Chapter 5

THE EFFECT OF ONLINE AND FACE-TO-FACE TEACHING ON LABORATORY ACTIVITIES BASED ON THE 5E MODEL DEVELOPED BY TEACHER CANDIDATES

Nimet AKBEN[1]

INTRODUCTION

Online education has started to be implemented compulsorily in many countries worldwide (Radhamani vd., 2021; Gupta ve Goplani, 2020) and in Turkey due to the COVID-19 (SARS-CoV-2) pandemic that started in 2020 (Radhamani vd., 2021). This system, which is new for many institutions and educators, has caused considerable anxiety and stress in the academic world. In the transition to online education, infrastructure deficiencies and the lack of sufficient knowledge, equipment, and experience of educators who will teach the course have been the leading causes of this anxiety and stress. Along with the compulsory transition, some advantages have been noticed during online classes. Being able to reach large audiences simultaneously, having no space limits, recording courses, and getting them again at any time have been among the essential advantages of online education felt at the first stage.

Furthermore, it is among the significant advantages of this education system that each individual can learn according to their learning speed (Balaman ve Hanbay-Tiryaki, 2021) and that time and money do not have to be spent to attend courses at school. In addition to the said advantages, some problems have been experienced in online education. Difficulties in access and the inability to ensure students' participation in some cases have been at the forefront of these problems. In addition to such physical challenges, issues such as not being able to create discussion environments with students, not being able to ensure their active participation in problem solutions, and not being able to provide a positive attitude have been experienced in this process (Kumaş ve Kan, 2022). Furthermore, the conduct of practice-based laboratory courses has been one of

[1] Assoc. Prof. Dr., Ankara University, nakben@ankara.edu.tr, ORCID iD: 0000-0002-2346-0494

the most significant difficulties encountered in the online education processes of students studying engineering and science disciplines, which has caused great anxiety in the academic environment (Radhamani vd., 2021; Sarvary et al.; 2022).

The critical role of laboratory courses in today's education system, where the active participation of students is considered essential, and inquiry-based teaching methods are taken as a basis (MoNE, 2018; NGSS, 2013; NRC, 2012), is accepted by all educators (Reid ve Shah, 2007). In this respect, it is clear that laboratory practices in which students engage in verification-based closed-ended experiments should be replaced by inquiry-based laboratory practices in which they discover knowledge by designing their experiments (Sarvary et al., 2022).

While verification-based closed-ended experiments' preparation and implementation stages only require a little time and effort, the situation is the opposite in inquiry-based laboratory activities. Scientific inquiry mainly includes hypothesis testing and problem-solving practices, including defining questions, establishing hypotheses, planning, conducting scientific research, and defending and reporting scientific evidence (NRC-NSES 1992). The 5E model is among the most common in using the inquiry method based on the constructivist approach as a teaching method in courses (Akben, 2011). The model consists of five stages, briefly described below (Smerdan & Burkam,1999; Çepni, 2005; Trowbridge & Bybee, 2000).

1. Engage: At this stage, it is aimed to reveal students' prior knowledge about the subject and draw their attention to the new subject to be taught. To this end, at the said stage, teachers should aim for students' active participation and mental focus on the subject to be taught.
2. Explore: At the stage in question, students are expected to establish hypotheses and make predictions. Teachers should guide students in planning experiments in line with their hypotheses without giving direct instructions. At this stage, students should be given opportunities to work with each other to discover new ideas, make observations, collect data, and test their hypotheses by testing their predictions. With these activities, students are expected to start finding answers to the questions raised during the attention-drawing stage. This stage is the stage where students are most active mentally and physically.
3. Explain: At this stage, students should be expected to explain concepts by revealing their conceptual understanding and process skills. It helps the teacher replace students' inadequate thoughts with new, more accurate ones. Although the said step seems to be the most teacher-centered stage of the

model, the student must express the first explanations and learned concepts using writing, drawing, drama, graphs, etc.

