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Proficiency Development in Science Laboratory Practices with the Flipped Learning Model in the Distance Education Process in the COVID-19 Pandemic

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Abstract: *In this action research study, it was aimed to develop proficiency in Science Laboratory Practices (SLP) for prospective classroom teachers (PCTs) with the online flipped learning model in the distance education process in the COVID-19 pandemic. A 14-week course was designed for the study. The results demonstrated that PCTs showed proficiency development in a variety of contexts, such as awareness of the importance of the laboratory, knowledge acquisition about laboratory materials, rules and skill development for planning and practising a science experiment. The study is of high importance in terms of being an exemplary application for the development of proficiency in online flipped SLP and offering suggestions about the problems encountered in this process and their solutions.*

Key Words: online flipped learning; prospective classroom teachers; science laboratory practices; science education

INTRODUCTION

Science education is of great importance for raising people who will produce knowledge and technology. (Bal Taştan et al., 2018). One of the primary goals of science education is to raise scientifically literate people (Bybee et al., 2009; Evans & Rennie, 2009; Laugksch, 2000; Kolstø, 2001; Pongsophon et al., 2010; Roberts & Gott, 2010). In general, science literacy is the understanding of the scientific method, basic scientific concepts and science policies (Miller, 1983). Science literacy skills function effectively in the acquisition of basic concepts and principles related to science, developing scientific thinking habits, producing scientific knowledge and technology, building a link between science and daily life, and gaining democratic citizenship skills. Students use the fundamentals skills of science literacy by using skills that scientist use, such as making observations and planning and conducting experiments (Jurecki & Wander, 2012). The implementation of laboratory practices that provide an opportunity to learn through experimentation and observation in science education needs to be realised for the improvement of science literacy of students.

The purpose of laboratory work in science education is to help students learn science by gaining theoretical and conceptual knowledge, and to help them learn about science by understanding the nature and methods of science. Another purpose is to enable students to do science using scientific research protocols. In addition, laboratory studies are important for the

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development of analytical and critical thinking skills (Ottander & Grelsson, 2006). Learning in the laboratory has long been a critical component of science education (Kwok, 2015; Isozaki, 2017; Olufunke, 2012). Science laboratory activities are learning experiences wherein students engage with materials and/or models in order to observe and comprehend the natural world (Hofstein & Lunetta, 2004). Science laboratories are environments where students create scientific knowledge, develop basic scientific thinking skills, comprehend the nature of science and learn by doing (Hofstein & Lunetta, 2004). While providing students the opportunity to see how nature works (Kwok, 2015), it supports the development of positive attitudes towards science (Freedman, 1997). Students embody science lab practice and science concepts through experimentation (Harman et al., 2016). At the same time, science laboratory practices provide students with the opportunity to gain the ability to observe, plan experiments, interpret experimental data, measure, classify, record data, form hypotheses and generate data, change and control variables (Platova & Walpuski, 2013).

Although science laboratory practices are of high value for all education levels where science education is carried out, they have a special importance in primary school science education. Methods of science education provide direct and meaningful learning for children in their early years to promote their natural curiosity (Barak & Dori, 2011; Murphy et al., 2012). Since the abstract thinking skills of children are not developed in these years, science laboratory studies should be carried out effectively in order to concretize science concepts, lay the foundation for the development of scientific thinking skills, raise awareness for the value of science and develop positive attitudes (Bilir, 2019; Tekin et al., 2012). In order to achieve this, classroom teachers should have the necessary professional development for science laboratory practices. In this direction, primary school teacher candidates need to gain knowledge, skills and attitudes for laboratory practices in science education. There are findings that classroom teachers have various problems in science laboratory experiments (Arslan, 2000; Tekin et al., 2012). As a matter of fact, it is observed that many teachers are afraid of laboratory practices and do not experiment because they cannot do enough experiments in their education life. Classroom teachers are afraid to experiment, even if they are very simple experiments (Tekin et al., 2012). Science lessons are taught by classroom teachers in primary school education. There are findings that classroom teachers have various problems in teaching science, they do not see themselves at a sufficient level in the field of science, and they do not take necessary precautions in terms of laboratory use and experiments. (Arslan, 2000).

In order to ensure professional development of pre-service teachers in laboratory practices and to develop positive attitudes towards laboratory practices, courses related to these should be taught in undergraduate education processes. The SLP course is defined for this purpose in the undergraduate education program prepared by the Council of Higher Education (CoHE) for PCTs in Turkey. Within the scope of this course, raising awareness for the purpose, importance and safety precautions of the laboratory in science teaching, the development of knowledge and skills about scientific method, scientific process skills and how they are gained, knowledge and skills acquisition for planning and applying laboratory experiments for primary school with simple and inexpensive materials are targeted (CoHE, 2018).

In the COVID-19 pandemic, starting in 2020, March, courses in universities shifted to online instruction in Turkey, as in many countries. The shifting decision was taken by CoHE, in Turkey. CoHE is an institution which is responsible for the strategic planning of higher education and coordination between universities in Turkey. The decision necessitated the SLP being delivered online like the other courses. As this course is a practical course, classes with at most 20 or 30 students were formed in the traditional education process. As for the distance education process, all students enrolling in this course had to complete it in a single class during the specified distance education course term. A single class delivery of the content presented a challenge presented the challenge of conducting a practical course with a remote practice, as well as the challenge of providing practical knowledge and skill development for a large number of PCTs in a short course term defined as weekly simultaneously. On the contrary, various limitations accompanied this process, such as the lack of access to very simple experiment tools and equipment, and the lack of internet in order to attend classes regularly. Those limitations necessitated the planning of this course, which would be held by distance education, for a crowded class. Therefore, in this study, the flipped learning model was completely transformed into the distance learning process and designated for the SLP course.

