 17 in the first grade (27.8%); 19 in the second grade (31.1%); 15 in the third grade (24.5%), and 10 in the fourth-grade (16.3%).

2.3. Data collection tools

Lab Equipment and Materials Recognition Form that is developed by the researcher of the present study was used to collect data. In the design of this form, the 9–12 grade biology curriculum was first analyzed, and a list of frequently-used equipment and materials of biology laboratories was created in line with the opinions of field experts. The list of frequently-used equipment and materials is given in Table 2.

Table 2. List of the frequently-used laboratories equipment and materials

Equipment		Material	
pH meter device	Laminar flow	Inoculation loop	Scalpel
Water-bath	Stereoscope microscope	Test tube rack	Slide staining jar
Microtone	Distilled water device	Pipette	Forceps
Electrophoresis Tank	Incubator	Spatula	Erlenmeyer Flask
Electro spectrophotometer	Magnetic stirrer	Cover glass	Beaker
Vortex	Centrifuge device	Micropipette	Test tube
Incubator-Machine	Light microscope	Balloon joje	Glass spreader
Fume cupboard		Glass slide	Dissection tray
Pasteur oven		Pipet filler	Pasteur pipette
Autoclave		Balloon	Wash bottle
Analytical balance		Petri dish	Graudated cylinder

The list included 40 equipment and materials and posed questions regarding the recognition of these items, their functions, and the related implementation process. An exemplary question of the form is presented in Figure 1.

Visual of the equipment/material	Please indicate the name of the equipment/material.	Please state the functions of the equipment/material.	In which experiments have you used the equipment/material? Please describe the procedure in those experiments.
			

Figure 1. Exemplary question of the data collection tool

In the form, a visual of the related item was first presented, and the preservice teachers were asked to indicate the name of the shown item, its functions, and the details of the experiments in which the shown item was used. The form was piloted with 10 preservice teachers and the form was finalized according to the feedback provided by these preservice teachers.

2.4. Data analysis

The preservice teachers' responses to the Lab Equipment and Materials Recognition Form was graded using a rubric developed by the researcher of the present study. In the rubric, each incorrect answer was graded with zero points, each partial answer with one point, and each correct answer with two points. The answers of the preservice teachers were evaluated by three field experts of whom one is the researcher of the present study and the other two are independent field experts. The inter-rater reliability between these three coders was examined using the reliability coefficient by Miles and Huberman this coefficient was found to be 92% [48].

In the analysis of the data, the distribution of the data was first investigated. The results revealed that the data is normally distributed by gender and grade level. Therefore, parametric tests were decided to be used for the analysis of the data.

Cluster analysis was used to grade the preservice teachers' on the data collection tool. According to the cutoff scores set, five groups that are very low, low, middle, sufficient, and quite sufficient, were determined. Descriptive statistics were used to provide a general insight regarding the preservice teachers' overall scores on the form. T-test was used to determine whether the preservice teachers' scores on the form differ by gender and one-way analysis of variance (ANOVA) in SPSS 27 was used to determine whether their scores differ by grade level. Polycoric correlation coefficient in Factor Analysis software was carried out to determine the correlation between the preservice teachers' scores on the three categories in the form. Polycoric correlation coefficient was preferred for this study because the dataset has an ordered form with categories of more than two [49], [50].

3. RESULTS

In this part of the study, the findings obtained from the statistical analyses were presented with tables. Descriptive statistics regarding the preservice teachers' knowledge regarding the lab are presented in Table 3.

Table 3. Descriptive statistics regarding the preservice teachers' knowledge regarding the lab equipment and materials.

	N	Min	Max	$\bar{X}$	SD	Level
Recognition	61	19	78	50.62	15.93	Middle
Identifying functions	61	12	71	48.31	13.31	Middle
Implementation	61	0	74	37.50	17.28	Low

As shown in Table 3, the preservice teachers scored between 19 and 78 with a mean of 50.62 on the category of recognizing the lab equipment and materials. They scored between 12 and 71 with a mean of

48.31 on the category of identifying the functions of lab equipment and materials. Also, they scored between 0 and 74 with a mean of 37.50 on the category of implementing lab equipment and materials.