4. Elaborate: It is the stage where students apply the knowledge or problem-solving approaches they have acquired at previous stages to new events, problems, and daily life.
5. Evaluate: It evaluates students' performance, skills, concepts, and practices throughout the process. This stage, where the teacher evaluates all aspects of the process in which students carry out educational activities, is where students are expected to demonstrate their understanding or change their thinking style or behavior.

Considering all stages of the model, it is clear that developing and implementing laboratory activities suitable for this model will require meticulous preparation and a careful implementation process. Therefore, ensuring that preservice teachers understand inquiry-based laboratory courses also involves difficulties. In particular, conducting the education of preservice teachers online rather than face-to-face increases this difficulty and increases the anxiety levels of academicians (Tran et al. v Vaze, 2020). This situation requires academicians to plan a more effective practice course in the online education process. In line with the said requirement, it is crucial to focus on how online courses can be more effective by comparing the effects of online and face-to-face laboratory practice courses on preservice teachers' ability to understand and develop inquiry-based laboratory activities. To this end, the activities developed by preservice teachers at the end of the online science laboratory course developed and implemented with unique content for primary school undergraduate students and the activities developed by preservice teachers who took this course face-to-face were considered in the present study. The examinations attempted to compare the skills of preservice teachers to understand and develop inquiry-based laboratory activities in the 5E model. For this purpose, answers to the following research questions were sought.

-Is there a difference between the levels of understanding the stages of the 5E model by preservice primary school teachers who take the science laboratory practice course in online and face-to-face learning environments?

-Is there a difference between the activity development levels in the 5E model of preservice primary school teachers who take the science laboratory practice course in online and face-to-face learning environments?

METHODS

Research Design

In the present study, the quantitative research method was employed, and inquiry-based course plans in the 5E model developed by preservice teachers in science laboratory courses conducted in online and face-to-face environments were used as a data source. By applying content analysis to these written data sources (Sak et al., 2021), it was investigated to what extent preservice teachers could reflect the inquiry approach and the criteria of the 5E model.

Participants

The current study's participants are preservice primary school teachers studying in different academic years. The participants studying in the online education environment are preservice teachers who were 2nd-grade students in the 2020-2021 academic year. The participants receiving face-to-face education are preservice teachers who were 2nd-grade students in the 2022-2023 academic year. All participants receive education in the Department of Primary Education, Primary School Teaching at a state university in Ankara, the capital of Turkey. The number of students receiving online education is 30, and the number of students receiving face-to-face education is 32. The laboratory activities developed by preservice teachers were collected as written sources at the end of the semester, and all the activities were evaluated in 2023.

Research Instruments

At the end of the literature review conducted to evaluate the compatibility of the laboratory activities designed by preservice teachers with the 5E model, a questionnaire in line with the objective of this study could not be reached. Hence, the researcher developed an objective-oriented questionnaire. In this process, the 5E model was investigated in depth from different sources (Akben, 2011; Benzer, 2015; Trowbridge & Bybee, 2000), and a form was created by considering the characteristics of each stage of the model.

The activities prepared by preservice teachers were also evaluated formally in the present study. This evaluation considered the general qualifications that a teacher should provide in a laboratory activity or a course plan.

Validity and Reliability

The forms developed by the researcher were first applied to the plans of preservice teachers studying in the 2020-2021 academic year. At the end of this application,

statements that did not fully reflect the model and were thought to be similar were removed from the questionnaire. Following the arrangement, the opinions of two faculty members who specialized in science education were sought for the content validity of the questionnaire.

For the reliability of the questionnaire, first, Cronbach's alpha coefficients were calculated for the five stages used in evaluating the 5E model and determined by separate criteria. Afterward, Cronbach's alpha coefficients of the questionnaire were developed to evaluate the overall questionnaire formally, and the prepared activities were computed. Table 1 contains the obtained values.