In the flipped learning model, students work with course-related materials, videos and digital media which were created using different instructional technologies before the lesson, while in-class time is devoted to discussions, analysis and problem solving activities (Youngkin, 2014). Various studies have been carried out in which flipped learning practices are used for laboratory practices (Bachnak & Maldonado, 2014; Çelik et al., 2021; Elkhatat & Al-Muhtaseb, 2021; Jeong et al., 2016; Loveys & Riggs, 2018; Tang et al., 2020) . Tang et al. (2020) studied the flipped learning model in the Electromagnetic Fields and Waves course for engineering students, while Jeong et al. (2016) studied the laboratory practices in a general science course, which is one of the second grade courses of the Primary Education bachelor program, using the flipped learning model. Elkhatat and Al-Muhtaseb (2021) conducted their study in the Unit Operations Laboratory course with the students of the Department of Chemical Engineering through the hybrid online-flipped learning model. Furthermore, Brown and Krzic (2021) studied the flipped learning model in the Introduction to Soil Science course, and Çelik et al. (2021) studied flipped learning in the General Physics Laboratory-II course with first-year university students studying in the Science Education department. Our study, aimed to develop proficiency for SLP for PCTs with the online flipped learning model. During the COVID-19 pandemic, an online flipped learning model was designed for PCTs to develop their ability to plan and practice experiments with real implementation, as in laboratory practices in the traditional education process. In the design process, it was planned to carry out both pre-lesson practices and in-class practices related to the SLP course with the online flipped learning model. Outcomes from this study will provide suggestions for the solution of the problems encountered in this process and what kind of a process can be followed for PCTs to acquire skills in the SLP course through distance education. Furthermore, the study will be an exemplary application for the instructors to provide students with the necessary proficiency in a SLP course through online education within the limitations of the COVID-19 pandemic. The study will also contribute to the literature on online flipped learning model, SLP and primary school teacher training.

The research questions for this study the study are the following:

1. How can proficiency for the SLP course be developed in PCTs with online flipped learning practices?
2. How should arrangements be made in the implementation process for this development?
3. What are the problems encountered during the SLP course and how can these problems be solved?

Method

Research Model

In the COVID-19 pandemic, this study was designed as an action research, with the aim of providing knowledge and skills to PCTs about SLP through distance education. Action researches are studies that aim to understand and improve the quality of teaching or action by explaining a problem encountered in the school or classroom environment and a possible solution (Johnson, 2005). In this study, there is a group of PCTs who have the problem of lack of knowledge and skills for SLP. Due to the COVID-19 pandemic, this proficiency development needs to be realized through distance education applications. The research is based on an impressionistic approach that includes continuous planning, implementation and evaluation in order to solve that problem with the online flipped learning model in the COVID-19 pandemic.

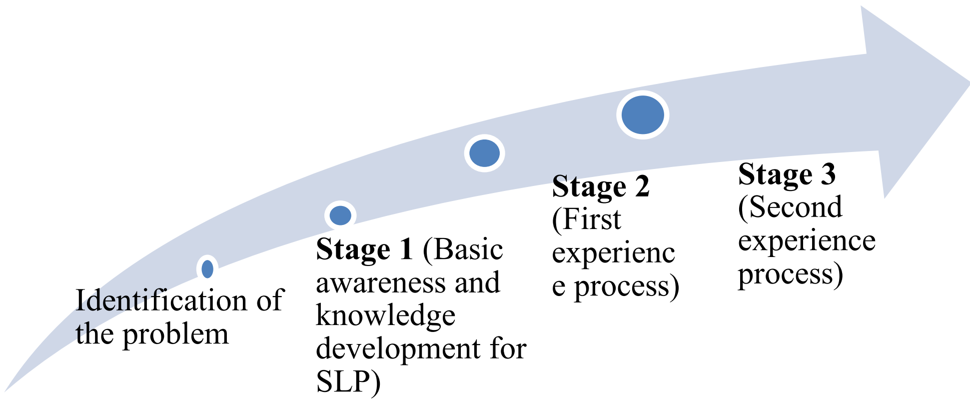
The Study Group

The study group consisted of 72 prospective classroom teachers in the second grade at a state university in Turkey. These PCTs have limited knowledge and skills of Science Laboratory Practices. The participants ranged in age between 19 and 20 and consisted of 54 females and 18 males. All the PCTs were taking the course for the first time in their course work. The course was taught by an instructor with two degrees in science education and eight years of experience teaching science laboratory practices in face-to-face settings.
The lecturer voluntarily participated in the research in order to solve this problem that she encountered in her teaching process during the COVID-19 pandemic, that is, to improve the aforementioned knowledge and skills in teacher candidates.

Studies Performed in the Research Process

The studies carried out within the scope of the research are presented in Figure 1 with their main lines.

Figure 1
Stages Followed in the Action Research



As seen in the Figure 1, after defining the research problem, the problem of the case was identified, and then an action plan consisting of three stages was prepared based on the data obtained from the problem of case identification. Detailed information on these processes is presented in stages.

Identification of the Problem

In order to determine the problem in the research, data was collected from the PCTs with the Science Laboratory Practices Proficiency Evaluation Form (SLPPEF). The results showed that PCTs could not make detailed explanations about the importance of science laboratory and experiments for science education, and they did not have knowledge about scientific process skills, scientific method, science laboratory rules, tools, experiment planning and implementation.

ACTION PLAN PREPARATION AND IMPLEMENTATION PROCESS

Based on the identification of the problem and literature review, a three-stage action plan was prepared in order to develop proficiency in SLP in PCTs. Data on these stages and implementation processes are presented respectively.

Stage 1

At this stage, it is aimed to develop basic awareness, knowledge and skills about SLP in PCTs. five weeks were allocated to gain knowledge about the importance of SLP for science education, science laboratory rules, scientific process skills, scientific method, laboratory materials, tools and equipment, the use of the microscope, and the preparation of an experiment plan. For the practices, first of all, the class was divided into 18 groups of 4 people and the groups were asked to come together and work on zoom in all practices. In the implementation process, students studied on the materials (video recordings, lecture notes, online resource suggestions, etc.) shared before the lesson. Discussion, question-answer, narration and activity studies were carried out on the related topics in the course via Adobe Connect. Thus, it was tried to gain prerequisite knowledge, awareness and skills in order to be able to plan and implement science experiments.

