Investigation of Laboratory Teaching Strategies in Chemistry Education: Opinions of Pre-service Chemistry Teachers

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ABSTRACT

This study aims to determine the opinions of pre-service chemistry teachers on the applicability of laboratory strategies, the purposes of their use, and the factors influencing strategy preference. The research was conducted through a phenomenological design, one of the qualitative research styles. The study includes 20 pre-service chemistry teachers enrolled at a state university in Ankara. A written questionnaire comprising three queries exploring the suitability of laboratory approaches, their objectives, and the determinants influencing the selection of approaches was employed for data collection. The opinions of the pre-service chemistry teachers were collected with the data collection tool 5 times during the implementation. The data was analyzed by content and descriptive analysis of the written responses. According to the research findings, 98.7% of the pre-service teachers believe the strategies are applicable or partially applicable. The lack of materials, crowded classrooms, unsuitable laboratories, and student level, as well as difficulties in classroom management, time limitations, safety issues, problems in achieving learning outcomes, and students' unfamiliarity with laboratory strategies, were cited by pre-service teachers as factors affecting the practical use of laboratories. Additionally, pre-service teachers applied laboratory strategies for learning, learning about science, learning about research, and skill development. Meanwhile, the other result of the study was that the factors for pre-service teachers to prefer laboratory strategies vary according to the acquisition, learning environment, learning outcomes, students, and chemistry topics. The study's findings again highlight the importance of exploring pre-service teachers' opinions about teaching in the laboratory.

Keywords:
Laboratory teaching strategies, pre-service chemistry teachers, purposes of use, applicability, preferences

INTRODUCTION

The main feature distinguishing science from other disciplines is its focus on developing students' reasoning skills. It supports their ability to form hypotheses with discovery-based strategies, conduct experiments, observations, and research, and interpret the results. In this context, laboratory teaching is almost a cornerstone of science (Herrington & Nakhleh, 2003) because it supports students' learning by allowing them to actively participate in their own learning (Hofstein & Lunetta, 2004).

Since chemistry is a branch of science that requires most of the work in the laboratory, laboratory studies are of great importance and provide students with the opportunity to conduct experimental research (Galloway & Bretz, 2015). It is assumed that laboratory experiences help students understand theoretical concepts. Chemistry laboratories enable many positive contributions, such as reasoning, critical thinking, gaining a scientific perspective, and developing problem-solving skills (Nakiboğlu & Şen, 2020). However, while many educators emphasize the laboratory's importance in teaching, they also make essential criticisms such as the laboratory can cause students' learning deficiencies when the effectiveness of laboratory teaching is low (Novak, 1988). In other words, laboratory studies may not always achieve targeted efficiency. The factors that prevent laboratory teaching from achieving its objectives include the quality of teaching, the teacher's laboratory experience, the student profile, the characteristics of experiments, and technical conditions (Şen & Nakiboğlu, 2013). The quality of laboratory teaching depends on how the teacher applies the preferred teaching strategies. Within the scope of this study, we focused on pre-service chemistry teachers' opinions on teaching strategies that could be used in a practical laboratory course to improve the teaching of laboratory courses, which are an essential part of chemistry education.

Although teaching strategies are classified in various ways in the literature, expository, discovery, problem-solving, and inquiry are generally regarded as the most conventional strategies (Domin, 1999). Their application in the laboratory has resulted in diversity of strategies. In this study, laboratory teaching strategies were analysed, including the verification (deductive) strategy, the inductive strategy, the scientific process

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skills (SPS) strategy, the technical skills strategy, and the inquiry strategy. These strategies are the most commonly used teaching strategies in laboratory courses (Seven & Engin, 2018). These strategies can be applied according to the purpose of laboratory courses, students' needs, and learning objectives. Among these strategies, the verification strategy aims to verify the theoretical knowledge with experiments. Closed-ended experiments are used for this. In other words, students know in advance what and how they will do and what they will find in the end (Demirtaş, 2006). The inductive strategy enables students to discover a general principle or notion by drawing conclusions from observations and experiments (Domin, 1999). Open-ended experiments are used. The students are left to perform the experiment as well as collect and analyse the results under this strategy. Another laboratory strategy, the scientific process skills strategy, attempts to teach students skills such as observing, measuring, determining, and controlling variables, analyzing data, and making conclusions (Alkan, 2016). This strategy is used in conjunction with others. The technical skills strategy attempts to educate students how to use various laboratory procedures and instruments. This strategy gives students the hands-on experience they need to conduct experiments safely and successfully. The final of the laboratory strategy, the inquiry strategy, strives to empower students with the skills to arrange and perform experiments to address a specific problem or discover a new phenomenon. The inquiry strategy can increase students' meaningful learning, conceptual knowledge, and understanding of science's nature (Gericke et al., 2023; Lazarowitz & Tamir, 1994; Tobin, 1990). Furthermore, this strategy allows students to discover the content for themselves, fostering a sense of customized learning (Ajewole, 1991; Merritt et al., 1993).

In a study conducted by Aydoğdu (1999) with 250 pre-service chemistry teachers, the difficulties encountered by students during chemistry laboratory applications were determined, and it was stated that the most critical difficulties were the incompatibility between the content of theoretical courses and laboratory applications courses, insufficient time allocated to application courses and lack of instructor guidance. In one of the studies on the use of laboratory strategies conducted by Şen and Nakiboğlu (2013) with 28 pre-service chemistry teachers, pre-service teachers were asked which strategy they thought to choose to carry out a laboratory lesson within the scope of the Laboratory Management course. It was determined that pre-service teachers' responses did not focus on a specific strategy and almost any strategy could be preferred. In addition, it was also highlighted that determining a strategy suitable for the lesson before the laboratory lesson would enable the teacher to conduct the lesson in a more organized way, which would positively affect student achievement.

Nakiboğlu and Şen's (2020) study aims to determine the teaching strategies, methods, and models preferred by pre-service chemistry teachers when preparing and implementing plans for laboratory courses and to examine the criteria they consider when making these choices. When the factors for pre-service chemistry teachers' preference for teaching strategies, methods, and models in the laboratory environment were analyzed, it was determined that providing active participation of students was the most critical factor. Another factor affecting the participants' preferences is limited time. In the least preferred expository strategy, factors such as finding the lecture boring and simple, not being suitable for the laboratory environment, and students remaining passive were revealed. In addition, Beasley's (1985) study emphasizes that students can better understand the concepts they learned in theoretical courses through laboratory applications and gain the ability to set up experimental setups on their own.

Kocaeren (2023) determined the opinions of pre-service chemistry teachers in order to get information about the applied experimental studies carried out in chemistry laboratory courses and to learn their expectations about the conduct of chemistry laboratory courses. According to the results of the study, it was determined that pre-service chemistry teachers mainly mentioned the lack of equipment and chemical materials in laboratories and the execution of laboratory applications and theoretical courses in parallel.