The cluster analysis results revealed that the preservice teachers' level of recognizing and lab equipment and materials is middle; that their level of identifying functions of lab equipment and materials is middle; and that their level of implementation is low.

Independent samples t-test was conducted to determine whether the preservice teachers' scores differ by gender and the related t-test scores are given in Table 4.

Table 4. Independent samples T-test results regarding the differentiation of the preservice teachers' scores regarding lab equipment and materials by gender

	Gender	N	$\bar{X}$	SD	DF	t	p
Recognition	Female	49	50.85	15.26	59	.20	.162
	Male	12	49.66	19.15			
Identifying functions	Female	49	48.87	11.88	59	.513	0.20*
	Male	12	46,00	18.53			
Implementation	Female	49	38.89	16.71	59	1.173	.631
	Male	12	31.83	19.15			

*p<.05

As shown in Table 4, the independent samples t-test results showed that the female preservice teachers, compared to the male preservice teachers, scored higher on recognizing lab equipment and materials. However, this difference was not found to be significant [$t_{(59)\text{-Recognition}}$ =.20; p>.05].

The female preservice teachers, compared to the male preservice teachers, scored higher on identifying the functions of lab equipment and materials. This difference was found to be significant in favor of the female preservice teachers [$t_{(59)\text{-Identifying functions}}$ =.513; p<.05].

The female preservice teachers, compared to the male preservice teachers, scored higher on the appropriateness of the implementation of lab equipment and materials. However, this difference was not found to be significant [$t_{(59)\text{-Implementation}}$ =1.173; p>.05].

The ANOVA results, as shown in Table 5, revealed that the preservice teachers' scores on recognizing lab equipment and materials significantly varied by grade level [$F_{\text{Recognition}}$=32.48 p<.05]. Tukey test was further carried out to determine between which groups this difference occurs. The Tukey test results showed that there is a significant difference between higher grades with lower grades in favor of the higher grades.

The ANOVA results revealed that the preservice teachers' scores on identifying the functions of lab equipment and materials significantly varied by grade level [$F_{\text{Identifying functions}}$=18.78 p<.05]. Tukey test was further carried out to determine between which groups this difference occurs. The Tukey test results showed that there is a significant difference between higher grades with lower grades in favor of the higher grades.

The ANOVA results revealed that the preservice teachers' scores on the appropriateness of the implementation of lab equipment and materials significantly varied by grade level [$F_{\text{Implementation}}$=21.47 p<.05]. Tukey test was further carried out to determine between which groups this difference occurs. The Tukey test results showed that there is a significant difference between higher grades with lower grades in favor of the higher grades.

Table 5. One-way analysis of variance (ANOVA) regarding the preservice teachers' scores on laboratories equipment and materials by gender

	Grade	N	$\bar{X}$	SD	DF	F	p	Significance Tukey test
Recognition	1	17	41.4706	11.95888	60	32.48	.000	(1-3.4). (2-3.4) (3-1.2). (4-1.2)
	2	19	39.1053	11.52242				
	3	15	64.3333	6.43280				
	4	10	67.5000	6.36396				
Identifying functions	1	17	43.6471	9.63030	60	18.78	.000	(1-3.4). (2-3.4) (3-1.2). (4-1.2)
	2	19	38.3158	10.97498				
	3	15	57.2667	9.70616				
	4	10	61.8000	6.49444				
Implementation	1	17	30.4118	15.26458	60	21.47	.000	(1-3.4). (2-3.4) (3-1.2). (4-1.2)
	2	19	25.0526	12.08522				
	3	15	47.8000	10.26227				
	4	10	57.8000	8.05260				

*p<.05 Levene Test $F_{\text{Recognition}}$=1.987, sd=3-57, p=.126; Levene Test $F_{\text{Identifying}}$=.449, sd=3-57, p=.719; Levene Test $F_{\text{Implementation}}$ =.780, sd=3-57, p=.510.

