EXPLORING PRESERVICE SCIENCE TEACHERS' PROGRESSION ON DESIGNING SIMULATION-ENHANCED INQUIRY-BASED LESSON FOR ASYNHRONOUS LEARNING ENVIRONMENTS

by

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ABSTRACT

EXPLORING PRESERVICE SCIENCE TEACHERS' PROGRESSION ON DESIGNING SIMULATION-ENHANCED INQUIRY-BASED LESSON FOR ASYNHRONOUS LEARNING ENVIRONMENTS

The aim of this study was to explore preservice science teachers' progression on designing simulation-enhanced inquiry-based lesson for asynchronous learning environments. A module entitled Simulation-enhanced Inquiry-based Asynchronous Environment, (SIMINA) was developed and implemented to explore progression through lesson plans, teaching video recordings, feedbacks, and reflections. In this phenomenographic study, the data were collected from ten preservice science teachers through pre- and post-interviews, lesson plans, teaching video recordings, feedbacks, reflections, and the researcher's field notes. Preservice science teachers' descriptions of lesson plan, 5E instructional model, inquiry-based science education, simulations, and asynchronous learning environments identified by the emerged categories; *purpose, tool (resource), process, learning and assessment, aspect, communication, technical, and learning environment.* Besides, in the post-descriptions, simulations and inquiry-based science education were found to be integrated more into asynchronous learning environments. The analysis of progression revealed that while the most progression observed in asynchronous learning environments, the least progression was observed in inquiry-based science education. According to the preservice science teachers, instructor's feedbacks were more effective in progressing lesson compared to peer feedbacks. Further, the nature and frequency of high-level of reflective thinking indicators increased continuously. Overall, this study has implications for the simulation-enhanced inquiry-based lessons for asynchronous learning environments through feedbacks and reflections.

ÖZET

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ SİMÜLASYON-DESTEKLİ ARAŞTIRMAYA-SORGULAMAYA DAYALI ASENKRON ÖĞRENME ORTAMLARI İÇİN DERS HAZIRLAMA SÜREÇLERİNİN ARAŞTIRILMASI

Bu çalışmanın amacı fen bilgisi öğretmen adaylarının simülasyon-destekli araştırmaya-sorgulamaya dayalı asenkron öğrenme ortamları için ders hazırlama süreçlerinin geliştirilmesinin araştırılmasıdır. Bu çalışmada, Simülasyon Destekli Araştırmaya-Sorgulamaya Dayalı Asenkron Öğrenme Ortamları (SIMINA) modülü geliştirilip uygulanarak bu süreçlerin geliştirilmesi ders planları, ders videoları, geribildirimler ve yansıtıcı günlükler ile araştırılmıştır. Bu fenomenografik çalışmanın veri toplama araçları on tane fen bilgisi öğretmen adayından gelen ön ve son görüşmeler, ders planları, ders videoları, geribildirimler, yansıtıcı günlükler ve alan notlarıdır. Fen bilgisi öğretmen adaylarının ders planı, 5E öğrenme modeli, sorgulamaya dayalı fen öğretimi, simülasyonlar ve asenkron öğrenme ortamlarını tanımlamalarından *amaç, araç (kaynak), süreç, öğrenme, değerlendirme, yön, iletişim ve teknik ve öğrenme ortamı kategorileri ortaya çıkmıştır.* Son görüşmelerdeki tanımlamalarda simülasyonlar ve araştırmaya-sorgulamaya dayalı fen eğitimi asenkron öğrenme ortamlarına daha fazla entegre edilmiştir. Ders planları ve videolarda ise en fazla gelişim asenkron öğrenme ortamlarında gerçekleşirken en az gelişim araştırmaya-sorgulamaya dayalı fen eğitiminde gerçekleştiği gözlemlenmiştir. Öğretmen adayları ders hazırlama süreçlerinin geliştirilmesinde eğitmenin geribildirimi akran geribildirimine göre daha etkili olduğunu söylemişlerdir. Ayrıca, yüksek düzeydeki yansıtıcı düşünme göstergelerin doğası ve sıklığı ilk yansıtıcı günlükten dördüncü yansıtıcı günlüğe doğru artmıştır. Sonuç olarak, bu çalışmanın simülasyon destekli sorgulamaya dayalı asenkron öğrenme ortamlarına katkı sağlayacağı düşünülmektedir.

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LIST OF ACRONYMS/ABBREVIATIONS

C-E	Claim-Evidence
COVID-19	Coronavirus-19
DE	Describing Evidences
EIN	Education Information Network
GED	Goal-experience discrepancy
IBSE	Inquiry-based Science Education
MoNE	Ministry of National Education
NRC	National Research Council
PhET	Physics Education Technology
POE	Predict-Observe-Explain
PST	Preservice Science Teacher
RECD	Recognizing and stating discrepancies between goals and experience
RNA	Reflection-in-action
ROA	Reflection-on-action
RTI	Reflective Thinking Indicators
SIMINA	Simulation-enhanced Inquiry-based Asynchronous
WISE	Web-based Inquiry Environment

1. INTRODUCTION

In today's world, technology takes an important part of each aspect of our lives, including education. Technology expands the horizon in education for students, teachers, administrators, parents, and curriculum developers (Ertmer, 2005). However, benefits of the technology integration into education remains still contentious. There are still arguments about which and how to integrate various types of media or methods into classrooms to improve students' learning process. Simulations are one type of technology tools as well as integration method which provides multiple representational, dynamic, and interactive learning environments with students. Accordingly, in science education, simulations allow students have the control over the learning environment via changing variables independently and then quickly demonstrate the result. One of the roles of integration of simulations into teaching and learning science is to provide authentic and student-centered learning environments for students and teachers (Edelson, 2001).

Inquiry-based science education is a student-centered teaching approach which is commonly used in science learning environments. For inquiry-based science education; research question(s) and data is needed to be involved (Bybee, 2006). Accordingly, with simulations data can be collected by considering the research questions therefore interactive simulation environments are widely used in inquiry-based science education (Tao and Gunstone, 1999). For this reason, computer simulations are also often used with inquiry-based science education which also enhance conceptual understanding by as students construct their own learning (Klahr and Nigam, 2004: McElhaney and Linn, 2010). With the help of simulation-enhanced inquiry-based science education, today's needs for education can be met.

Preservice science teachers take courses related to different science teaching methods and technology integration in a general manner during their undergraduate years. In these courses they get a chance to apply science teaching methods via microteaching of lesson plans. They also might integrate technology in their lessons. Even though

preservice science teachers rarely use inquiry-based science education and simulations, microteaching of lesson plans improves their teaching practices (McBride *et al.*, 2004; Lehtinen *et al.*, 2016). In addition, during microteachings preservice science teachers receive feedback from the instructor of the course, and sometimes they give and receive feedback from their peers. Giving and receiving feedback as well as reflecting on the feedback received are important points for improving teaching practices (Williams, 1992). Reflection is a process for preservice science teachers to reinterpret and reframe their work through different perspectives (Munby and Russell, 1990).

By the 21^{st} century, learning environments have gone beyond traditional classrooms and there have been distant and online choices for teaching and learning. However online education was not widely used in neither higher education nor in K-12 until the unpredictable worldwide pandemic Coronavirus-2019 (COVID-19) has arisen. COVID-19 easily transmits through droplets or touching surfaces which might cause to diseases related to respiratory systems among humans. Since nobody has immunity to COVID-19, it became a pandemic very quickly all around the World (WHO, 2020). Since school environments are vulnerable and young children are easily infected, thousands of schools from 138 countries are closed by March 2020 (UNESCO, 2020). Lockdown of schools caused immediate transition to emergency online learning education programs which were necessarily established due to the COVID-19 pandemic. This situation caused difficulties in teaching and learning for both K-12 and higher education for all around the world because neither teachers nor students got ready for online education (Toquero, 2020). During COVID-19 pandemic, it was understood that students and teachers need to prepare themselves for online teaching and learning environments for the future.

Accordingly, the present study focuses on preservice science teachers' design and teaching of simulations-enhanced inquiry-based science education for online learning environments. Therefore, this study aims to explore preservice science teachers' progression on designing simulation-enhanced inquiry-based lesson for asynchronous learning environments. From online learning environments purposively selected asynchronous learning environments where the teacher and learners participate the learning environ-

ment at different times and places (Hrastinski, 2008). The progression was investigated through lesson plans, teaching videos, instructor and peer feedbacks and reflections.

2. LITERATURE REVIEW

This chapter aims to provide a summary about the previous related literature, including, inquiry-based science education, computer simulations in science education, constructive feedback, and asynchronous learning environments.

2.1. Inquiry-based Science Education

Scientists try to understand the world around themselves by considering the content and the process which constitute the term scientific inquiry (Bell, *et al.*, 2005). Scientific inquiry can be defined as a process in which scientists investigate the world around them by questioning and through seeking answer for their questions.

In other words, scientific inquiry is a process which includes these aspects; observing environment, asking research question, collecting, or interpreting existing data, explaining results (Abd-El-Khalick, *et al.*, 2004). Scientific inquiry can be used in education through activities and processes which enable students to understand how scientists study the world (Howes, *et al.*, 2008).

In education, inquiry is a kind of learning approach by which learners investigate real-life scientific questions by using already existing data (Bybee and Landes, 1990). In simplified terms, inquiry is about knowledge and explanation. Accordingly, inquiry as a well-known instructional approach defined by National Research Council (NRC) (2000):

> "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (NRC, 2000, p. 14).

By using this definition NRC (2000) identified *five essential features for classroom inquiry:*

(i) Learners are engaged by scientifically oriented questions.
(ii) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
(iii) Learners formulate explanations from evidence to address scientifically oriented questions.
(iv) Learners evaluate their explanations in light of alternative explanations, particularly reflecting scientific understanding.
(v) Learners communicate and justify their proposed explanations. (p.25)

It is understood from NRC (2000) that for successful inquiry, an orientation question, an investigation, explanation regarding the investigation and communication about the explanation are needed. By considering NRC (2000) definition of inquiry and essential features of inquiry, Bell and colleagues (2005) argued that inquiry is appropriate for science education where students can investigate the world to improve their understandings. Bybee (2006) argued that the aim of inquiry-based education is doing science in order to understand the nature of science. Then inquiry-based science education became an educational approach. In the inquiry-based science education students are located at the center of the lesson. For inquiry-based science education students need to engage in asking a scientific question, design a scientific investigation, collect and/or interpret data, explain the results, and communicate the results (Abd-El-Khalick *et al.*, 2004). According to Bell and colleagues (2005) students do not need to collect their own data, but students can use already existed data so that they can analyze it.

Bybee (2006) discussed that inquiry-based science education was often confused with hands-on science activities. However, inquiry does not mean an activity but an approach when there is research question and data are involved. Similarly, Bell and colleagues (2005) argued that inquiry-based science education can be determined by a simple question "*Are students answering a research question through data analysis?*".

Therefore, in the inquiry-based science education, it is expected from science teachers that designing a lesson by improving students' conceptual knowledge and scientific practices through investigation of a scientific phenomenon (Goldston *et al.*, 2013). Science teachers can prepare lessons which have different complexities in which either giving research question and method to students or students developing their own research question and data. These lessons can be prepared in four different levels of complexities which will be explained in the following sub-section.

2.1.1. Four Level Model of Inquiry

Bell and colleagues (2005) offered four level of inquiry-based science education approach. These levels are classified according to their complexities and each one of them are called *confirmation, structured, guided*, and open inquiry from the most structured to the least structured format. In the *confirmation inquiry*, teachers give students the research question(s), the procedure, and the expected solution in order to let them verify a concept. In the *structured inquiry*, teachers give them the research question(s) and the procedure, and then students investigate the problem to come up with a solution. In the *guided inquiry*, teachers only give them the research question(s), and the students are set free to select and apply their own procedure and find their own results for the question(s). In the *open inquiry*, there is no research question, procedure or solution given to students, but they raise problems related to the concept and try to answer their own research questions. Table 2.1 ilustrates the four levels of inquiry developed by Bell *et al.*, (2005).

Table 2.1. Four Level Model of Inquiry.

How much information is given to the students?			
Level of Inquiry	Question	Methods	Solution
Confirmation	+	+	+
Structured	+	+	
Guided	+		
Open			

According to the Bell and colleagues' (2005) four level model of inquiry; level of complexity in the inquiry-based science education starts from the most teacher-centered inquiries to the most student-centered inquiries from confirmation to open inquiry. Confirmation inquiry is the most teacher-centered inquiry whereas open inquiry is the most student-centered inquiry. In other words, from confirmation inquiry to open inquiry, the guidance provided by the teacher decreases (Lazonder and Harmsen, 2016). However, Settleage (2007) and Zhang and Quintana (2012) reported in their studies that open inquiry might be unrealistic for middle school science classes since students might get lost at the open inquiry environment. Similarly, Bunterm *et al.* (2014) recommended preservice science teachers to use confirmation or structured inquiry for their future inquiry-based science education classrooms so that students easily follow the inquiry process.

Bell and colleagues's (2005) four level of inquiry model have been taught in science teaching method course of preservice science teachers (Goldston *et al.*, 2013; Namdar and Kucuk, 2018). The following part will give information about the importance of inquiry-based science education on preservice and inservice teacher education.

2.1.2. Inquiry-based Science Education in Preservice and Inservice Science Teacher Education

Undergraduate science teacher education programs include different courses focusing on science teaching and learning strategies for preservice science teachers. Inquiry-based science education is one of the most well-known science teaching approach in science teacher education programs (Haefner and Zembal-Saul 2004). Generally, preservice science teachers learn inquiry-based science education strategies during science teaching and learning methods courses (Goldston *et al.*, 2013) or science teaching laboratory courses (Trumbull and Kerr, 1993) during their undergraduate programs.

However, preservice science teachers are not always internalizing inquiry-based science education (McBride *et al.*, 2004). Therefore, implementation of inquiry-based science education is rarely used in science classrooms. For this reason, professional

development modules might be emphasized on inquiry-based science education for not only preservice but also inservice science teachers.

Previous studies revealed that successful implementation and internalization of inquiry-based science education strategies are directly related to instructors' supportive mentorship (Haney and McArthur, 2002) and teachers' beliefs about inquiry (Lotter *et al.*, 2007; Luft, 2001). Luft (2001) developed a professional development module for experienced and inexperienced in-service science teachers. In their module, inquiry-based science education was implemented by considering NRC (2000) standards of inquiry. Throughout the module, in-service teachers prepared inquiry-based science lesson plans and discussed about strengths and weaknesses of their lesson plans. Results of Luft's (2001) study demonstrated that experienced teachers only changed their behaviors of implementation of inquiry in their science lesson whereas inexperienced teachers only changed their beliefs about inquiry. In other words, experienced teachers' beliefs of inquiry and inexperienced teachers' implementation of inquiry in their science classes remained the same. In addition, Pajares's (1992) study focused on teachers' beliefs about inquiry. In this study, it is said that teachers' beliefs regarding the teaching and learning relies on their previous experiences about teaching and learning. Therefore, implementation of inquiry significantly depends on teachers' beliefs. Since experienced teachers have more experiences about inquiry-based science education, it is hard to change their beliefs. However, hearing from other teachers' examples helped them change their actions hence their discussions and conversations about inquiry promoted the changes of behaviors of inquiry implementation (Luft, 2001; Pajares, 1992).

As stated above, inquiry-based science education is a challenging process for both preservice and inservice science teachers. Bybee *et al.* (2006) suggested adopting 5E instructional model by which teachers could easily facilitate inquiry in their science lessons. Usually, 5E instructional model is taught for inquiry-based science education at professional development modules for inservice science teacher and at preservice science teachers' teaching method courses for successful implementation. Accordingly, in the literature there are empirical research on preservice science teacher education programs widely combine with 5E instructional cycle with inquiry-based science ed-

ucation approaches (Mesci *et al.*, 2020; Namdar and Kucuk, 2018). In the following sub-sections 5E instructional model is introduced and the empirical studies on 5E instructional model used in the inquiry-based science education environments are discussed, respectively.