Stage 2

In this process, which is called the first experimentation process, the first experimentation studies were carried out for the development of competence so that the PCTs could prepare and practice an experiment plan for the primary school science lesson.

Four new groups in each four weeks and two new groups in one week presented their experiment results. One of the themes in the science curriculum was determined for each week, and the PCTs were asked to prepare an experiment plan for the objectives under these themes as a group and work on their implementation. Before the lesson, the PCTs communicated via the Zoom application, phone, and e-mail, and communicated for planning and implementation of the experiment. In this process, they prepared the experiment plan(s), recorded their experiments, implemented them and reported them. They uploaded the reports and implementation records they prepared three days before the lesson to the Adobe Connect. Reports and video recordings of experiments uploaded to the system were shared on the system of all students. Before the lesson, all PCTs were asked to examine the experiment reports and recordings, and attend the course. During the course, with the participation of one representative as spokespeople from each group that prepared the experiments, all PCTs were asked to criticise the experiments. In the criticism process, the characteristics that an experiment plan should have and the criteria in the evaluation rubric were taken as basis. In this process, in addition to the well-done steps, deficiencies and mistakes were determined with the participation of all PCTs under the guidance of the lecturer. These processes also served as instructive for PCTs who would practice later. Moreover, after the evaluations of the weekly practices, the groups who wanted were given the opportunity to rearrange the experimental processes and upload them to the system, and corrective feedback was given by the lecturer. At this stage, each group had the opportunity to observe and criticise the practice of 17 groups. PCTs carried out 71 experiments in total and each PCT was provided with the opportunity to observe and evaluate at least 66 different experiments apart from their own group implementation.

Stage 3

At this stage, which is called the second experimentation process, the second experimentation studies were carried out after the first experience of the science experiments of the PCTs and the observation and evaluation process of the first experiences of the other groups. In this process, it was aimed to make the planning and implementation skills of PCTs more accurate. At this stage, a similar implementation process was followed with the first experimentation process, and a total of five weeks of implementation was made. PCTs carried out 44 experiments in total, and each PCT had the opportunity to observe and evaluate at least 39 different experiments apart from their own group implementation. At this stage, each group also compared their second practice with their first experience and made their development-based self-assessment.

Data Collection Tools

Self-Assessment Form for Basic Awareness Development (SAFBAD)

In the study, the SAFBAD was used in order to evaluate the basic awareness, knowledge and skill development of the PCTs regarding SLP. Five open-ended questions were asked to the PCTs to assess their competencies related to knowledge, skills and awareness in the SAFBAD. The questions are about the importance of science laboratory applications for science education, science laboratory rules, scientific process skills, scientific method, laboratory tools and equipment.

Experiment Reports and Recordings

In the study, the experiment reports and recordings prepared by the PCTs regarding weekly practices generated data about the development of experiment planning and implementation proficiency, and data for determining the deficiencies and mistakes on this development.

Self-Evaluation Papers (SEP)

In the study, data was collected through SEPs in order to evaluate the proficiency development and the effectiveness of the practices for primary school SLP from the PCTs' perspective.

Course Meeting Recordings

In the study, course meeting recordings were used to determine the proficiency developments related to weekly experiment implementation and the problems encountered in the process.

Data Collection

In the study, the implementation was made for 14 weeks. Before the implementation process, the PCTs uploaded the experiment reports they prepared and the video recordings of the experiments to the system. Furthermore, weekly courses on the Adobe Connect were recorded on the system. After the first stage was completed, the SAFBAD has been filled in by the PCTs through the system. The SEPs were filled through the system after the implementation process was completed.

Analysis of Data

The data are presented under separate headings as analysis of SAFBAD, analysis of planning and performing science experiments skill development, analysis of problem data related to planning and performing science experiments, and analysis of self-evaluation papers.

Analysis of Self-Assessment Form for Basic Awareness Development (SAFBAD)

In the study, the data collected with the SAFBAD were analysed by content analysis. The transcripts prepared in the content analysis process were examined line by line, and categories were created based on the codes. Five categories emerged as a result of the analysis. These categories are headed under the names of the importance of SLP, experiment equipment and laboratory rules, scientific method and scientific process skills, knowledge of planning and reporting a science experiment, and knowledge of science curriculum.

Analysis of Planning and Performing Science Experiments Skill Development

The reports and recordings data of the weekly science experiments were examined together in order to observe the development of the PCTs' skills of planning and performing primary school science experiments. The analysis process was carried out in two stages. In this process, first of all, the performance levels related to the planning and performing science experiments, and then, the skill development levels of planning and performing science experiments were analysed by using performance levels and data related to science experiments were analysed using The Evaluation Rubric for the Skill of Planning and Doing Science Experiments (ERSE) (Table 1) which was created with expert opinions in the first stage. Seven components are based on the analysis of performance levels in the ERSE (See Table 1).

Table 1
The Evaluation Rubric for the Skill of Planning and Doing Science Experiments

The Evaluation Rubric for the Skill of Planning and Doing Science Experiments				
Number of the Group: **Beginning/First/Second Stage** **Name of the Experiment:**				
The performance components for the skill of designing an experiment plan and performing the plan	**The Performance Levels**			
	3	**2**	**1**	**0**
	If the required proficiency in the component is fully realized	If the performance has been carried out for the required proficiency in the component, but it contains deficiencies	If the component has been studied for the required proficiency but contains errors	If the performance carried out for the required proficiency in the component is completely faulty or not done at all
To be able to determine (an) appropriate aim/s for an experiment (To be able to realise aims in the primary school science courses and scientific process skills)	Appropriate objective(s)for the science experiments have been determined in a way to realise aims of the primary school science courses and the development of scientific process skills.	Appropriate objective(s)for the science experiments have been determined in a way to realise aims of the primary school science courses and the development of scientific process skills, but they contain deficiencies.	Appropriate objective(s)for the science experiments have been determined in a way to realise aims of the primary school science courses and the development of scientific process skills, they also contain false aims.	Appropriate objective(s) has/have not been set or no aims have been set to realise aims of the primary school science courses and the development of scientific process skills.
To be able to determine an appropriate experiment to achieve the aim(s) (To be able to prepare an experiment to realise the determined aim(s))	An experiment that can be done with simple tools to achieve the set objectives has been determined.	An experiment that can be done with simple tools to achieve the set objectives has been determined, but it contains deficiencies.	An experiment that can be done with simple tools to achieve the set objectives has been tried to be determined, but it contains errors.	No experiments are not determined to be done with simple tools to achieve the set objectives.