The Polycoric correlation analysis results, as shown in Table 6, put forward a high-level positive correlation between the preservice teachers' scores on recognizing lab equipment and materials, identifying their functions, and implementing them.

Table 6. Polycoric correlation analysis results regarding the preservice teachers' scores on laboratories equipment and materials

		Recognition* Function	Recognition* Implementation	Function* Implementation
EQUIPMENT	pH meter device	0.998*	0.987*	0.955*
	Water-bath	0.985*	0.983*	0.938*
	Microtone	0.980*	0.756*	0.755*
	Electrophoresis Tank	0.964*	0.929*	0.957*
	Electro spectrophotometer	0.963*	0.960*	0.850*
	Vortex	0.940*	0.864*	0.956*
	Incubator-Machine	0.902*	0.638*	0.688*
	Fume cupboard	0.878*	0.917*	0.654*
	Pasteur oven	0.873*	0.748*	0.821*
	Autoclave	0.850*	0.687*	0.791*
	Analytical balance	0.844*	0.528*	0.644*
	Laminar flow	0.821*	0.697*	0.827*
	Stereoscope microscope	0.815*	0.366*	0.782*
	Distilled water device	0.807*	0.334*	0.662*
	Incubator	0.758*	0.632*	0.729*
	Magnetic stirrer	0.694*	0.803*	0.882*
	Centrifuge device	0.691*	0.640*	0.783*
	Light microscope	0.217*	0.343*	0.485*
MATERIAL	Inoculation loop	0.987*	0.900*	0.998*
	Test tube rack	0.996*	0.415*	0.917*
	Pipette	0.936*	0.773*	0.749*
	Spatula	0.932*	0.617*	0.890*
	Cover glass	0.920*	0.870*	0.843*
	Micropipette	0.921*	0.908*	0.840*
	Balloon joje	0.860*	0.508*	0.731*
	Glass slide	0.852*	0.513*	0.771*
	Pipet filler (Puar)	0.837*	0.710*	0.799*
	Balloon	0.804*	0.511*	0.854*
	Petri dish	0.777*	0.589*	0.712*
	Scalpel	0.774*	0.753*	0.683*
	Slide staining jar	0.732*	0.560*	0.628*
	Forceps	0.720*	0.449*	0.620*
	Erlenmeyer Flask	0.691*	0.626*	0.804*
	Beaker	0.691*	0.755*	0.604*
	Test tube	0.682*	0.632*	0.594*
	Glass spreader	0.604*	0.659*	0.786*
	Dissection tray	0.578*	0.566*	0.656*
	Pasteur pipette	0.526*	0.147	0.661*
	Wash bottle	0.361*	0.620*	0.544*
	Graudated cylinder	0.188	0.452*	0.207*

*p<.05

4. DISCUSSIONS

The study results showed that the preservice teachers' scores on recognizing laboratory equipment and materials were at a medium level, and their implementation scores at a low level. These results might infer that the preservice teachers are far from being at a high or very high level regarding laboratory equipment and materials; in other words, they are not at the desired level. Studies reporting similar results are encountered in the relevant literature. Köseoğlu and Soran conducted a study on teachers' competencies regarding the use of lab equipment and found that teachers have a mid-level cognitive competency [51]. Harman found that teachers have some incomplete or inaccurate information regarding equipment frequently used in the science and technology course such as the components of a microscope, and the functions of each component, and the use of microscopes in general [52]. This situation is even observed in preservice teachers' self-evaluation regarding their use of lab equipment. Böyük, *et al.* found that teachers do not consider themselves competent in recognizing and using equipment that is used in the Science and Technology course [43].

The study results showed that the preservice teachers avoided the use of laboratories, which might stem from the fact that they could not get sufficient applied training regarding the use of laboratories during their preservice education and these deficiencies should be compensated with in-service training [53], [54] in their study to monitor the science and technology lesson teachers' views on laboratory conditions and use and technological innovations, stated that 53.1% of the participants stated that an in-service training program was needed for the use of laboratory equipment and materials.

