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Examining the Views of Preservice Teachers about Online Science Education during the Covid-19 Lockdown: Expectations, Opportunities, Threats, Motivations, and Beliefs

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ABSTRACT

Switching from face-to-face learning to mandatory online education during the coronavirus pandemic brought much uncertainty and new experiences for undergraduate students who were unfamiliar with that type of learning. This research aimed to identify perceptions and experiences of preservice [PST] teachers about taking science courses online in the teacher education programs during the Covid-19 lockdown. 180 PSTs voluntarily participated in this study from three public universities located in different regions of Turkey. These PSTs enrolled in seven different science and science education courses, including Science, Technology, and Society - Science Teaching Methods, Introduction to Science, Science and Technology Teaching, Radiation and Health Physics, Science Curriculum, Application of Science in Technology. The data was collected via online questionnaires, which were applied before and after online learning and analyzed via deductive and inductive content analysis. As a result, we identified six different categories, representing their perspectives, including concerns, expectations, opportunities, threats, motivation/interests, and beliefs. In each category, PSTs' responses were given with different codes, which were gathered under sub-categories. The results indicated that initially, PSTs had many expectations/opportunities, concerns, and beliefs toward the online education process. While some of these expectations, beliefs, and opportunities were fulfilled during the online learning process, some fundamental issues caused various obstacles in this process as well.

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Introduction

The pandemic lockdown that started with the spread of the Covid-19 virus at the beginning of 2020 has brought an unexpected process to the whole world. Many educational institutions were caught unprepared for this period; therefore, a quick adaptation to the new normal has become necessary to continue education effectively (CoSN, 2020). It is essential to examine various stakeholders' opinions and experiences of this process to minimize the adverse effects of this sudden transition.

Researchers worldwide have been researching to display the experiences of teachers, students, parents, and school administrators in transitioning to online education during the Covid-19 pandemic (Chakraborty, Mittal, Gupta, Yadav, & Arora, 2020; Croft, Moore, Guffy, Hayes, Gragnaniello, & Vitale,2020; Marek, Chew, & Wu, 2021; Kapasia et. al., 2020; Levrini, Fantini, Barelli, Branchetti, Satanassi, & Tasquier, 2020; Okebukola et. al., 2020; Sintema, 2020; Ünal & Bulunuz, 2020). However, there are still gaps in our understanding of how these experiences are unique and vary across disciplines, grade levels, and contexts. Therefore, further research is needed to better understand students' and teachers' experiences and perceptions to initiate innovations and support students' journey in online education.

Adaptation to online education is challenging for educators (Adıgüzel, 2020; Guangul, Suhail, Khalit, & Khidhir, 2020; World Bank, 2020) and students (Bataineh, Atoum, Alsmadi, & Shikhali, 2020) in various studies. Along with the general drawbacks of online education, such as technological infrastructure and lack of interaction between students and teachers, there are also concerns for online science teaching and learning as it involves practical applications such as experiments and hands-on activities. Therefore, it is important to be aware of opportunities, threats, concerns, beliefs, and expectations of online science education future teachers' eyes.

Literature Review

As with students in all levels, undergraduate students also had to switch from face-to-face learning to mandatory online learning in many countries during the coronavirus pandemic. In Turkey, the first Covid-19 case was declared on March 11. Shortly after, the Council of Higher Education of Turkey (YOK) announced that education in all public universities must switch to online education until further notice. This sudden shift brought much uncertainty and new experiences for teachers, academicians, parents, and students who were unfamiliar or less familiar with online education.

Recent research from various countries found that the implementation of online education during the Covid-19 pandemic was challenging. These challenges include, but are not limited to, technological competence, access to online lessons, motivational issues, and assessment issues. One of the biggest challenges of online education is undoubtedly about reaching all students. Kapasia and colleagues (2020) argue that online education is discriminatory against students who do not have an internet connection, and for this reason, cannot attend the classes. In parallel with this argument, research have found that students especially those who live in rural areas and have poor internet connection, as well as lack of technological devices, cannot take full advantage of online learning (Bataineh et al., 2020; Croft et.al., 2020; Kapasia et. al., 2020; Özdoğan & Berkant, 2020; Sarıoğlan, Altaş, & Şen, 2020).

According to the survey results administered by the American College Testing [ACT], 14% of 13,000 U.S. high school students reported having unpredictable and terrible internet connection, and 13% of students reported having access to only one technological device. In response to the same survey, students from rural areas reported having less access to online learning and therefore needed to have printouts of the classroom materials. The same survey results addressed other stressors during the pandemic along with the challenges of online education itself. Some of these stressors were related to students' socioeconomic status and their increased duties at home, including watching after siblings (Croft et al., 2020).

Inequities in opportunities could be a concern in every country, but the situation appeared more severe in various countries. Kapasia and colleagues (2020) examined undergraduate and postgraduate students' perceptions and experiences about online education in India during the Covid-19 pandemic. They found that only about 15% of students attended online courses daily, and most students attended online classes using their cell phones. A small percentage of them followed the lesson using a laptop. These students also stated that they did not have an appropriate home environment to study (Kapasia et al., 2020). Similarly, Karatepe, Küçükgencay and Peker (2020) investigated mathematics, science, and elementary PSTs' perceptions about online education in Turkey. The researchers found that most of the participants used only smartphones to attend the online classes.

In another study, Sintema (2020) examined Zambian mathematics and science teachers' views about students' performance in STEM subjects during the pandemic. Teachers predicted a drop in the students' performance in school and on the national examinations because of a lack of facilities for e-learning and loss of connection hours. Okebukola and colleagues (2020) provided a brief look at chemistry education in five African countries, including Burundi, Ghana, Senegal, Morocco, and Nigeria. The researchers addressed challenges regarding online education in these countries. They argued that these challenges would persist in the near future due to the loss of teacher motivation diminished by low, irregular wages and lack of funding to solve problems.

Another challenge of online education is the difficulty of keeping students motivated and engaged. Gonçalvez, José Sousa, and Santos Pereira (2020) examined Portugal university students' perceptions about distance learning using an online survey. Students participated the study reported a lack of motivation and concentration during online learning. Similarly, Bataineh and colleagues (2020) conducted a study with Jordanian undergraduate and postgraduate students from various universities and found that students were not satisfied with distance learning due to technological deficiencies and a lack of motivation. In another study, Özdogan and Berkant (2020) examined the views of various Turkish stakeholders, including teachers, students, academicians, parents, and school administrators, about the advantages and disadvantages of teaching and learning in the Covid-19 pandemic. Students' lack of motivation was one of the commonly stated disadvantages of online education. Chakraborty and colleagues (2020) investigated undergraduate students' ideas about online learning. They found that students thought instructors could make their lessons more interactive by using different educational tools such as digital pens.

Conducting student assessments online during the pandemic has brought challenges for instructors due to the lack of preparation combined with the issues that exist in the nature of online assessment (Guangul et al., 2020). Adıgüzel (2020) examined teachers' views of student assessments during the pandemic. The findings showed that teachers preferred to use exams that involved open-ended questions. The results also showed that teachers did not use other assessment methods, including students' learning folders and self and peer assessments. Departing from this, current literature suggests using alternative student assessments in online education such as homework assignments (Adıgüzel, 2020; Ali, 2020; García-Peñalvo, Corell, Abella-García, & Grande-de-Prad, 2021).