2.1.3. The 5E Instructional Model

Science education researchers have been using inquiry-based science education approach in the preservice science teachers lesson plans which prepared according to the 5E instructional model (Mesci *et al.*, 2020; Namdar and Kucuk, 2018). The 5E instructional model, developed by Bybee and Landes (1990), is widely used by science educators while preparing lesson plans. This model is named 5E since it includes five stages and name of each stage starts by the letter "E". These stages are *engagement, exploration*, *explanation, elaboration*, and *evaluation*, respectively. In the *engagement* stage, teachers introduce a new concept to students in order to gather students' attention, promote curiosity, and reveal existing knowledge on the given concept. In the *exploration*, teachers involve students to the concept by providing to test their prior knowledge through a research question, an activity, or a model which is based on a concept. In order to answer the research question; students make an activity, collect their data, or investigate the existing data given by the teacher. In the *explanation*, students have an idea explaining the research question and teachers help students build conceptual understanding. In the elaboration, teachers extend students' understanding by engaging them with the new contents and experiences. In the *evaluation*, teachers evaluate whether the learning objectives are achieved or not while students assess their understandings (Bybee and Landes, 1990; Bybee *et al.*, 2006).

Goldston and colleagues (2013) claimed that inquiry-based science education approach, specifically guided inquiry, was appropriate for the 5E instructional model. Because in the exploration stage of the 5E instructional model, students develop scientific research questions, and collect data based on their research questions. In the

explanation stage, students explain to research questions through data analysis. Bell *et al.*, (2005) argued that research question and data were the two main components of inquiry-based science education. The exploration stage is suitable for research question and explanation stage is suitable for data analysis (Goldston *et al.*, 2013). Jun and colleagues (2013) argued that the 5E instructional model is suitable for engaging students in the inquiry-based science education.

Studies have reported many advantages of using 5E instructional model as used by the preservice science teachers. In Mesci and colleagues' (2020) study, preservice science teachers individually prepared lesson plans for inquiry-based science education by using 5E instructional model in their science teaching method courses. Preservice teachers claimed that they did not know inquiry before, but with the help of 5E instructional method, the implementation of inquiry was easy. It was reported that planning before teaching and getting revision to lesson plans' had positive influence of improving lesson plans. Similarly, the interviews conducted with the preservice science teachers demonstrated that inquiry orientation of lesson plans could be improved by planning and revision of lesson plans (Mesci *et al.*, 2020).

In Namdar and Kucuk's (2018) study, preservice science teachers worked in groups and prepared lesson plans for inquiry-based science education by using 5E instructional model. Then, the preservice science teachers criticized their peers' lesson plans and revised their own lesson plans according to the feedbacks that they received. The results of the study showed that students took criticism on each stage of the 5E. Most of these criticisms were on the exploration and explanation stages. After criticisms while some students improved their lesson plans, some of them did not change lesson plans' 5E instructional model integration. In this study, researchers suggested that preservice science teachers needed more practical opportunities in planning and designing lesson plans while using 5E instructional model approach. However, it was found in their research that half of the preservice science teachers' lesson plans did not include any scientific research questions. According to general inquiry orientation; in the beginning only a few groups' lesson plan was sufficient, after the critiques and revisions more than half of the groups' lesson plans became sufficient (Namdar and Kucuk, 2018).

Goldston *et al.*, (2010) indicated the importance of both theoretical knowledge and practical implementations for the effective usage of 5E instructional model approach in preservice teacher education. Therefore, it can be claimed that inquiry orientation can be improved by careful planning, constructive feedback, and revisions before teaching. Although there is strong emphasis on inquiry-based science education with 5E instructional model, implementation of inquiry is not an easy process. Implementation of inquiry into science education might be challenging for preservice science teachers. The reasons for this might stem from their teaching orientations (Eick and Reed, 2002; Namdar and Kucuk, 2018), teachers' knowledge (Anderson, 2002; Beyer and Davis, 2009), lack of experience, (Luft, 2001; Welch, 1981), personal characteristics (Mesci *et al.*, 2020), or lack of theoretical knowledge on both 5E instructional model and inquiry-based science teaching (Hanuscin, Lee, and Akerson, 2011; Meyer *et al.*, 2013). For this reason, while teaching inquiry-based science education with 5E instructional model to preservice teachers requires more time, theoretical knowledge and application are needed.

Hence inquiry-based science education is one of the important educational approaches used in science education, technology-based science inquiry environments have become popular in last decades (Zhang and Quintana, 2012). Recent technological developments make inquiry-based teaching possible to adapt learning environments into online tools and resources. Accordingly, some researchers combine inquiry-based science education with web-based learning environments. In the following sub-section these environments are used in the science education with their advantages and disadvantages is discussed.

2.1.4. Inquiry-based Science Education on the Web

Developments in technology facilitate integration of inquiry-based instruction by using the tools available on the web. Technology provides web-based environments where students work collaboratively for inquiry-based instruction by providing data collection and analysis software where the users control the variables (Windschitl, 2000). Inquiry-based science education with integration of technology can be used

for various purposes in science education including improving argumentation (Walker and Zeidler, 2007), conceptual learning (Fang *et al.*, 2016; Marshall *et al.*, 2017), and understanding nature of science (Capps *et al.*, 2012; Zhang and Quintana, 2012).

Some researchers (Walker and Zeidler, 2007; Zhang and Quintana, 2012) focused on students' argumentation skills in simulation-enhanced inquiry-based education. First, Walker and Zeidler (2007) studied with high school students on genetically modified organisms' topic in order to analyze students' scientific discourse skills through inquiry. Classroom observations have shown that during the unit students understood the nature of socio-scientific issues through discussing their results.

Technology-based inquiry environments can be also used for the purpose of conceptual understanding. Bybee (2006) claimed that inquiry instruction improved conceptual knowledge since it requires higher level of thinking as the students develop research questions, collect, analyze, and interpret data. Similarly, studies which focused on technology integration into inquiry-based science education environment (Fang *et al.*, 2016; Marshall *et al.*, 2017) reported that technology facilitates inquiry integration through scaffolding, and data collection and analysis. In both studies students' conceptual understandings in the technology-based inquiry learning environments was investigated. Fang and colleagues (2016) reported that students who had higher conceptual knowledge, were also better in asking scientific questions, collecting data, and interpreting results of the data. On the contrary, students who had lower conceptual knowledge, also had lower inquiry skills.

More importantly, Inquiry-based science teaching facilitates understanding of scientific inquiry by doing science (Lederman *et al.*, 2013). Some of the inquiry research in science education focused on inquiry skills itself like developing research questions, collecting, and analyzing data in web-based inquiry environments (Kyza, 2009). Kyza's (2009) study emphasized students' generating and testing alternative hypotheses through' classroom discourse, actions in classroom and group, inquiry products, and interactions with their teacher and peers. The analysis of pre-and post-conceptual test score indicated statistically significant learning gains on inquiry and conceptual

understanding. Also, it is found that students' inquiry orientations improved according to the examination of the students' discourse analysis and classroom actions.

With technology integration, the implementation of inquiry attempts to satisfy the needs of today's education. Therefore, all inquiry studies mentioned in this section conducted with technology integration. Since inquiry requires research question and data; inquiry-based science teaching can be combined with other science teacher and learning strategies. Therefore, knowing how to design and implement inquiry-based science teaching is necessary for science teachers.

2.2. Computer Simulations in Science Education

Simulation is defined by Banks and colleagues (2001) *as an approximate imitation of the operation of a process or system that represents its operation over time (p.3).* A simulation provides a model or an artificial system from reality life (Rutten *et al.*, 2012). Simulations can be used in various environments including engineering, gaming or healthcare. However, in the last decades, simulation has widespread to education and teacher educational programs (Kaufman and Ireland, 2016). In education, computer simulations are mostly used. Computer simulation is defined by de Jong and van de Joolingen (1998) *as a program that contains a model of a system (natural or artificial, e.g., equipment) or a process* (p.180). In computer simulations, a system is simulated. Therefore, computer simulation is a computer program which explains a process or how a system works artificially.

Computer simulations are mostly used to provide models and modeling into learning environments. Accordingly, simulation in education is defined by Ainsworth and VanLabeke (2004) as educational simulations are the environments that allow students to conduct experiments by observing hypothetical situations; especially visualize the nature of invisible phenomena. In other words, simulations support "*what-if*" situations; learners can manipulate the variables so that they could observe what is happing and then make inferences to discover patterns or relationships among the variables.

Simulations have become interactive learning environments that are widely used in science teaching and learning. For science education, simulations allow students to explore hypothetical situations of natural or artificial phenomena by changing or manipulating variables within a system or a process. Simulations also motivate students to learn by providing enjoyable environments (Wieman *et al.*, 2008). In addition, simulations enable interactive learning environments to students where they discover simplified version of scientific facts, processes, or models. Then students can conceptually understand how scientific facts or processes occur (NRC, 2000). In computer simulations, students actively participate into learning process which enables consistent learning in comparison to traditional science classrooms (Rutten *et al.*, 2012).

In contrast to traditional classrooms where the instructions are based on teacher-centered approaches, simulations enable interactive learning environments where students discover simplified version of scientific facts, processes, or models. Since simulations make hypothetical situations possible, they are widely used in science education. In the interactive computer simulations students actively participate into learning process which enables consistent learning in comparison to traditional science classrooms (Rutten *et al.*, 2012).

Although in computer simulation environments student-centered approaches outweigh teacher-centered approaches, teacher guidance is needed in simulation based authentic inquiry learning environments. Rutten *et al.*, (2012) and Smetana and Bell (2012) conducted metanalysis on learning effects of simulations in different learning environments. Results of both studies indicated that simulations are supplementary resources for students' learning where there is teacher guidance.

In today's world, there is a variety of computer simulation sources which include both websites and programs so that teachers can easily access to simulations from free of charge from the internet sites or computer software programs. All of these simulation websites and programs have aimed to provide digital teaching and learning environments via dynamic visualizations and interactive models of natural or artificial phenomena (Bradley and Kendall, 2014; Rutten *et al.*, 2012; Smetana and Bell, 2012).

In the following sub-section simulation websites and computer programs which are widely used in science education will be introduced.

2.2.1. Simulation Websites and Computer Programs used in Science Education

Simulation websites or computer programs to used in science education should be well-designed in order to provide effective and engaging learning environments (Adams *et al.*, 2008). This is because students do not learn science not only by watching videos or animations but also by asking questions to understand scientific phenomena they watched. Hence simulations provide interactive learning environments where students might learn by engaging with the simulations (Wieman *et al.*, 2009). Computer-based simulations should be used as an alternative educational tool in the classrooms to improve students' understanding of science concepts. On the internet, there is a variety of website or software source for simulations. The following sub-sections will provide general information about specific simulation learning environments and the empirical studies conducted in these environments. Some of the simulations used in science education include PhET Simulations, Algodoo, Concord Consortium, and netLogo and WISE respectively.

2.2.1.1. PhET Simulations. Among all computer-based learning programs Physics Education Technology (PhET) simulations are one of the most known computer simulations. The design of PhET simulation learning environment is compatible constructivist learning environment and the principle of how students learn (Bransford, Brown and Cocking, 2000). By using PhET simulations effective inquiry-based learning environments designed, too (Chen, 2010).

PhET simulations can run through standard web browsers, and they can be integrated into an instruction, used with laboratories or as homework assignments, or used as informal resources (Wieman *et al.*, 2008). Science teachers have been widely using PhET simulations because they are easy to use, understandable, appropriate for

objectives, and available for free . On the PhET simulations website, there are plenty of simulations for all K-16 level and disciplines including physics, chemistry, biology, and astronomy. PhET simulations are specifically designed for creating dynamic visual representations of difficult, invisible, and abstract concepts in science like atomic representations. Figure 2.1 shows a screenshot of an example atomic representation from PhET:

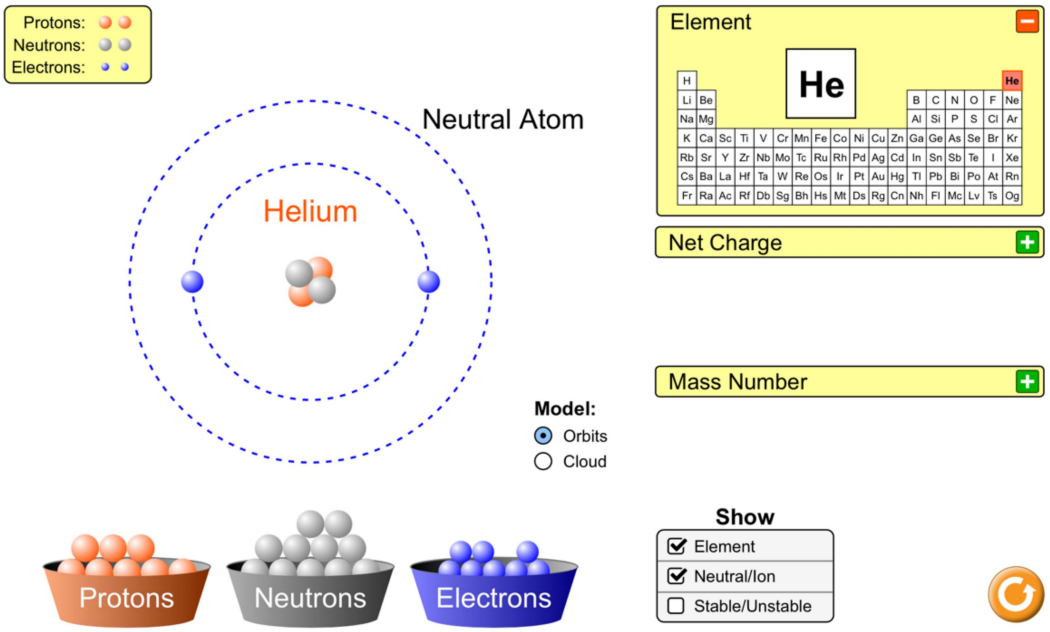


Figure 2.1. A Screenshot of Built an Atom Simulation from PhET.

In addition, on PhET website, there are many lesson plans which have been developed and uploaded by the users. Perkins and colleagues (2012) argued that PhET simulations can be used in middle school science classroom in order to increase students' motivation and learning in science. In their study, researchers studied with middle school students by using 12 different simulations selected from PhET. Results showed that middle school students were actively engaged and learned science concept through PhET simulations. (Perkins *et al.*, 2012). Furthermore, Wieman *et al.*, (2009) used the *Wave Interference* simulation from PhET and found that students discover simulations as scientist thus they learned at funny and intellectually engaging environment. Moore *et al.* (2014) and Yuliati *et al.* (2018) used PhET simulations by inquiry-based science education purposes. Moore and colleagues (2014) analyzed

PhET chemistry simulations in their research. It is reported in the research that, PhET chemistry simulations could be used in middle or high school chemistry topics with guided-inquiry activities. Yuliati *et al.*, (2018) studied to analyze problem solving skills through inquiry-based science education with preservice physics teachers and in this study electricity simulation at PhET was used. It is reported that few preservice physics teachers prefer structured problem-solving skills. For this reason, it is suggested that preservice teachers should be exposed to more inquiry-based simulations in their teaching practices lessons.