Considering the studies mentioned above, it is possible to say that there are many studies on chemistry laboratory education. This situation may cause practitioners who want to improve their laboratory practices to get lost in this literature density. In this overview, it is very important to talk directly with practitioners, to ask them which aspects they consider when designing a laboratory activity, and to identify them (Seery et al., 2019). In the chemistry education curriculum, there are courses (chemistry teaching, laboratory applications in chemistry teaching, etc.) that provide opportunities for pre-service teachers to improve their content knowledge and conduct laboratory courses. In this context, it is very valuable to get the opinions of pre-service chemistry teachers, who are one of the future practitioners, about teaching in the laboratory. Therefore, the present study aims to determine pre-service chemistry teachers' knowledge, experience, and opinions about the strategies that can be applied in laboratory teaching within the framework of a laboratory course aiming to help them perform laboratory teaching effectively. In this context, the research questions of the study are as follows:

a) What are the opinions of the pre-service chemistry teachers about the applicability of laboratory strategies?

b) What are the opinions of the pre-service chemistry teachers about the purposes of using laboratory strategies?

c) What are the opinions of the pre-service chemistry teachers about the preference for laboratory strategies?

Since the findings obtained as a result of this research will reflect the experiences of pre-service chemistry teachers during their undergraduate education, it is thought that it will contribute to both new teachers who will start the teaching profession and experienced teachers about their ability to use the laboratory in their lessons.

METHOD

RESEARCH DESIGN

This research was conducted by the phenomenology design, one of the qualitative research designs. Phenomenology is a research design that aims to reveal the perceptions and opinions of people about an event or phenomenon (Meriam, 2013, p.124). This research design was preferred in this study since it aimed to determine pre-service teachers' opinions on laboratory strategies used in the laboratory.

STUDY GROUP

The study group of the research consisted of 20 pre-service chemistry teachers studying at a state university in Ankara and taking a course on chemistry teaching in the laboratory. Four of the pre-service teachers were male, and 16 were female. The ages of the study group ranged between 20-24. The study group was chosen among students in their final year (fourth year, eighth semester) who had finished the chemistry course required by their curriculum and most of the chemical education courses. They had taken courses in which teaching strategies were introduced (e.g., chemistry teaching course), but they had not taken a course in which the laboratory strategies mentioned in this study were introduced. The research was conducted within the scope of an undergraduate course, and the study group was determined by convenience sampling method.

DATA COLLECTION TOOL

The data of this study were collected from pre-service teachers through written opinion forms. This opinion form was given to the pre-service teachers after the micro-teaching related to each laboratory strategy (verification strategy, induction strategy, scientific process skills strategy, technical skills strategy, and inquiry strategy) was completed, and they were asked to answer the form by considering only the relevant laboratory strategy. There are three questions in the form. In the first question, the pre-service teacher was asked about his/her opinion on the applicability of the related laboratory strategy, and if the answer was “not applicable” or “partially applicable”, he/she was asked to explain the reasons. The second question was asked to determine the relevant laboratory strategy's purpose. The aim of this question was to find out what the pre-service teacher is trying to achieve with the student when he/she uses this strategy. In the last question, the pre-service teacher was asked to explain which situations/conditions he/she would prefer this strategy. The objective of this inquiry is to identify the elements that affect the pre-service teacher's strategy preference at the lesson planning stage. The pre-service teachers filled out this opinion form in writing five times during the research process (after the micro-teaching practices related to each laboratory strategy were completed). The study group was given 15 minutes to complete the opinion form. The researchers examined the written opinion forms completed by the study group, and the statements/explanations that were not understood were explained again.

The opinion form used in the study was prepared by the researchers. Three science education experts were consulted for the data collection tool's content validity. Since the experts stated that each item was appropriate, it was decided that the content validity of the form was high (Davis, 1992).

RESEARCH PROCESS

This research was conducted within the scope of the "Laboratory Applications in Chemistry Teaching" course in the 4th-grade chemistry education program. This course is four hours per week and is an applied and compulsory course. This course aims to ensure that the acquisitions in the secondary chemistry curriculum are realized through applicable experiments in the chemistry laboratory. Pre-service teachers gain experience in this process by preparing lesson plans according to appropriate laboratory strategies. For this purpose, pre-service teachers plan a lesson that includes an experiment by considering an acquisition in the secondary chemistry curriculum. They apply this lesson in a laboratory environment where their peers play the role of students, and they play the role of teachers.

The data collection of the research lasted 14 weeks in total. In the first two weeks, discussions were held with the pre-service teachers about the role and importance of the laboratory in science teaching, and information was given about the strategies that can be applied in the laboratory. At the end of the second week, the pre-service teachers were informed that they should choose an acquisition in the secondary chemistry curriculum and prepare a lesson plan appropriate to this acquisition. In addition, this week, the pre-service teachers were also asked to determine which strategy they would use to plan the lesson. Each strategy was performed by four different participants during the data collection process, total of 20 pre-service teachers. process of determining this strategy was left entirely to the pre-service teachers' preference.

In the third and fourth weeks, the pre-service teachers presented the lesson plans they had started to prepare in advance to the researchers, and the lesson plans were finalized by eliminating the problems encountered during the planning process. Starting from the fifth week, micro-teaching sessions were started. In each lesson, two pre-service teachers applied the lesson plan they prepared to their peers, and after each application, this micro-teaching was criticized by their peers. In micro-teaching, verification, inductive, technical skills, scientific process skills (SPS), and inquiry strategies were practiced, respectively. When the practices related to a strategy were completed, the pre-service teachers' opinions about this strategy were taken in writing with an opinion form. Thus, each pre-service teacher expressed their opinions five times for five laboratory strategies.