To be able to organize the implementation process of the experiment	The implementation process of the experiment has been organised in detail so that the objectives are realized in a safe environment.	The implementation process of the experiment has been organised in detail so that the objectives are realized in a safe environment, but it contains deficiencies.	The implementation process of the experiment has been tried to be organised in detail to realise the objectives in a safe environment, but it contains errors.	The implementation process of the experiment has not been organised in such a way as to achieve the objectives in a safe environment.
To be able to organize the theoretical information about the experiment	Theoretical information about the experiment is comprehensively organised according to the level of the students so that they can interpret the results of the experiment in connection with daily life.	Theoretical information about the experiment is comprehensively organised according to the level of the students so that they can interpret the results of the experiment in connection with daily life, but it contains deficiencies.	Theoretical information about the experiment is comprehensively organised according to the level of the students so that they can interpret the results of the experiment in connection with daily life, but it contains errors.	Theoretical information about the experiment was not arranged according to the level of the students so that they could interpret the results of the experiment in connection with daily life.
To be able to implement the experiment	The experiment has been carried out by making detailed explanations in accordance with the process steps.	The experiment has been tried to be implemented by making explanations in accordance with the process steps, but it contains deficiencies.	The experiment has been tried to be implemented by making explanations in accordance with the process steps, but it contains errors.	The experiment was not carried out by making detailed explanations in accordance with the process steps.
To be able to determine the results of the experiment	The results of the experiment are explained in detail, including the relationships between the variables.	The results of the experiment are tried to be explained in a way to include the relationships between the variables, but they contain deficiencies.	Experiment results are tried to be explained in a way to include the relationships between variables, but they contain errors.	Experiment results were not explained to include the relationships between variables.

To be able to determine the results of the experiment	The results obtained in the experiment were interpreted in detail by using theoretical information by associating them with daily life.	The results obtained in the experiment were interpreted in detail by using theoretical information by associating them with daily life, but they contain deficiencies.	The results obtained in the experiment were interpreted in detail by using theoretical information by associating them with daily life, but they contain errors.	The results obtained in the experiment were not interpreted using theoretical information by associating them with daily life.
NOTES:				

For each of the components of the rubric, four performance levels ranging from 0 to 3 were determined. In the process of determining these performance levels, four descriptive criteria were determined and the components were evaluated according to the descriptive criteria.

When the performance levels and the descriptive criteria related to these levels are examined in Figure 1, it is seen that a process from performing the required qualification for the performance component from the highest level to the lowest is completely faulty or not done at all. In the study, analysis was made for the seven components specified for each experiment.

After determining the performance levels, based on the performance levels of the components, skill levels related to science experiment planning and implementation were used in the second stage. In the creation of the skill levels, the levels in Öztürk's (2019) study were taken as a basis. Based on the levels, An Evaluation Guide for Planning and Implementation Skill Levels for Science Experiments (EGSL) was created. The EGSL is given in Table 2.

Table 2
An Evaluation Guide for Planning and Implementation Skill Levels for Science Experiments

Levels	Point Scale
Very Good	The performance level of all components is 3.
Good	The performance level of the components varies between 3 and 2.
Medium	The performance level of all components is 2.
Needs improvement	The performance level of one of the components is 0* or 1*,while the others are above 1
Weak	• The performance level of at least two of the components is 1 or 0. • The performance level of the component of goal setting is 1 or 0.

**0 and 1 performance levels cannot be in the setting of goals component

Table 2 displays that there are five levels for the development of planning and application skills for primary school science experiments. In the study, skill development level analysis was made based on the performance levels for all experiments. The experiments in the beginning, first and second stages were analysed through the ERSE and EGSL. The findings of the analysis are elaborated in detail in the findings section.

Analysis of Problem Data for Skill Development Related to Planning and Implementing Science Experiments

The problems encountered in the process should be determined and resolved as soon as they occur in action research (Best & Kahn, 2006). Problems encountered during the skill development process for science experiments were identified and resolved during the implementation process. For this purpose, data related to course records, experiment reports and video recordings were analysed. The findings obtained from the problem analysis are presented together with the findings of the development of planning and implementation skills for science experiments.

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Analysis of Self-Evaluation Papers

The transcripts of the SEP were analysed by content analysis. In this process, the codes were created by examining the transcripts. These codes were then examined and categories were created by bringing together those that serve similar purposes. After these examinations, six categories and 55 codes gathered under these categories were reached. The categories are named as knowledge and skills development for science experiment, awareness development with science experiments, finding the implementation process effective, benefits of the way the lesson is taught, professional and individual development, and problems encountered in the process.

Reliability and Validity of the Study

Various procedures have been carried out to ensure validity and reliability in the research process based on the literature (Lincoln & Guba, 1985, p.300; Johnson, 2005). There was a long-term interaction, the process was recorded, data diversity was made through recording the courses and experiments, self-assessment forms and self-assessment papers and research processes were defined in detail to ensure transferability (Lincoln & Guba, 1985, p.301) Encoder reliability was ensured for the reliability of the analysis results. The coding made by the coder, who is an expert in the field of science education, was compared with the coding made by the researchers. The coder reliability was calculated as 97,39%, 98,50% and 97, 05% for the SAFBAD, the data of the recordings and reports of the experiments and the SEP respectively (Miles & Huberman, 1994). Consensus and disagreement analysis were made, and consensus was reached by discussing the codes with disagreement with the expert

Findings

Findings of Basic Awareness, Knowledge and Skills Development for Science Experiments

In the study, within the scope of the SAFBAD findings, the PCTs stated that they had achieved the necessary awareness, knowledge and skills before starting the experiment. These findings were gathered in five categories: the importance of SLP, experiment equipment and laboratory rules, scientific method and scientific process skills, knowledge of planning and reporting a science experiment, and knowledge of science curriculum. Regarding the importance of SLP, PCTs stated that they gained knowledge and awareness about why science laboratory practices are important in science education. PCTs were in the opinion that SLP is important to concretize abstract information, gain the habit of scientific thinking, develop scientific process skills, understand the relationship between real life and science subjects, make science lessons fun, realize learning by doing, achieve permanent learning, and provide interest and motivation for science courses. One of the students (S36) stated as follows: "In science teaching, it is very important for students to learn the topics through experiments and embody abstract concepts rather than narration. Therefore, it is necessary to provide an environment for experiments. Here, the laboratory comes into play. Therefore, in order for the science course to be effective, permanent and persuasive, the course should be held and supported in a laboratory environment."