Table 1. Reliability Coefficients of Research Instruments

Domain	Cronbach Alpha Coefficients
Engage	.721
Explore	.898
Explain	.733
Elaborate	.848
Evaluate	.828
General 5E	.862
Formal	.810

Data Analysis

The forms developed by the researcher were first applied to the plans of preservice teachers studying in the 2020-2021 academic year. At the end of this application, statements that did not fully reflect the model and/or were thought to be similar were removed from the questionnaire. Following the arrangement, the opinions of two faculty members who specialized in the field of science education were sought for the content validity of the questionnaire.

FINDINGS

To find an answer to the first question in the study, differences between the levels of understanding of the stages of the 5E model by preservice classroom teachers who took the science laboratory practice course in the primary school teaching undergraduate program in online and face-to-face learning environments were compared. To this end, the activities developed by preservice teachers were first evaluated separately for each stage of the 5E model, and finally, a general evaluation

was performed. Table 2 presents the criteria to be included in the engage stage, the first stage of the 5E model, and the comparison of the mean scores obtained by preservice teachers from these criteria.

Table 2. t-Test Results for the Mean Scores of the Engage Stage Criteria of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face.

Variables	Groups	N	X_{ort}	S	sd	t	p
The attention has been fully drawn to the subject.	Online	30	2.133	0.776	60	1.712	.0920
	Face to face	32	2.437	0.618			
It fully covers the acquisition(s).	Online	30	2.066	0.739	60	2.320	0.024
	Face to face	32	2.437	0.619			
It has been supported with appropriate materials/images.	Online	30	1.667	0.844	60	0.659	0.513
	Face to face	32	1.812	0.895			
Students' prior knowledge has been revealed.	Online	30	1.767	0.817	60	1.850	0.069
	Face to face	32	2.125	0.707			
A problem has been created in the student's mind.	Online	30	1.875	0.787	60	0.591	0.556
	Face to face	32	2.000	0.870			

The values in Table 2 show that the mean scores of preservice teachers who received face-to-face education in all engagement stage criteria were higher than those of preservice teachers who received online education. When the t-test is applied to understand whether there is a significant difference between these mean scores, a significant difference is observed in favor of preservice teachers who received face-to-face education only in the criterion of "covering all the acquisitions" of the stage ($t_{(60)}$= 2.320 $p<0.05$). No significant difference was found in other criteria.

Table 3 contains the results of the comparison of the criteria belonging to the explore step, the second stage of the 5E model, with the t-test.

Table 3. t-Test Results for the Mean Scores of the Explore Stage Criteria of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face.

Variables	Groups	N	X_{ort}	S	sd	t	p
The experiment(s) is(are) interesting for the student.	Online	30	1.900	0.712	60	0.927	0.358
	Face to face	32	2.062	0.669			
The experiment(s) is(are) appropriate for the student's level.	Online	30	2.100	0.803	60	1.433	0.157
	Face to face	32	2.375	0.707			
The level of openness of the experiment(s) is (are) appropriate.	Online	30	1.733	0.785	60	2.494	0.015
	Face to face	32	2.250	0.842			
Experimental tools have been selected from daily life.	Online	30	2.800	0.407	60	0.122	0.903
	Face to face	32	2.812	0.396			
Experiment(s) allow the student to discover knowledge.	Online	30	1.900	0.758	60	3.065	0.003
	Face to face	32	2.437	0.618			
At the end of the stage, an answer is given to the question in the engage stage.	Online	30	2.033	0.668	60	0.490	0.626
	Face to face	32	2.125	0.793			
At the end of the stage, students can obtain all the targeted knowledge.	Online	30	1.966	0.668	60	1.988	0.050
	Face to face	32	2.312	0.692			

The findings of the explore stage are similar to the findings of the engage stage. Upon examining the mean values in the criteria of this stage, it is seen that the mean scores of preservice teachers who received face-to-face education are slightly higher. When these differences are compared by the t-test, a significant difference is observed between the "appropriateness of the openness levels of the experiments" ($t_{(60)}$= 2.494 $p<0.05$) and "experiments allowing students to discover knowledge" ($t_{(60)}$= 3.065 $p<0.05$) criteria. No significant difference was revealed in other criteria.