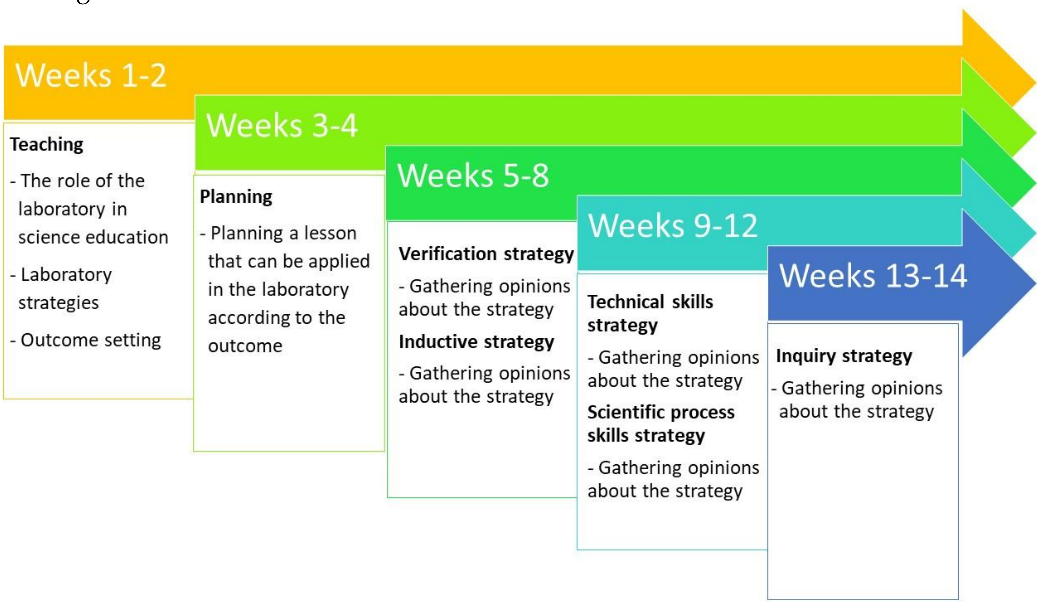

Figure 1. Stages of the research process

DATA ANALYSIS

The opinion forms applied to the pre-service teachers were analyzed using descriptive analysis and content analysis. In the research, one of the questions in the interview form was analyzed by taking into account the pre-determined code/categories/theme, so descriptive analysis was used during the analysis of this question. In descriptive analysis, the analysis is performed according to the categories determined before the analysis (Merriam, 2013, p. 125; Yıldırım & Şimşek, 2018, p. 239). Other categories/themes emerged during the analysis, so these categories and themes were emerged (?) through content analysis. Content analysis is the process of determining codes from the analyzed item and reaching categories and themes from these codes (Creswell, 2009, p. 71; Yıldırım & Şimşek, 2018, p. 242).

During the analysis, firstly, the researchers transcribed the statements in the opinion forms into written text. Then, codes were determined from each statement. The first question in the opinion form was about the applicability of the laboratory strategies and the factors if they could not be applied. In this question, the answers of the study group were obtained in three: "applicable," "partially applicable" and "not applicable". Therefore, the analysis of this question was carried out with descriptive analysis. In the second part of the same question, content analysis was used. In the second part of this question and the other questions, codes were created from the student responses separately by both researchers. The codes were classified into categories, and the categories were classified among themselves to form themes. After the interview forms were analyzed separately, the codes/categories and themes belonging to the questions that serve the purpose were evaluated together and combined. Analyses were conducted by both researchers. Inconsistencies identified during creation of codes/categories and themes were discussed and incompatibilities were eliminated. The results of the themes and categories obtained from the opinion forms were presented in terms of percentages or frequencies. In some cases, the frequency of categories and themes was higher than the total number of participants since pre-service teachers expressed more than one opinion about a strategy. Additionally, there were cases where some participants did not answer all questions, so the total number of categories or themes were less than the number of participants.

In order to increase the internal reliability of the study, participant statements related to the themes/categories were given within direct quotations. To protect the privacy of the participants' identities, the participants in this study were all given numbers.

RESULTS

The results of the study are given under three headings: (i) the applicability of the laboratory strategies, (ii) the purposes of using laboratory strategies, and (iii) the factors for preferring the laboratory strategies.

APPLICABILITY OF LABORATORY STRATEGIES

The results obtained when pre-service teachers' opinions on the applicability of laboratory strategies were analyzed are given in Figure 2.

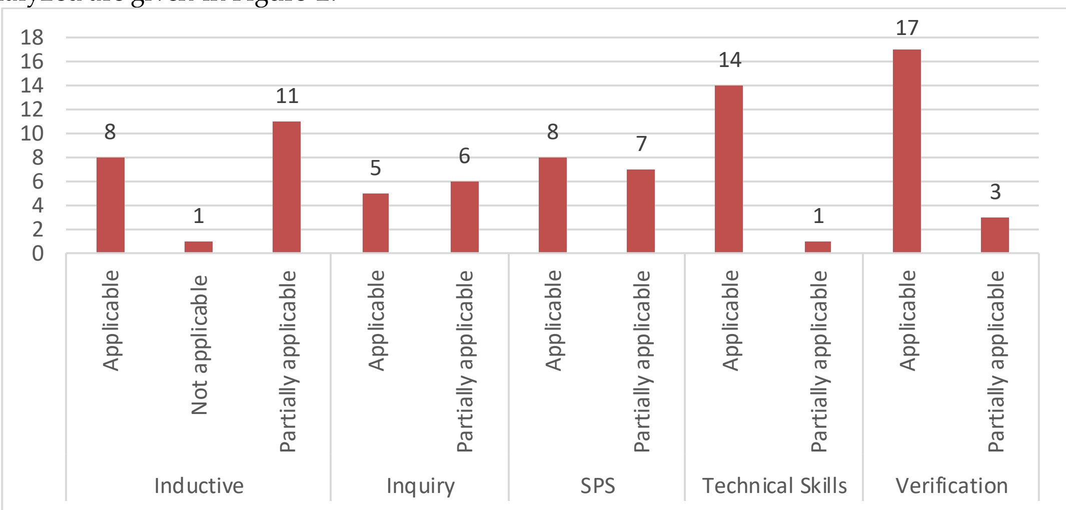

Figure 2. Distribution of opinions on the applicability of laboratory strategies

According to Figure 2, most pre-service teachers (52 opinions, 64.2%) stated that these laboratory strategies can be applied, while some (n=28 opinions, 34.5%) stated that they can be applied depending on certain conditions. According to pre-service teachers, the most applicable laboratory strategy is the verification strategy. This strategy is followed by technical skills, inductive, scientific process skills, and inquiry strategies, respectively. Only one pre-service teacher thinks that the inductive strategy cannot be applied. Some of the pre-service teachers think that laboratory strategies can be partially applied. They attributed the partial applicability to different (one or more than one) factors. The factors for the partial applicability of the strategies are given in Figure 3.