PCTs stated that they gained a lot of knowledge about the experiment tools and equipment and laboratory rules used in SLP. They stated that they learned about the tools and equipment used in the laboratory, for what purposes they are used, how they are used, the structure of the microscope and how it is used, laboratory rules and how to take safety precautions. However, three of the PCTs stated that they have knowledge about these tools, but it would be better if they had the opportunity to learn by touching. As an example, one of them (S19) stated, “Unfortunately, I don't feel improved enough about the tools and equipment. Since the course is not face-to-face and so we weren’t in the lab, we couldn't learn the tools and materials. I think I learned superficially.”

PCTs stated that they gained overall awareness and knowledge for scientific methods and scientific process skills, their importance and how they are employed. “…both the experiments I did and the curricula I prepared helped me understand scientific methods and scientific process skills.” said one of the PCTs (S25).

Regarding the knowledge of science experiment planning and reporting, PCTs stated that they gained necessary theoretical knowledge for planning experiments in primary school science lessons. One of them (S28) stated, “…..Because I learned this planning by doing it on my own….” They obtained various information about the sections that should be included in an experiment report, determining goals while planning an experiment, deciding the experiment to realize the aims, choosing the appropriate experiment tools and equipment, organizing the application process of the experiment, and organizing the theoretical knowledge. However, some of the PCTs reported that since they learned them in theory, could see the competencies of what they really learned during the implementation process and believed that they would make up for their deficiencies in that process. In terms of knowledge of science curriculum, the PCTs remarked having had information about the general structure, goals, classification of units and subjects, aims, learning-teaching processes, and assessment approaches of the primary school science curriculum.

The PCTs understood the importance of SLP knowledge for planning experiment planning. In the findings, PCTs achieved various aims for the necessary theoretical knowledge and awareness before planning and applying science experiments.

Findings of Skills Development Regarding Planning and Implementing Science Experiments

Experiment reports and video recordings were examined in order to determine whether there was an improvement in the planning and implementation skills of PCTs for science experiments. The findings regarding processes of the development of science experiment planning and application skills of the SLAs are presented in three stages, which are the beginning developmental stage, the first stage and the second stage. Findings of the beginning developmental stage are given below in Table 3.

Table 3
Findings Regarding Performance Levels of the Skills of Planning and Implementing Science Experiment Plans at *the Beginning Developmental Stage*

	Frequency Values				
Group No	Very Good	Good	Medium	Needs Improvement	Weak
G1	0	0	0	0	4
G2	0	0	0	0	4
G3	0	0	0	0	4
G4	0	0	0	0	4
G5	0	0	0	0	4
G6	0	0	0	0	4
G7	0	0	0	0	4
G8	0	0	0	0	4
G9	0	0	0	0	4
G10	0	0	0	0	4
G11	0	0	0	0	4
G12	0	0	0	0	4
G13	0	0	0	0	4
G14	0	0	0	0	4
G15	0	0	0	0	4
G16	0	0	0	0	4
G17	0	0	0	0	4
G18	0	0	0	0	4
Total	0	0	0	0	72

It is seen in Table 3 that none of the PCTs at the "beginning" stage, which includes identifying the problem, have the skills to plan and implement a science experiment, and they perform at a "needs improvement" level. At this stage, PCTs stated that they would not be able to plan and implement experiments because they did not have any previous experience in science laboratory.

In the study, a two-stage process, 1st and 2nd stages, was followed for the development of planning and implementation skills for science experiments for PCTs. Findings of the first stage is presented in Table 4 in detail.

Table 4
Findings Regarding Performance Levels of the Skills of Planning and Implementing Science Experiment Plans at *the First Stage*

	Frequency Values				
Group No	Very Good (f)	Good (f)	Medium (f)	Needs Improvement (f)	Weak (f)
G1	0	0	2	3	0
G2	0	1	1	3	0
G3	0	0	0	4	0
G4	0	0	0	5	0
G5	0	2	1	3	0
G6	0	1	0	3	0
G7	0	3	0	1	0
G8	0	0	0	3	0
G9	0	4	1	2	0
G10	0	1	0	2	0
G11	0	4	0	0	0
G12	0	2	0	2	0
G13	0	2	0	0	0
G14	0	6	0	0	0
G15	0	0	0	4	0
G16	0	3	0	2	0
G17	0	0	0	0	0
G18	0	0	0	0	0
Total	0	29	5	37	0