The values in Table 4 are the findings of the explain stage of the model.

Table 4. t-Test Results for the Mean Scores of the Explain Stage Criteria of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face

Criteria	Groups	N	X ort	S	sd	t	p
Students have been given the opportunity to make explanations.	Online	30	1.733	0.907	60	1,430	0.158
	Face to face	32	1.437	0.715			
Additional explanations have been brought to the knowledge obtained in the previous stages.	Online	30	2.250	0.776	60	0.734	0.466
	Face to face	32	2.375	0.440			
It has been supported by necessary images or materials.	Online	30	1.766	0.817	60	2.550	0.013
	Face to face	32	2.250	0.672			

The most important criterion at this stage of the model is the first criterion in Table 4. At the explain stage, first, students should be given the opportunity to make explanations. Students should express the knowledge they have acquired from the previous stages in their own way so that the teacher can correct the mistakes and complete the deficiencies. However, the findings demonstrate that the mean scores in this criterion are quite low. Although there is no significant difference between the mean scores, it is seen that the mean scores of preservice teachers who received face-to-face education are lower than those who received online education. This finding shows that preservice teachers prefer to explain instead of giving students the right to speak. The reason why the mean values in the second criterion of the stage are higher than the other criteria is that preservice teachers try to make students understand the acquisitions with their own expressions instead of making them discover the acquisitions. At this stage, the knowledge not included in the explore stage is attempted to be made understood through explanation.

Table 5 presents the findings of the elaborate stage, which were examined in 3 criteria.

Table 5. t-test Results for the Mean Scores of the Elaborate Stage Criteria of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face.

Criteria	Groups	N	X_{ort}	S	sd	t	p
The knowledge obtained at the previous stages has been associated with other disciplines.	Online	30	1.667	0.884	60	1.369	0.176
	Face to face	32	1.375	0.793			
The concepts acquired at the previous stages have been used in the learning of new concepts.	Online	30	1.933	0.827	60	0.577	0.566
	Face to face	32	1.812	0.820			
The knowledge obtained at the previous stages has been elaborated with examples from daily life.	Online	30	2.133	0.776	60	2.599	0.012
	Face to face	32	2.562	0.504			

Concerning the values in Table 5, the mean scores of preservice teachers for the first two criteria are quite low. These findings demonstrate that preservice teachers are not adequate in associating science course subjects with other disciplines. Furthermore, preservice teachers are also inadequate in integrating the learned concept/concepts into a new concept. This finding does not show any difference, whether preservice teachers received online or face-to-face education. At the stage in question, preservice teachers mostly preferred to give examples from daily life. Preservice teachers may have preferred this way since it is the easiest one. In this criterion, there is a significant difference between preservice teachers who received online and face-to-face education in favor of preservice teachers who received face-to-face education ($t_{(60)}= 2.599$ $p<0.05$).

The findings for the evaluate stage, the last stage of the model, are shown in Table 6.

Table 6. t-Test Results for the Mean Scores of the Evaluate Stage Criteria of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face.

Criteria	Groups	N	X_{ort}	S	sd	t	p
It is directly related to acquisitions.	Online	30	2.500	0.572	60	1.935	0.580
	Face to face	32	2.750	0.439			
It stimulates students' thinking skills.	Online	30	1.766	0.817	60	0.439	0.662
	Face to face	32	1.687	0.592			
Traditional assessment and evaluation techniques have been employed.	Online	30	1.433	0.727	60	5.156	0.000
	Face to face	32	2.437	0.800			

Considering Table 6, which includes the values of the criteria at the evaluate stage, a significant difference is observed between preservice teachers studying in online and face-to-face learning environments only in the last criterion ($t_{(60)}$= 5.156 $p<0.05$). Whereas preservice teachers studying in the online learning environment used traditional assessment and evaluation techniques, preservice teachers studying in the face-to-face learning environment also included alternative assessment and evaluation techniques such as puzzles and diagnostic branched trees.