Along with the general shortcomings of online education, there are also challenges in teaching science online. The biggest concern that has been discussed in the literature about online science teaching is about the implementation of science practices, including experiments and hands-on activities (al Darayseh, 2020; Bakioğlu & Çevik, 2020; Chadwick & McLoughlin, 2020; Sarıoğlan, Altaş, & Şen, 2020; Ünal & Bulunuz, 2020). Bakioğlu and Çevik (2020) investigated middle school science teachers' online education experiences during the pandemic. Teachers reported that they had concerns about not covering the curriculum and providing laboratory experiences for students. Ünal and Bulunuz (2020) investigated science teachers' experiences of teaching during the pandemic. The majority of teachers stated that they could not do experiments during online teaching and found it as the major disadvantage of online science education. Similarly, Sarıoğlan, Altaş, and Şen (2020) investigated Turkish science teachers' views and experiences about conducting experiments in science lessons during the pandemic. Teachers in the study argued that they were not able to either integrate experiments in their science lessons or just made demonstration experiments at the synchronous lessons during the pandemic. Chadwick and McLoughlin (2020) addressed Irish teachers' concerns about implementing science experiments in online education because of students' poor access to technology for carrying out practical activities and safety concerns about home experiments.

Although the Covid-19 pandemic brought challenges, this new process also introduced educators and students to new experiences and opportunities. Bergeler and Read (2020) conducted a quasi-experimental study to examine face-to-face and online learning processes of non-physics majors. The research findings showed that students enrolled in online course groups reported slightly higher satisfaction with the flexibility due to asynchronous and systematic organization of the lessons. The authors also argued that online learning rituals encouraged students to improve their self-motivation and time management skills compared to their face-to-face peers. Science teachers, in another study, stated that online science education is advantageous in respect to being safer in experimenting, being less time consuming, involving parents in activities, and sharing links of videos and simulations shown in lessons (Sarıoğlan et al., 2020). In another study, science teachers reported that they could improve their experiences with educational technology during the pandemic and evaluated that as a positive professional development experience (Bakioğlu & Çevik, 2020).

Based on the findings of the literature review, we have seen that the sudden shift to online science education brought unprecedented challenges. At the same time, this new process appeared to open up new avenues for those who have started to adapt to the process and utilized opportunities of online education. However, online education is very new for many and needs to be further explored to support arguments. As teacher educators in science and elementary education departments, we aimed to work with PSTs to better understand their transition to online science learning in the era of Covid-19. More specifically, we aimed to examine their perceptions and experiences of taking online science education courses to fill the gap in the literature. Furthermore, the findings of this study might support future students and teachers in their online science teaching/learning as online education is assumed to be part of education systems in the future (Daniel, 2020). In line with that purpose, the following research questions guided our study:

1. What are middle school science and elementary PSTs' perceptions of taking science education courses online when the Covid-19 lockdown started?
2. What are middle school science and elementary PSTs' perceptions and experiences of taking science education courses online during the Covid-19 lockdown?

Methodology

In this research study, we aimed to identify PSTs' perceptions and experiences about online science education during the Covid-19 lockdown. In line with this purpose, we used a survey research design. Survey research designs are commonly used in education and used for identifying trends in survey respondents' attitudes, opinions, and beliefs about an issue (Creswell, 2008). Therefore, survey research design can be used in quantitative, qualitative, or mixed-method research (Ponto, 2015). In this type of research design, it is common to use closed-ended survey questions; however, when the researchers aim to delve more into the data, they may use open-ended questions (Creswell, 2008; Williams, 2007). In this research, we used open-ended questions via electronic surveys for a similar purpose.

There are various benefits associated with using electronic surveys. Electronic surveys will increase respondent rate, especially when conditions are impractical to collect manual data (Andrews, Nonnecke, & Preece, 2003; Creswell, 2008). Electronic surveys provide quick delivery and return of responses (Jansen, Corley, & Jansen, 2007). Besides the advantages, there may be potential drawbacks of using electronic surveys, as discussed in the previous literature (e.g., Creswell, 2008; Jansen, Corley, & Jansen, 2007). For example, participants may not have a good internet connection or appropriate technological devices to access the survey. Considering the current pandemic situation, however, collecting data via electronic survey was the only convenient option for this study.

Context and Participants

180 PSTs voluntarily participated in this study from three public universities located in different regions, including the west, northeast, and south of Turkey. One of these universities was established after the 2000s and considered a young university, while the other two universities were established before the 2000s. These PSTs enrolled in seven different science and science education courses, including Science, Technology, and Society, Science Teaching Methods, Introduction to Science, Science and Technology Teaching, Radiation and Health Physics, Science Curriculum, and Application of Science in Technology. The majority of these PSTs enrolled in the science education department (N=122), while the rest enrolled in the elementary education department (N=58). All four authors of this study were the instructors of the courses in which the data were collected. Thus, we used a convenience sampling method to reach the participants.

Table 1

Number of Participants Attended At The Initial and The Final Questionnaire

Total number of participants		Female	Male	Whether they have previous online course experience before Covid-19 lockdown	N	f
Initial	180	152	28	Yes	66	36,7
Final	119	91	28	No	114	63,3

Before the covid-19 lockdown in the 2019-2020 spring semester, the first five weeks of classes were carried out face-to-face. Students were sent to their homes after the first death due to covid-19, and universities switched to online education until the end of the semester. Since the announcement of lockdown was sudden, students and faculty were caught off guard by online education. Therefore, the number of students participating in online classes was relatively low in comparison to face-to-face classes. Another critical point was that since the pandemic provoked extraordinary conditions in students, some of the students who participated in the initial questionnaire could not respond to the final questionnaire (due to lack of motivation, health issues, etc.). Thus, we have a lower number of participants in the final questionnaire.

When we coded students, we used a labeling system to maintain confidential information. The labeling system includes course abbreviations, gender and participant numbers, and the duration of the questionnaire. Thus, when we take the label "STT_F24_IN" as an example, STT stands for Science and Technology Teaching course, F24 stands for the female participant at 24th in the participant list, IN stands for initial questionnaire.

Data Collection

We used an online open-ended questionnaire, an appropriate social distance method, and enables accessing geographically distant participants (Lefever, Dal, & Matthiasdottir, 2007; Lobe, Morgan, & Hoffman, 2020). We applied the online questionnaires twice; at the beginning of and at the end of online learning. The initial questionnaire involved questions about PSTs' expectations of the course, their perceptions of positive and negative aspects of online science learning, their evaluations of online education, and general other questions such as the type of technological tools they possessed. The final questionnaire involved questions about PSTs' evaluations of the online course, their beliefs toward online science learning, their motivation and interest in online learning, their views of whether or not online learning met their expectations, general other questions such as the type of course attendance (synchronous vs. asynchronous). We sent out the questionnaires via the online classroom platform. We gave ample time for students to access the questionnaires without a strict time limitation.

The researchers initially worked individually to generate questionnaire questions and then discussed selecting the questions that respond to the study's research questions. In this process, the questions that all four researchers agreed upon were included in the questionnaire. It is necessary to use a pilot study in survey design research to ensure the appropriateness of clarity of the questions (Andrews, Nonnecke, & Preece, 2003; Rattray & Jones, 2007). Therefore, after developing the questionnaire, we asked five preservice teachers to read the questions and give us feedback on whether the questions were clear and understandable, so we made the necessary revisions to ensure clarity.

Data Analysis

For the analysis of research data, we used deductive and inductive content analysis (Elo & Kyngäs, 2008). First, the questions in the questionnaire enabled us to determine main categories (such as expectations, opportunities, beliefs…), which was part of the deductive analysis. Then we used inductive analysis to identify sub-categories under each main category through grouping codes. During the data analysis, first, all the responses PSTs wrote to the open-ended questionnaire were read by four researchers multiple times to gain familiarity with the data. After a close reading of the entire data set, we set tentative main categories based on the questions in the questionnaire. Then, each researcher separately put the student responses under the main categories to organize data. Then, researchers read each PST's answer to each question organized under the categories and assigned a relevant code based on the meaning of the quotes through open coding. As the new codes emerged, we checked the similarities and differences between the codes we already assigned to ensure that it is a new code (Strauss & Corbin, 1990).