The preservice teachers scored higher on the categories of recognizing lab equipment and materials and using them than on the category of implementing them, which might refer that the preservice teachers were not provided with sufficient opportunity of implementation regarding lab equipment and materials. Çoştu, *et al.* stated that preservice teachers have incomplete or incorrect information about the appropriate use of lab materials, use these materials outside of their intended use during solution preparation processes, and use inappropriate equipment to take the chemical to be included in the solution [41]. Uluçınar, *et al.* in their study reported that teachers are unwilling to carry out experiments due to the insufficient knowledge received during the preservice education [55].

Preservice teachers who do not make implementation sufficiently in educational faculties will not be able to trust themselves in their professional life; therefore, they will avoid performing experiments with their students. Thus, students will not have sufficient applied knowledge regarding the use of laboratories. In this regard, Kızılcık, *et al.* in their study revealed that secondary school students are not able to define physics laboratory materials in general or even to put forward an idea about many materials [42].

The differences between the preservice teachers' scores of recognizing and applying lab equipment and materials were not found to be significant by gender. Kızılcık, *et al.* stated that recognizing lab materials is a gender-independent issue [42]. However, a significant difference was found between male and female preservice teachers in favor of the female preservice teachers in identifying lab equipment and materials.

The preservice teachers' recognition of laboratory equipment and materials, identifying their functions and implementation scores differ significantly by grade level. This difference is generally between higher grades and lower grades in favor of the higher grades. This result can be explained by the fact that higher-grade students take more lab courses during their education; therefore, they have more opportunities to use lab equipment and materials.

The relationships between the preservice teachers' scores on recognizing lab equipment and materials, identifying their functions, and implementing them were found to be high and positive in the present study. Therefore, it is concluded that factual information and functional information are interdependent. Similarly, Kızılcık, *et al.* in their study found a significant relationship between students' knowledge regarding experimental materials correctly and stating their functions correctly [42].

5. CONCLUSION

It is of critical importance to recognize lab equipment and materials, state their functions, and implement for an experiment to be carried out safely. During the COVID 19 pandemic process, laboratory courses in educational faculties are carried as distance education. For this reason, many laboratories equipment and materials cannot be introduced to students in an applied way but are generally explained in a theoretical way. However, by knowing laboratories equipment and materials well, students can carry out experiments involving the same or similar tasks at home. Therefore, knowing the properties of laboratory equipment and materials enables students to continue implementation even under limited circumstances conditions by using their creativity skills as well as increasing factors such as success, attitude, motivation and safety.

From the conclusion, authors recommend: 1) Increasing the opportunities (lessons, lesson hours, and physical conditions) that will enable preservice teachers to know lab equipment and materials; 2) Determining teaching methods and techniques and using them more commonly to create more effective lab environments; and 3) Conducting longitudinal studies from preservice teachers' undergraduate education to their professional lives to reveal cause-and-effect relationships.

ACKNOWLEDGEMENTS

Some parts of this article was presented as an oral paper at the Globets 2019 conference, which was held in Northern Cyprus between the dates of 11-14 April, 2019.

REFERENCES

[1] S. Keleşoğlu and N. Kalaycı, "On the threshold of the fourth industrial revolution, innovation and education relationship," *Creative Drama Journal*, vol. 12, no. 1, pp. 69-86, 2017, doi: https://doi.org/10.21612/yader.2017.004.

[2] M. Yılmazlar and A. Çorapçıgil, "A study on promoting pre-service science teachers' readiness for general physics laboratory course," *Çukurova University Faculty of Education Journal,* vol. 48, no. 2, pp. 1400-1428, 2019.

[3] Ministry of National Edication, *Primary school science curriculum.* Board of Education and Discipline. Ankara, 2018.

[4] R. Mohan, *Innovative science teaching*. PHI Learning Pvt. Ltd., 2019.