After the activities developed by preservice teachers who took the science laboratory practice course in online and face-to-face learning environments were compared according to the criteria that should be present in the steps of the 5E model, the overall mean scores at each step were compared. Table 7 contains these scores and t-test results.

Table 7. t-Test Results for the Mean Scores of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face.

Variables	Groups	N	X_{ort}	S	sd	t	p
Engage	Online	30	9.633	3.746	60	1.167	0.249
	Face to face	32	10.687	3.383			
Explore	Online	30	14.433	1.568	60	2.306	0.025
	Face to face	32	16.375	4.353			

Table 7. t-Test Results for the Mean Scores of Laboratory Activities Compatible with the 5E Model Developed by Preservice Teachers Studying Online and Face-to-Face.

Variables	Groups	N	X_{ort}	S	sd	t	p
Explain	Online	30	5.633	1.033	60	0.858	0.394
	Face to face	32	5.937	1.664			
Elaborate	Online	30	5.733	0.583	60	0.046	0.963
	Face to face	32	5.750	1.883			
Evaluate	Online	30	5.700	1.022	60	3.245	0.002
	Face to face	32	6.875	1.718			

Concerning the values in Table 7, a significant difference is revealed in favor of preservice teachers who received face-to-face education at the explore ($t_{(60)}$= 2.306 $p<0.05$) and evaluate ($t_{(60)}$= 3.245 $p<0.05$) stages.

After comparing the laboratory activities based on the 5E model developed by preservice teachers on the basis of the model's stages, they were also compared through a general evaluation. At the end of the activities carried out in the general evaluation, criteria such as whether the acquisitions were gained by students, the quality of the sources and visuals used, originality and spelling rules were determined. The mean scores and t-test results for this evaluation are presented in Table 8.

Table 8. t-Test Results for the Formal Mean Scores of Activities Developed by Pre-service Teachers Studying Online and Face-to-Face.

Variables	Grps	N	X ort	S	sd	t	p
It is capable of fully providing acquisitions to students.	Online	30	2.000	0.694	60	0.701	0.486
	Face to face	32	2.125	0.707			
Concepts have been used fully and correctly.	Online	30	2.133	0.730	60	1.773	0.081
	Face to face	32	2.437	0.618			
The number and quality of the sources used are sufficient.	Online	30	1.766	0.727	60	1.451	0.152
	Face to face	32	1.500	0.718			
The content of the images/videos used is appropriate and sufficient for the subject.	Online	30	2.067	0.639	60	1.445	0.154
	Face to face	32	1.812	0.737			

Table 8. t-Test Results for the Formal Mean Scores of Activities Developed by Pre-service Teachers Studying Online and Face-to-Face.

Variables	Grps	N	X ort	S	sd	t	p
It is specific to the preservice teacher.	Online	30	1.400	0.621	60	0.238	0.813
	Face to face	32	1.437	0.618			
The language used is understandable and in accordance with the spelling rules.	Online	30	2.233	0.728	60	1.478	0.145
	Face to face	32	1.937	0.840			

The results in Table 8 show no significant difference between preservice teachers who took the course face-to-face and online in any of the general evaluation criteria. The values in the table also demonstrate that preservice teachers who took the course online had a higher mean score in terms of the sufficiency and quality of the sources and visuals used and the compliance with the spelling rules.

Finally, the general compatibility of the activities with the 5E model and formal evaluations were compared within the scope of the study. The findings of these comparisons are given in Table 9.

Table 9. t-Test Results for the Mean Scores of Activities Developed by Preservice Teachers Studying Online and Face-to-Face.