2.2.1.2. Algodoo. Algodoo is another type of simulation software which can be downloaded for free and used in tablets or computers. Algodoo provides 2D learning environments for learners in physics topics including simple machines, light or density. Figure 2.2 demonstrates a screenshot taken from the pulley simulation of Algodoo, as an example:

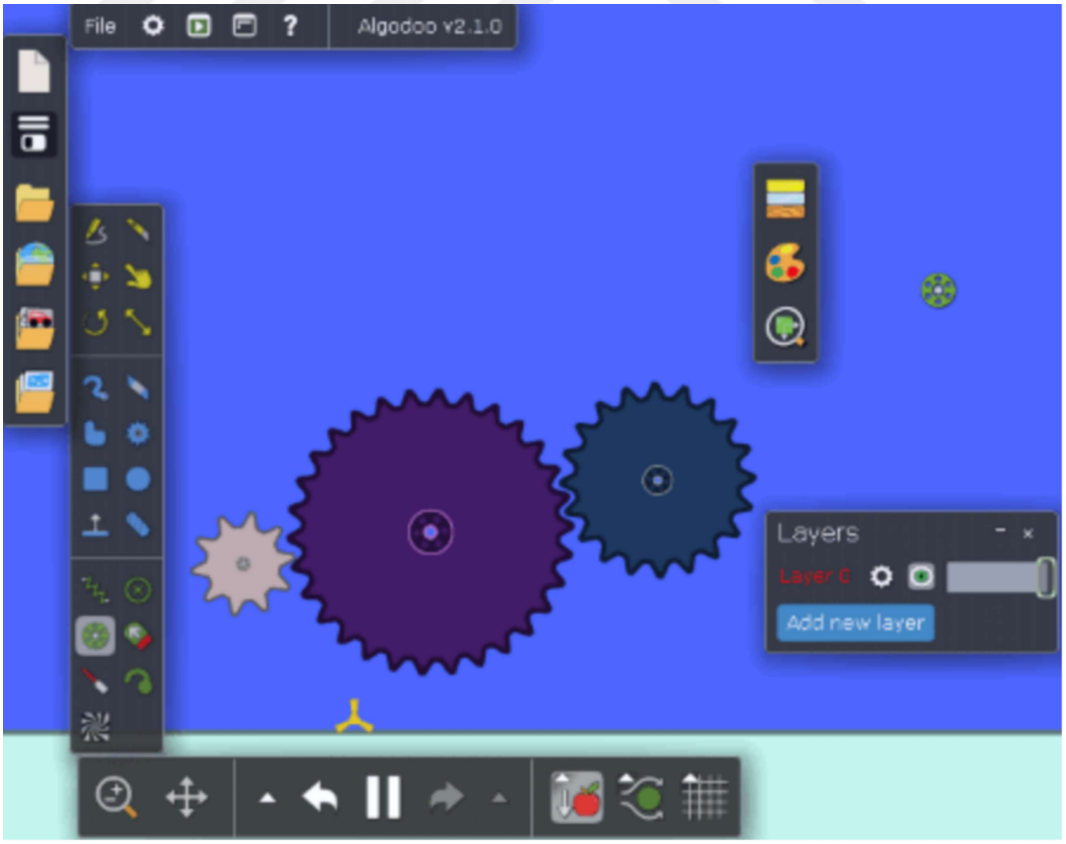


Figure 2.2. A Screenshot of Pulley Simulation from Algodoo.

The aim of using Algodoo in science education is various such as increasing conceptual understanding, science learning, motivation, attitude on science, and academic achievement (Akdag and Gunes, 2015; Celik *et al.*, 2015). Celik, *et al.* (2015) investigated with preservice teachers and interview results indicated that Algodoo was an effective simulation since it was easy to learn, and improved creativity for teachers and learners. However, it requires time to prepare a learning environment. On the other hand, Akdağ and Gunes (2015) studied with high school students to investigate advantages and drawbacks of Algodoo from high school students' perspectives. The mostly stated drawback was that Algodoo topics were limited to physics.

2.2.1.3. Concord Consortium. Concord Consortium is a nonprofit organization for creating interactive simulation-based learning environments for different levels of science education. Through inquiry-based simulations, invisible phenomena become explorable and visible through Concord Consortium's simulation projects. On their website, each specific project's suitable grade level, learning objectives and topics compared to other simulation websites for inquiry-based science education.

Concord Consortium aims to develop and implement interdisciplinary concepts in their simulations. Some of the example topics included in the Concord Consortium simulations are pollution, atoms and molecules, light and diffusion. The simulations designed to cover these topics are aimed to be given in interdisciplinary manner. Chao *et al.* (2017), who were the researchers of Concord Consortium learning scientist team, focused on engineering design activities through simulations. It was reported that the representation, the analysis and the reflection parts of the simulations foster students' conceptual understanding (Chao *et al.*, 2017). *Molecular Workbench (MW)* is an example simulation program developed by Concord Consortium research team and it has been actively used in science and chemistry education (Chao *et al.*, 2017; Xie *et al.*, 2011). Xie and colleagues (2011) reported in their research that MW allowed students to construct their own research question(s), collect data, analyze and evaluate the results through computational simulation environments. In addition, Chao *et al.* (2017) used Energy-Efficient Home Design Challenge simulation of the Concord Consortium,

to evaluate high school students' engineering design skills and learning goals. Results have showed that, students' conceptual knowledge and design skills improved.

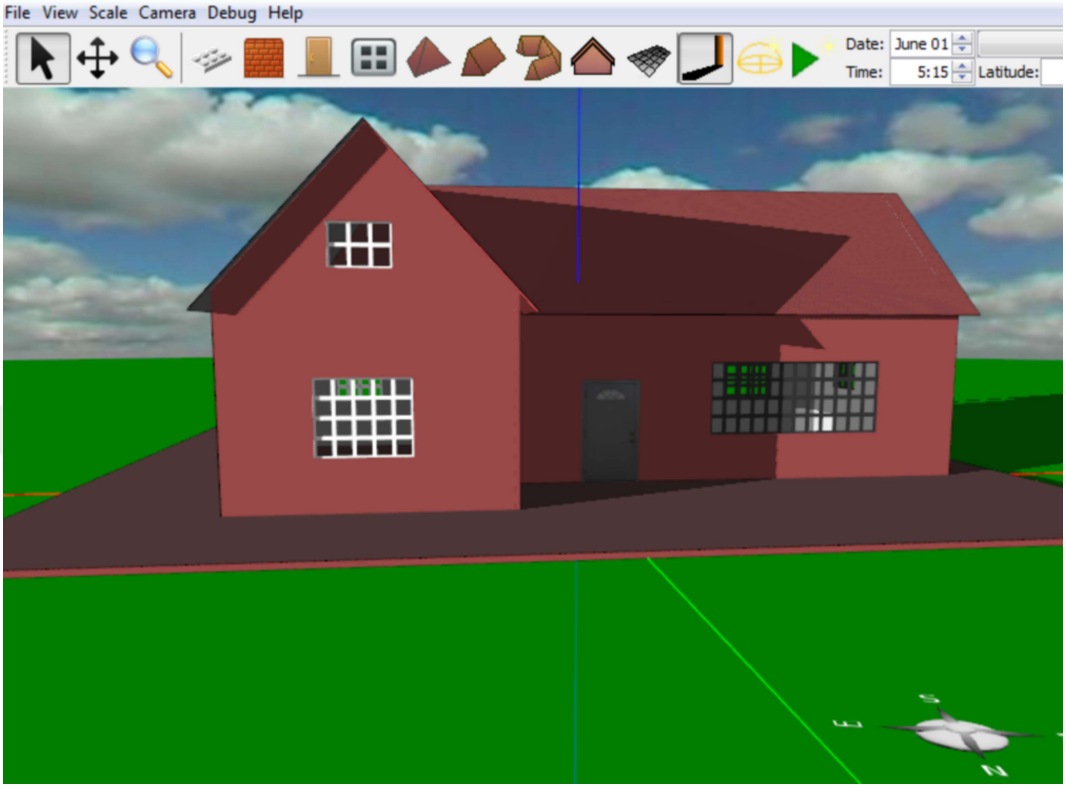


Figure 2.3. A Screenshot of Energy Efficient Home Design Simulation from Concord Consortium.

2.2.1.4. WISE (Web-based Inquiry Science Environment). WISE is a platform where simulations are delivered as units available online. WISE is a free, open-source, and one of the most popular online learning environments nowadays. Exemplar units include global warming, chemical reactions, genetics and motion. WISE offers lots of inquiry tools via multiple representations, including but not limited to visualization, virtual laboratories, drawings, animations, simulations, written texts, and online discussions. In units, students collect and interpret their own data in accordance with their research questions. In short, WISE provides modern technology-based inquiry environments for researchers, teachers, and students.

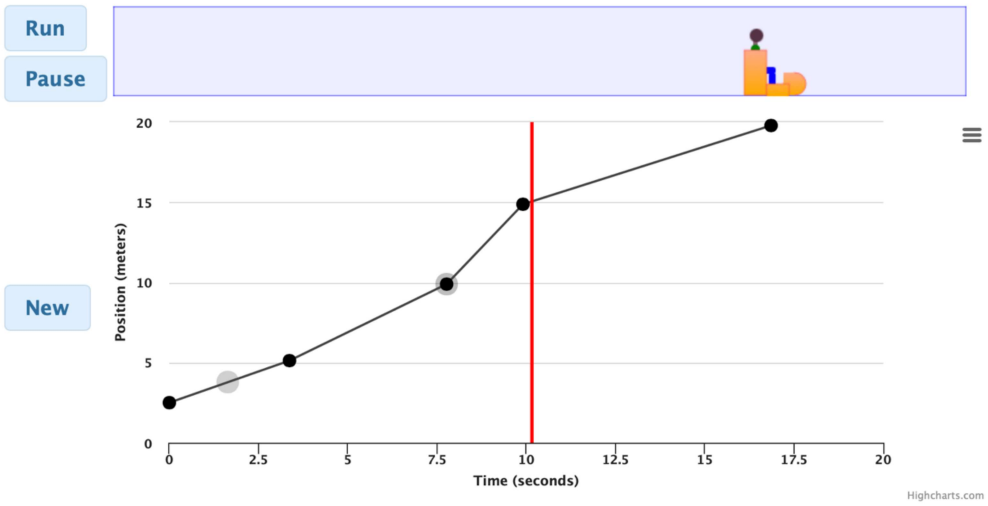


Figure 2.4. A Screenshot of Motion Simulation from WISE.

In the literature there is empirical research conducted by using WISE environment in middle and high school science education (Fang *et al.*, 2016; Ryoo and Linn, 2011). Fang and colleagues (2016) used six differe' conceptual understandings related to science including physics, chemistry and biology topics and inquiry skills increased significantly. Moreover, Ryoo and Linn (2011) used photosynthesis unit from WISE to explore high school students' conceptual understandings. In this study dynamic representation group learned photosynthesis through simulation whereas static representation group learned through images. Results of the study indicated that students from dynamic simulation groups had more conceptual understanding about photosynthesis compared to static representation group.

All simulation websites or programs stated above offer students quick data collection and analysis tools to investigate their research question. This opportunity of simulations enables inquiry-based science education for learners. The following subsection provides previous literature on simulations used for implementing inquiry-based science education approach.

2.2.2. Simulations in the Inquiry-based Science Education

Simulations are also aimed to enhance inquiry. According to Bybee (2006), the research question(s) and the data collection and analysis are the integral parts of the inquiry-based science education. Therefore, it seems that inquiry-based science education can be enhanced via simulations. For example, WISE environment provides inquiry-based and simulation-enhanced learning environments for students. Slotta and Linn (2009) reported that simulations allow users to investigate their research question(s) through data collection and analysis. Therefore, it can be deduced that simulations can be used in inquiry-based science learning environments. Inquiry-based simulations can be used for increasing conceptual understanding (Fang *et al.*, 2016; Kukkonen *et al.*, 2014), teaching inquiry skills (Rutten *et al.*, 2015) teaching complex or abstract scientific phenomenon (Chang and Linn, 2013; Olmpiou *et al.*, 2013), and scaffolding (Apkan, 2001; Huang *et al.*, 2016).

Kukkonen and Colleagues (2014) used The Greenhouse Effect simulation from PhET to explore middle school students' conceptual understandings related to greenhouse effect. Students drew their conceptions about greenhouse effect in the first lesson. In the second lesson, students used simulation in order to change variables so that to observe which and how the variables affect greenhouse effect. In the last lesson, students again drew their conceptual, images about greenhouse effect. After the simulation-enhanced inquiry instruction, students' drawings included more conceptual details related to the greenhouse effect.

Similarly, Chen (2010) argued that the predict-observe-explain (POE) technique was needed to be used with the simulations for creating an inquiry-based environment. Then Rutten and colleagues (2015) designed a professional development module for in-service physics teachers to embed inquiry-based simulations while teaching physics.

In this module, physics teachers used inquiry-based simulation for pendulum topic with POE techniques. Physics teachers said that POE technique is suitable for inquiry-based education because they can design a lesson by considering research question and

data. In addition, physics teachers reported that using simulations facilitated asking research questions and collecting data.

Moreover, inquiry-based simulation can also be used for teaching complex, abstract, or invisible scientific phenomenon. Students observe simplified versions of the scientific phenomenon via simulations. This opportunity of simulations facilitates students' understandings of complex or invisible scientific phenomenon (NRC, 2000). Olympiou and colleagues (2013) explored effectiveness of integrating Light and Color simulation from PhET to teach abstract and concrete topics for conceptual understandings. While one group of students investigated both abstract and concrete simulations, the other group investigated only the concrete simulation. Results indicated that conceptual understandings of students in both groups significantly improved. In addition, students' mental models related to invisible phenomenon of light enhanced better in students who used both abstract and concrete simulations. Chang and Linn (2013) explored the middle school students' investigation and critiquing skills in *Thermodynamics* inquiry unit developed by WISE environments. Students investigated movements of different molecules at different temperatures through simulation. Then students discussed their findings with their peers. Results showed that when the simulations are embedded into inquiry-based science learning environments, students' ability to make critiques increased while they are discussing their findings (Chang and Linn, 2013).

Furthermore, Apkan (2001) claimed that scaffolding supports inquiry process of with increasing students' conceptual understandings. Inquiry-based simulations can also be implemented by scaffolding strategies. For example, Huang *et al.* (2016) investigated students' conceptual knowledge about force and motion unit using Moving Man and Forces simulation of PhET. In this study, students either individually discovered the simulations or their science teachers scaffolded them while using the simulations. Results indicated that scaffolding enhanced students' conceptual understandings.

In addition, some drawbacks of using simulations in the inquiry-based science learning environments were also determined (Gonczi *et al.*, 2016; Rutten *et al.*, 2015). Most teachers argued that simulations were not suitable for whole class teaching be-

cause neither there was a simulation suitable for every learning objective (Rutten *et al.*, 2015) nor was there enough time for using simulation in each lesson time (Gonczi *et al.*, 2016). Therefore, in both study, science teachers claimed that they used inquiry-based simulations as an additional activity. Therefore, it can be deduced that inquiry and simulation are complementary approaches in science education.

There are also empirical studies on simulations in preservice teacher education programs. The following sub-section will give information about the previous literature on simulations used in preservice teacher education programs.

2.2.3. Simulations in Preservice Science Teacher Education

Since simulations are widely used in science learning environments, preservice teachers' use of simulation in their future classrooms is important. Previous studies have reported that although simulations are effective tools in learning, they are not widely used by preservice teachers (Gonczi *et al.*, 2016). The reasons for preservice teachers' use of simulations in their future classroom mostly involve improving conceptual understanding, content knowledge, technological beliefs, and attitudes towards technology. This specific framework is called Technological Pedagogical Content Knowledge (TPACK) introduced by Koehler and Mishra (2005). TPACK framework aims to integrate content, pedagogy, and technology all together (Koehler and Mishra, 2005). Chen (2010) argued that preservice teachers' beliefs about technology has large impact on usage of technology in their classroom. Accordingly, there is limited study on inquiry-based simulations in preservice teacher education (Gonczi *et al.*, 2016). In this section, previous empirical studies on simulation usage of preservice education are given.

Ertmer (2005) reported that if teachers feel comfortable to use technology, then they tend to integrate technology in their classrooms. Similarly, Lehtinen *et al.* (2016) studied with preservice teachers iso that comparing their beliefs and orientations about technology while using simulations. Results of the study indicated that preservice teachers' technological knowledge was significantly related with the use of simulations

during their teaching. For this reason, it is important to shape preservice science teachers' beliefs on teaching orientations including belief about technology. It is suggested that to increase the effective use of simulations in science teaching and learning environments, preservice teachers' technological pedagogical content knowledge should be enhanced (Chen, 2010; Lehtinen *et al.*, 2016).

Theelen, *et al.* (2019) reported in their review paper that simulations in education seemed to be additional resources used to improve attitude or motivation towards learning science. Similarly, Ulukok and Sari (2016) examined what preservice science teachers thought about using simulations in their classrooms. Preservice teachers said that simulations were useful in science education because they were interactive, interesting, and might increase students' motivation towards science (Ulukok and Sari, 206). Moreover, Bell *et al.*, (2013) studied with preservice science teachers to examine how and why preservice teachers used different forms of technology (including simulations) into their lesson plans or microteachings. Results showed that only a few preservice science teachers integrated simulations into their lesson plan and microteaching. They said that their aim of using simulations was to engage students into inquiry-based science education.

Simulations have some drawbacks, too. For example, they might cause misconceptions, or simulations might be expensive or time consuming (De Jong *et al.*, 2013). There were also some drawbacks of using simulations in the inquiry-based science learning environments determined (Gonczi *et al.*, 2016; Rutten *et al.*, 2015). Most teachers argued that simulations were not suitable for whole class teaching because neither there was a simulation which was suitable for each learning objective (Rutten *et al.*, 2015) nor was there was enough time for using simulation for each lesson time. Therefore, in both study science teachers claimed that they used inquiry-based simulations as an additional activity. Therefore, it can be deduced that inquiry and simulation are complementary approaches in science education.