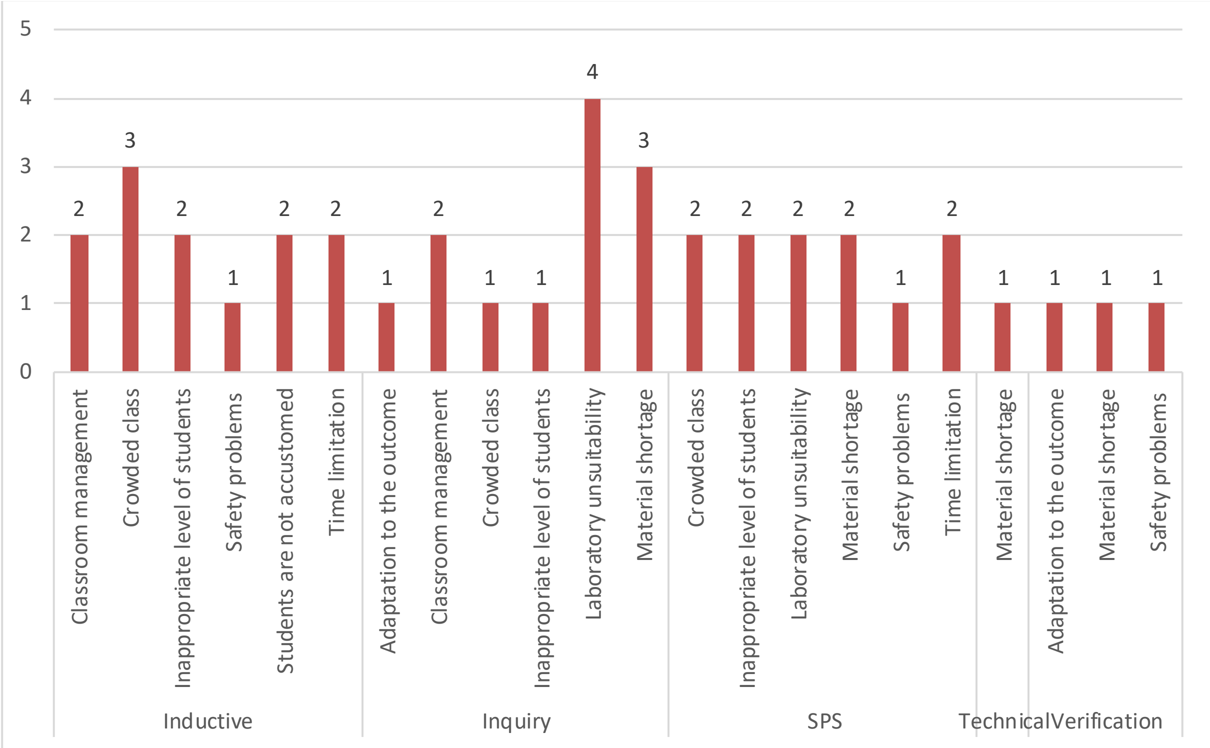

Figure 3. Distribution of factors affecting the applicability of laboratory strategies

According to Figure 3, the factor most frequently mentioned by the pre-service teachers as an obstacle to the application of laboratory strategies was the shortage of materials to be used in the laboratory (n=7). In addition, crowded classrooms (n=6), unsuitability of laboratories (n=6), inappropriate student level (n=5), complex classroom management (n=4), time limitation (n=4), safety problems (n=3), problems in determining acquisition (n=2), and students' unfamiliarity with laboratory strategies (n=2) are other factors.

The crowded classrooms are the most frequently mentioned factor in limiting the applicability of the inductive strategy. Pre-service Teacher (PT) 1 expressed this opinion: "*Classes are too crowded, it becomes difficult to apply the inductive strategy*". The most frequently mentioned factor for the inquiry strategy was the unsuitability of laboratories. Pre-service teachers see the learning environment's deficiencies as a problem in applying the inquiry strategy. PT 11 expressed this opinion: "*The lack of appropriate conditions in schools and the lack of laboratories limit the application of this strategy.*" For the SPS strategy, more than one factor comes to the fore. These are crowded classrooms, unsuitable laboratories, lack of materials in the laboratory, inappropriate student level, and time constraints. PT 19 expressed his opinion as "*There is a need for an environment where students can make observations and design experiments, this deficiency makes it difficult to implement the SPS strategy*". The obstacle to applying the technical skills strategy is the lack/absence of laboratory materials. PT 10 expressed this opinion: "*Technical skills strategy can be partially implemented in schools. Because schools are inadequate regarding laboratory materials and tools*". Finally, the factors of acquisition adaptation/appropriate acquisition determination, lack of material, and safety problems affect the pre-service teachers' application of the verification strategy. PT 12 expressed his opinion on this issue: "*Verification strategy may not be suitable for every acquisition.*"

THE PURPOSE OF USING LABORATORY STRATEGIES

When the pre-service teachers' answers to the opinion forms were analyzed, it was determined that laboratory strategies could be used for four purposes. These purposes are learning, learning about science, learning about research, and skill development. These four themes and the categories under these themes are given in Table 1.

Table 1. Distribution of the categories and themes related to the purposes of the use of the laboratory strategies

Themes	Categories	f	%
Learning	attitude	9	6.3
	establishing relationships between topics	1	0.7
	learning to work in collaboration	3	2.1
	learning device/to use the device	10	6.9
	making generalizations	10	6.9
	meaningful learning	8	5.6
	motivation	3	2.1
	student-centered learning	20	13.9
	subject/concept learning	13	9.0
	Total	**77**	53.5
Learning about science	learning the scientific process	3	2.1
	recognizing science	3	2.1
	working like a scientist	3	2.1
	Total	**9**	6.3
Learning about research	being able to carry out experiments	4	2.8
	being able to plan an experiment	5	3.5
	conducting experiments in a short time	1	0.7
	encouraging research	1	0.7
	learning to obtain reliable data	3	2.1
	supporting discovery process	10	6.9
	Total	**24**	16.7
Skill development	creativity	2	1.4
	decision-making skills/interpretation skills	2	1.4
	developing 21st-century skills	1	0.7
	developing a sense of responsibility	1	0.7
	development of psychomotor skills	9	6.3
	developing scientific process skills	18	12.5
	gainining critical thinking skills	1	0.7
	Total	**34**	23.6
	General total	**144**	100

According to Table 1, pre-service teachers mostly use laboratory strategies to improve students' learning (53.5%). The second most common purpose of using laboratory strategies is students' skill development (23.6%). Among the purposes of pre-service teachers' use of laboratory strategies, enabling students to learn about science is the least targeted purpose (6.3%). The "learning" theme obtained from the analysis of pre-service teachers' answers includes the categories of supporting attitude and motivation development, learning subject/concept, learning to work collaboratively, learning to use devices/instruments, providing meaningful learning, providing a student-centered learning environment and supporting the relationship between subjects. In the "Learning" theme, "creating a student-centered learning environment" is the most frequently expressed category for using laboratory strategies. PT 10 said, "*I use the SPS strategy to keep students active during the experiment.*"

The categories of working like a scientist, recognizing science, and learning the scientific process were grouped under the theme of "learning about science." This theme has the lowest percentage among the purposes of pre-service teachers' use of laboratory strategies. PT 5 said, "*I use the verification strategy to make students feel like scientists.*"

The "learning about research" theme includes planning an experiment, conducting an experiment (in a short period), obtaining reliable data, and supporting research and discovery. In this theme, pre-service teachers mostly expressed the purpose of "supporting discovery." PT 3 said, "*I use inductive strategy when I aim for students to discover something they do not know.*"

Finally, the categories of creativity, developing 21st-century skills, developing scientific process skills, gaining manual (psychomotor) skills, critical thinking, taking responsibility, and decision-making skills were grouped under the theme of "skill development." The dominant category in this theme is "developing of scientific process skills." Pre-service teachers mostly use laboratory strategies to develop students' scientific process skills.

When the research findings are analyzed in terms of themes, the pre-service teachers use laboratory strategies mostly to support students' learning and least for students to recognize/learn science. For example, PT 9 stated, "*I use SPS strategy to develop students' skills such as observing, recording data, measuring, using number space relationships, making predictions, interpreting data, drawing conclusions...*".