After discussion among the researchers, we added new codes to the coding table. The general structure of inductive content analysis follows the stages of data reduction, data grouping, categorization, and abstraction, including the reporting of results via various methods such as conceptual systems or categories (Elo & Kyngäs, 2008). We simultaneously developed our coding book with initial codes for the entire data set as we did open coding. After open coding, we combined similar codes and grouped them into sub-categories. For example, we have individual codes: *accessibility to course notes and materials, recording course for later viewing, accessibility of the course instructor and receiving instant answers to questions, the course to be at the same time every week in a certain program,* and *technological infrastructure* under the subcategory of *expectation about accessibility*. Then, we compiled the sub-categories into main categories for the entire data set. For example, under the *Expectation* category, we have *Expectation about the accessibility, Expectation about the online course process,* and *Expectation about the learning outcomes of the course* subcategories. The codes, subcategories, and categories were all derived from the analysis of raw data, thus emerging from the data.

We used a deductive approach by applying the same codes in our coding book to analyze the final data set. However, new codes also emerged from the final data set different from the initial codes, thus yielding an inductive approach. Some of the codes that emerged in the initial analysis did not appear in the final analysis. On the other hand, we reached new sub-categories in the analysis of the final data set. We presented our codebook, organized through categories, sub-categories, codes in a table in Appendix. We also showed the frequency identified for each code.

Trustworthiness of the Study

It is crucial to establish the trustworthiness of each phase of the content analysis, from preparation to analyzing and reporting the results. The credibility of content analysis research, similar to all qualitative research, deals with whether or not the research findings display a reliable interpretation of the original data. We maintained credibility by carefully designing the research process, providing detailed descriptions of how we conducted each part of the study, and providing a comprehensive discussion of the findings along with strengths and limitations of our research (Elo et al. 2014; Kyngäs, 2020; Kyngäs, Kääriäinen, & Elo, 2020).

We gave a detailed description of the context and participants and the stages of data collection and analysis to facilitate the transferability of the research. Dependability of research concerns how another researcher can easily follow the categorization process. We strengthened dependability by explaining the categorization process along with providing tables, figures, and attachments. Furthermore, we, as four researchers of the paper, analyzed and re-analyzed the data together to check the consistency of the results. We strengthened the confirmability of the data by providing details of how the data and the results were connected. We maintained authenticity by supporting our findings and discussion by using various citations that clearly show the connection between the results and data (Elo et al. 2014; Kyngäs, 2020; Kyngäs, Kääriäinen, & Elo, 2020).

Findings

In order to support our analysis of PSTs' views and identify their background information, we have obtained some descriptive data along with their qualitative statements. In Table 2, we provide the frequency and percentage of PSTs with access to devices to participate in courses as well as the number of students who attended an online course before the Covid-19 lockdown. As seen in the table, a meaningful percentage of students (44 %) reported having access to only one device to attend the courses.

We have also identified the types of course attendance. Although, as it is seen in Table 2, more than 50% of students reported attending lessons both synchronous and asynchronous, about 10% of students reported not being able to attend courses on time and therefore needing to watch lessons later. In the final questionnaire, we have included a question to determine PSTs' views about whether or not the education should continue online in the following semester. As seen in Table 2, most of PSTs (70%) preferred face-to-face learning in the coming semester.

Table 2

Descriptive Characteristics of Participants about Online Education

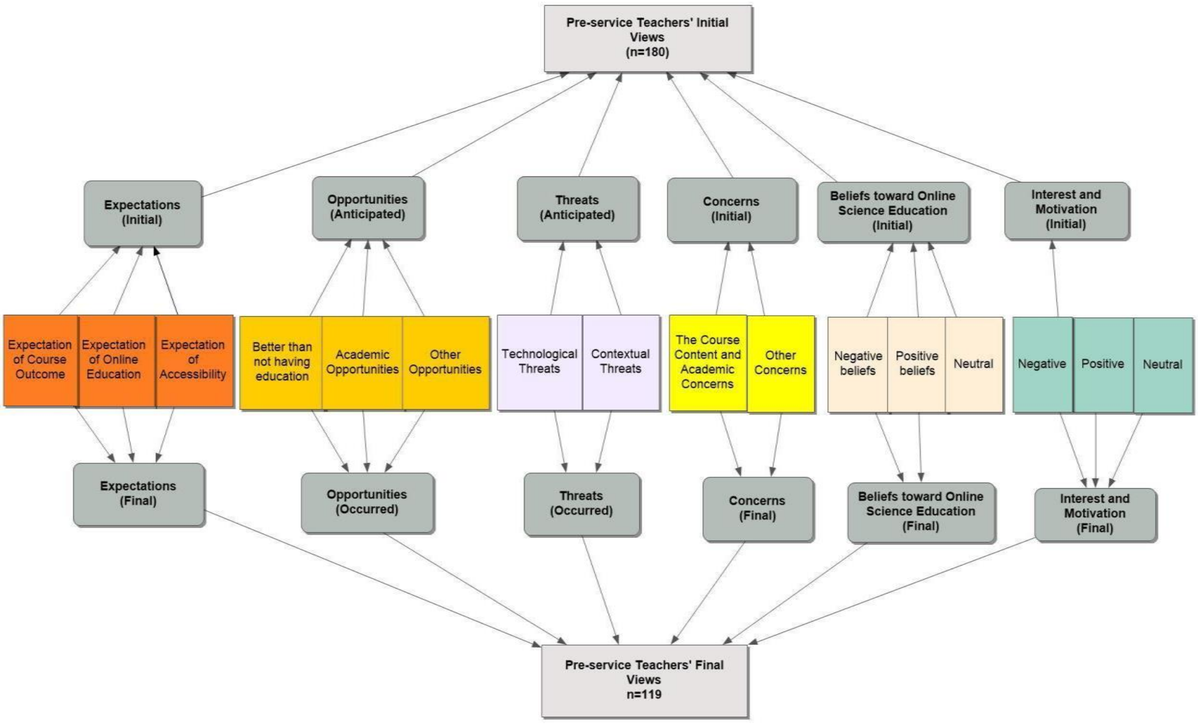
	Frequency (n)	Percentage (%)
Device of attendance to the course		
Multiple Devic	92	51,1
Mobile Phone	80	44,4
Laptop or PC	4	2,2
No Attendance	4	2,2
Participation type to the online classes	Frequency (n)	Percentage (%)
Synchronous	37	33,0
Asynchronous	11	9,8
Both	60	53,6
No attendance	4	3,6
Total	112	100,0

Should online education continue in the future?	Frequency (n)	Percentage (%)
It should continue	17	15,7
It should not continue	75	69,4
I am not sure	16	14,8
Total	108	100,0

In the next section, we present qualitative findings that display the categories and sub-categories and codes that emerged from PSTs' initial and final responses. Students' initial views for online courses and the process were elaborated parallel with the first research question. Next, we examined and reported how their ideas evolved with the completion of that particular semester as parallel with the second research question. Finally, we present the findings based on the main and sub-categories that we identified from the initial and the final analysis. General information about initial and final categories and sub-categories associated with these categories are shown in Figure 1.

Figure 1

Frequencies of Categories Under Each Theme in The Initial and Final Questionnaire



As shown in Figure 1, the PSTs' responses about the online learning process were gathered up around six main categories. These were expectations, opportunities, threats, concerns, interest and motivation, and beliefs toward online science education. PSTs' views after experiencing online teaching were grouped into the same main categories we found in the initial responses. However, views were based on their experiences rather than their ideas of what would happen. Our main categories for the final views were whether or not the expectations were fulfilled, if the opportunities were used, whether or not PSTs experienced threats and concerns, PSTs' beliefs towards online science education after attending online courses, and their interest and motivation. In the following sections, we delved into explaining our sub-categories in detail. We focused on their beliefs toward online science education first, and then we will discuss their perceptions of expectations, opportunities, motivation and interest, concerns, and threats of online science education.