It is seen that the students conducted a total of 71 experiments in groups during the first stage. When the results of the first stage are examined, 29 (40.85%) experiments were at the good performance level, 5 (7.04%) were at the medium performance level, and 37 (52.11%) were at the level of needs improvement performance in terms of carrying out experiment planning and implementation., it is clear that medium or good skills development has been achieved in a significant portion (47.89%) of the experiment implementations carried out by the PCTs during the first experience stage. Furthermore, a significant portion of the experiment implementations (52.11%) is at the needs improvement level. Additionally, at least one of the experiments carried out by 13 out of 18 groups is at the needs improvement level. On the other hand, one of the most striking findings regarding the skill development of the groups at this stage is that among the experiments performed by eight of the groups, there were simultaneous experiments at both needs improvement and medium/good performance levels. This situation shows that although there is an awareness for skills development in planning and conducting science experiments in PCTs, skills development is not fully achieved. Moreover, at this stage, only three groups' all experiments are at good performance level. An example of the "needs improvement" skill level, which is the highest rate skill level in the experiment implementations performed at this stage, the third experiment performed by the 6th Group at the first stage can be given as an example. The main goal of the group's experiment, which was carried out within the scope of force and motion unit, was determined as “students explain the effect of force on objects by observing". The aims related to that main goal were determined as "students learn the accelerating and shape-changing effects of force, and do experiments on the force to gain movement and change the shape of the objects". However, when both the selected experiment and the results were evaluated, it was determined that the experiment was conducted not for the accelerating effect of the force, but only for the effect of changing the shape and for distinguishing the flexible and inflexible objects. It is understood that the experiment was not designed to realize all of the aims. Experiment results, on the other hand, were structured on flexible and inflexible objects, not in the context of the accelerating and shape-changing effects of force in accordance with the aims of the experiment. In addition, there was no interpretation of the experiment results linking with theoretical knowledge and daily life. However, the theoretical knowledge about the experiment was partially sufficient and the stages of the experiment were applied in accordance with the prepared plan. Consequently, the experiment contains faulty, incomplete and fully performed parts. The proficiency of the group performing this experiment was evaluated at the needs improvement skill level. The most encountered problems in this process were related to aims. the most prevalent problems encountered in the process of determining the aims are determined as the inability to determine the aims suitable for primary school science curriculum aims, determining the aims above the level of primary school students, inability to create aims for the development of scientific process skills, setting aims for scientific process skills unrelated to experiment and setting missing aims for scientific process skill development. Out of these, the “Based on the flow properties of gases and liquid, he/she deduces that their molecules are capable of translational motion " aim in the second experiment of the 12th group on the matter and its properties, can be given as an example for setting aims for experiments that are not suitable for the students’ level. Moreover, there were various problems related to determining the appropriate experiment, organization of the process, structuring the theoretical knowledge correctly, creating, interpreting and applying the results. For instance, within the scope of the process organization, PCTs have experienced problems such as not being able to take adequate security measures, insufficient, incomplete or incorrect process steps to achieve the aims, and deficiencies in the selection of appropriate tools and equipment for the experiment. In solving these problems, corrective and improving feedbacks were provided in the online lessons, make-up lessons were made with the flipped learning method depending on the needs, and the students were given the opportunity to correct their deficiencies/mistakes and upload them to the system again. The groups were given feedback again. The groups that conducted experiments again were given feedback again. Regarding the second stage, the findings are given in Table 5 below.

Table 5
Findings Regarding Performance Levels of the Skills of Planning and Implementing Science Experiment Plans at *the Second Phase*

	Frequency Values				
Group No	Very Good	Good	Medium	Needs Improvement	Weak
G1	0	2	0	0	0
G2	0	2	0	0	0
G3	0	4	0	0	0
G4	0	2	0	0	0
G5	0	2	0	0	0
G6	0	2	0	0	0
G7	0	2	0	0	0
G8	0	2	0	0	0
G9	1	3	0	0	0
G10	0	3	0	0	0
G11	0	2	0	0	0
G12	1	1	0	0	0
G13	0	2	0	0	0
G14	1	2	0	0	0
G15	0	4	0	0	0
G16	0	3	0	0	0
G17	0	1	0	0	0
G18	0	2	0	0	0
Total	3	41	0	0	0

When the second stage findings related to the experience process were examined 3 (6.8 %) are at very good skill level and 41 (93.2%) are at good skill level among 44 experiment implementations developed by the PCTs. These findings show that as a result of the implementations, at least good level of experiment planning and application skills development was achieved in all experiments. In the second stage, the skills level with the highest rate in terms of planning and performing science experiments was the "good" skill level. In planning and conducting experiment tasks evaluated in good skills development, the levels of all performance components varied between 2 or 3. The desired proficiency in the performance components of planning and applying science experiments skills has been fully realized, which means 3 points or the desired proficiency has been studied, but contains deficiencies, which means 2 points. As an example of the experiments evaluated at this level, the second experiment carried out by the 13th Group, "What is required for the germination of plants" can be given. The main goal of the group's experiment was determined as "Examines the environmental factors necessary for the germination of a seed". The aims for that main goal were determined as "Explains the conditions required for germination; observes the germination status of seeds of the same plant in different environmental conditions; records the observation data and explains the results". For this purpose, water, temperature and oxygen were determined as the independent variables and the germination status of the seed was determined as the dependent variable in the experiment. In addition, control variables were specified in the experiment. Within the scope of the experiment, six different experimental preparations were prepared and the germination status of the seed was observed at certain intervals, and both visual data and measurement data were recorded. The experiment was carried out in accordance with the steps of the procedure, the observation data were recorded, a table was created and the results were structured. However, it was determined that there were some deficiencies in the process of associating the experimental results with daily life and scientific theoretical knowledge in the process of discussion and interpretation. Therefore, this experiment was evaluated at good skills level. At this stage, another science skill level achieved was very good skill level. An example of the experiment performed at this skill level is the first experiment which 9th Group carried out in this stage. With that experiment, it was aimed to understand the function of light in vision. Therefore, it was aimed to gain scientific process skills such as observing that vision occurs in the presence of light, making observations and drawing conclusions.

The experimental setup prepared in the experiment consisted of a box that would allow the flow of light when desired and the objects placed inside it. In addition, a flashlight was used as a light source in the experiment. In the first stage of the experiment, the inside of the box was observed without light (in the dark) and then when the box was illuminated with a light source, observation was made, and inferences were made by recording and evaluating the results. The results were interpreted together with scientific information about how the phenomenon of seeing occurs biologically and the function of light in this process. In addition, detailed information about the function of light in the visual process with examples from daily life was included in the experiment report. This experiment was rated at the "very good" skills level because of fully adequate performance for all performance level components. The most encountered problem in this process was related to the interpretation of the experimental results. The PCTs had problems in interpreting the results in connection with daily life, taking into account the relationships between the variables and using the relevant theoretical knowledge. In order to solve these problems, feedback was provided by the PCTs outside the group and the course instructor in the online lessons, and support was provided for the group members who made the implementation to make self-evaluations and to identify the source of their mistakes and correct them.