The results regarding the purposes for which pre-service teachers used each laboratory strategy are given in Figure 4.

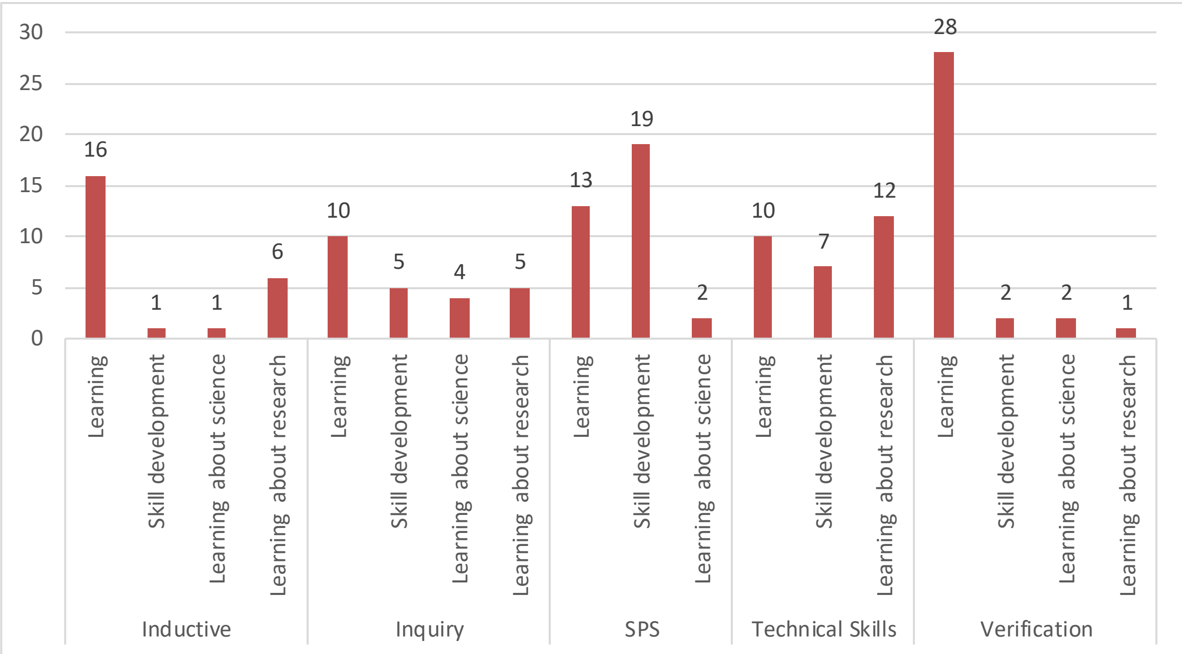

Figure 4. Distribution of students' answers regarding purposes of use according to laboratory strategies

According to Figure 4, pre-service teachers stated that each laboratory strategy (inductive, inquiry, and verification) can be used mostly to support students' learning. They also stated that they could use the scientific process skills strategy frequently to develop students' skills (creativity, developing 21st-century skills, developing scientific process skills, developing motor skills, gaining critical thinking, taking responsibility, and decision-making skills...). In addition, they stated that technical skills strategy could be used to support students in planning experiments, performing experiments, obtaining reliable data, and exploring. From another point of view, pre-service teachers would prefer inductive and verification strategies very little if they aim to develop skills in the laboratory course. Finally, pre-service teachers use laboratory strategies least to enable students to recognize/learn science.

THE FACTORS FOR PREFERRING THE LABORATORY STRATEGIES

Finally, the factors for pre-service teachers' preference for laboratory strategies were determined. From the analysis of the opinion forms, the factors for pre-service teachers' preference for laboratory strategies were grouped under 5 themes: (i) acquisition, (ii) learning environment, (iii) learning outcomes, (iv) student, and (v) topic. These five themes and the categories under these themes are given in Table 2.

Table 2. Categories and Themes Related to Pre-service Teachers' Factors for Preferring Laboratory Strategies

Themes	Categories	f	%
Acquisition	difficulty of the acquisition	2	1.6
	Total	**2**	1.6
Learning environment	ensure safety in the lab	6	4.7
	difficulty of classroom management	2	1.6
	presence of the lab materials	1	0.8
	out-of-lab activity	1	0.8
	Total	**10**	7.8
Learning outcomes	enhancing creativity	2	1.6
	gaining skills	12	9.4
	improving SPSs	6	4.7
	inhibiting rote learning	1	0.8
	learning cause-effect relationship	1	0.8
	learning new device	10	7.8
	learning to design experiments	4	3.1
	meaningful learning	11	8.6
	Total	**47**	36.7
Student	attracting student interest	1	0.8
	sufficiency of readiness	3	2.3
	uncertainty of how to carry out the experiment	4	3.1
	presence of misconceptions	3	2.3
	making the student active	14	10.9
	Total	**25**	19.5
Topic-specific	abstract matters	2	1.6
	difficult issues	9	7.0
	experimentation in a short time	3	2.3
	presence of dependent/independent variables	8	6.3
	possibility of asking a research question	2	1.6
	no need for creativity	1	0.8
	requiring technical skills	3	2.3
	matters that can be generalized	6	4.7
	matters that need to be reinforced	1	0.8
	related to other subjects	2	1.6
	simple topic	1	0.8
	situations to be explored	6	4.7
	Total	**44**	34.4
	General total	**128**	100.0

According to Table 2, the pre-service teachers prefer strategies that consider learning outcomes (n=47, 36.7%) and topic-specific situations (34.4%) the most during instruction in the laboratory. However, acquisition (1.6%) and learning environment (7.8%) were the least important factors when choosing a strategy. According to the learning outcomes theme, students' skill-gaining, meaningful learning, and learning new devices are essential situations to consider when determining a laboratory strategy. PT12 expressed his opinion on this theme: "*I prefer this strategy if I want them to plan the experiment, set up the experiment apparatus, make observations, write their data on paper, and reach an inference from them.*" Similarly, PT 3 expressed the factor affecting the strategy preference with the statement, "*Especially if I want them to be able to perform basic skills such as weighing, measuring, filtering and separation processes, these are the factors affect my strategy preference.*"

The topic to be taught is also essential in determining the laboratory strategy to use. The difficulty of the issues, the presence of dependent/independent variables, and the ability to make generalizations or discoveries are essential in making a choice. PT 7 stated that he considered the subject in his strategy preference with the words, "*I prefer one strategy in subjects such as gas laws or solubility where they can conduct* *experiments involving dependent/independent variables, and another strategy in experiments where they will use tools and devices such as filtration and distillation*".

Desiring the students to be active in the learning environment, whether the students know how to do the experiment or not, their lack of readiness or having misconceptions has little effect on the pre-service teacher's preference for the laboratory strategy. These categories were grouped under the “student” theme. The category with the highest frequency in this theme is "ensuring that students are active". PT 13 expressed her opinion about this theme with the words, "*I use this strategy if I want students to be active in the lesson*".