[5] Ç. Ç. Barış, "The metaphoric perceptions of pre-service science teachers to the concept of "Biology laboratory," *Journal of Higher Education and Science*, vol. 10, no. 3, pp. 615-624, 2020, doi: https://doi.org/10.5961/jhes.2020.421.

[6] M. Yadigaroğlu, *et al.,* "The level of pre-science student teachers of relating their chemistry knowledge in daily life," *Ege Education Journal*, vol. 18-2, pp. 795-812, 2017, doi: https://doi.org/10.12984/egeefd.310426.

[7] H. Kapıcı, *et al*., "How do different laboratory environments influence students' attitudes toward science courses and laboratories?," *Journal of Research on Technology in Education*, vol. 52, no. 4, pp. 534-549, 2020, doi: https://doi.org/10.1080/15391523.2020.1750075.

[8] S. Çepni and H. Ş. Ayvacı, *Fen ve teknoloji eğitiminde ölçme ve değerlendirme. Kuramdan uygulamaya fen ve teknoloji öğretimi, 13rd ed*. Ankara: Pegem Yayıncılık, 2016.

[9] O. M. Olubu, "Effects of laboratory learning environment on students learning outcomes in secondary school chemistry," *International Journal of Arts and Sciences*, vol. 8, no. 2, pp. 507-525, 2015.

[10] N. Mistry and S. G. Gorman, "What laboratory skills do students think they possess at the start of university?," *Chemistry Education Research and Practice*, vol. 21, no. 3, pp. 823-838, 2020, doi: https://doi.org/10.1039/C9RP00104B.

[11] M. P. Clough, "Using the laboratory to enhance student learning," *Learning science and the science of learning,* pp. 55-94, 2002.

[12] National Science Teachers Association, *Standards for science teacher preparation.* Faculty Publications: Department of Teaching, Learning and Teacher Education, 2020.

[13] B. T. Olufunke, "Effect of availability and utilization of physics laboratory equipment on students' academic achievement in senior secondary school physics," *World Journal of Education,* vol. 2, no. 5, pp. 1-7, 2012, doi: \https://doi.org/10.5430/wje.v2n5p1.

[14] M. Altıparmak and M. Nakiboğlu, "The effect of cooperative learning on attitudes to laboratory and achievement in high school biology laboratories," *The Journal of Turkish Educational Sciences,* vol. 3, no. 1, pp. 105-123, 2005.

[15] A. Hofstein and V. N. Lunetta, "The laboratory in science education: Foundations for the twenty-first century," *Science Education,* vol. 88, no. 1, pp. 28-54, 2004, doi: https://doi.org/10.1002/sce.10106.

[16] N. Najami, *et al*., "The laboratory as a vehicle for enhancing argumentation among pre-service science teachers," *Science and Education,* vol. 29, no. 2, pp. 377-393, 2020, doi: https://doi.org/10.1007/s11191-020-00107-9.

[17] A. Çetin and M. Cengiz, "The effects of laboratory applications on pre-service science teachers achievements and attitudes about tissues subject," *Academia Journal of Educational Research,* vol. 6, no. 1, pp. 37-45. 2021.

[18] G. Karaer, *et al*., "Evaluating the use of project based teaching on the science laboratory course according to the views of the classroom teacher candidates," *Journal of Qualitative Research in Education,* vol. 8, no. 1, pp. 73-95, 2020, doi: https://doi.org/10.14689/issn.2148-2624.1.8c.1s.4m.

[19] M. Demirci and Z. Yüce, "Experimental planning of the lesson for 8th grade students in the teaching of biotechnology and genetic engineering," *Sakarya University Journal of Education Faculty*, vol. 35, pp. 87-108, 2018.

[20] S. Dinçol Özgür, *et al*., "Preparation of prospective teachers for teaching profession through the chemistry laboratory practices," *Electronic Journal of Social Sciences,* vol. 16, no. 61, pp. 534-550, 2017, doi: https://doi.org/10.17755/esosder.304691.