The effects of using simulations on preservice teachers' conceptual understanding of a science concepts was another research area for science teacher education re-

searchers. Only a few preservice teachers said that simulations can improve conceptual understanding and learning (Theelen *et al.*, 2016). Kumar and Sherwood (2007) studied with preservice science teachers in order to examine their conceptual understandings of environmental science topic in the simulation-enhanced problem-based learning environments during the undergraduate course. In this course preservice science teachers learnt environmental science topics like ecosystems, pollution, and marine organism. Comparison of pre-test and post-test results showed that preservice teachers' conceptual understandings and problem-solving skills have increased. However, delayed-post test results demonstrated that improvement on the conceptual understanding was not permanent (Kumar and Sherwood, 2007).

Gonczi *et al.* (2016) designed a professional development program to teach inservice science teachers how to use simulations effectively in inquiry-based science education. Most of the teachers argued that they did not use simulations due to time limitation and limited simulation resources. However, after professional development program, science teachers claimed that there were a variety of different simulations to be used in teaching science. Accordingly, Gonczi *et al.* (2016) suggested that more professional development programs are needed to increase the use of simulations in science education.

2.3. Asynchronous Learning Environments

By 21^{st} century, distance and online learning environments has become important opportunities among worldwide. Among with newer technological opportunities, distance education provides modern opportunity for education. Accordingly, distance education became an opportunity from educators, instructors, and learners (Simonson, *et al.*, 2015). There is emphasis on learning place, learning experience and communication in online learning environments. However, improvements in technology has changed communication part of the distance education since media channels are evolved. In the past communication between students and teachers are limited to e-mails in distance education, today's audial and visual communications are widely used. In today's online learning environments, learners and teachers (facilitators) are at physically dif-

ferent environments and they can either participate either *synchronously* (at the same time) *or asynchronously* (in different times) to the instruction via computer mediated communication media (Hrastinski, 2008). In the following paragraphs asynchronous learning environments will be introduced.

Asynchronous learning generally refers to a way of distance education where communications between instructor and learner occurs any time by using the Internet (Moore and Kearsley 2012). Asynchronous learning environments especially useful when learners need time for thinking about a topic, a question, or a task (Brierton *et al.*, 2016). Asynchronous learning environments are flexible in time so that learners have more time to understand or think about a phenomenon or topic. Then learners have much time for preparing responses of teachers' questions about a topic or a phenomenon. This opportunity of asynchronous learning environments specifically an opportunity for students who are low achievers, shy, or slow learners (Meyer, 2003).

On the other hand, asynchronous learning environments have drawbacks, too. Haythornthwaite and Kazmer (2002) argued that lack of discussion opportunities decreases peer discussion and interaction between learner and instructor. However, Hrastinski (2008) claimed that immediate discussion was not needed, discussion forums were sufficient. In discussion forums instructors or learners have a chance to look at to the internet or a book so that giving more reflective answer or question (Hrastinski, 2008). If well-designed discussion forums or synchronous meetings can be added to asynchronous learning design, discussion environments can be managed which minimize disadvantages of asynchronous learning environments. Therefore, asynchronous learning environments' advantages outweighs its disadvantages.

By considering improvements in technology and advantages of asynchronous learning environments, it is suggested to include asynchronous course for preservice teachers so that preparing preservice teachers to design lessons for asynchronous learning environments (Ertmer, 2003; Jang, 2008). The following parts will provide previous literature on asynchronous learning environments used in teacher education programs.

2.3.1. Asynchronous Learning Environments in Preservice Teacher Education Programs

Teacher education programs need to collaborative learning environments where preservice teachers learn teaching pedagogy from themselves, their peers, academicians, and nonacademic community (Hiltz, 2000). Online preservice education programs overcome time and space barriers in preservice teachers' access into instruction and manage time in their learning process (Tallent-Runnels *et al.*, 2006).

Even though online learning environments increase over time, there is less emphasis on asynchronous learning environments in preservice teacher education programs (Hiltz, 2000). Empirical research on asynchronous learning environments in preservice teacher education programs emphasized on comparing synchronous and asynchronous instruction (Jang, 2008), participation in asynchronous learning environments (Burns *et al.*, 2020), discussion in asynchronous learning environments (Wang and Wang, 2020), learning goals in asynchronous learning environments (O'Brien *et al.*, 2020).

Participation is an important issue in preservice teacher education courses. Therefore, in the asynchronous learning environments designers think about preservice teachers' active participation into course itself and discussions. Burns and colleagues (2020) designed both asynchronous and synchronous learning environment for their first-year biology course to compare students' participation into those environments. The interactive online biology course both include synchronous and asynchronous parts. Students' average engagement on interactive synchronous parts are 60%, while 95-95% of students participate asynchronous discussions and stated that asynchronous feature of the course helps their self-directed learning (Burns *et al.*, 2020).

Other issue for asynchronous learning environments is to determine learning goals objectives. O'Brien *et al.* (2020) argued that it is not realistic to expect same learning goal or strategy during asynchronous environments compared to face-to-face learning. Therefore, instructors should revise their expectations for asynchronous learning and should give more constructive feedback to learners in order to improve their task

(O'Brien *et al.*, 2020). Discussion constitutes a significant part for asynchronous learning environments.

Choi (2016) taught one of the undergraduate preservice teacher education program courses fully asynchronously. Results showed that preservice teachers' satisfaction about asynchronous course was high because time and study environment is flexible. However, preservice teachers felt dissatisfied in help-seeking process. Moreover, Griffiths and Graham (2010) taught integration of technology in teaching course asynchronous. In this course, the instructor shouted asynchronous video while giving a lecture, then preservice teachers individually shouted asynchronous video in order to share their ideas with their peers or the instructor. In addition, preservice teachers uploaded their assignments on Moodle (*modular object orientated dynamic learning environment*). Again, the instructor gave feedback through asynchronous video. In short asynchronous videos are comprise large majority of the lesson. Most of the preservice teachers actively participated to the course through asynchronous videos and they said that they have positive relationship between their instructors and peer. In addition, at the end of the course preservice teachers' technological abilities substantially increased. Therefore, it can be deduced that preservice teachers need help in asynchronous learning environments, and this help can be given through constructive feedback (Griffiths and Graham, 2010).

Jang (2008) conduct a research by integrating asynchronous learning environments into preservice teachers' teaching method course. There were homework, e-journals, group discussion forums, and quizzes which can be done by asynchronously at experimental groups' treatment. However, control groups took the course face-to-face. Most of the preservice teachers at experimental group stated that although asynchronous learning materials drove to learn via discussion, they need traditional face-to-face classroom for deeper discussions. Similarly, Wang and Wang (2020) in their study expected preservice science teachers to design 5E inquiry lesson plan as a part of asynchronous undergraduate science teaching methods course. Preservice science teachers' explanation and elaboration parts of the 5E lesson plan was under average. Researchers claimed that the reason might be there is not peer interaction in

asynchronous science teaching methods course. Therefore, it is suggested either add discussion forums into asynchronous learning environments or taught discussion parts of the lesson asynchronously.

Baran and Keles (2011) designed asynchronous instructional design course for preservice computer education technology teachers. Participants of this study argued that exclusively long and repetitive discussions were happened on the discussion forum. For this reason, they would prefer face-to-face discussion rather than online discussion forum. Furthermore, as an advantage of asynchronous undergraduate course, participant preservice teachers from both Jang's (2008) and Baran and Keles's (2011) study argued that they have experienced how to integrate asynchronous instructional design into their future classroom. Hrantinski (2008) reported that asynchronous learning environments best fits when thinking about and reflecting on complex phenomenon are needed. Hence inquiry-based science education is complex for students, asynchronous learning environments is suitable to implement it. Then students can repeatedly watch the lesson, think about research question, and explain phenomenon. Even though there are several advantages of asynchronous learning environments, in education context, these environments were not to first choice.

2.3.2. Asynchronous Learning Environments in Preservice Teacher Education During Times of COVID-19

Asynchronous learning was an option up to COVID-19 pandemic. However, after COVID-19 spreads the World, education has affected significantly. As a result of the closure of schools, remote learning opportunities was emerged. Like all other educational levels and disciplines, teacher education programs have started to remote learning opportunities. Preservice teacher training programs also adopted to alternative plans including synchronous or asynchronous opportunities. Due to the fact that all students neither have constant internet in their homes nor have personal computer or tablet, courses started to teach asynchronously (Ozkaral and Bozyigit, 2020; Quezada *et al.*, 2020). Following paragraphs will provide information about asynchronous learning environments in preservice teacher education after COVID-19.

Scull and colleagues (2020) also investigated four academics', who work in the faculty of education, experiences related to remote online learning during COVID-19. Academics said that when preparing syllabus for synchronous or asynchronous online learning three aspects should be considered: accessibility, participation and engagement. In first, accessibility can be considered as internet access. When learners or teachers did not have continuous access to internet, asynchronous course design is needed. Secondly, participation highly related to positive pedagogical relationship between student and teacher relationship. Therefore, it is suggested teachers to respective and productive relationships with students. Third aspect was engagement which can be increased by more discussion or group works (Scull *et al.*, 2020).

Quezada and colleagues (2020) conducted a case study to examine how faculty of education transitioned to remote online teaching because of COVID-19. At first, all courses began synchronous at currently assigned time. However due to internet problems, academicians started to record lessons asynchronously and upload into university's Moodle system. In addition, preservice teachers presented their assignments and projects at online platforms. Various different forms of meeting platforms, web 2.0 tools and applications were used. For this reason, both academicians' and preservice teachers' exposed more technology. As a gain of this situation their skills related to technology increased (Quezada *et al.*, 2020).

Ozkaral and Bozyigit (2020) have conducted a study with senior year preservice teachers to identify their experiences related to remote online teaching. Most of the preservice teachers stated that they have concerns related to online presentations. In order words, they feel insecure about taught lesson in front of computer. For this reason, it is suggested to provide more online (including synchronous and asynchronous) courses during preservice teachers' undergraduate years. Thus, preservice teachers might learn teaching for online classes (Ozkaral and Bozyigit, 2020). Previous research on remote online learning environments in preservice teacher education during COVID-19 discussed that preservice teachers have concern related to internet accessibility, their technological skills or taking online lessons. Therefore, it is suggested on the literature that preservice teachers should exposed more to asynchronous learning environments.

2.4. Constructive Feedback and Reflection on Feedback

In the last decades, there has been great emphasis on shifting assessment and evaluation techniques from summative assessment to formative assessment. Accordingly, the importance of assessment is not only giving grades but also giving a chance to a learner to improve him/herself (Evans, 2013). Feedback is an evaluative information given to a learner for improving his/her task. Accordingly, feedback has become an integral part of the assessment process for both teaching and learning. In the field of education, feedback is simply defined by Boud and Molloy (2013) as *information provided by teachers to students about their work. (p.700).* Ferguson (2011) reported that giving and receiving feedback is a lifelong and an ongoing practice for educators. An educator might receive feedback from his/her instructor, peer, administrator, or coordinator.

Since feedback is a lifelong process, Ferguson (2011) argued that effectiveness of feedback is important. For this reason, learners and teachers are supposed to know how to give and receive constructive feedback. According to Gibbs and Simpson (2005), constructive feedback has the following features: focusing on performance, timing, frequency, relevance, understandable, actionable and in-detailed. Similarly, Carless and Boud (2018) claimed that constructive feedback focuses on improving a task's performance. Thurlings *et al.* (2013) argued that feedback should provide neither positive nor negative statement, personalized, goal and/or task oriented.

Preservice teachers learn from not only their personal experiences but also the feedbacks that they took from their peers and instructor (Williams, 1992). Therefore, feedback given after each teaching practice is an important aspect in improving teaching approach. Therefore, in their teaching methods courses, preservice teachers have the opportunity to do microteaching which they pretend being a teacher, in reality they implement their lesson plans in front of their peers and instructors. Preservice teachers receive feedback from their peers and instructors after microteaching (Mesci *et al.*, 2020; Namdar and Kucuk, 2018). In the literature, there are studies who emphasized on how to give feedback (Carless and Bound, 2018; Gibbss and Simpson, 2005) and perceptions

of feedback (Ferguson, 2011) in preservice teacher education.

Preservice science teachers receive feedback both from their instructors and peers in general (Lynch *et al.*, 2012). However, feedback is not solely enough for improving teaching practice. Since teaching beliefs shape teaching practices, how preservice science teachers reflect through feedback is important. For this reason, instructors might want preservice science teachers' opinions, taught, or answers to feedbacks through reflection (Ferguson, 2011). Sargeant and colleagues (2009) defined reflection as "*a link between receiving and using assessment feedback*". In the following subsections how, preservice teachers experience about feedbacks from their instructor and peer are discussed. Then preservice science teachers' reflections about teaching through both instructor and peer feedbacks are reported.

2.4.1. Instructor Feedback in Preservice Teacher Education

Preservice teachers receive feedback from their instructor for their lesson plan, microteaching, or teaching practice during their internships. There is no doubt on the literature that feedbacks should be personalized, in-detailed, and task-oriented. However, there is several ways to giving feedback to preservice teachers. For example, instructor feedback can be oral or written, long passages or ticks and cross, immediate or later the teaching practice, one by one or in front of the classroom. A few instructors supported giving feedback out of class time so that individually meet with preservice teachers via office hours or e-mail (Ferguson, 2011), some other instructors supported giving feedback during class time in front of classroom in case of some students might have same concerns or problems (Mesci *et al.*, 2020). Ferguson (2011) claimed that both of them are required and helpful to preservice teachers.

From preservice teachers' view, they claimed that they would prefer personalized feedbacks including concrete examples about their task rather than taking tick or cross. In addition, preservice teachers also said that these feedbacks should be include both positive and negative aspects of their lesson plan, microteaching and teaching practice (Ferguson, 2011).

Luft (2001) stated that feedback should include both strengths and weaknesses about specific teaching approach. For example, if a preservice teacher prepares a lesson for inquiry-based science education, feedbacks should include specific aspects of inquiry including researchable scientific questions and collecting or analyzing data. By this way preservice teachers have a chance to think and reflect on their teaching practice in terms of inquiry-based science education (Luft, 2001). Providing feedback to preservice teachers has significant effect on their instruction. After feedback on their teaching practice, they have a chance to alter their science teaching and learning approach (Clara' *et al.*, 2019).

In Rodriguez and colleagues' (2018) study preservice teachers' experiences about giving and receiving feedback during internship course was examined. It was revealed that preservice teachers prefer written feedbacks from the instructor rather than immediate face-to-face feedback after the teaching practice during their internship. It was claimed that when verbal feedbacks were giving immediately after the teaching practice, they were not ready to critique and reflect on their own teaching experience (Rodriguez *et al.*, 2018). Besides, Ellis and Loughland (2017) discussed that immediate feedback is monologue where an instructor told his/her thoughts and a preservice teacher listened. However, when feedback is given later than the teaching experience an instructor and a preservice teacher have discussed about teaching experience. From both studies it can be claimed that preservice teachers prefer feedback after their teaching experience (Ellis and Loughland, 2017; Rodriguez *et al.*, 2018).

2.4.2. Peer Feedback in Preservice Teacher Education

It is important to include modern teaching and learning strategies both theoretically and practically in preservice teacher education programs. By 21st century a significant change has occurred in the assessment and evaluation practice, from teacher-centered to learner-centered. By this shift, learners become actively participants of the assessment process (Topping, 1998). Peer assessment is a kind of modern assessment technique where a student judges his/her peer's performance. This assessment technique provides students to raise responsibly criticize, discuss, and evaluate peers' work

(Strijbos and Sluijmans, 2010). Furthermore, Wen and Tsai (2008) argued that peer assessment enhances preservice teachers' respect and responses to their peers' opinions about their task.

Giving feedback is an integral responsibility of teachers' routine, preservice teachers need to learn how to give feedback during their preservice teacher education years (Lynch *et al.*, 2012). By peer assessment, preservice teachers both learn how to assess and improve their work (Anker-Hansen and Andree, 2019). Similarly, in the literature there is suggestion on peer feedback in preservice teacher education programs (Strijbos and Sluijmans, 2010; Wen and Tsai, 2008). This is suggested because giving feedback to peers prepare preservice teachers to evaluate their future assessments. In other words, it is necessary to embed peer assessment through feedbacks into preservice teachers' undergraduate courses.