Variables	Groups	N	X_{ort}	S	sd	t	p
Compatibility with Model 5E	Online	30	41.133	3.319	60	0.489	0.626
	Face to face	32	45.625	12.275			
Formal general evaluation	Online	30	11.600	1.220	60	1.938	0.057
	Face to face	32	11.250	3.733			

In the present study, in which activities based on the 5E model developed by preservice primary school teachers who took the science laboratory course in online and face-to-face learning environments were compared, the compatibility of the activities with the 5E model and their general formal qualities were compared. The findings in Table 9 indicate that conducting the course in online or face-to-face learning environments is not effective enough to cause a significant difference in the success of preservice teachers.

DISCUSSION-CONCLUSION

Online education was started in March 2020 due to the COVID-19 pandemic, and this mandatory and rapid change has caused significant concerns in the education world. Although conducting theoretical courses online seems more understandable and more accessible, deep concerns (some concerns) were experienced about the conduct of applied courses such as laboratories. In laboratory courses, students must carry out experiments/activities one-to-one and develop and implement them. How this process will be carried out in online education, how to provide experimental skills to students, and what role academicians will play in courses have emerged as important problems. The compulsory "science laboratory practice" course in the primary school teaching undergraduate program is among the courses in which this problem is experienced. The fact that students who took this course were preservice teachers increased the problem of the course conduct even more because, in the course, students are expected not only to do experiments but also to understand the objective and application methods of experiments and have the equipment to reflect this knowledge and experience to their professional lives. This expectation increased the difficulty and uneasiness in the online conduct of the "science laboratory practice" course, necessitating more meticulous planning of courses. This requirement has led to investigating whether the online laboratory course is as effective as face-to-face courses and comparing the effects of two different learning environments. To this end, laboratory activities based on the 5E model developed by preservice primary school teachers who took the course in online and face-to-face learning environments were compared in the present study.

In the comparison, the characteristics of the 5E model stages were first considered, and the criteria that should be present in these stages were determined. In line with the determined criteria, the activities developed by preservice primary school teachers who took the course in online and face-to-face learning environments were evaluated. Primarily, the criteria that should be present in each stage and then the scores of the five stages were compared. Afterward, the compatibility of the activities with a course plan in general was compared, and finally, their compatibilities with the 5E model and the general course plan were compared. The results acquired from the findings are attempted to be explained briefly below.

In the comparison made by considering the criteria in the "engage" stage, the first stage of the 5E model, the mean scores of preservice teachers who took the

course face-to-face had a significant difference only in the criterion of "covering all the acquisitions." It is thought that this difference originated from preservice teachers having the chance to share their activities with their peers in the face-to-face education environment, and the mentioned criterion was frequently emphasized during these practices. In the second and most crucial stage of the model, the "explore" stage, significant differences were found in the criteria of "appropriateness of the openness levels of the experiments" and "experiments allowing students to discover knowledge." It is thought that this significant difference in the two criteria, which are very important for the explore stage, is due to the lack of understanding of the openness levels of experiments and what "exploration" means during online courses. This result, which aligns with the finding obtained in the study by Benzer (2015), is thought to originate from the fact that the participants accept that these are the procedures also employed in the experiments conducted with the traditional method. Moreover, the fact that preservice teachers usually design experiments such as those applied to them in previous education periods rather than taught to them (Hanuscin & Lee, 2008) supports this result. Furthermore, it is assumed that preservice teachers who take courses online tend to provide more direct information due to the sources they use.

The most essential criterion in the explained stage of the 5E model is prioritizing student statements. However, the findings demonstrate that preservice teachers have low mean scores and mostly prefer to explain themselves. The finding mentioned above shows that preservice teachers take the methods applied to them as a basis, different from what they have learned. At the elaborate stage, preservice teachers mostly gave examples from daily life. The fact that a concept learned at the explore stage is not used in teaching a new concept or cannot be associated with other disciplines indicates that preservice teachers have a lack of knowledge about the subject (Benzer, 2015) and they do not have confidence in themselves (Akben, 2011). At the evaluation stage, most preservice teachers benefited from traditional assessment and evaluation techniques. The thought that the reason for this is that preservice teachers do not have sufficient knowledge about alternative assessment and evaluation approaches is in line with the study by Taşdere and Özsevgeç (2012).