[21] A. Aydın and M. Y. Güney, "The effects of activities developed in accordance with the constructivist approach on pre-school teacher candidates' learning the science concepts," *Journal of Kırşehir Education Faculty,* vol. 11-18, pp. 181-201, 2017.

[22] O. Partalcı, Ü. U. Topsakal and G. Özkan, "Effect of laboratory activities on students ' attitude towards the laboratory," *presented at the ERPA 2019 International Congresses on Education*, 2019, pp. 1-5.

[23] J. J. Park, *et al*., "The chemical engineering research laboratory as context for graduate students' training: the role of lab structure and cultural climate in collaborative work," L*earning, Culture and Social Interaction*, vol. 13, pp. 113-122, 2017, doi: https://doi.org/10.1016/j.lcsi.2017.04.001.

[24] S. J. Wolf and B. J. Fraser, "Learning environment, attitudes and achievement among middle-school science students using inquiry-based laboratory activities," *Research in Science Education,* vol. 38, pp. 321–341, 2008, doi: https://doi.org/10.1007/s11165-007-9052-y.

[25] H. Baykara, "A study of effectiveness of inquiry-based science laboratory activities," M.S. thesis, Dept. Institute of Science, Pamukkale University, Denizli, Turkey, 2011.

[26] K. Knutson, *et al*., "Bringing the excitement and motivation of research to students; Using inquiry and research-based learning in a year-long biochemistry laboratory: Part I–guided inquiry–purification and characterization of a fusion protein: Histidine tag, malate dehydrogenase, and green fluorescent protein," *Biochemistry and Molecular Biology Education*, vol. 38, pp. 317-323, 2010.