However, peer feedback seems less accurate and reliable compared to the instructor feedback (Topping, 1998). Therefore, it is important to teach how to give impartial, reliable, and accurate feedback to peers. This will also provide impartial, reliable and accurate feedback to future students. For this situation Topping (1998) suggested to compare peer and instructor feedback. On the one hand, Gielen *et al.*, (2010) suggested justification through feedback to preservice teachers. With justification, preservice teachers should justify their claims while giving feedback to their peers. On the other hand, Strijbos, *et al.* (2010) claimed that giving comments on peer's concrete example provides accuracy to peer feedback process. In this method preservice teachers comment on their peers' specific example or approach.

Despite the importance of peer feedback in the last decade in the preservice teacher education programs, there is much less emphasize on peer feedbacks compared to instructor feedback (Haughney *et al.*, 2020). In the following paragraphs empirical research on peer feedback during preservice teacher education programs is explained.

Lynch *et al.* (2012) compared preservice teachers' perceptions about receiving feedback from their peers. First round of feedback's indicated that only a few feedbacks

focused on synthesis or evaluation phases. At the end of the course feedback's quality was increased. However, preservice teachers indicated that they still would prefer instructor feedback because it is more personalized and accurate.

Levin and Flaivan (2020) observed preservice teachers' peer assessment behavior during simulation-based methods course. Results showed that giving feedback to a peer and receiving feedback from a peer enhances reflective thinking about experience by seeing one's view of the situation. Similarly, in d'Alessio's (2018) study, future science teachers gave and receive feedbacks from their peers about microteaching. These feedbacks included scoring rubric and written passages. Most of the preservice teachers claimed that peer feedback was a helpful for learning from each other's' task. It is deduced from Levin and Flaivan's (2020) and d'Alesio's (2018) study that that receiving feedback from peer enabled reflective look for the microteaching.

Furthermore, Wanner and Palmer (2018) added peer-assessment through feedback into one of the preservice teachers' course. In this course, preservice teachers send their assignment to their peers before sending it to the instructor of the course. Peers did not grade the assignment but gave suggestion to improve it. Preservice teachers stated difficulty in giving feedback to their peers at first. However, they also claimed that receiving feedback from their peers was helpful to improve their assignment before the instructor evaluated it. Wanner and Palmer (2008) suggested peer assessment when learners criticize their peer and then learn from each other's experience. Moreover, Pekbay and Koray (2020) embedded peer assessment into undergraduate material design course of third year of preservice teachers. In this course, preservice teachers prepared alternative assessment tools such as concept map, mind map or diagnostic tree. Peers evaluate effectiveness of these assessment tools in terms of suitability with objectives and students' cognitive level. Results showed that majority of students revised their assessment tools by considering feedback of their peers.

Previous studies have shown that teacher candidates who take negative feedback from their peer about their task are less likely to change their assessment task to improve it (Evans, 2013). Similarly, Alqassab *et al.*, (2019) examined the preservice

teachers' opinions related to peer feedback during undergraduate course. Preservice teachers stated that they did not want to change their task when there is negative feedback without an explanation. However, when an explanation is given to feedback or suggestion to improve a task, it helped students improve the task. For this reason, while giving negative feedback to a peer, Alqassab *et al.* (2019) offered that providing comments to specific task is necessary in order to increase accuracy of the feedback.

Even though there is focus on peer feedback in teacher education programs, peer feedback still seems less accurate and beneficial. However, giving feedback is an important part of the teacher. For this reason, preservice teachers need to learn how to give constructive feedback to their peers. Therefore, preservice teacher education programs should more focus on peer feedback.

Receiving feedback from the instructor or a peer do not mean that preservice science teachers change their behavior, or work. They can either accept the feedback and change their work, or they reject the feedback and hold their previous work. Both accepting or rejecting feedbacks are important for improving. For this reason, giving reflection to feedback is essential. In the following part, preservice science teachers' reflection on feedback is discussed.

2.4.3. Reflections

Receiving and giving feedback facilitate looking own or someone's work from different perspective. At the same time, reflection makes possible to think deeply about one's own work. Just like feedback, reflection is an important part for teaching and learning. Therefore, there is great emphasis on the importance of reflection in teacher education (Loughran, 2002). It is argued that reflection is an essential skill for teachers' professional development. Through reflective practices preservice teachers have a chance to investigate their own experience, belief, and practice with an analytic perspective (Kolb, 1996). Similarly, empirical research (Korkko, *et al.*, 2016; Oner and Adadan, 2011; Oner and Adadan, 2016) demonstrated that feedback and reflection are two important things for improving teaching practices.

Sargeant *et al.* (2009) explored physicians' reflection after assessment feedback. Physicians who receive inconsistent feedback from their peer, started to think about their work. Therefore, it can be deduced that reflection make deeper thinking possible. It is suggested that there is need for more reflection practices for improving one's own work to promote learning through reflection (Sargeant *et al.*, 2009). Similarly, Mortari (2012) studied with preservice teachers to explore relation between reflection and learning. Mortari (2012) designed reflection practice class for voluntary preservice teachers. In this class, preservice teachers wrote a reflective journal about their learning context then meet the researcher for discussing about learning and reflection. It is reported that thinking about reflection promotes reflective thinking.

Oner and Adadan (2011) analysed preservice chemistry teachers' reflective skills through their internship experiences. In this study preservice chemistry teachers first prepared a lesson plan and took feedback from their peers and the instructor. Then they applied and videotaped the lesson plan. They also took feedback about videotaped lesson plan and at the end wrote a reflection paper. In reflection paper, preservice chemistry teachers reflect their own videotaped lesson in relation to their plan and videotaped lesson. They wrote reflection by considering feedbacks about their own work. At the end, preservice chemistry teachers reflective thinking skills in the second reflection paper was statistically significantly higher compared to their first reflection (Oner and Adadan, 2011). Then, Oner and Adadan (2016) conducted another study to explore preservice chemistry teachers' progression on reflective thinking skills through teaching experience by using e-portfolios by using reflective cycle. Similar to Oner and Adadan's (2011) findings, again, participating preservice teachers' reflective thinking skills increased (Oner and Adadan, 2016).

In Korkko *et al.*'s (2016) research context, preservice teachers first took a theoretical part of the teaching methods. Then they apply the teaching methods as either microteaching or internship. At last, they wrote a portfolio about their practical experiences and how these experiences related to theoretical framework. Results indicated that preservice teachers' teaching practices reflect their teaching beliefs, and it proceeds over time. While preservice teachers first reflections concentrated on their own

teaching practices, later reflections focused on how theoretical framework relates to their teaching practice and how students reacted their teaching practices (Korkko *et al.*, 2016). All studies above for this section, demonstrated importance of reflection in preservice teacher education.

In the following section online learning environments will be introduced and an example empirical studies on asynchronous learning environments in preservice teacher education will discussed.

3. SIGNIFICANCE OF THE STUDY

There has been a significant shift in expectations of science education over the past decades. Inquiry-based science education is an approach where students act like a scientist by raising research question and collecting data for that question in science classrooms. It is expected from preservice and in-service teachers to teach science as inquiry (Bell *et al.*, 2005; Bybee, 2006). Preservice science teachers' experiences on inquiry-based science education is generally limited to science teaching methods courses. For this reason, implementation of inquiry is challenging for preservice science teachers. It is strongly suggested in the literature that preservice science teacher education programs emphasize more on inquiry-based science teaching to encourage future science teachers have ability to implement science as inquiry (NRC, 2000).

In addition, simulations allow students to test their research question by quickly collecting and analyzing data. This feature of simulations might facilitate adaptation of inquiry-based education strategies into science lessons. It is suggested to teach inquiry-based science education by simulations (Chang and Linn, 2013; NRC, 2000). However, simulation integration into science lesson is challenging for preservice science teachers just as teaching inquiry-based science education. Therefore, it is valuable to train preservice science teachers for designing simulation-enhanced inquiry-based lesson.

With the development of technology in today's world and with the demanding need to engage students in inquiry, simulation-enhanced inquiry-based education has been used to integrate science education. Thus, this study was intentionally situated in the inquiry-based science education approach which enhanced by simulations for the purpose of progressing preservice science teachers' lesson plans and microteachings. Neither inquiry nor simulations are relatively new in science education, but these approaches are still challenging for both students and teachers (Lehtinen *et al.*, 2016; McBride *et al.*, 2004). This study has a potential to provide guidance on how to design simulations-enhanced inquiry-based science education.

Further, both feedbacks and reflections are used in this study to explore how preservice science teachers reflect on the feedback and whether or not change their lesson plans. Each of these aims improving teaching practice of preservice science teachers. While giving and receiving feedback targets analyzing and criticizing one's own and peers' work, writing reflection on feedback targets deeply thinking about one's own work and peers' feedback. Therefore, for this study, giving and receiving feedback and writing reflections through these feedbacks enhances progression on lesson.

Besides, by 21^{st} century teaching and learning environments have gone beyond school classrooms. Online learning environments was an opportunity up to COVID-19pandemic. Due to the rapid spread of the pandemic, all K-12 and higher education has transitioned to online. Computers and web tools became new learning environments for students and teachers. However, design of the courses was prepared face-to-face teaching (Moorhouse, 2020). It is taught that online learning opportunities is going to continue after COVID-19. For online learning, asynchronous learning environments is suggested because of lack of internet or computer access. Therefore, it is believed that preservice teachers need to learn how to design a lesson for asynchronous learning environments.

As stated, the literature suggested to use simulations at the inquiry-based science education. Yet, it is unknown if simulation-enhanced inquiry-based science education lesson can be designed for asynchronous learning environments. This present study has a potential to contributes literature through inclusion of asynchronous learning environments in simulation-enhanced inquiry-based lesson design. The findings of this study might give information preservice science teachers, in-service science teachers, science teacher educators, and instructional designers to prepare not only simulation-enhanced inquiry-based science education but also how these approaches can be implemented at asynchronous learning environments.

3.1. Purpose of the Study

The purpose of this present study is to explore the progression of preservice science teachers on designing a simulation-enhanced inquiry-based lesson for asynchronous learning environments. Thus, this study emphasizes on three criteria: (i) inquiry-based science education, (ii) inclusion of simulations for inquiry-based science education, (iii) inclusion of simulations for inquiry-based science education is suitable with asynchronous learning environment. In other words, the focus of this study has three dimension which are inquiry-based science education, simulations, and asynchronous learning environments. The progression in these three dimensions' were explored through the study. The progression explored through different ways including preparing lesson plans, teaching video recordings, giving and receiving feedback and how a preservice science teacher reflects on these feedbacks.

In the first stage, inquiry-based science education, simulation, and asynchronous learning environments need to be operationally defined. In this study inquiry-based science education defined as "*doing science in order to understand nature of science*" (NRC, 2000). Then, simulation is defined by de Jong and Jong van Joolingen (1998) as "*a computer program which explains a process or system artificially by representing an operation over time*". Lastly, asynchronous learning environment refers to "*Forms of education, instruction, and learning that do not occur in the same place or at the same time*" (Mayadas, 1997). In the second stage, feedback and reflection on feedback also need operational definitions. Feedback defined by Boud and Molloy (2013) as information provided by teachers to students about their work. (p.700). Reflection, for the context of teaching and learning defined by Sargeant *et al.* (2009) as ''*a link between receiving and using assessment feedback*".

3.2. Research Questions

By considering purpose of this study following research questions guided:

(i) How do preservice science teachers describe simulation-enhanced inquiry-based

5E lesson plan for asynchronous learning environments before and after the intervention on professional development module?

- How do preservice science teachers describe lesson plan before and after the intervention on professional development module?
- How do preservice science teachers describe 5E instructional model before and after the intervention on professional development module?
- How do preservice science teachers describe inquiry-based science education before and after the intervention on professional development module?
- How do preservice science teachers describe simulations before and after the intervention on professional development module?
- How do preservice science teachers describe asynchronous learning environments before and after the intervention on professional development module?

(ii) How do preservice science teachers describe purpose of inclusion of a simulation-enhanced inquiry-based science education for asynchronous learning environments before and after the intervention on professional development module?

- How do preservice science teachers describe inclusion of a simulations in asynchronous learning environments before and after the intervention on professional development module?
- How do preservice science teachers describe inclusion of an inquiry-based science education in asynchronous learning environments before and after the intervention on professional development module?

(iii) How are preservice science teachers' progression on designing a simulation-enhanced inquiry-based lesson for asynchronous learning environments?

- What are preservice science teachers' progression on designing inquiry-based science lesson?
- What are preservice science teachers' progression on designing simulation-enhanced science lesson?
- What are preservice science teachers' progression on designing science lesson for asynchronous learning environments?

(iv) What are the strengthens and limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments?

- What are the possible strengthens of designing simulation-enhanced inquiry-

based lesson for asynchronous learning environments?

- What are the possible limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments?

(v) How do preservice science teachers reflect on feedback while they are progress their lesson?

- How do preservice science teachers reflect on feedback from the instructor while they are progress and record their lesson?
- How do preservice science teachers reflect on feedback from a peer while they are progress and record their lesson?
- How do preservice science teachers' nature and frequency of reflective thinking indicators on their reflections?

4. METHODOLOGY

This chapter presents the salient features of the methodology used to conduct this study: the design of the study, information about the sample, procedure, data collection, data analysis techniques and ethical considerations were explained respectively in detail at the following sub-sections.

4.1. Design of the Study

This study had both *exploratory and descriptive* purposes by considering the aim of the study and research questions. An exploratory study aims to explore and discover features through observation of a specific social phenomenon in detail (Swanson and Holton, 2005). Therefore, this study aimed to explore preservice science teachers' progression on designing simulation-enhanced inquiry-based lesson for asynchronous learning environments. This progression is related with effective use of simulation, high level of inquiry-orientation, appropriate for asynchronous learning environments. Accordingly, a descriptive study aims to describe the framework for researcher in order to follow during the study (Berg and Lune, 2017). Therefore, from a descriptive perspective this study aims to describe features of inquiry-based instruction through simulations designed for asynchronous learning environments. For this reason, this study adopted qualitative research design methods by considering both descriptive and exploratory purposes while conducting the study.

Qualitative design provides researcher to inquire in-depth analysis of participants' understandings, feelings, experiences and meanings about real-life (Creswell, 2014; Gay, *et al.*, 2009). This qualitative study adopted phenomenography as the research methodology. Phenomenography is a kind of qualitative research methodology which was developed by Swiss educational researcher called Ference Marton for educational research framework by 1981. According to Marton (1981) phenomenography is a qualitative research method which investigates descriptions of different understandings of a phenomenon or a concept at the world around us. Accordingly, phenomenography

interested in people's various perceptions about concepts and the meanings of these concepts for them in the world. Then different aspects for the perceived reality were created (Marton, 1981). According to phenomenography different aspects of reality comes from different experiences, understandings, and interpretations of the World.

Phenomenography is a research methodology which explores the qualitatively different ways of people's experiences or conceptualizations in the world around them. The focus of a phenomenographic study is to investigate various individual understandings about the same concept (Marton, 1986). Description of a phenomenon might differ between people since they have experience and conceptualize different aspect of the reality. In other words, there is a relation between understanding of concept and the experiences of each individual. A phenomenography researcher tries to understand people's understandings of phenomenon by considering their experiences and investigate these understandings (Hasselgren and Beach, 1997). In short, phenomenography aims to investigate collective analysis of people's different experiences on a specific phenomenon through an innovative educational research design (Akerlind, 2005; Marton, 1986).

In this study, the essence of phenomenon is a module that participating preservice science teachers attend, and an issue is their lesson plans and video recordings of this lesson plans revised and progressed via peer and instructor feedbacks during the module. This study aims to explore preservice science teacher's understandings of and about simulation-enhanced inquiry-based science education for asynchronous learning environments. In order to explore this, preservice science teachers' understandings of and about inquiry-based science education is important and these understandings might be different. Preservice science teachers have preconceived conceptions about inquiry-based science education. These conceptions come from their experiences about it. Up to the study, each participant might have different experiences about the same concept. Conceptions about inquiry (the phenomenon for this study) is described and changed by people's various experiences about the concept. While the comprehensiveness of understandings of and about phenomenon is increased, an individual can be aware of higher aspects of the phenomenon being experienced. Besides, low level of

awareness restricts the aspects of the phenomenon to be deeply experienced (Hasselgren and Beach, 1997). This research's aim was the same as aim of phenomenography, in this study each participating preservice teachers' interviews, lesson plans, and video recordings of their lesson plans were analyzed so that discovering their understandings about inquiry-based science education, simulations, and asynchronous learning environments.