The distribution of pre-service teachers' factors for preferring each laboratory strategy according to the strategies is given in Figure 5.

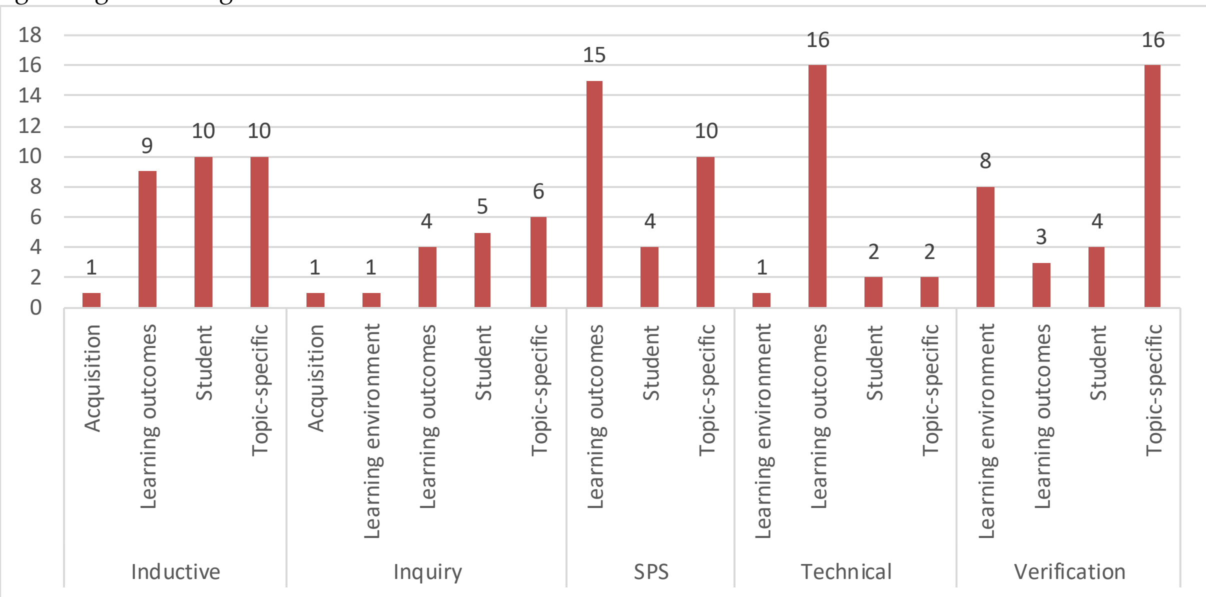

Figure 5. The distribution of pre-service teachers' factors for preferring each laboratory strategy

According to Figure 5, the pre-service teachers prefer the inductive strategy by considering student and topic-specific factors. The least considered factor when choosing this strategy is the acquisition. Similarly, the acquisition and the learning environment are the least considered in the inquiry strategy. However, it is also seen in Figure 5 that "acquisition" is not a factor affecting pre-service teachers' preferences other than these two strategies. While pre-service teachers prefer the inquiry strategy, they frequently consider topic-specific situations. Learning outcomes are the most crucial factor affecting pre-service teachers' preference for SPS and technical skills strategies. Student factors are not considered much in the preference of these strategies. Finally, it is seen that topic-specific factors affect the preference for verification strategy the most, while student and learning outcomes affect it less.

DISCUSSION, and SUGGESTIONS

This study, which examined the opinions of pre-service chemistry teachers about the strategies that can be applied in the laboratory, was handled in terms of the applicability of these strategies, the purposes of their use, and the factors of their preferences. Since the pre-service teachers had not taken a course that included laboratory teaching strategies before, the data obtained from the study represent the opinions reflected by the pre-service teachers without being influenced by other courses.

Regarding the applicability of laboratory strategies, while most of the pre-service teachers stated that laboratory strategies can be applied, some stated that they can be partially applied. The pre-service teachers who stated that the strategies could be partially applied attributed this situation mainly to the lack of materials to be used in the laboratory, and then to the inappropriateness of the student level, crowded classrooms, classroom management difficulties, time, and safety problems. Although laboratories have many benefits, limited laboratory resources in schools and some physical inadequacies result in the inability to utilize laboratories effectively (Coştu et al., 2005; Koretsky et al., 2011; Uluçınar et al., 2004). As stated in the study of K.Çoban et al. (2021), the applicability of the strategies is affected by factors such as the lack of laboratory/laboratory equipment and materials in schools, the unsuitability of the laboratory to ensure the safety of teachers and students and the insufficiency of lesson hours. It is of great importance that laboratories are equipped with chemicals, materials, and equipment. Tobin (1990) also emphasized this importance as meaningful learning in the laboratory is possible if students are given opportunities to use equipment and materials to create their understanding of phenomena and associated scientific ideas. In addition, Ayas et al. (2001) also emphasized that meaningful learning can be achieved in the laboratory and explained the situations that may cause learning difficulties as the laboratories are not adequately equipped in terms of environment and equipment, and the experiments are not integrated with the theoretical courses.

In this study, pre-service chemistry teachers determined the verification strategy as the most applicable laboratory strategy. Technical skills, inductive, scientific process skills, and inquiry strategies follow this. The factor that is thought to affect the applicability of the inductive strategy among the laboratory strategies the most is the crowded classrooms. For the inquiry strategy, this factor is the unsuitability of the laboratories. For the SPS strategy, the factors of crowded classrooms, laboratories' unsuitability, lack of laboratory materials, inappropriate student level, and time limitation are determinative. In contrast, the biggest obstacle to applying the technical skills strategy is the lack/absence of laboratory materials. The fact that classes are overcrowded makes factors such as (i) classroom management more difficult, (ii) lack of materials more apparent, and (iii) inappropriate laboratory environment more apparent. Therefore, even if pre-service teachers know how to incorporate laboratory strategies into their lessons, it is obvious that they will have difficulties in planning and implementing their teaching using these strategies due to the crowded classrooms (Freiberg, 2002; Kocakulah & Savas, 2011). These difficulties are also expressed in different studies in the literature (Yalcin-Celik et al., 2017; Yoon & Kim, 2010).

In many researches in the literature, it is emphasized that laboratories are very helpful for learning in terms of supporting conceptual learning of various subjects (Ayas et al., 1994; Hermanns et al., 2022; Hofstein & Lunetta, 1982; Wolf & Fraser, 2008). In the current study, when the purposes of pre-service teachers' use of laboratory strategies were examined, the finding that they would use these strategies mostly to ensure learning is in line with the findings of these studies. In addition, another purpose of pre-service teachers' use of laboratory strategies in the current study, which is to provide skill development in students, is also one of the purposes of laboratory use in the literature (Baseya & Francis, 2011; Bowen, 1999, Ural, 2016). These studies indicate that laboratories contribute to students' gain and development of reasoning, critical thinking, and scientific process skills. In addition, the purposes of laboratories include developing students' understanding of the nature of science, such as thinking like a scientist and understanding the properties of scientific knowledge (Domin, 1999; Gaddis & Schoffstall, 2007). In the current study conducted with pre-service teachers, students expressed this and stated they could also use laboratory strategies to learn about science and scientific methodology.