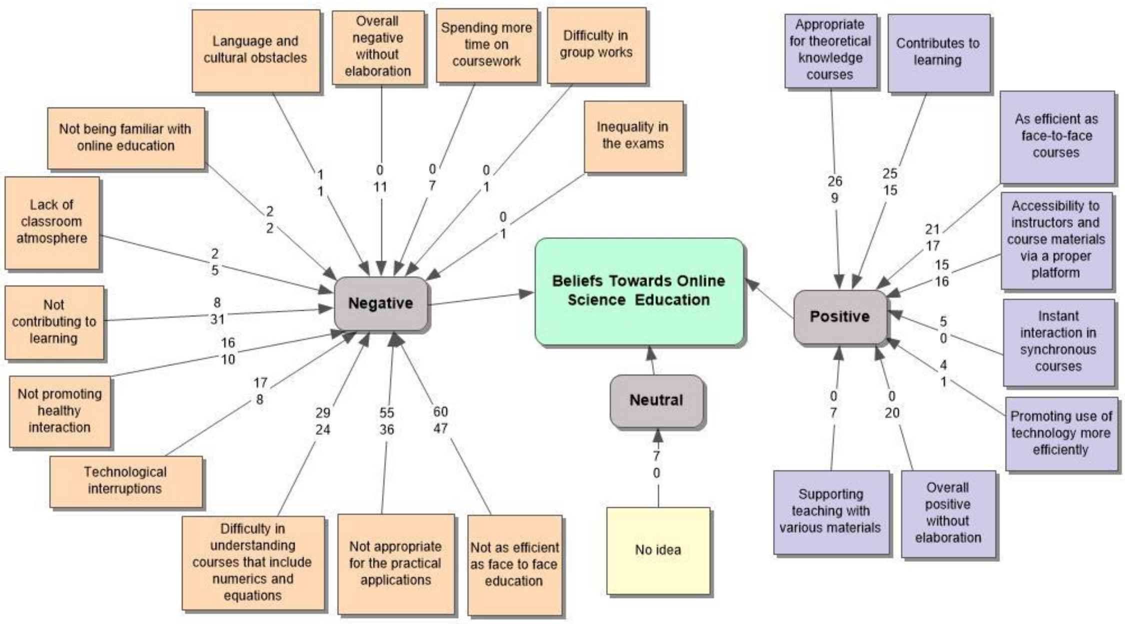
Beliefs Toward Online Science Learning

PSTs' beliefs towards online science education were grouped into three main sub-categories: positive, negative, and neutral, as represented in Figure 2. Figure 2 shows *beliefs towards the online science education* category at the center; *positive, negative, and neutral* sub-categories, feeding the main beliefs category; and various codes contributing to the sub-categories; and the frequency of codes that emerged in the initial and final questionnaires. The codes showed how PSTs attributed multiple reasons for both positive and negative beliefs toward online science education.

If we look into Figure 2 in detail, we can see that PSTs hold predominantly negative beliefs toward online science education in initial and final questionnaires (Positive f_i=96, Negative f_i=190; Positive f_f=85, Negative f_f=184). In the initial questionnaire, while 190 responses were categorized as negative beliefs, 96 responses were categorized as positive beliefs. On the other hand, in the final questionnaire, 184 responses were categorized as negative beliefs, while 85 responses were categorized as positive beliefs. When we look at Figure 2 at large, we can see more diverse codes that correspond to the negative beliefs sub-category than the codes that correspond to the positive beliefs sub-category. We described the codes that constituted each sub-category, then highlighted the critical areas with example quotes from PSTs.

Figure 2

PSTs' Initial and Final Beliefs Towards Online Science Education



Positive Beliefs Towards Online Science Education

As shown in Figure 2, positive beliefs toward the online science education sub-category consist of various codes. The predominant positive beliefs that emerged in the initial questionnaire included; *online science education is appropriate for theoretical knowledge courses* (f_i=26), online science education *contributes to learning* (f_i=25), *could be as efficient as face to face courses* (f_i=21), and *accessing instructors and course materials via the proper platform* (*Google classroom)*(f_i=15). As we can see in Figure 2, three of these four dominant codes continued to be predominant positive beliefs in the final questionnaire.

PSTs believed that online science education *contributed to their learning.* In the initial questionnaire, 25 PSTs expressed that they thought they would learn through online science education. In the final questionnaire, 15 PSTs expressed the same view. For example, *STT_F29_IN said, "Being able to continue the courses provides us with the education we need, from this perspective it is very positive".* Another dominant belief in both questionnaires was online science education was *as efficient as face-to-face.* In the initial questionnaire, while 21 PSTs thought online science education is as efficient as face-to-face, in the final questionnaire, 17 PSTs expressed the same view based on their experiences in the courses. For example, SC_F17_IN declared, *"I don't think there is a difference between sitting in the class and watching the recorded lesson".* STS_F30_IN expressed that *"I believe that online education will be implemented successfully. Even if it's with distance education we will continue to learn efficiently".* As we see from these quotes, PSTs did not see a difference between in-class experience and watching the lesson from the video. Another dominant code in the positive beliefs sub-category was *accessing the instructors and the course materials through a proper platform.* While 15 PSTs expressed this idea in the initial questionnaire, 16 PSTs continued to express this in the final questionnaire. For example, *IS_F11_IN* in the initial questionnaire *stated, "I believe it will be useful because we can access the course instructors".* From the same course, IS_F55_FIN in the final questionnaire said, *"Actually, I think it was more effective in online learning since we had the opportunity to listen to the lessons later, that's why I did not have any problem".* In both of these quotes, PSTs found online learning a positive experience due to their access to the course materials and the instructors.

While some beliefs continued to be predominant both in the initial and final questionnaires, as we explained above, the frequency of other codes in the positive beliefs sub-category changed from the initial to the final questionnaire. For example, if we consider the belief that online science education is *appropriate for theoretical knowledge courses,* while in the initial views, 26 PSTs stated that online science education is appropriate for theoretical knowledge courses. This view is expressed by only 9 PSTs in the final form. For example, RHP_F24_IN stated, "*Online education is useful as long as there are theoretical courses because when the course is delivered orally, I believe that teaching and understanding will be easy".*

Finally, when we compared the codes in the positive beliefs sub-category in the initial and final questionnaires, we saw that while some codes emerged only initially, others emerged only in the final form. For example, *instant interaction in synchronous courses* code appeared only in the initial views and did not come up in the final statements. PSTs expressed the ability to have *instant interaction in synchronous courses* as a positive thing in the initial questionnaire and did not mention it again in the final form. STT_F9_IN stated, *"Positively, even though it is distant, we can have interaction and continue our education".* Some PSTs see online education as a positive idea due to the value of instant interaction they could have in synchronous courses. Other codes emerged only in the final questionnaire; for example, 20 PSTs expressed *overall positive beliefs without elaboration* for online science education and 7 PSTs found that course instructors' efforts in s*upporting teaching with various materials* as useful based on their experiences in the online education. For example, IS_F19 stated, *"I think I learned well. At the beginning, I had difficulty understanding the concepts, but when you [the instructor] used the whiteboard, that problem disappeared".* IS_F20_FIN stated, *"I could not understand the concepts at the beginning. But you [the instructor] used a program [PheT simulations] when teaching, I think that program was very beneficial".* Similarly, STS_F41_IN stated. *"As it can be understood from the name of the course [Science, Technology, and Society], we have fully grasped how technology is necessary for societies, especially in times of crisis. I agree with learning such courses online as long as the courses are supported with appropriate technology".* Here in three quotes, the PSTs referred to the teaching materials that the instructors used during teaching, one being the whiteboard to help them solve problems and the other one, the program they found useful, was PheT simulations to make the physics concepts more concrete.

Negative Beliefs Towards Online Science Education

As shown in Figure 2, *negative beliefs toward the online science education* sub-category consist of various codes. Some PSTs held *overall negative* beliefs (f_i=0, f_f=11) toward online science education without elaboration and believed that *online science education is not as efficient as face-to-face education* (f_i=60, f_f=47) and *does not contribute to their learning* (f_i=8, f_f=:31). Others held negative beliefs due to some constraints and difficulties they experienced or thought they would face during online science education. Some of these constraints were more dominant than others.