[27] G. Uyanık, "Effect of hands on science experiments on academic achievement, attitude towards science course and retention," *OPUS-International Journal of Society Researches*, vol. 9, no. 16, pp. 600-624, 2018, doi: https://doi.org/10.26466/opus.462761.
[28] C. Aydoğdu and S. Erbaş, "Determination of persistence status of information learned in laboratory applications in chemistry education," *Hacettepe University Journal of Education*, vol. 7, no. 7, pp. 279-286, 1992.
[29] H. Kırıktaş and T. Kesercioğlu, "The effect of inquiry-based science teaching on preservice teachers' scientific process skills, academic achievement and attitudes towards laboratory," *Academia Journal of Educational Research*, vol. 6, no. 1 , pp. 78-92, 2021.
[30] P. Köseoğlu and H. Soran, "The attitudes of biology teachers towards material use," *Hacettepe University Journal of Education*, vol. 30, no. 30, pp. 159-165, 2006.
[31] E. Benzer and G. Muşlu-Kaygısız, "Designing lab experiments based on constructivist approach: a junior-high preservice science teachers' case," *Gaziantep University Journal of Social Sciences*, vol. 16, no. 2, pp. 386-409, 2017.
[32] A. Hofstein, *et al*., "Research Report," *International Journal of Science Education*, vol. 26, no. 1, pp. 47-62, 2004, doi: https://doi.org/10.1080/0950069032000070342.
[33] K. Tobin, "Teaching science in urban high schools: when the rubber hits the road" in *Establishing Scientific classroom discourse communities: Multiple voices of research on teaching and learning,* R. K. Yerrick and W. M. Roth Ed, 2004, pp. 265-286.
[34] R Soğukpınar and K. Gündoğdu, "Students' and teachers' views on science lesson and laboratory practices: a case study," *IBAD Journal of Social Sciences,* vol. 8, no. 8, pp. 275-294, 2020, doi: https://doi.org/10.21733/ibad.733953.
[35] H. Dindar and S. Yaman, "The using condition of educational tools by science teachers in first grade of primary schools," *Pamukkale University Journal of Education*, vol. 13, no. 13, pp. 167-176, 2003.
[36] A. Akçöltekin, "Place of laboratories and laboratory qualifications in elementary science courses," M.S. thesis, Dept. Institute of Science, Kafkas Univ., Kars, Turkey, 2008.
[37] S. Reid and P. Fara, "*The Usborne book of scientists—from Archimedes to Einstein,*" Transl.: in R. L. Aysever, Ed., *(in Turkish)*, TUBITAK Popüler Science Books, 2008.
[38] H. Bakırcı and E. Kutlu, "Determination of science teachers' views on STEM approach," *Turkish Journal of Computer and Mathematics Education*, vol. 9, no. 2, pp. 367-389, 2018, doi: https://10.16949/turkbilmat.417939.
[39] M. H. Güneş, "Teacher and student assessments regarding to use of science and technology laboratory," *Dicle University Journal of Ziya Gökalp Faculty of Education*, vol. 20, no. 20, pp. 1-11, 2013.
[40] Ş. Bardak, and O. Karamustafaoğlu, "Examination of teaching strategies, methods and techniques used by science teachers in the context of pedagogical field knowledge," *Amasya Education Journal*, vol. 5, no. 2, pp. 567-605, 2016, doi: https://doi.org/ 10.17539/aej.63460.
[41] B. Çoştu, *et al*., "Determining preservice science teachers' competences in preparing solutions and in use of laboratory tools," *Hacettepe University Journal of Education*, vol. 28, no. 28, pp. 65-72, 2005.
[42] H. Ş. Kızılcık, *et al*., "Ninth grade students ' level of recognition of physics laboratory materials," Elementary Education Online, vol. 18, no. 1, pp. 190-206, 2019, doi: https://doi.org/10.17051/ilkonline.2019.527198.
[43] U. Böyük, *et al*., "Analyzing the proficiency views of science and technology teachers on laboratory studies in terms of different varriables," *Journal of TÜBAV Science*, vol. 3, no. 4, pp. 342-349, 2010.
[44] Ş. Büyüköztürk, E. Kılıç-Çakmak, Ö. E Akgün, Ş. Karadeniz, and F. Demirel, "*Bilimsel araştırma yöntemleri 25rd ed*," Ankara: Pegem Akademi, 2018.
[45] N. Karasar, *Bilimsel araştırma yöntemi 17rd ed*. Ankara: Nobel Yayın Dağıtım, 2018.
[46] S. Çepni, *Araştırma ve proje çalışmalarına giriş 8th ed*. Trabzon: Celepler Press, 2018.
[47] A. Yıldırım and H. Şimşek, *Sosyal bilimlerde nitel araştırma yöntemleri 11th ed.* Ankara: Seçkin Yayıncılık, 2018.
[48] M. Miles, *et al.*, *Qualitative data analysis: An ecpanded sourcebook, 4th ed*. London: SAGE Publication, 2019.
[49] M. J. Allen and W. M. Yen, *Introduction to measurement theory*. Monterey: Brooks/Cole, 1979.
[50] R. E. Schumacker and R. G. Lomax, *A beginner's guide to structural equation modelling, 3rd ed.* New York: Routledge, 2010.
[51] P. Köseoğlu and H. Soran, "Teachers' competency regarding the use of instuctional tools in teaching biology," *Hacettepe University Journal of Education*, vol. 28-28, pp. 150-158, 2005, doi: https://doi.org/10.1002/bmb.20400.
[52] G. Harman, "Examination of classroom teacher candidates' knowledge about laboratory tools used in science and technology teaching," *Journal of Education and İnstructional Studies in the World*, vol. 2, no. 1, pp. 122-127, 2012.
[53] C. Gerçek and H. Soran, "Investigation of teachers' use of experimental methods in teaching biology," *Hacettepe University Journal of Education*, vol. 29, no. 29, pp. 95-102, 2005.
[54] S. Demir, *et al*., "Science and technology course teachers ' views on laboratory conditions and use and trends in monitoring technological innovations," *Mersin University Journal of the Faculty of Education*, vol. 7, no. 2, pp. 66-79, 2011, doi: https://doi.org/ 10.17860/efd.02843.
[55] Ş. Uluçınar, *et al*., "The evaluation of laboratory studies in science," *The Journal of Turkish Educational Sciences,* vol. 2, no. 4, pp. 465-475, 2004.