The qualitative study cannot be thought being separate from its researcher. The researcher brings his/her background, perspectives of self and other, and ethical views. Whether a researcher follows quantitative or qualitative design, the researcher's beliefs about reality affect the research from beginning to end (Lin, 1976). In this study, the researcher was also the instructor of the module. Therefore, her role is both researcher and instructor. The researcher focused on preservice science teacher's understanding of and about inquiry-based science education, simulations and asynchronous learning environments. Considering the nature of phenomenography, the researcher's background, her experiences, her values, and what she wants to study in this research might shape findings of this study. The researcher and participants might have different understandings about inquiry, simulations, and asynchronous learning environments. Since understandings of and about different phenomenon are important in this research phenomenography is selected.

4.2. Sample and Context

By considering the nature of qualitative research, purposeful sampling method is recommended for the selection of the participants (Creswell, 2014; Gay *et al.*, 2009). Purposeful sampling is a kind of sampling method which provides detailed and in-depth information to the researcher for the research. Even though there are limitations in generalizability at purposive sampling it is highly used in qualitative studies (Berg and Lune, 2017). Therefore, in this study purposive sampling technique is used where the researcher easily accesses participants and collect data from them.

This study took place during 2020-2021 spring term at a mid-size university located in northwest Turkey. This semester was the last semester for all participant preservice teachers. In other words, after the data collection term they graduated as science teachers. During the data collection term, all participants registered to "Practice Teaching in Science" course. From total fifty-four preservice science teachers who registered to the course ten preservice science teachers voluntarily participated to this study.

4.3. Data Collection

According to Creswell and Poth (2016) extensive data collection is needed in qualitative studies. For this reason, data sources of this study were; pre- and post-interviews with all participants, lesson plans prepared by the participants, instructor's and peers' feedbacks provided with the lesson plans, video recordings of the final version of lesson plan, reflections on feedbacks to lesson plans and video recordings, and field notes taken during the implementation of the module. Many sources of data are needed in qualitative studies in order to increase reliability of data and in-depth analysis of the data. In other words, multiple sources of data provided triangulation and then in-depth analysis of the phenomena under investigation (Creswell, 2014).

4.3.1. Pre- and Post-Interviews

The first data sources of this study are pre- and post- semi-structured interviews. The main aim of pre-interview was to familiarize participants to research setting. Then the researcher aimed to explore preservice science teachers' conceptualizations about inquiry, simulations, and asynchronous learning environments. In other words, during pre-interviews the researcher got familiar with the participants' thoughts and understandings about the three dimensions. Accordingly, the aim of post-interviews was to understand participants' progression on thoughts and understandings about the research phenomenon. The researcher was audio of record both pre- and post-interviews with the permission of the participants.

During the interviews, the researcher was trying to understand participants' understanding about lesson plan, 5E instructional model, inquiry-based science education, simulations, asynchronous learning environments, and how they are integrated. For this reason, semi-structured interview protocol is prepared for pre- and post-interviews. Interview protocol is a kind of inquiry instrument as a procedural guide for qualitative researcher. An interview protocol includes a script of what a researcher said before and after the interview, how to collect an informed consent from participants, why the interviewer interested information, and set of questions. The researcher was sent the developed interview protocol to the science education expert who is also advisor for this study to get feedback. Then, required revisions and modifications were applied to improve the interviews. Interview protocol and interview questions for before and after module can be found in Appendix A and Appendix D, respectively.

4.3.2. Lesson Plans

Second data source was lesson plans prepared individually by each participant. These lesson plans were prepared by considering 5E instructional model stages which are engage, explore, explain, elaborate, and evaluate. It is asked preservice science teachers to prepare a lesson plan which include inquiry-based science education, simulations and should be suitable with asynchronous learning environment. Participant teachers were free to select specific objective(s) from middle school science curriculum of MoNe (2018).

While evaluating inquiry-based science education criteria for lesson plans, the researcher was used *Inquiry Scoring Rubric for Lesson Plans* developed by Forbes and Davis (2010). This rubric meets the criteria of NRC (2000) inquiry-based science education therefore it seemed to be useful for this research. Only first and second drafts of the lesson plans was used to explore whether there is change in inquiry orientation or not. Scoring rubric has shown at Table 4.3.3.

4.3.3. Instructor and Peer Feedbacks

Third data source was feedbacks given by the instructor and the peers. Both the instructor and a peer were giving feedback to preservice science teachers' lesson plan and teaching video of lesson plan. For lesson plans, feedbacks were given for three dimensions (inquiry-based science education, simulations, and asynchronous learning environments) of the lesson plan. Preservice science teachers prepared one lesson plan and revise this lesson plan according to three dimensions at the end of the module. At first, they revised their lesson plans according to asynchronous learning environments, then according to inquiry-based science education criteria, at last according to simulation usage. By considering the three feedbacks received it was expected to increase the quality of lesson plans according to all three criteria. In addition, after three feedbacks lesson plan reached final version. Then the preservice science teachers recorded the lesson plan as a teaching video. Preservice science teachers took feedback to this teaching video. An example feedback sheet can be found in Appendix E.

Table 4.1. Inquiry scoring rubric for lesson plans. (Forbes and Davis, 2010).

Criteria	3	2	1	0
Lesson engages students in scientifically oriented questions	Lesson uses investigation question that is feasible, worthwhile, contextualized, meaningful, ethical, and sustainable. Inv. questions and other questions are in "how" rather than "why" form. Inv. question is answerable in light of the lesson activities and other questions explicitly scaffold students' investigation and sense-making	Lesson uses investigation question that meets at least some of the criteria for effective inv. questions. Inv. question may be in "why" or "how" form. Question is at least to some extent answerable in light of the lesson activities. Lesson provides at least some additional questions teachers may use to reasonably support students? investigation and sense-making	Minimal evidence of use of scientific question and questioning. Investigation question may be present but meet few to no criteria for effective investigation questions. Questions may be in "why" rather than "how" form. Lesson makes unproductive suggestions for additional questions teachers can use to support students. Questions are likely not answerable in the classroom contexts	No evidence
Lesson engages students in gathering, organizing, and analyzing data	Students collect, organize, and analyze data / evidence. Opportunities to gather, organize, and analyze evidence are linked to the investigation question and/or phenomenon under investigation	Students do 2 out of 3 of the following: collect, organize, and analyze data / evidence. Opportunities to gather, organize, and analyze evidence are at least somewhat linked to the investigation question and / or phenomenon under investigation	Students do 1 out of 3 of the following: collect, organize, and analyze data/ evidence. Opportunities to gather, organize, and analyze evidence are marginally linked to the investigation question and/or phenomenon under investigation	No evidence
Lesson engages students in formulating explanations from evidence to address scientifically oriented questions	Opportunities to construct explanations are connected to the evidence and data collected. Claims can be supported by evidence collected. Opportunities to construct Explanations are connected to the investigation question and / or phenomenon under investigation	Opportunities to construct explanations are less explicitly connected to the evidence and data collected and the investigation question and/or phenomenon under investigation or lesser degrees of both. Claims may be supported by evidence collected	Opportunities to construct explanations are either marginally connected to the evidence and data collected and the investigation question and/or phenomenon under investigation or, in one case or the other, not at all linked. Claims are likely not to be able to be supported with evidence collected	No evidence

Table 4.1. Inquiry scoring rubric for lesson plans. (Forbes and Davis, 2010) Table (cont.).

Criteria	3	2	1	0
Lesson engages students in evaluating their explanations in light of alternative explanations	Lesson supports students to engage in dialogs, compare results, or check their results with those proposed by the teacher or instructional materials Lesson supports students to do so in ways that are highly likely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standard-based learning goals	Lesson supports students to evaluate their explanations by comparing to at least one alternative explanation Lesson supports students to do so in ways that are reasonably likely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standard-based learning goals	Lesson supports students to evaluate explanations without taking alternative explanations into account Lesson is unlikely to lead students to explanations that are consistent with currently accepted scientific knowledge and the lesson's standard-based learning goals	No evidence
Lesson engages students in communicating and justifying their explanations	Lesson provides students with opportunities to share and justify their question, procedures, evidence, proposed explanation, and review of alternative explanations	Lesson provides students with opportunities to share AND justify some aspects of their question, procedures, evidence, proposed explanation, and review of alternative explanations	Lesson provides students with opportunities to share OR justify some aspects of their question, procedures, evidence, proposed explanation, and review of alternative explanations	No evidence

4.3.4. Teaching Video Recordings

The fifth source of data came from participants' video themselves in front of the camera for using second version of the lesson plan for asynchronous learning environments. This video was called teaching video. Each recording took 15-25 minutes which is shorter than normal lesson time but suitable for online lessons. In the video recording participants' record all parts of 5E instructional model.

In order to analyse video recording. Miles *et al.*, (2014) suggested to transcript them in textual format. Therefore, the researcher transferred and transcript them so that analyzing codes and themes if fit criteria of simulation-enhanced inquiry-based science education asynchronous learning environments. The video recordings of lesson plans lasted approximately 15-25 minutes. Analysis of the video recordings of lesson plans was analysed according to research questions, codes and themes arise at lesson plans. Both codes and themes came from video recordings of lesson plan explained in tables.

4.3.5. Reflection on Lesson Plan and Video Recordings

Fifth data source was reflections on feedbacks. After taking feedback from both the instructor and a peer for lesson plans' three dimensions (inquiry, simulation, asynchronous) and teaching video the preservice science teachers write a reflection about feedbacks. Teachers were free to agree or disagree the instructor's or a peer's feedback. These reflections demonstrate preservice science teacher's opinions, thoughts, and answers to the feedbacks. These feedbacks also demonstrated their views about their lesson plan and video recording experiences. There were a total four reflections (inquiry, simulation, asynchronous, teaching video) from each preservice science teachers. Preservice science teachers' reflections analyzed according to Oner and Adadan's (2011) reflective thinking indicators which demonstrated at Table 4.2. An example reflection sheet can be found in Appendix F.

Table 4.2. High- and low-level reflective thinking indicators (Oner and Adadan 2011).

High-level reflective thinking indicators	Low-level reflective thinking indicators
Claim-Evidence (C-E): Making claims about whether certain goals are met during teaching and providing acceptable experience-based evidence to support the claims to associate goals and experiences.	Goal-experience discrepancy (GED): Simply realizing and stating that some goals are not met during teaching.
Reflection-in-action (RNA): Evaluating experience and describing the emergent action taken (not always planned beforehand) during the experience to deal with the situation.	Describing experience (DE): Describing experience from the point of view of the participants that does not qualify as C-E.
Recognizing and stating discrepancies between goals and experience by referring to observations and suggestions from others (RECD): Reflecting back on the peer and instructor feedback and recognizing discrepancies after they are pointed out by peers or the course instructor.	
Reflection-on-action (ROA): Reflecting on self-experience regarding goals and experience and elaborating on possible changes as a result of observing oneself from outside. In addition, expressing a form of higher level awareness regarding one's teaching, students' characteristics, or student learning that goes beyond survival concerns.	

4.3.6. Field Notes

Field notes were the last source of data for this study. According to Creswell (2014) field notes come from observations. During the study, the researcher took field notes throughout the study module in order to guide research purpose and questions. Researcher's field notes were coming from observations so that understanding what was going on during module implementation to collect specific facts or situations during module. These notes also reflected researcher's observations and thoughts during study.

4.4. Procedure

First, semi-structured interviews conducted with all participants to collect their pre-descriptions. After interviews, participants individually prepared lesson plans according to Ministry of National Education middle school (from 5^{th} to 8^{th} grade) science curriculum. Hence middle school curriculum is spiral (Ornstein and Hunkins, 1988), students learn the same topic but more deeply across the years. In total there are seven units in middle school science curriculum. While there is one unit in astronomy, there are two units in physics, chemistry, and biology. Preservice science teachers were free to select grade, discipline, topic, and objective while preparing their lesson plans. This is because students need to feel free to select the most suitable topic for inquiry and simulation. Then preservice science teachers prepared their first plans.

Preservice science teachers had one week to prepare their first version lesson plans. They prepared first lesson plans according to their pre-knowledge and experience about the inquiry, simulation, and asynchronous learning environments. Then preservice science teachers participated the simulation-enhanced inquiry-based science education (SIMINA) module for 5 weeks. During SIMINA preservice science teacher experienced how to design simulation-enhanced inquiry-based lesson plan for asynchronous learning environments.

The first theme of the SIMINA was asynchronous learning environments. In this theme, preservice science teachers' recognized concepts related to the online and asynchronous learning environments. Then features of asynchronous learning environments discussed with advantages and disadvantages. Lastly, preservice science teachers discussed about how to prepare a lesson plan and record a video for asynchronous learning environments. The second theme of the SIMINA was inquiry-based science education. In this theme, firstly preservice science teachers remembered 5E instructional model and inquiry-based science education framework. Then they developed research questions and data collection/analysis strategies for selected example objective's from MEB (2018). Then preservice science teachers discussed about how to conduct an inquiry-based science education in asynchronous learning environments.

The third and the last theme of SIMINA was simulations. In this theme, pre-service science teachers experienced four simulation resources (PhET, Algodoo, WISE, and Concord Consortium) by considering advantages and disadvantages. While expe-riencing these simulation resources, they filled a worksheet in order to integrate simu-lations into inquiry-based science education and asynchronous learning environments. An example slides and worksheets that used in SIMINA can be found in Appendix B and C, respectively. Brief information about the module is given at Table 4.3.

Table 4.3. Module content, time, and objectives about each module.

Content	Time	Short Description & Objectives
Asynchronous Learning Environments	40 mins x 2	-recognize asynchronous learning environments (Hrantinski, 2008) -discuss how to develop lesson plans suitable with asynchronous learning environments
Inquiry-based Science Education	40 mins x 3	-remember inquiry-based science education framework (NRC, 2000; Bell et al., 2005) -remember 5E instructional model (Bybee et al., 2006) -remember and discuss inquiry-based 5E instructional lesson plan -associate inquiry-based 5E instructional lesson for some specific topics with examples -discuss how to design inquiry-based 5E instructional lesson suitable with asynchronous learning environments
Simulations	40 mins x 4	-identify importance of simulations science education (Acar-Sesen & Mutlu, 2020; Rutten et al., 2012) -recognize simulation software and websites that use in in science education (PhET, Algodoo, WISE, Condord Consortium) -integrate simulations into inquiry-based 5E instructional lesson -integrate simulations into inquiry-based 5E instructional lesson suitable with asynchronous learning environments

During the implementation of the module participants were free to revise their lesson plans by considering what they learned during the module. The researcher and

a peer also gave feedback for each specific topic. For peer feedback, the researcher determined feedback pair for each preservice science teacher. Then the researcher gave the instructions about how to give constructive feedback to a peer.

After taking feedback from both the instructor and a feedback peer for lesson plans' three dimensions (inquiry-based science education, simulation, asynchronous) and teaching video the preservice science teachers wrote a reflection on feedbacks. Preservice science teachers were free to agree or disagree the instructor's or a peer's feedback. These reflections demonstrate preservice science teacher's opinions, thoughts, and answers on the feedbacks. These feedbacks also demonstrate their experiences while preparing and progressing their lesson plan and teaching video recordings.

Next, the participants shouted a video of the lesson. In the video, participants taught their lessons in front of the camera. This video is to be used for asynchronous learning environments and took 15-25 minutes. Participants sent videos to the researcher. Researcher analyzed both first and second lesson plans and teaching video according to simulation-enhanced inquiry-based science education and asynchronous learning environments criteria.

At last, the researcher conducted semi-structured interviews as post-interviews. Post- interviews took at least 25 minutes with each participant. During the interviews, the researcher tried to understand how their thoughts change about inquiry-based science education, simulations, and asynchronous learning environments. In the post-interviews, the researcher focused on participants' experiences, thoughts and conceptualizations after the SIMINA Module. Similarly, the researcher asked the strengths and weaknesses of designing instruction for asynchronous learning environments, challenges that they meet, impact of peer feedback, and professional development module.