When the skills development findings for planning and implementing science experiments are evaluated in general, it can be said that with online flipped applications, skills development has been provided for science experiments for PCTs from the initial stage to the first experience stage, and from the first experience stage to the second experience stage, and that students have developed at least "good skill" level after the practices.

Findings of the SEP on the Implementation Process and Individual Development

In the study, data were collected through self-assessment papers for PCTs to evaluate their development of experiment planning and implementation skills for the science course and the effectiveness of the application process. Opinions about the implementation process and individual development were grouped under six categories. Among them, they stated that they gained theoretical knowledge about experiment planning and implementation, preparing reports, taking safety precautions, creating aims for science experiments, learning scientific process skills and how to gain them, theoretical knowledge about laboratory materials and science topics within the scope of the category of "knowledge and skills development for science experiment". Of these, gaining knowledge with science topics was expressed by one of the PCTs as "I gained knowledge about primary school science subjects thanks to experiments and reports" (S2).

Within the scope of "awareness development with science experiments", which is another category stated aims related to realizing the importance of aims in experiment planning, understanding the purpose of experimental studies, their contribution to science and their importance for permanent learning, realizing the importance of implementations in science lessons, the importance of scientific process skills, the relationship between science and real life, and awareness formation for science curriculum have been achieved. Among these, realizing the importance of scientific process skills was expressed by one of the PCTs as "I realized that scientific process skills are of great importance in the comprehension, implementation and teaching of science course" (S4). Another PCT (S54) stated, "Our report was very good in our last study. After preparing this report, I looked through our first report for revision and I saw that our first report was extremely confusing and incomplete. If I had not prepared the report and taken this course, the report wouldn't have helped me a lot." "When we looked at our first and second studies while preparing for the experiments, I saw how much I improved myself." said the other PCT (S47).

Within the scope of the category of "finding the implementation process effective", PCTs stated that they found the flipped online learning process for science experiments effective. They stated that they found the lesson instructive, productive, fun and enjoyable, that the lesson was as good as face-to-face education, that it increased motivation and that they were happy to take the lesson. One of the PCTs said that he/she was happy to take the course, "First of all, I am very happy that I took this course… Because this course has contributed a lot to me…" (S13).

Within the scope of the "benefits of the way the lesson is taught" category, the PCTs stated that they had the opportunity to see different experiments, the way of teaching the course enabled multidimensional thinking, gained them critical thinking skills, provided educational and instructive feedback, provided opportunities for self-assessment and peer assessment, provided socialization and communication in the classroom, provided unity and solidarity, ensured not to break away from the process, created an archive for primary school science experiments, allowed them to see the individual development process and taught to identify the deficiencies. Among these, multidimensional thinking, socialization, communication and seeing different experiments are stated by one of the PCTs as: "First of all, in this course, I was prompted to think multi-dimensionally. We increased in-group interaction and communication. We examined the experiments of our friends. There were different experiments. I saw experiments that I had never seen before…" (S68). Another student (S27) explained the benefits of the feedback, "Our instructor's comments and the comments we made on each other's experiments revealed our deficiencies and errors, and we prepared for the second assignment in our minds about what we should do."

With regard to "professional and individual development", PCTs stated that they improved themselves in teaching appropriate to the level of the student, doing experiments in schools without laboratories, doing science experiments with simple materials, learning information to be used in teaching life, understanding the importance of teaching scientific thinking, understanding the relationship of science lesson with daily life, science literacy critical thinking, reflective thinking and scientific process skills. They also stated that their desire to do research, question and learn has increased and they have gained permanent knowledge and skills. Among these, science literacy and learning to experiment in schools without a laboratory were asked by two of the PCTs, "…I started to behave like a scientifically literate individual" (S9) "…We learned that if we were to work in a school without a laboratory, we could do our experiments very well with materials that are everywhere and I experienced it" (S7). Another PCT (S20) expressed the professional contribution of the course, “At the same time, I learned how the instruction I will give in the future should be and how to evaluate it according to the perspectives of the children, how to make them love this lesson and how to convey the information.” As for the importance of doing experiments in the course, one of the PCTs (S33) pointed out, “I learned that it is not enough to just give a lecture without doing experiments. Instead, students learn better with experiments, and teaching science by doing experiments is a more effective and permanent way of learning and teaching.” It is seen that the problems experienced in the context of "problems encountered in the process" are generally focused on online connection problems. In this context, PCTs stated that they had problems in attending the course online, finding a regular internet connection, getting excited while shooting the experiment videos, and having problems uploading the experiment videos.

When the results are evaluated in general, it is seen that the PCTs found the SLP course designed on online flipped learning useful in many contexts and they thought that they gained various aims in the context of both individual and professional development in this process, and that it can be said that the problems experienced in the process are generally related to the online system. As an example, one of the PCTs (S9) stated, “I sometimes couldn't attend the course, couldn't be active all the time, couldn't intervene immediately when I got stuck, the internet was intermittent. There were many times that I had communication difficulties.” Another PCT (S18) expressed the difficulties in recording videos, “However, the most challenging thing for me for this course was video recording the experiments. Because I sometimes uttered the wrong sentences, and so I recorded the video from the beginning at the slightest mistake and submit it in that way.”