When the purposes of using laboratory strategies were analyzed separately in terms of each laboratory strategy, the pre-service teachers revealed that they would use the inductive, inquiry, and verification strategies mostly to support learning. In contrast, they would use the scientific process skills strategy to ensure skill development in students. In addition, it was determined that the technical skills strategy could be used to support students to plan/perform experiments and to support their discovery. In general, it is possible to say from these findings that pre-service teachers use laboratory strategies mostly for "learning purposes" with sub-goals such as providing meaningful learning, improving attitude, concept learning, increasing students' motivation, providing student-centered learning, and learning to work collaboratively. Hoffstein (2004) also emphasized student-centered learning and stated that by making students active in the laboratory through the use of a student-centered strategy, the laboratory can achieve its purpose, that is, it can support meaningful learning. In addition, in the same study, it was stated that this situation would contribute to the improvement of students' attitudes and motivation.

According to another study finding, the factors for pre-service chemistry teachers' preference for laboratory strategies vary according to the characteristics of acquisition, topic, student, learning environment, and learning outcomes. Pre-service chemistry teachers mostly prefer strategies that consider learning outcomes and topic-specific situations. Similarly, according to the findings of the study conducted by Nakiboğlu and Şen (2020) with pre-service chemistry teachers, it was determined that pre-service teachers took into account criteria such as being suitable for the topic, student characteristics, being suitable for the experiment, using time efficiently and being suitable for the learning environment while determining the strategies they used. Similar results were found in studies conducted with teachers. For example, K.Çoban et al. (2021) found that students, learning environment, and technological deficiencies affect teachers' planning of lessons and laboratory applications. When the current study's findings are considered separately in terms of each laboratory strategy, pre-service teachers prefer the inductive strategy mostly depending on student characteristics and subject matter. Interestingly, the outcome is the least important aspect they consider while choosing this strategy. Similarly, in the inquiry strategy, the learning outcome and the learning environment were the least considered factors. However, the first point that the teacher should consider during the instruction planning should be "acquisition". Because the acquisition reveals the goal of a lesson and is the starting point of lesson planning (Jalongo et al., 2007, p.12). Yalcin-Celik (2022), who suggested a template for planning a lesson in the laboratory effectively and easily, took the first step of the planning stage as the outcome. It was determined that the most important factor in pre-service teachers' preference for SPS and technical skills strategies was learning outcomes. Factors related to student characteristics are not considered much in the preference of these strategies. Finally, it is seen that the factors related to the subject matter affect the preference of the verification strategy the most, while student characteristics and learning outcomes affect it less.

Just as teachers' classroom practices are an indicator of their knowledge, it is possible to say that the process of pre-service teachers planning a lecture is an indicator of their own experiences. In this study, pre-service chemistry teachers taught only once using one laboratory strategy within the scope of the laboratory course. They experienced other laboratory strategies by following the micro-teaching of other pre-service chemistry teachers. This may have caused them to be more familiar with the laboratory strategy they taught and experienced and to express fewer opinions about other laboratory strategies. It was the limitation of the current study. For this reason, it is thought that microteaching of pre-service chemistry teachers using more diverse laboratory strategies may provide them with more experience. It is thought that providing more opportunities to pre-service chemistry teachers will allow them to recognize better and understand these strategies and to change and diversify their opinions on these strategies.

Declarations

Conflict of Interest

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Research and Publication Ethics Statement

Hereby, we as the authors consciously assure that for the manuscript “Investigation of Laboratory Teaching Strategies in Chemistry Education: Opinions of Pre-service Chemistry Teachers” the following is fulfilled:

- This material is the authors' own original work, which has not been previously published elsewhere.
- The paper reflects the authors' own research and analysis in a truthful and complete manner.
- The results are appropriately placed in the context of prior and existing research.
- All sources used are properly disclosed.

Contribution Rates of Authors to the Article

The authors provide equal contribution to this work.

REFERENCES

Ajewole, G. A. (1991). Effects of discovery and expository instructional methods on the attitude of students to biology. *Journal of Research in Science Teaching, 28*(5), 401-409. https://doi.org/10.1002/tea.3660280504

Alkan, F. (2016). Experiential learning: Its effects on achievement and scientific process skills. *Journal of Turkish Science Education, 13*(2), 15-26. https://doi.org/doi: 10.12973/tused.10164a

Ayas, A., Akdeniz, A. R., & Çepni, S. (1994). Fen bilimlerinde laboratuvarın yeri ve önemi-I [The place and importance of the laboratory in science-I]. *Çağdaş Eğitim,* 19, 21-25.

Ayas, A., Karamustafaoglu, S., Sevim, S., & Karamustafaoglu O. (2001, September 4-7). *Evaluation of the advantages and disadvantages of general chemistry laboratory applications from the perspective of students and teachers.* XV. National Chemistry Congress, Istanbul, Turkey.

Aydoğdu, C. (1999). Determination of the difficulties encountered in chemistry laboratory applications. *Hacettepe University Journal of Faculty of Education*, 15, 30-35.

Baseya, J. M., & Francis, C. D. (2011). Design of inquiry-oriented science labs: impacts on students’ attitudes. *Research in Science & Technological Education, 29*(3), 241-255. https://doi.org/10.1080/02635143.2011.589379

Beasley, W. (1985). Improving student laboratory performance: How much practice makes perfect?. *Science Education, 69*(4), 567-576. https://doi.org/10.1002/sce.3730690412

Bowen, C. W. (1999). Development and score validation of a chemistry laboratory anxiety instrument (CLAI) for college chemistry students. *Educational and Psychological Measurement, 59*(1), 171-187. https://doi.org/10.1177/0013164499591

Coştu, B., Ayas, A., Çalık, M., Ünal, S., & Karataş, F.Ö. (2005). Determining preservice science teachers' competences in preparing solutions and in use of laboratory tools. *Hacettepe University Journal of Education,* 28, 65–72.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd Edition). Sage publications.

Davis, L. L. (1992). Instrument review: Getting the most from a panel of experts. *Applied nursing research, 5*(4), 194-197. https://doi.org/10.1016/S0897-1897(05)80008-4

Demirtaş, B. (2006). *Kimya deneylerinde "v" diyagramlari ile ögretim etkinliginin incelenmesi [The Investigation of the effectiveness of teaching in chemistry experiments with Vee diagrams]* (Doctoral dissertation). Dokuz Eylül University, İzmir.