4.5. Data Analysis

In this study triangulation of data provided with an in-detailed analysis for the phenomenon from various data sources including pre- and post-interviews, first and

second lesson plans, instructor and peer feedbacks, and teaching video recordings. Systematical and in-depth focus were required for data analysis in qualitative studies. A qualitative researcher accumulates as much as possible data from different sources such as interviews, transcripts, field notes, video, or non-textual materials so that understanding the case deeply (Yin, 2011). In order to analyze the data, constant comparison method developed by Glaser and Strauss (1967) for grounded theory, but also commonly used in other qualitative studies, was used. In this method, first, the researcher transcribed pre-interviews to reveal variables, codes, or themes that directly related with conceptualizations about inquiry, simulation and asynchronous learning environments.

From all data sources content came with "words" as a nature of data sources which were interviews, lesson plans, and video recordings of that lesson plans. In order to deeply examine and categorize data themes were determined with help of codes emerged from data sources. It was expected to identify emerged codes and relationship with these codes and categories. Then it was expected to observe these codes and themes further findings came from the lesson plans, video recordings of the lesson plans, and post-interview (Creswell, 2014; Lewis-Beck *et al.*, 2003). However, it was also expected that some new codes or themes may reveal at the post-interview due to the treatment. To clearly determine and analyze codes and themes specific quotations which demonstrate themes were written and explained at results section. During study, each participant considered as an individual. In other worlds, the researcher evaluated progression separately. In addition, by comparing pre- and post-interviews the researcher also looked overall progression in designing simulation-enhanced inquiry-based lesson for asynchronous learning environments by considering research questions' of the study. In short, Table 4.4. summarizes each research question, and how data were collected and analyzed according to the research questions.

Table 4.4. Summary Table for Research Questions, Data Collection and Data Analysis.

Research Questions	Data Collection	Data Analysis
1) How do preservice science teachers describe simulation-enhanced inquiry-based 5E lesson plan for asynchronous learning environments before and after attending SIMINA Module?	-Pre-interview -Post-interview -field notes	-Open coding -Constant comparison method
2)How do preservice science teachers describe purpose of inclusion of a simulation in inquiry-based science education before and after attending SIMINA Module?	-Pre-interview -Post-interview -field notes	-Open coding -Constant comparison method
3)How do preservice science teachers' progression on designing a simulation-enhanced inquiry-based instruction design for asynchronous learning environments?	-Lesson plans -Teaching video -Instructor and feedbacks -Lesson plan	-Inquiry Scoring Rubric (Forbes & Davis, 2010) -Open coding -Constant comparison method
4)What are the possible strengthens and limitations of designing simulation-enhanced inquiry-based instruction for asynchronous learning environments?	-Post-interviews	-Open coding -Constant comparison method
5)How do preservice science teachers reflect on feedback while they are progress their lesson plan?	-Post-interviews -Instructor and feedbacks -Reflections	-Open coding -Constant comparison method

4.6. Validity and Reliability of the Study

An important issue during data collection and data analysis are providing validity and reliability. However qualitative studies have different terminology while expressing validity and reliability (Creswell and Poth, 2016). In this study both Lincoln and Guba's (1985) and Creswell snd Poth's (2016) terminology was used to express validity and reliability. Lincoln and Guba (1985) follow naturalistic view for trustworthiness of the research. For trustworthiness they used *credibility, transferability, dependability*, and *confirmability*. For credibility, multiple sources of data for triangulation and prolonged engagement and observation in the research field is needed. To establish this, data collection process lasted 9 weeks. For transferable research findings, rich and thick description of the participants and researcher are needed.

At first, the researcher clearly introduced herself, explain the aim of the study, ensure anonymity and volunteer participation before the data collection process begin. The participation was totally voluntarily. For getting to know the participants more deeply, the researcher gave detailed information about participants, study setting and the case. This strategy was used in both data collection and presenting findings processes. During the study, it is expected to gain participants trust to get valid and truthful findings for the research. During data collection process the researcher and participants got familiar with each other and got know the research phenomenon deeply. Lincoln and Guba (1985) preferred to use *dependability* regardless of reliability. To establish dependability; not only supportive evidence but also negative evidence about the phenomenon was given via quotations at results section. This process is called negative case analysis (Creswell and Poth, 1016). This strategy was useful during whole study and whole data sources. Lastly, confirmability provided by research findings through findings that found at multiple sources of data which support each other.

Besides iInter-rater reliability of the qualitative study can be established by consistency of findings from different data sources and from stability of coding process from different coders. The process is called Cohen's Kappa and Creswell (2014) suggested to use Cohen's Kappa for reliability in normal coding in qualitative research

studies. According to Cohen's Kappa 0.81-1.00 represent almost perfect agreement score. Therefore at least two coders are required. The main coder is the researcher of this study. The other coder, who has Master of Science in science education, was determined by the researcher. After the researcher coded all data, randomly selected two sample from each data collection tool were sent to the other coder for inter-rater reliability. In order to increase reliability in this research agreement is aimed to find between .81-1.00.

The first data source was pre- and post-interviews. After transcribing pre- and post-interviews, the researcher used open coding strategy to explore codes, themes, and categories to constant comparative method. Inter-rater reliability was found .89 for interviews. The second data source was lesson plans which were analysed according to inquiry-based science education, simulations, and asynchronous learning environments and inter-rater reliability was found .91 for inquiry-based science education, .90 for simulations, and .84 for asynchronous learning environments. The third data source was feedbacks from instructor and peer. Inter-rater reliability for instructor feedback was found .92 and for peer feedback .90 peer feedbacks. The fourth data source was reflections and inter-rater reliability for reflections was found .87. The last data source was teaching videos. Teaching videos were analysed according to inquiry-based science education, simulations, and asynchronous learning environments. Inter-rater reliability was found .93 for inquiry-based science education, was found to be .95 for simulations, and .89 for asynchronous learning environments. Inter-rater reliability was provided for all data sources since Cohen's Kappa scores were bigger than .81 for all data sources.

Accordingly, Creswell (2014) also mentioned that researcher's bias may affect the reliability the study. In order to clarify the researcher's bias, the researcher introduced herself and her background so that if the background may interpret analyzing the findings and her role during the research. How these methods or providing credibility is explained in detailly as follows. In the following subtitles how, data is collected in each data sources and how validity and reliability are provided explained separately. Data sources of this study are explained respectively as; pre- and post-interviews with all participants, lesson plans prepared by participants, video recordings of the final

version of lesson plan, instructor, and peer feedbacks to lesson plans and teaching videos, reflections on lesson plans and video recordings, and field notes from the module.

4.7. Ethical Considerations

There are some important concerns should be considered during carrying out qualitative research. These concerns were confidentiality, anonymity of participants and being volunteer to participate to study (Creswell, 2014). Before the data collection process, the researcher got informed consent from all participants to participate study. Accordingly, the aim of the study was share with the participants.

As an ethical consideration, during whole study, names of all participants were changed with pseudonyms in this study to ensure participants' confidentiality and anonymity. Throughout the collection of the data the researcher knows each participants' real names however while representing the findings of the study pseudonyms were used for each subject in the quoted speech or any other reference to specific individuals.

During the interviews, the researcher got permission to save audio-recordings of interviews. Interview protocol shared with participants if they want to see it. In addition, participants' own thoughts, feelings and experiences might shape findings of this study. For this reason, the researcher must not share any of personal idea or thoughts with the participants. In other words, researcher's understandings about nature of the study may affect the originality of the case. For video recordings of the lesson plans, only the researcher watched all of them and the second coder watched two randomly selected teaching video for transcribing them to determine codes. Participants' permissions were also taking for video recordings of their lesson plan. While presenting this study's findings pseudonyms were used regardless of participants' real names.

5. FINDINGS

In this phenomenographic qualitative study, data collection tools were pre- and post-interviews, lesson plans, instructor and peer feedbacks, reflections, teaching video recordings, and field notes. For the analysis of all the data, *constant comparative method* was used to focus on words or images which transferred into verbal descriptions via transcriptions (Glaser and Strauss, 1967). In the constant comparative method, *the researcher simultaneously codes and analyses data to develop concepts* (Taylor *et al.*, 2015; p. 164). Similarly, in this study, the researcher identified codes and refined their properties to find their meaning at the same time.

5.1. Analysis of Preservice Science Teachers' Pre- and Post-Descriptions

Research question 1 was "How do preservice science teachers describe purpose of inclusion of a simulation in inquiry-based science education before and after the intervention on professional development module?". This research question has five themes which are lesson plan, 5E instructional model, inquiry-based science education, simulations, and asynchronous learning environments. Data for this research question came from pre-interviews and post-interviews. Each theme analysed, compared, and contrasted separately.

5.1.1. Analysis of Descriptions of Lesson Plan

Research question 1A was "How do preservice science teachers describe lesson plan before and after the intervention on professional development module?". In the pre-interviews all participants stated that they have prepared lesson plans since the second year of their undergraduate education. They said they presented these lesson plans in front of their instructors and their peers as microteaching. In the pre-interview, first, the question of "What is a lesson plan?" was asked to all the participants. A total of 60 statements revealed 16 codes which were classified into 3 categories as aspect, process, and product demonstrated in Table 5.1.

Table 5.1. The categories and codes emerged for the lesson plan in the participants' pre- and post-descriptions.

Category	Code	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Aspect	Time management	4	1
	In accordance with the science curriculum	4	5
Process	Guiding	5	4
	Preparatory process for lesson	1	5
	Programming the process	-	3
	Continuing process before, during and after a lesson	-	2
	Teaching process	2	1
	Presentation	2	1
	Scheming the lesson	-	2
	Step by step process	1	-
Product	Plan	5	4
	Preparatory product	2	-
	Text	2	-
	Tool	1	1
	Document	1	-
	Draft	1	-

One considerable change from the pre-descriptions to post-descriptions of preservice science teachers were an increase in the *process* category while there was a decrease in the *product* category. In the pre-descriptions, there were eleven codes related to the *process* category while there were eighteen codes in the post-descriptions. Further, in the pre-descriptions there were twelve codes related to product category whereas, only five codes emerged in the post-descriptions. This situation can be mean that preservice science teachers were more likely seeing lesson plans as a product before the SIMINA Module. After the SIMINA Module they started to see lesson plans as a process. The following example quotations from pre- and post-descriptions demonstrate how the description of lesson plan moved from preparatory product to preparatory process;

> It is the product we prepared before the lesson to use while teaching the lesson (Işıl, pre-description).

> Before a lesson, a teacher plans the lesson to guide his/her lesson that is what s/he will teach, which materials s/he will use ... I mean it is the preparation process of the lesson (Işıl, post-description).

Furthermore, in the process category, post-descriptions revealed that two of the preservice teachers started to perceive lesson plan as a continuing process before, during, and after the lesson while no one stated this statement in the pre-descriptions. An example quotation from lesson plan as *a continuing process before, during, and after the lesson* code is given below;

> It is a plan that we prepare before the lesson how we will teach the lesson. Although we aim to teach our lesson according to the plan, it is a process that also includes before and after the lesson (Ferah, post-description).

In addition, an interesting change occurred in the aspect category. In the pre-descriptions while four preservice teachers stated that lesson plan enabled time management, there was only one statement about post-descriptions about time management. An example quotation from time management code;

> ...to use the time effectively ... (Aylin, pre-description) ...demonstrating how to manage the lesson ...(Aylin, post-description)

5.1.2. Analysis of Descriptions of 5E Instructional Model

Research question 1B was "How do preservice science teachers describe 5E instructional model before and after the intervention on professional development module?". In the pre-interviews all the preservice teachers stated that so far, they had prepared lesson plans according to 5E instructional model. Up to data collection times, they said they only prepared and presented their lesson plans as a microteaching. However, since all preservice teachers were studying their last term of their undergraduate science teacher education program, they taught their lesson plans to middle school students as a part of their internships. First, it was asked to all participants the ques-

tion; "What is 5E instructional model?". Their answers were found to focus on two categories which are *approach* and *structure*. A total of 30 statements, revealed codes categorized into three categories which represented in Table 5.2.

Table 5.2. The categories and codes emerged for 5E instructional model in the participants' pre- and post-descriptions.

Category	Code	Frequency in Post-Descriptions	Frequency in Pre-descriptions
Focus on Approach	Constructivism	1	10
Focus on Structure	A link between the stages of 5E	2	5
	Aspects of each stage of 5E	3	-
	Cyclic nature of 5E	-	2

The comparison of the findings of the pre- and post-interviews for the theme of 5E instructional model revealed that all preservice science teachers focused on constructivism in the post-interviews. In addition to that one considerable change was observed in focus on structure category. Codes from this category demonstrated that preservice science teachers thought stages of 5E instructional model were either separate or integrated. In pre-interviews, three preservice science teachers said that each stage has its own aspects which demonstrated that stages of 5E instructional model was separate. However, in the post-interviews from total seven statements, all codes in the focus on structure indicated that 5E there were links between stages of 5E instructional model. An example quotation of how preservice science teachers' descriptions about focus on structure category for stages of 5E changed.

> I see that each stage should be evaluated in itself. There are factors that we need to do in each of them. (Ezgi, pre-description).

> 5E instructional model is a cycle with integrated steps (Ezgi, post-description)

> There are things we must do at every stage; I don't know where and what to do. (Gizem, pre-description).

> Now, I'm connecting one another, so we talked about the need to connect exploration and explanation that day in the lesson. Now I think that engagement, exploration, explanation, elaboration, and evaluation as a whole (Gizem, post-description).

Moreover, in both pre- and post-interviews, it was asked preservice science teachers to answer, "What are stages of 5E instructional model?". Analysis of pre- and post-interviews indicated that while some of the preservice teachers accurately stated and explained all the stages, some of them did not explain all of them, and described the stages in mixed order, and one of them did not state the stages because she did not remember them. Figure 5.1 ddemonstrates how preservice science teachers stated and explained the stages of 5E instructional model in the pre- and post-interviews.

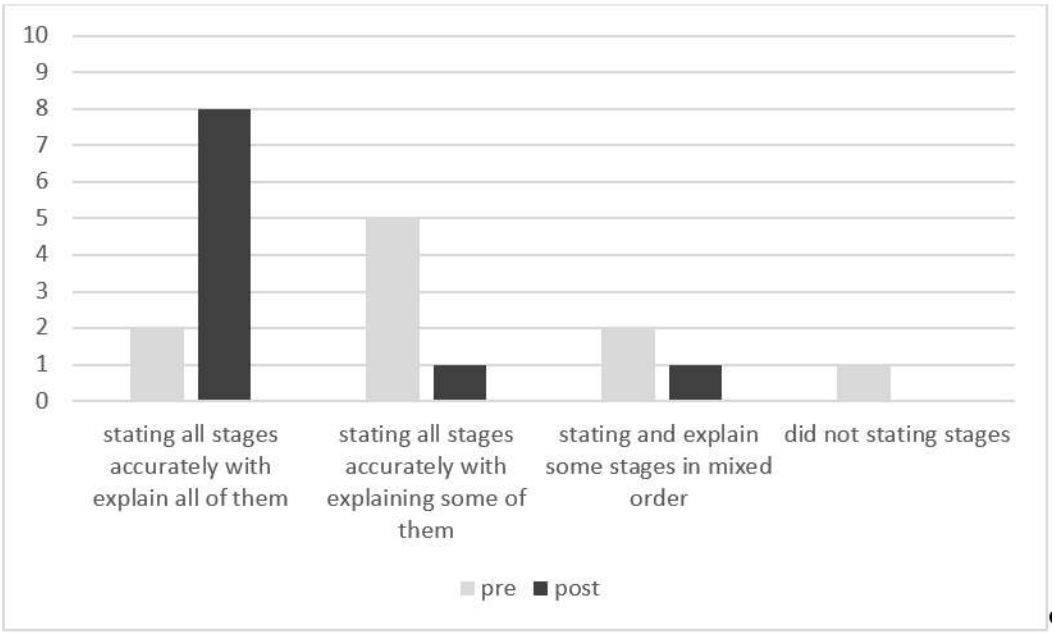


Figure 5.1. The Number of Preservice Science Teachers Stating and Explaining 5E Instructional Model's Stages.

For the engagement stage, from a total of 30 statements, the emerging six codes were classified into two categories which were *purpose* and *process*. For the exploration stage, from a total of 15 statements, five codes emerged and classified into two categories which were *process* and *tool*. For the explanation stage, from a total of 20 statements, 7 codes revealed and classified into two categories which were *process* and *product*. In

elaboration stage, from total 15 statements, 5 codes revealed and classified into two categories which *purpose* and *process*. For the evaluation stage, from a total of 21 statements, 5 codes emerged and classified into three categories which were *purpose, process* and *product*. In total, from 101 statements, 30 codes revealed and classified into 4 categories which were *purpose, process*, *product*, and *tool* as demonstrated in Table 5.3.