The majority of constraints and difficulties that PSTs described that contributed to their negative beliefs included the *difficulty in understanding courses that include numeric and equations* (f_i=29, f_f=24), *online education not being appropriate for practical applications* (f_i=55, f_f=36), *the fact that online education not promoting healthy interaction* (f_i=16, f_f=10), and *technological interruptions* (f_i=17, f_f=8). Less dominant constraints that PSTs expressed were *spending more time on course work* (f_i=0, f_f=7), *lack of classroom atmosphere* (f_i=2, f_f=5), *not being familiar with online education* (f_i=2, f_f=2), *difficulty in group work (*f_i*=0,* f_f*=1), inequality in the exams,* (f_i=0, f_f=1), and *language and cultural barriers* (f_i=1, f_f=1).

One of the most dominant codes among the negative beliefs included online science education is "*not as efficient as face-to-face education*". While in the initial questionnaire, 60 PSTs expressed that "online science education will not be as efficient as face-to-face", in the final questionnaire, 47 PSTs continued to express the same view. High frequency both in the initial and final questionnaire compared to the frequencies of other codes respectively shows that this is still a dominant view both in the initial and final forms. For example, *SC_F24_IN* stated, *"I don't think it will be as useful as it was face to face"*. In the final questionnaire, STM_F10_FIN stated, *"Online science learning is not as effective as face to face. Face to face instruction provides more hands-on learning opportunities".*

Another most dominant view among the negative beliefs included *online education not being suitable for practical applications.* While in the initial questionnaire, *55* PSTs expressed that "online science education will not be appropriate for practical applications"; in the final questionnaire, 36 PSTs expressed the same view. SC_F21_IN stated*, "There is no obstacle for theoretical courses that mostly involve conceptual learning but it is difficult to do practical applications".* Another prominent view among the negative beliefs included the difficulty in understanding courses that include numeric and equations. While in the initial questionnaire, 29 PSTs expressed difficulty understanding science courses that include numeric and equations based on their experiences and preconceptions. In the final questionnaire, 24 PSTs, especially from the elementary majors, continued to express this difficulty based on their experiences during online science education. For example, IS_F24_FIN stated,

> "*I can't say that it went well because it was not efficient. Courses that involve equations and numeric like science should be taught face to face, especially following physics concepts in online education was very difficult for me*".

Like the struggle shared in the quote, PSTs expressed challenges about numerical courses such as physics. They believe that online platforms do not help them overcome this challenge. Another most dominant belief in the negative beliefs sub-category was regarding the contribution of online science education courses into students' learning. Some PSTs held the belief that online science education *does not contribute to their learning (*f_i*=8,* f_f*=31)*. While at the beginning only 8 PSTs mentioned this, later 31 PSTs mentioned that online science education does not contribute to their learning. For example, in her final form, *STT_F7_FIN stated, "I do not think the courses I took during online education contributed to my learning"*.

Some PSTs believed that online education does not promote healthy interaction. While in the initial questionnaire, 16 PSTs expressed that online science education does not promote healthy interaction, 10 PSTs continued to express this difficulty based on their experiences during online science education. STS_F14_IN stated, "*I do not think it will be as useful as face-to-face education because there will not be efficient engagement and classroom atmosphere".* Another group of PSTs described the difficulty they had with *technological interruptions.* While in the initial questionnaire, 17 PSTs expressed the fact that online education causes technological interruptions and challenges, eight PSTs continued to express this difficulty based on their experiences during classes. For example, STT_F29_IN stated, "*Online science education has some negative effects due to requiring practical applications, and not everyone has appropriate technological devices to follow the course".* As the PST indicated, they believe that science courses require more practical applications, and therefore, online science learning needs to be supported with proper technological devices.

As we see in Figure 2, there are less frequently mentioned codes by the PSTs. While some of these codes include some reasons PSTs attributed for online science education, others only represent *overall negative beliefs* without elaboration. Only in the final questionnaire, 11 PSTs expressed that online science education is overall a negative experience for them; they did not provide any reasons for why the experience was negative. Seven PSTs believed that online science education required students to *spend more time on course work,* and PSTs mentioned this idea only after they experienced online science education, thus in the final form. Some PSTs believe that online education *lacks the classroom atmosphere* (f_i=2, f_f=5), and it causes *difficulty in group work* (f_i=0, f_f=1). These views as mentioned earlier are expressed more in the final questionnaire. Some PSTs attributed negative beliefs toward online science education because they *are not familiar with online education* (f_i=2, f_f=2). Some PSTs believe that online science education causes *inequality in the exams* (f_i=0, f_f=1), and expands *language and cultural barriers* (f_i=1, f_f=1). For example, an international PST, STM_M12_FIN stated, *"Online science education impacted my learning negatively. Because I am an international student, it is difficult for me to understand, but now with distance education, it is more difficult for me".*

Threats

The category of threats that students expressed for online science education are divided into two subcategories: Technological threats and Contextual threats. Among technological threats, the biggest problem was the lack of internet access. 56 PSTs who participated from different regions of Turkey pointed out the lack of internet access and/or poor connection may impede them from following online courses, and 18 PSTs in response to the final questionnaire confirmed that this threat occurred during the online learning process. Similar to this threat, *lack of technological tools* was also considered a threat by nine PSTs in the initial and by six PSTs in the final questionnaire, since many PSTs (N=80) had to follow online courses from their phones (see Table 2). For example, SC_F1_IN said that "*I have a phone, but it does not support the applications that are used for online education, so I struggle a lot. Additionally, the internet connection was very poor*".

Another noteworthy code under technical threats that PSTs initially stated was *technical issues related to the university's distance education system*; however, PSTs did not have a problem with the university's distance education system during the semester as none of them mentioned this threat in the final questionnaire. The second subcategory, contextual threats, consisted of codes such as *family-related threats*, *financial threats*, *being student workers*, *lack of classroom atmosphere*, *responsibility for housework*. Among these codes, family-related threats are the most frequently mentioned code in both initial (f_i=7) and even more in the final (f_f=15) responses. The root of this threat is that some PSTs' houses do not have a private room to participate in online courses.

During the pandemic, some households had financial crises due to the preventive measures taken by the authorities to prevent the spread of covid-19. Therefore, some PSTs had to work to help the family economy. However, interestingly only one PST (STT_F22_IN) mentioned a threat originated from this situation:

> "*In this case, I will not be able to follow most of these online lessons because I live in a village. As long as I am here, I have to work on a daily wage due to family and financial conditions. Therefore, I cannot use my phone as I work during the day*".

Opportunities

The sudden shift to a compulsory online learning process appears to have brought some opportunities along with some threats in many ways. These opportunities were subcategorized as *better than not having education, academic convenience*, and *other opportunities*. Initially, 62 PSTs expressed that continuing their education in an online platform was better than nothing at all in such exceptional conditions. Being able to continue without getting away from the courses was the main idea behind students' responses associated with this opportunity. One of the PSTs (STM_M4_IN) explained this opportunity as "*Considering the situation, I agree with receiving education remotely rather than not having any education*".

Besides that, 23 PSTs mentioned that this online learning process has turned out to provide academic opportunities. These opportunities include *more time to study* (f_i=2; f_f=2), *more integration of technology in lessons* (f_i=7; f_f=4), *accessibility of instructors* (f_i=5; f_f=1), *studying more productively at home* (f_i=1; f_f=3), and *self-paced learning* (f_i=2; f_f=1). Some of these academic opportunities are related to the effective use of time and circumstances, which were confirmed by some PSTs after completion of the online learning process. PSTs' initial and final views are presented as an example. "*The time loss during classroom teaching could be reduced a bit via online learning. Additionally, recording the instructions allows us to take notes*" (STT_F8_IN). "*When I was not able to attend the class, I was able to watch the lessons later, and it was easy for me to take notes by pausing the video*".
As stated here, watching the course videos at their working speed seemed to help PSTs understand science concepts better.