Domin, D. S. (1999). A review of laboratory instruction styles. *Journal of chemical education, 76*(4), 543-547. https://doi.org/10.1021/ed076p543

Freiberg, H. J. 2002. Essential skills for new teachers. *Educational Leadership, 59*(6), 56–60.

Gaddis, B.A., & Schoffstall A. (2007). Incorporating guided-inquiry learning into the organic chemistry laboratory. *Journal of Chemical Ecology, 84(*5), 848–51. https://doi.org/10.1021/ed084p848

Galloway, K. R., & Bretz, S. L. (2015). Using cluster analysis to characterize meaningful learning in a first-year university chemistry laboratory course. *Chemistry Education Research and Practice,* 16, 879−892. https://doi.org/10.1039/C5RP00077G

Gericke, N., Högström, P., & Wallin, J. (2023). A systematic review of research on laboratory work in secondary school. *Studies in science education, 59*(2), 245-285. https://doi.org/10.1080/03057267.2022.2090125

Hermanns, J., Zöllner, L., & Filschke, C. (2022). Newly designed laboratory course for preservice chemistry teachers: do the students rate their practical skills as relevant for their future profession?. *Journal of Chemical Education, 99*(11), 3713-3722. https://doi.org/10.1021/acs.jchemed.2c00618

Herrington D. G., & Nakhleh M. B. (2003). What defines effective chemistry laboratory instruction? teaching assistant and student perspectives. *Journal of Chemical Education, 80*(10), 1197-1205. https://doi.org/10.1021/ed080p1197

Hofstein, A., & Lunetta, N. V. (2004). The laboratory in science education: foundations for the twenty-first century. *Science Education, 88*(1), 28-54. https://doi.org/10.1002/sce.10106

Hofstein, A. (2004). The laboratory in chemistry education: thirty years of experience with developments, implementation, and research. *Chemistry Education Research and Practice, 5*(3), 247–264. doi:10.1039/B4RP90027H

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52*(2), 201-217. https://doi.org/10.3102/00346543052002201

Jalongo, M. R., Rieg, S., & Helterbran, V. (2007). *Planning for learning: Collaborative approaches to lesson design and review.* Teachers College Press.

K.Çoban, Ö., Yalcin-Celik, A., & Kılıç, Z. (2021). Kimya öğretmenlerinin öğretim stratejileri ve bu stratejilere etki eden faktörler [Chemistry teachers' instructional strategies and the factors that affect these strategies]. *Journal of Research in Education and Society, 8*(2), 345-361. https://doi.org/10.51725/etad.1030346

Kocaeren, A. A. (2023). Üniversite eğitimine yeni başlayan kimya öğretmenliği öğrencilerinin kimya laboratuvar uygulamalari ile ilgili görüşleri [Opinions of chemistry education students about chemistry laboratory practices at the beginning of university education] International Conference on Frontiers in Academic Research, vol 1, pp. 277-284. Retrieved from https://as-proceeding.com/index.php/icfar/article/view/88.

Kocakulah, A., & Savas, E. (2011). Fen bilgisi öğretmen adaylarının deney tasarlama ve uygulama sürecine ilişkin görüşleri [Prospective primary science teachers' views about the process of designing and practising experiments]." *Ondokuz Mayis University Journal of Education Faculty, 30*(1), 1-28.30. https://doi.org/10.12738/estp.2013.4.1853

Koretsky, M., Kelly, C., & Gummer, E. (2011). Student perceptions of learning in the laboratory: Comparison of industrially situated virtual laboratories to capstone physical laboratories. *Journal of Engineering Education, 100*(3), 540-573. https://doi.org/10.1002/j.2168-9830.2011.tb00026.x

Lazarowitz, R., & Tamir, P. (1994). Research on using laboratory instruction in science. In D.L. Gabel (Ed.), *Handbook of research on science teaching* (pp. 94–127). New York: Macmillan.

Merriam, S.B. (2013). *Qualitative research: A guide to design and implementation.* John Wiley & Sons Inc., New York.

Merritt, M. V., Schneider, M. J., & Darlington, J. A. (1993). Experimental design in the general chemistry laboratory. *Journal of Chemical Education, 70*(8), 660-662. https://doi.org/10.1021/ed070p660

Nakiboğlu, C., & Şen, A. Z. (2020). Examination of prospective chemistry teachers' opinions about instructional strategies and methods that can be used in chemistry laboratories. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 14*(1), 717-760. https://10.17522/balikesirnef.746186

Novak J. D. (1988). Learning science and the science of learning. *Studies in Science Education, 15*(1), 77-101. https://doi.org/10.1080/03057268808559949

Seery, M. K., Agustian, H. Y., & Zhang, X. (2019). A framework for learning in the chemistry laboratory. *Israel Journal of Chemistry,* 59, 546-553. https://doi.org/10.1002/ijch.201800093

Şen, A. Z., & Nakiboğlu, C., (2013, September 5-7)). *Chemistry teacher candidates' thoughts on different laboratory teaching strategies* [Conference presentation]. III. National Chemistry Education Congress, Trabzon, Turkey.

Seven, M.A., & Engin, A.O. (2018). Fen bilimleri eğitiminde laboratuvarın önemi [The importance of laboratory in science education] *TURAN: Center for Strategic Researches, 10*(38), 256-265. http://dx.doi.org/10.15189/1308-8041

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics,* 90, 403–418. https://doi.org/10.1111/j.1949-8594.1990.tb17229.x

Uluçınar, Ş., Cansaran, A., & Karaca, A. (2004). Fen bilimleri laboratuvar uygulamalarının değerlendirilmesi [The evaluation of laboratory studies in science]. *The Journal of Turkish Educational Sciences, 2*(4), 465-475. Retrieved from https://dergipark.org.tr/tr/pub/tebd/issue/26126/275208

Ural, E. (2016). The Effect of Guided-Inquiry Laboratory Experiments on Science Education Students' Chemistry Laboratory Attitudes, Anxiety and Achievement. *Journal of Education and Training Studies, 4*(4), 217-227. https://doi.org/10.11114/jets.v4i4.1395

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

Yalcin-Celik, A. (2022). Determination of the effectiveness of a template for lesson planning based on inquiry. *International Journal of Education Technology and Scientific Researches*, *7*(20), 2402-2416. http://dx.doi.org/10.35826/ijetsar.531

Yalcin-Celik, A., Kadayifci, H., Uner, S., & Turan-Oluk, N. (2017). Challenges faced by pre-service chemistry teachers teaching in a laboratory and their solution proposals. *European Journal of Teacher Education, 40*(2), 210-230. https://doi.org/10.1080/02619768.2017.1284792

Yıldırım, A., & Şimşek, H. (2005). Sosyal bilimlerde nitel araştirma yöntemleri [Qualitative research methods in social sciences], 11th Edition. Ankara: Seckin Publisher.

Yoon, H. G., & M. Kim. (2010). Collaborative reflection through dilemma cases of science practical work during practicum. *International Journal of Science Education*, *32*(3), 283–301. https://doi.org/10.1080/09500690802516538