Discussion, Conclusion and Recommendations

When the results are evaluated generally, it can be said that the SLP, which has been carried out with online flipped learning, has contributed to the development of knowledge and skills so that the PCTs can practice science experiments in primary schools., it was determined that the SLP showed skill development for the PCTs to plan and implement science experiments. Considering that the main purpose of the SLP is to develop experiment planning and implementation skills for pre-service teachers (CoHE, 2018), it can be concluded that an important development has taken place with online flipped SLP. Gaining knowledge and awareness about the laboratory rules, tools and safety precautions in science laboratory education is important for implementing experiments in a safe manner (Aladejana & Aderibigbe, 2007). In the experiments carried out in this study, knowledge development was provided. One of the main purposes of science education is to gain scientific process skills, and science laboratory practices are an important method. In this study, the PCTs gained knowledge and skills about scientific process skills, their importance and how to gain them. It can be inferred that the instruction carried out with online flipped SLP has achieved various aims for gaining scientific process skills in science education. Moreover, the PCTs stated that the course helped to gain theoretical knowledge about science subjects, to learn science curricula, and to see the connection between science and real life. In order to carry out science education effectively, it is necessary to establish connections with daily life (Andrée, 2005, p.107; Campbell & Lubben, 2000). In the implementations carried out in the study, connections with daily life were established both in theoretical knowledge and in the interpretation of the results, and PCTs achieved aims in this way. Furthermore, the PCTs stated that they realized the importance of experiments in science education through experiments, and they gained awareness for the contribution of science experiment implementations to science and permanent learning.

These results point to the development of a positive attitude for experimentation in science lessons. Consequently, it can be inferred that the online flipped SLP also contributes to the development of attitude.

In the study, the PCTs stated that they achieved various aims such as learning to teach appropriately to the students' level, learning to conduct experiments in schools without laboratories, learning to do science experiments with simple materials, learning knowledge that can be used in the classroom, understanding the importance of teaching scientific thinking, with the online flipped SLP in the context of professional development. When the professional development of the teaching profession is examined, it is observed that the acquisition of knowledge and skills for effective learning comes to the fore. It can thus be suggested that these aims which are evaluated within the scope of professional development are important in terms of teacher professional development for effective science education in primary school.

The PCTs stated that they found the online flipped SLP instructive, productive, fun and enjoyable, that the lesson was as good as face-to-face education, that it increased motivation and that they were happy to take the lesson. Similarly, in different studies on flipped learning practices (González-Gómez et al., 2016; Jeong et al., 2016; Sanandaji & Ghanbartehrani, 2021) the courses are enjoyable and fun and the students were in a positive opinion towards flipped education. Jeong et al. (2016) concluded that students' perceptions of flipped learning are positive in their study in general science course. The students stated that a flipped classroom lesson was fun and interactive. Çelik et al. (2021) stated that the flipped learning model positively affected students' laboratory self-efficacy and attitudes towards the laboratory. In addition, within the scope of the "benefits of the way the course is taught" category, the PCTs stated that they had the opportunity to see different experiments, that online flipped education provided multi-faceted thinking, gave critical thinking skills, and provided educational and instructive feedback, which the authors reached the similar conclusion in this study. Sanandaji and Ghanbartehrani (2021) also concluded that online flipped learning is effective. They suggested that online flipped learning affects students' learning better than traditional online learning. They also stated that the combined model of online and flipped learning had a positive effect on students' assessment and attracting students' attention. Additionally, Karalis and Raiko (2021) stated that all elements of distance online learning (better allocation of time, increased cooperation, active participation, interaction between students and between students and faculty, opportunity to develop critical thinking) are functional and that students expressed positive opinions about online flipped learning.

One of the results of the study is the students' opinions that online flipped learning model provides an opportunity for self-assessment and peer assessment, in-class socialization and communication, and in-class unity and solidarity, and ensures that they are not disconnected from the process. During the process, it was observed that the communication within the groups and the communication between the groups were at a good level. Yen (2020) also concluded in his study that online flipped learning and sharing the experiences and ideas of teachers and students improves the classroom atmosphere. In addition, Yen (2020) stated that in online flipped teaching, post-lesson activities have an emotional function in group cohesion; thus, in addition to everyone's ability to learn, communicate and work in teams, students have more opportunities to learn and collaborate. As a matter of fact, in the current study, students communicated with each other on the experiments they wanted to do, carried out their experiments in the direction they planned and wrote their reports. In this study, students stated that they created an archive for primary school science experiments. Since the students plan and conduct the experiments within the scope of the course according to the units and their aims in the current science curriculum of the primary education, each experiment conducted is an example in the archive for future science lessons, reinforced with feedback.

In another result, students stated that flipped learning model enables them to see individual development processes and teaches them to identify their deficiencies. In his study, Yen (2020) revealed that group activities bring students together to discuss certain issues not only to improve students' thinking skills, but also to train students in solo struggle and team skills, and to improve students' ability to adapt to study. In other words, group work contributed to the positive development of individual students as well. In their study, Hao (2016) concluded that working in groups in flipped learning provides students with significant help, insight and mental support, and this can strengthen their learning levels in the flipped classroom. Lee and Choi (2019) revealed the positive effect of learning materials given before the lesson on success. Loveys and Riggs (2019) reached a similar conclusion. As for this study, the videos prepared for the students were published on the platform before the lesson. Thus, the students came to the lesson ready, having critiqued the relevant videos. As a result, no time was wasted in the lesson. Karalis and Raiko (2021) also revealed that students spent more time studying the learning material in online flipped learning. Furthermore, the authors concluded that students were able to take a great deal of responsibility for studying the material, which is an essential prerequisite for the successful implementation of flipped learning approaches. Students working in online groups before the lesson developed their collaborative skills. Elkhatat and Al-Muhtaseb (2021) also concluded that students' teamwork, critical thinking and learning skills increased through collaborative discussions in online sessions.

When the study results are evaluated in general, it can be said that the online flipped SLP provides many aims in the context of knowledge and skill development for the science laboratory and supports the professional development of the PCTs. However, in this study, practices have been carried out with action research on the PCTs, and thus there are limitations. In order to test the effectiveness of the online flipped SLP, it may be recommended to conduct experimental studies in which comparative studies of the online flipped SLP and face-to-face SLP are carried out, and to conduct studies on different groups.

However, most of the PCTs showed improvement to a good skill level, but they did not develop at a very good skill level in the process of commenting because they did not gain sufficient science education knowledge in their previous education life. Thus, it can be recommended to increase the number of courses in undergraduate education in order for PCTs to gain theoretical knowledge about science education for the undergraduate education processes.

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