Another notable focus of these opportunities was supporting professional growth. For example, some PSTs appreciated more technology integration into science courses since they could learn by experiencing how to use web-based applications in science teaching. Excerpts from PSTs' initial responses are given as an example.

> "*Thanks to technology, we will watch experiments that cannot be implemented in a classroom environment. Technology will be used in lessons more than it used to be, bringing innovations. We can learn different things.*" (STT_F11_IN).
> "T*he faculty of education prepares us both for our future life and the profession we will do in the future. In this context, we have been taught lessons in both traditional and modern classroom environments. At this point, we have learned how a teacher should take action even in situations that are not expected. Therefore, we will gain knowledge and experience in distance education*" (STS_M05_IN).

In the final questionnaire, a comparable number of PSTs expressed the opportunity to have *more technology-integrated science courses* as an opportunity. However, the *easy access to course materials* received the higher frequency among all sub-categories in the final analysis. A few PSTs also listed social opportunities, economic opportunities, and health-based opportunities that came with online education. In the initial questionnaire, PSTs mentioned that they would have more spare time during the online learning process (f_i=3). However, the final responses showed that PSTs did not have the spare time that they expected (f_f=0). Economic opportunity was mentioned only once at the beginning of the courses and three times at the end of the semester. Only one student indicated that distance learning could prevent contamination of coronavirus in the initial questionnaire.

Interest and Motivation

It is essential to investigate the PSTs' interest in online courses and their motivations since they have received lessons in online platforms as a replacement to traditional learning environments in unpredictable, extraordinary conditions. Therefore, we have divided PSTs' responses into sub-categories of positive and negative. Looking at the initial responses, most PSTs did not believe their motivation to be high during online learning. The views about losing motivation were accumulated around three factors: *being in the home environment* (f_i=8), *lack of extrinsic motivation* (f_i=5), *sitting in front* *of a computer for long hours* (f_i=6). Final responses indicated that being at home was an important cause for loss of motivation (f_f=68), followed by sitting in front of a computer for long hours (f_f=15). Excerpts from two different PSTs are given as an example. "*It is not like face-to-face lessons. Listening to lessons for hours in front of the computer is boring and inefficient*" (IS_F5_FIN). "*My interest and motivation were lower due to being at home. Since we have not received such an education before, the comfort of the house and other external factors affected me*" (STT_F31_FIN).

The uncertainty about the pandemic influenced PST's motivation as well. "*I could not even listen to the lessons that I was interested in. We had concerns about the pandemic. To tell the truth, I listened to some lessons like listening to podcasts*" (STT_F42_FIN). As seen in STT_F42_FIN's statement, following the pandemic news influenced PSTs and their families adversely. Therefore, they could not concentrate on their courses. Another salient code that emerged from the negative category of interest and motivation was being exhausted with excessive homework. Some PSTs believed that the course instructors gave more homework than they do in face-to-face learning, and these homework assignments were overwhelming sometimes.

After completing the semester, PSTs realized some factors also helped them increase their motivation and interest in online learning. For instance, 12 PSTs reported that online learning was as attractive as face-to-face learning, contrary to what they believed. Yet, after the PSTs went through the adaptation process, they argued to become more motivated toward the lessons by developing self-discipline.

"*In the beginning, my motivation and interest were very low. But since the process was uncertain, I thought that I had to recover and close the gap by increasing my motivation. Distance education is a process that cannot be seen as 'I can be lazy easily'. On the contrary, the student needs to show effort, which is a better learning method*" (STT_F25_FIN).

Concerns

Comments in response to the initial questionnaire suggested that the PSTs' concerns were mostly centered on the course content and academics. Considering the higher frequency of PSTs' indication about the *anxiety of not being able to cope with the course and not understanding course content* (f_i=15), it is possible to say that PSTs developed a fear due to the obscurity of online learning at the beginning of this process. This fear is derived from various reasons. For example, one of the PSTs (IS_F22_IN) said, "*It was easier to show whether we understood something or not, in face-to-face learning. Distance education will be difficult in this regard*". Another common reason for academic concern was how to do the application-based lessons. Many PSTs stated that courses requiring theoretical knowledge are suitable for online education but not application-based courses. An excerpt for this concern expressed by STT_F10_IN is "*I am concerned about practical application courses because theoretical knowledge can be given through an online platform, but I think their applications cannot be done*". Additionally, the issue of how to conduct the exams also created a question mark in the minds of PSTs. About this concern, STS_F31_IN said, "*It will be difficult for us because I don't know how efficient it will be. I do not know if active participation will be ensured, and I have concerns about how it will affect our exams*".

Although most of these concerns seemed to be resolved in the final survey, there were still some concerns related to *not being able to understand the course* (f_f=3) and *online exams* (f_f=2). Beside the academical concern, PSTs also mentioned other concerns including *technology addiction* (f_i=1, f_f=0), *limitation of social life* (f_i=1, f_f=1), and *pandemic* (f_i=1, f_f=4). Among these codes, pandemic-related concerns appeared to increase from the beginning to the end of the semester. "*I used to approach my homework and my lessons meticulously. But the uncertainty related to the pandemic completely influenced my motivation. The vague thought of what we will be is worrisome*".

Expectations

The data showed PSTs' expectations followed some patterns that we could cluster them as *online learning accessibility*, *online learning process,* and *the course outcomes*. For the expectation of online learning accessibility, the total frequency decreased in the final views (16 positives, nine negatives) compared to the initial views (32). In this sub-category, although five different codes were identified in the initial questionnaire (see Appendix), PSTs mainly focused on accessibility to course materials (f_i=15) and recording course videos for later viewing (f_i=12). However, these two expectations seem to be fulfilled during the online courses. Two out of three PSTs confirmed that they did not have a problem accessing the course materials and all seven PSTs mentioned that they could easily access video records. For example, one of the PSTs (IS_F40_FIN) stated, "*Frankly speaking, being able to re-watch the lessons afterward was quite beneficial for me. I watched the parts that I had not understood again and again*".

In the other codes of accessibility, PSTs reported that their expectations are generally fulfilled. The only reason PSTs stated that online education did not fulfill their expectations was the problems with the technological infrastructure they faced during online lessons. PSTs reported those problems in the initial views as a threat to online science education, as well. PSTs' expectations of the online learning process were also dropped in the final questionnaire (26 positives, ten negatives) in comparison to initial responses (f_i=75). Initially, the expectations in this sub-category were accumulated under ten different codes; however, most mentioned ones were carrying out the course at a slow pace and synchronous or asynchronous teaching, respectively. For example, 26 PSTs initially reported that they expected to have simple but comprehensible lessons where the assignments were given individually rather than as group assignments, and they could run the given experiments at home. However, in the final questionnaire, six PSTs indicated dissatisfaction with that expectation while the rest did not provide any opinion. "*The assignments are given to measure our understanding seemed superfluous. We tried very hard, but I think they were not very useful*" (STS_F49_FIN). Similar to this expectation, receiving abundant and understandable examples was also frequently verbalized by PSTs. Another notable code for the online learning process was carrying out the course professionally, which seemed to be fulfilled during the online courses as well.

Finally, PSTs' expectation of course outcome sub-category is clustered into five different codes. Among those, *having efficient learning outcomes as face-to-face* (f_i=46) and *covering everything given in the course syllabus* (f_i=43) were the most frequent codes in the initial questionnaire. In terms of the efficiency of online courses, 25 PSTs out of 40 reported satisfaction at the end of the semester. An excerpt from STT_M2_FIN is given below for each.

> "*I think it was more efficient than expected. I think it was productive even though we have occasional difficulties. I think this lesson has contributed a lot to us both in terms of homework, presentations and the subjects we covered in the lesson*".