In comparing the activities compatible with the 5E model only based on stages, a significant difference was observed in favor of preservice teachers who received face-to-face education in the explore and evaluate stages, which is quite remarkable for the importance of face-to-face education. Although preservice teachers have

acquired a lot of knowledge and skills in online learning environments, it is clear that face-to-face education is more effective in practice courses. According to this result, these deficiencies found in preservice teachers studying in an online learning environment should be eliminated. In this respect, it may be appropriate to compensate for these deficiencies with additional courses to be given in the period after the COVID-19 pandemic.

In the general evaluation of the activities developed by preservice teachers, no significant difference was found between preservice teachers who took the course in face-to-face and online learning environments. However, although there was no significant difference, it is quite thought-provoking that preservice primary school teachers had such a low mean score, especially in the criterion of "using an understandable language and complying with the spelling rules." It is a problem that should be stressed that preservice teachers will be teaching primarily at the education level at which students will learn the information about spelling rules for the first time. It can be said that particularly academicians who provide literacy education should address the problem in question. Furthermore, it should be ensured that preservice teachers feel that not only sources but also their own original practices are very important in the course content that they will prepare, and it should be stressed that changes should be made in these contents according to their grade levels in their professional lives.

REFERENCES

Akben, N. (2011). *Öğretmen adayları için bilimsel sorgulama destekli laboratuvar dersi geliştirilmesi*. Yayınlanmamış doktora tezi, Gazi Üniversitesi, Ankara.

Benzer, E. (2015). Examination on science teacher candidates' levels in designing experiments based on 5e and their opinions about the designing. *Dicle Üniversitesi Ziya Gökalp Eğitim Fakültesi Dergisi*, 25, 302-328.

Çepni, S. (2005). *Fen ve teknoloji öğretimi*. Ankara: Pegem A Yayıncılık.

Hanuscin, D. L. & Lee, M.H. (2008). Using the learning cycle as a model for teaching the learning cycle to preservice elementary teachers. *Journal of Elementary Science Education,* 20(2), 51-66.

Ministry of National Education (MoNE) (2018). Primary education science curriculum. T.C. Ministry of National Education, Board of Education. http://ttkb.MoNE.gov.tr/. Accessed 7 Jan 2023.

National Research Council (1996). *National Science Education Standarts [NSES]*. Washington, DC: National Academy Press.

National Research Council (NRC) (2012). A framework for K–12 science education: practices, crosscutting concepts, and core ideas. Washington, DC: National Academies Press. https://www.nap.edu. Accessed 10 June 2023.

NGSS Lead States (2013). *Next generation science standards: for states, by states. Washington*. DC: National Academies Press. http://www.nextgenscience.org/. Accessed 10 June 2023.

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

Sak, R., Şahin Sak, İ. T., Öneren Şendil, Ç. & Nas, E. (2021). Bir araştırma yöntemi olarak doküman analizi. *Kocaeli Üniversitesi Eğitim Dergisi*, 4(1), 227-250.

Smerdan, B.A. & Burkam, D.T. (1999). Access to constructivist and didactic teaching, Who gets it? Where is it practiced?. *Teachers College Record*, 101 (1), 5

Taşdere, A. & Özsevgeç, T. (2012). Fen ve teknoloji öğretmen adaylarının pedagojik alan bilgisi bağlamında strateji-yöntem-teknik ve ölçmedeğerlendirme bilgilerinin incelenmesi. *X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi*, Niğde Üniversitesi Eğitim Fakültesi, 2730 Haziran, Niğde.

Trowbridge, L.W. ve R.W. Bybee, (2000). *Models for effective science teaching, teaching secondary school science*. PrenticeHall, Inc., New Jersey.