The final responses revealed that not every code of expectation for course outcome was met. For instance, 10 out of 14 PSTs indicated that they did cover everything in the course syllabus. "*Online education did not meet my expectations. We were not able to do activities that we would do in class*" (STM_F7_FIN).

Discussion

In our discussion, we first delved into PSTs' beliefs about online science education. We then discussed their perceptions about online science learning in terms of expectations, opportunities, threats, motivation and interest, and concerns. Our findings showed that PSTs held predominantly negative beliefs towards online science education in initial and final questionnaires. Many of these PSTs believed that online science education was appropriate for theoretical knowledge courses rather than courses that involve practical applications, abstract concepts, numeric, and equations.

The data was collected from both science content courses and science teaching methods courses, in which PSTs experience practical applications in both types of courses. Science content courses include designing, conducting experiments, and solving numerical problems, while others include teaching methods, applying those methods, and preparing learning environments in microteaching. Science teachers in different studies also indicated the difficulty of doing experiments and practical applications in online education (Bakioğlu & Çevik, 2020; Ünal & Bulunuz, 2020) and therefore needed to support their teaching with simulations, videos, or demonstration experiments (Sarıoğlan et al., 2020).

Online education requires the use of various materials to support instruction. Some PSTs in our study found course instructors' efforts helpful when the instructors supported science teaching with various materials such as whiteboard, web 2.0 tools, and online simulations. Literature also discussed students' appreciation of various materials to support online education (Chakraborty, et. al, 2020). Students in Chakraborty et al.'s study found digital pens as a useful device to make online lessons more interactive. In our research, PSTs thought the instructor's use of a whiteboard in synchronous lessons to solve problems helpful in understanding the physics concepts.

Another educational support PSTs benefited from was using online simulations to understand physics concepts better. Online educational tools may bring various benefits to teaching and learning science when they are used effectively. Web 2.0 tools, for example, can increase healthy interaction between teacher and students, can improve students' technological literacy, and can increase students' interest and motivation toward learning as discussed by many researchers (An & Williams, 2010; Kamalodeen, Figaro-Henry, Ramsawak-Jodha, & Dedovets, 2017). Virtual labs, which provides personal and self-directed learning environments and can be accessed from anywhere and anytime and enable students to progress with their learning pace (Bhargava, Antonakakis, Cunningham, & Zehnder, 2006; Darrah, Humbert, Finstein, Simon, & Hopkins, 2014; Ghergulescu, Moldovan, Muntean, & Muntean, 2019), could be a useful tool for laboratory applications during Covid-19 breakdown (Ray & Srivastava, 2020). Some PSTs in our study argued that online science education did not promote healthy interaction between teachers and students. Moreover, most PSTs indicated that they had a lack of motivation and interest in online science learning. Such online tools can boost interaction in online education as well as increase students' motivation. Supporting lectures with these tools may also help increase students' motivation and interest.

Research studies conducted before the Covid-19 lockdown process started have revealed that Web-based PBL and collaborative inquiry environments are an alternative to face-to-face science teaching, and such approaches have been found to increase students' motivation in learning science (Brown, Lawless, & Boyer, 2013; Raes, Schellens, & De Wever, 2014). Meta-analysis studies have also shown the effect of computer-assisted instruction on academic achievement in science learning (Dinçer, 2015; Tekbiyik & Akdeniz, 2010). PSTs' negative beliefs toward online science education in the pandemic may stem from the uncertainty of the process and PSTs' lack of knowledge about the advantages of online education.

Our findings indicated that a sudden transition from face-to-face learning to online synchronous and/or asynchronous science learning challenged PSTs in many ways. Lack of internet connection and lack of technological devices have been found major threats to online education in many countries (Bataineh et al., 2020; Croft et.al., 2020; Kapasia et. al., 2020; Özdoğan & Berkant, 2020; Sarıoğlan et. al., 2020). Similarly, PSTs in our study mentioned this deficiency as one of the significant threats to online science education. Many PSTs mentioned that they had access to only one device and followed the online lessons from their cell phones. Some PSTs lived in rural areas and small mountain villages, therefore, they did not have good internet access to support online education. The results of the final questionnaire indicated that this problem was still an obstacle for students' learning process.

Following the lessons from home brought some threats that may arise from the house environment. Some PSTs had to share their room with their siblings; therefore, they could not freely participate in synchronous online lessons. Some PSTs indicated that their motivation was negatively influenced by the inconvenient household situation and their increased duties at home. Also, the preventive measures taken by the authorities influenced some families' economic conditions. Therefore, some PSTs had to work to contribute to the family budget and could not participate in the synchronous online lessons. This finding is in line with the results of previous studies. For example, Croft and colleagues (2020) reported that some high school students in the U.S. had more household responsibilities or needed to work to support the economy of their families during the Covid-19 pandemic. Similarly, Kapasia and colleagues (2020) addressed that some students lacked an appropriate home environment to support effective learning during the pandemic. While the home environment has negatively influenced some PSTs in our study, some PSTs did not complain about learning at home. Some PSTs considered this as an opportunity and mentioned that they had more time to focus on their academic work. Thus, different socioeconomic statuses may lead to differing experiences for PSTs in online education; while for some it is beneficial, but it is disadvantageous for others.

Some PSTs seemed to adapt to the new process more quickly than others and highlighted opportunities associated with online education. For example, some PSTs addressed the chance of having more technology integrated courses as an academic opportunity. Accessing course videos to watch later has also been indicated as an opportunity for online education. Watching the course videos at their working speed seemed to help PSTs progress at their speed and support their understanding of science concepts better. Also, some PSTs indicated that online learning was more time-efficient as it reduced time loss to be present in the classroom. Similar to this finding, the findings of other studies conducted with various stakeholders indicated the advantage of online learning in terms of flexibility of time and space (Goncalves et. al., 2020; Özdoğan & Berkant, 2020).

When closely examining PSTs' expectations addressed in the initial and final questionnaire, we realized that some of these expectations were met through online learning. For example, in the initial questionnaire, one of the most frequently stated expectations was accessibility to course materials and recorded course videos for later viewing. None of the PSTs made negative statements in the final questionnaire shows that this expectation was fulfilled in online courses. Some PSTs expected at the beginning of the online learning process that the course would be implemented professionally. This expectation also seems to be met for the PSTs as none of them addressed a negative statement about it. A well-organized lesson and necessary guidance in online learning are crucial, as suggested in the World Bank report (World Bank, 2020).

Although some expectations of PSTs met online learning, some expectations were not. Some PSTs, in our study, expected instructors to simplify the lesson in favor of them by adjusting the teaching pace. Some of them indicated that instructors should assign the homework and tasks that can be done at home individually rather than having group work. Similar to Elgart's (2021) findings that reported increased students' workload, some PSTs indicated that they were exhausted from the workload and therefore not satisfied with the online education in the final questionnaire. When the amount of homework to support students' learning is not well-adjusted, it may even be a disadvantage in education. For example, Bataineh and colleagues' (2020) findings indicated that having lots of homework assignments decreased students' academic performances. Some PSTs stated that the course instructors gave more homework than they do in face-to-face learning. The views about online learning differ in the literature. While some research addressed students' satisfaction with online education (Bergeler & Read, 2020; Blau & Drennan, 2017), some of them addressed contradictory results.

Conclusion and Implications

The results indicated that initially, PSTs had many expectations/opportunities, concerns, and beliefs toward the online education process. While some of these expectations, beliefs, and opportunities are fulfilled during the online learning process, some fundamental issues caused some obstacles in this process.

Although the sudden transition to online learning worried PSTs initially, when they experienced the online courses, they changed some of their views. For example, they did not have a problem with accessing the course materials and the course instructors. Moreover, their concerns of understanding the science content through online lessons and having exams appeared to be resolved after going through this process. However, as similar studies pointed out, deficiency in technological infrastructure and poor internet connection created the biggest problem in students' online learning. This situation is considered discrimination against the students who lived in rural areas and did not have quality internet connections and technological devices (Kapasia et al., 2020).

In addition to the technological infrastructure, PSTs did not have a private room to do their homework and participate in online courses. Yet, some of them had to work during the pandemic since the family's breadwinner lost her/his job and cannot afford essential needs (Tienken, 2020). International students are also challenged in online education. Previous research showed that international undergraduate and graduate students face sociocultural and linguistic challenges even at face-to-face teaching (Avsar Erumit, Akerson, & Buck, 2021; Kuo, 2011; Zhang, 2016). Online education may bring new hurdles to this group of students. Therefore, it is worth studying these groups of students in the future.

Besides the aforementioned threats above, online education brings some opportunities for teaching and learning. As Barak (2017) discussed, teachers have not had sufficient knowledge to integrate technology and web 2.0 tools into their lessons to advance science teaching or are motivated to do so before the pandemic. The compulsory transition to online education may increase teachers' and students' technology literacy and lead teachers to integrate technology into lessons.

This study has potential limitations. One of them is related to web-based data collection. Persuading learners to participate and having enough response rates were quite challenging (Lefever, Dal, & Matthíasdóttir, 2007). Although a larger number of PSTs consented to fill out the initial questionnaire (N=180), fewer PSTs volunteered to fill out the final questionnaire (N=122) due to being overwhelmed with online assignments and engagement during the semester. Another limitation was technological disparity. Since not all PSTs had equal access to the internet, some students could neither regularly attend the course nor participate in the study.

Despite the limitations mentioned above, this study adds to the existing literature about the experiences of preservice science and elementary teachers in mandatory transitioning to online science learning from face-to-face learning. As UNESCO argued in the 2020 report, pedagogical transition to online learning, especially on a larger scale, would not be easy, yet it has become an imperative situation (UNESCO, 2020). Since all of these changes had to happen quickly, the educators made the transition without sufficient research, analysis, and documentation behind the decisions (World Bank, 2020). The World Bank highlights the importance of a smooth transition in this pandemic situation (World Bank, 2020). Considering that the post-pandemic impact will last for many years (Erduran, 2020), more research and knowledge should be gathered for online education. The findings of this study might help to better support future PSTs and teacher educators in their online science teaching and learning as online education is assumed to be part of education systems, especially in higher education in the future (Daniel, 2020).

As discussions continue about how education should be during the pandemic, the research propounded mixed claims that one learning mode is better than another (Czerniewicz, 2020). However, online education seems to be part of the future educational system. Therefore, we need to be prepared for more effective online learning as a science education community. Based on the findings of this study and supported with the current literature, some recommendations to teachers as well as other stakeholders are as follows:

- Technology infrastructures and internet access appear to be the biggest problem in front of the online education system. To ensure equality in education, we have to make sure that each student has access to the internet and necessary technological devices to participate in online learning.
- Teaching science on online platforms brings additional preparations due to its practical and numerical nature. Therefore, teachers need to include various materials and web-based applications such as web 2.0 tools and virtual labs to support students' learning.
- Assessing students' understanding seems to be another compelling part of online education from teachers' and students' perspectives. Teachers suffer from the integrity of the online

exams while students have concerned about potential technical problems. Trying alternative assessments that are suitable for online education could be a solution for both groups.

- Using technology more effectively emerges as an opportunity for distance education. Teachers should take this opportunity to improve their technology skills to advance their science teaching.

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Appendix

Initial and Final codes with frequencies

(Category)	(Sub-Category)	(Codes)	Initial (f_i) (n=180)	Final (f_f) (n=119)
Expectation	Expectation Of Accessibility	Accessibility to course materials	15	2 (+)/1 (-)***
		Recording course videos for later viewing	12	7 (+)
		Accessibility to instructor - receiving instant answers to questions	3	5 (+)/1 (-)
		Following the weekly schedule	2	1 (+)/1 (-)
		Technological infrastructure		1 (+)/6 (-)
	Expectation of Process of Online Education	Having homework	3	1 (+)
		Supporting with slides sharing comprehensive presentations	4	0
		Supporting with abundant and understandable examples	8	1 (+)/1 (-)
		Carrying out the course in slow pace	26	6 (-)
		Interactive learning	4	4 (+)/2 (-)
		synchronous or asynchronous teaching	11	4 (+)
		Expectations of teaching methods	6	5 (+)
		Effective use of technology in teaching	8	2 (+)
		Receiving assignments instead of exams	2	1 (-)
		Carrying out the course in a professional manner	3	7 (+)
	Expectation Of Course Outcome	Having efficient learning outcomes as face-to-face	46	25 (+)/15 (-)
		Covering everything given in the course syllabus	43	4 (+)/10 (-)
		Learning the subjects not only theoretically but also practically	4	1 (+)/2 (-)
		Passing the exams	1	0
		Gaining experience in the teaching profession	7	3 (+)
Opportunities	Better Than Not Having Education	Continuation of education - The best option considering the pandemic. Being able to continue without getting away from the courses too much	62	18
		Graduating on time (for seniors)	1	0
	Academic Opportunities	More time to study	2	2
		More integration of technology in lessons (better access to resources and more efficient use of Web-based applications)	7	4
		Access to course materials easily	4	7
		Accessibility of instructors	5	1
		Promoting students in conducting research	1	4
		Studying more productively at home	1	3

		Self-paced learning	2	1
		Gaining experience in online teaching	1	2
	Other Opportunities	Social Opportunities		
		Having more spare time	3	0
		More comfortable home environment	1	3
		Economic Opportunities		
		Reducing expenses	2	0
		Health-based opportunities		
		Preventing contamination	1	0
Threats	Technological Threats	Lack of internet access	56	18
		Lack of technological tools	9	6
		Technological illiteracy	2	2
		Technical issues related to university's distance learning system	7	0
	Contextual Threats	Family-related threats	7	15
		Financial Threats -Being a student-worker (Need to work because of financial reasons)		1
		Lack of classroom atmosphere	2	4
		Responsibility for house work	1	0
Interest and Motivation	Negative	Losing motivation due to home environment (Not as interesting as it was face to face)	8	68
		Lack of extrinsic motivation*	5	7
		Sitting in front of computer for long hours (To be bored due to long videos)	6	15
		Difficulty of comprehending courses		2
		Following pandemic news		6
		Exhausted with excessive homework		5
	Positive	As attractive as face to face learning		12
		Accessibility to course materials when needed		2
		The effect of students' self-discipline		5
		Depends on instructors' way of teaching		2
Concerns	The Course Content and Academic Concerns	Anxiety about not understanding the course (Anxiety about not being able to cope with the course, not understanding course content and not being able to follow the course)	15	3
		Exam anxiety (passing or failing anxiety)	11	2
	Other Concerns	Technology addiction	1	0
		Concerns about social life-less mobility	1	1
		Concerns about pandemic	1	4
Beliefs Towards	Positive	Appropriate for theoretical knowledge courses	**26**	**9**
		As efficient as face-to-face courses	21	17

Online Science Education		Accessibility to instructors and course materials via a proper platform (e.g. Google Classroom)	15	16
		Contributes to learning	25	15
		Overall positive without elaboration		20
		Promoting use of technology more efficiently	4	1
		Instant interaction in synchronous courses	5	0
		Supporting teaching with various materials	0	7
	Negative	Not contributing to learning	8	31
		Not promoting healthy interaction	16	10
		Not as efficient as face to face education	60	47
		Not appropriate for the practical applications	55	36
		Not being familiar with online education	2	2
		Technological interruptions	17	8
		Lack of classroom atmosphere	2	5
		Language and culture barrier (international students) Language and cultural obstacles	1	1
		Difficulty in understanding courses that include numeric and equations	29	24
		Overall negative without elaboration		11
		Spending more time on coursework		7
		Inequality in the exams		1
		Difficulty in group works		1
	Neutral	No idea	7	0