Table 5.3. The categories and codes emerged for the stages of 5E instructional model in the participants' pre- and post-interviews.

Stages of 5E Instructional Model	Categories	Sub-categories	Codes	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Engagement	Purpose	Affective	Gathering attention	6	6
			Increasing curiosity	3	3
			Increasing excitement	1	-
			Motivating the students	1	4
		Cognitive	Students' prior knowledge	2	3
	Process		The most active stage of students	1	-
Exploration	Process	Method	Argumentation	1	-
			Inquiry-based	1	-
			Teacher guidance	-	1
	Tool	Inquiry-based science education	Research question or problem to explore	3	6
			Data collection	-	3

Table 5.3. The categories and codes emerged for the stages of 5E instructional model in the participants' pre- and post-interviews (cont.).

Stages of 5E Instructional Model	Categories	Sub-categories	Codes	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Explanation			Teacher's lecturing	3	3
			Images, videos, or animations	1	-
	Process	Inquiry-based science education	Data explanation	-	6
			Data analysis	-	2
			Data interpretation	-	1
			Activity or experiment	1	1
	Product		Representing results through graph or table	-	2
Elaboration	Process		Self-actualization	1	
			Elaborating theconcept	1	3
	Purpose		Using models and modeling	2	-
			Giving example from daily life	-	4
			Finding solution to real life problems	-	4
Evaluation	Purpose		Assessing students' knowledge	1	6
	Process		Formative assessment	1	
			Peer assessment	1	3
			Assessing whole lesson	-	4
	Product		Summative assessment	1	4

Analysis of the stages of 5E instructional model demonstrated that compared to pre-descriptions, there were more codes in post-descriptions. There were 35 codes in the pre-descriptions, whereas there were 69 codes in the post-descriptions. A considerable change from pre-descriptions to post descriptions about the stages of 5E instructional model was on explaining the exploration and explanation stages. For the exploration stage, three preservice teachers said *research question or problem to explore* in the pre-interviews. However, in the post interviews six preservice science teachers

referred to *research question* and three of them referred to *data collection* which were related to inquiry-based science instruction. In addition, in the pre-descriptions, of the explanation stage, there was no code referring to inquiry-based science instruction. Post-description codes revealed codes related to the inquiry-based science education including 4 codes referring *data explanation*, 2 codes referring *data analysis*, and 1 one code referring *data interpretation*, on the contrary. An example quotation indicated how to use inquiry-based science education in 5E instructional model:

> During the exploration stage, a research question is given to students. They are trying to find out this research question through experiments, activities, or worksheets so ummm they collect data. In the Explanation stage; they are trying to analyze data that they collected, ...they are explaining the data they collected. Here they analyze the tables, graphs ...they reach conclusions. The teacher guides them there if they have misconceptions or deficiencies (Pınar, post-description).

Moreover, the analysis of the interviews about the stages of 5E further revealed that four preservice science teachers indicated in the pre-interviews that they had difficulties in preparing lesson plans for 5E instructional model. Based on the analysis of interviews, one important difficulty was about who would explain the concept. In the pre-interviews, four preservice science teachers stated that teachers should explain the concept and two preservice science teachers stated that they did not know whether the teacher or the students would explain the concept. An example quotation of Aylin's confusion about whether teacher or students explain the concept in pre-description and how she described it in her post-description.

> In explanation ... are we going to explain? Are the students, you know, so after they explore it, are they going to explain? This often misleads me. I, actually, think I need to explain a little bit. I don't know why, maybe I'm just doing it because we're used to it a bit like this (Aylin, pre-description).

> In my opinion, students should explain with the information they have found in the exploration stage. They can draw tables or describe what they have explored. I was confused about this. (Aylin, post-description).

5.1.3. Analysis of Descriptions of Inquiry-based Science Education

Research question 1C was "How do preservice science teachers describe inquiry-based science education before and after the intervention on professional development module?". In the pre-interviews, all preservice science teachers stated that they did not know what inquiry-based science education was. Therefore, they only claimed their predictions about the concept in the pre-descriptions. Analysis of transcriptions revealed that a total of 43 statements revealed 18 codes which were classified into 5 categories which were purpose, tool, process, assessment, and learning which are presented in Table 5.1.3.

Table 5.4. The categories and codes emerged for the inquiry-based science education in the participants' pre- and post-interviews.

Categories	Sub-categories	Codes	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Purpose	Affective	Increasing curiosity	3	1
		Gathering attention	1	1
	Cognitive	Exploring what they want to know	2	-
		Accessing knowledge through inquiry	1	-
		Permanent learning	-	1
Tool		Asking research questions	2	6
		Inquiry-based activities or experiments	2	-
		Learning by doing	2	-
		Data collection and analysis	-	2
		Changing variables to explore or explain	1	3
		Activity, experiment, or simulations	-	3

Table 5.4. The categories and codes emerged for the inquiry-based science education in the participants' pre- and post-interviews (cont.).

Categories	Sub-categories	Codes	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Process		Hypothesis testing	-	2
		Making inferences	-	2
		Interpreting results	-	3
		Activity of students	1	-
Assessment		Long term assessments	1	-
Learning	Knowledge	Developing scientific method	1	-
	Skills	Using science process skills	1	1

Comparison of pre- and post-descriptions about inquiry-based science education indicated that the total number of statements increased in the post-descriptions. While there were 18 statements in pre-descriptions, there were 25 statements in post-descriptions. In addition, in the pre-descriptions, preservice science teachers mostly focused *purpose* category with four codes whereas, in the post-descriptions they mostly focused tool category with four codes. One of considerable change occurred in the tool category on post-descriptions. In the pre-descriptions only two preservice science teachers stated the code of *research question* and none of them stated the code of data. However, in the post-descriptions six of them stated *research* question and two of them stated *data collection* and analysis.

The other considerable change occurred in *process* category. In the pre-descriptions only one preservice science teacher stated students are active in the pre-descriptions. In the post-description, the same preservice science teacher stated the category of *process* but with explaining how students actively participate the process which exemplified in the following quotation.

> Students should be active in the lesson process (Deniz, pre-description). They (students) will do research on a research question. They will explore research question, test their hypotheses, seek answers, making inferences and reach a solution (Deniz, post-description).

5.1.4. Analysis of Descriptions of Simulations

Research question 1D was "How do preservice science teachers describe simulations before and after the intervention on professional development module?". For this research question, the analysis of preservice science teachers' pre- and post-descriptions were performed. Analysis of transcriptions revealed a total of 56 statements which revealed 19 codes classified into 5 categories which were *purpose, process, tool, resource*, and *learning environment*, which are presented in Table 5.1.4.

Table 5.5. The categories and codes emerged in for simulations the participants' pre- and post-interviews.

Categories	Codes	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Purpose	Making invisible to visible	4	4
	Providing suitable environment for experiments	1	3
	Individualized learning	-	2
	Computer-supported learning		2
	Permanent learning	1	-
Process	Changing variables	2	4
	Exploring different conditions	-	3
	Activity of students	-	2

Table 5.5. The categories and codes emerged in for simulations the participants' pre- and post-interviews (cont.).

Categories	Codes	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Tool	Real-like model	3	-
	Imitation	-	3
	Virtual reality	2	-
	Game	1	1
Resources	PhET	-	5
	Algodoo	-	3
	EduMedia	-	2
	WISE	-	1
Learning Environment	Interactive learning environment	-	3
	Student-centered	-	2
	Design of learning environments by teachers	-	2

One considerable change from the pre-descriptions to post-descriptions of preservice science teachers were an increase in number of codes for all categories. While in pre-descriptions there was no code emerged for the *resource* category, 11 simulation resources were stated in the post-descriptions. Similarly, in the pre-descriptions there was no code emerged for the *learning environment* category, whereas 7 statements referring to the same category, were found in the post-descriptions.

The other considerable statement was that the analysis of pre-descriptions showed that one preservice teacher did not know what a simulation was, and four preservice science teachers supposed that simulation was augmented reality. On the other hand, four preservice teachers described simulations without confusing with any other educational technology tools.

Example quotations pre-descriptions demonstrate how preservice science teachers described simulation as a tool.

> To make something that is not in the World feel as if it is in the World, ummm, things that we will not be able to see, but we can show instantaneously. Simulation ... As I said I used Queer application. I think it is a simulation. So, it allows us to see cell in 3-Dimension. It is impossible to see with naked eye. (Buse, pre-description).

> Simulation is let's say; pilots, or while getting a driver licence we're not driving a real car but driving something that it feels we're driving a car. Actually, I think right now, it can be used in astronomy topics. For example, they can drive a spacecraft. I couldn't think of anything else. Well... it could be also, ummm, let's say living things. There is a vehicle going on a trip to the forest. They (students) separate living and non-living things as if they really went to that environment (Ferah, pre-description).

5.1.5. Analysis of Descriptions of Asynchronous Learning Environments

The purpose of this research question was examining how preservice science teachers described asynchronous learning environments before and after the intervention on professional development module. The analysis of this research question was performed through pre- and post-interviews. All preservice science teachers stated in the pre-interview that their experiences for asynchronous learning environments were limited to the video recorded versions of their undergraduate courses. They neither participated nor prepared lessons for asynchronous learning environments. From twenty (10 pre-, 10 post) transcripts, a total of 82 statements, 21 codes emerged and classified into 5 categories which were *learning, communication, resources, assessment, and technical* Table 5.6.

Table 5.6. The categories and codes emerged in for asynchronous learning environments in the participants' pre- and post-interviews.

Categories	Codes	Frequency in Pre-Descriptions	Frequency in Post-Descriptions
Learning	Individualized learning	-	5
	Independent from time and space	4	-
	Watching repeatedly	4	2
	Individualized learning	3	4
	Setting learning goals and objectives	-	4
	Remembering students to note-taking	-	4
	Exploring through simulations	-	3
	Asking research questions	-	2
Communication	No interaction between teacher or peer	9	-
	Guiding students' learning	-	6
	Creating virtual classroom	-	3
Resources	EBA	3	2
	YouTube	2	1
	Khan Academy	-	1
Assessment	No immediate feedback from teacher	2	1
	Self-feedback	1	3
	Giving summative assignments	1	3
Technical	Technical problems	2	-
	Multiple representation	-	3
	Speaking in front of camera	-	2
	Speaking fluently	-	2

Comparison of pre-descriptions and post-descriptions revealed that while there were 28 statements in pre-descriptions, there were 49 codes in post-descriptions. Also, the number of statements for the codes increased in the categories of *learning, assessment, and technical*. One considerable change from the pre-descriptions to post-descriptions of preservice science teachers were the increase in the number of statements for the *learning* category as the number of codes for this category increased from eight to twenty.

In the pre-descriptions preservice science teachers focused more on there was no individualized learning. However, in the post-descriptions preservice science teachers

focused more on students' learning. For the *assessment* category, there were four statements in the pre-descriptions, whereas there were seven statements in post-descriptions. For the *technical* category, while in the pre-descriptions two preservice science teachers stated technical problems in general, without specifying them, in the post-descriptions preservice science teachers stated technical problems that they had experienced. Regarding the *technics* category, in the post-descriptions, three preservice science teachers stated the codes related to *multiple representations*, two of them stated the codes related to *speaking in front of camera* and another two stated codes related to *speaking fluently.* An example quotation exemplified preservice science teachers' statements about technics category.

> Technical problems may occur, this spoils my mood (Ceren, pre-description). I had some difficulty in how much space should I give to the text, whether it was too much or too little, whether I should write this or whether the students could see this too. I also had difficulty in speaking and teaching. I had to shoot several times because I made a mistake. (Ceren, post-description).

In addition, while the number of codes decreased in the *resource* category, and the number of codes remained same in the *communication* category. Although number of codes remained, an interesting change occurred in communication category. In the pre-descriptions all the codes in the *communication* category were negative, such as *no interaction between teacher or peer* and *not asking questions to teacher*, whereas in the post-descriptions, they were positive, such as six preservice science teachers stated how to *provide communication in asynchronous learning environments.*

5.2. Analysis of Inclusion of a Simulation-enhanced Inquiry-based science education for Asynchronous Learning Environments

Research question 2 was "How do preservice science teachers describe inclusion of a simulation-enhanced inquiry-based science education for asynchronous learning environments before and after the intervention on professional development module?". This research question has two sub-questions which concentrate on inclusion of a simulations in asynchronous learning environments and inclusion of an inquiry-based science edu-

cation in asynchronous learning environments. Data for this research question came from pre-interviews and post-interviews. Each theme was analysed, compared, and contrasted separately.

5.2.1. Analysis of Inclusion of a Simulations in Asynchronous Learning Environments

Research question 2A was "How do preservice science teachers describe inclusion of a simulations in asynchronous learning environments before and after the intervention on professional development module?". The first analysis performed for the research question 2A was the analysis of preservice science teachers' descriptions of inclusion of simulations in asynchronous learning environments from pre- and post-interviews. From a total of 20 verbatim transcripts, preservice science teachers' statements about the inclusion of simulations in asynchronous learning environments were classified into three groups: *yes, no, or not sure.* This transformation in preservice science teachers' statements demonstrated in Figure 5.2 which indicates the changing frequencies of number of preservice science teachers' statements about inclusion of simulations in asynchronous learning environments.

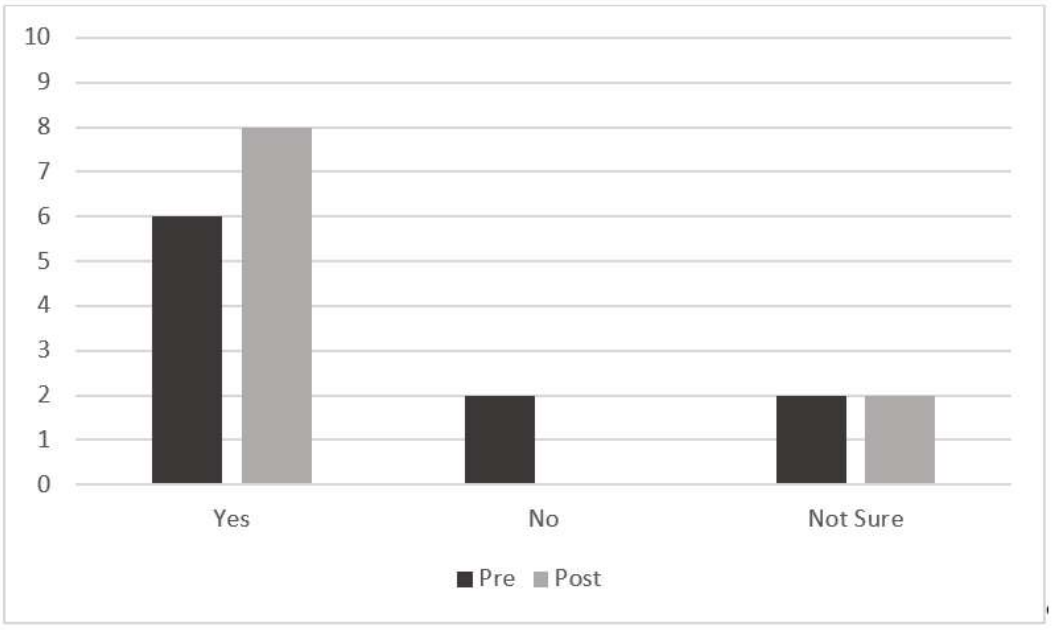


Figure 5.2. The Number of Preservice Science Teachers' Statements about the Inclusion of Simulations in Asynchronous Learning Environments.

The analysis of descriptions showed that there was an increase in the number of yes statement about the inclusion of simulations in asynchronous learning environments. In other words, after the SIMINA module, a greater number of preservice teachers thought that they could integrate simulations into asynchronous learning environments. Also, in the post-descriptions none of the preservice science teachers stated that simulations could not be used in asynchronous learning environments.

Then, preservice science teachers' statements about how simulations could be used in asynchronous learning environments or why simulations could not be used in asynchronous learning environments were obtained and clustered into two categories which were the *role of teachers* and the *role of students*. From these two categories, a total of 36 statements, 15 codes obtained from the pre-descriptions and the post-descriptions, which are presented in Table 5.2.1.

Table 5.7. Categories and codes identified in preservice science teachers' pre- and post-descriptions about inclusion of simulations in asynchronous learning environments.

Statement	Category	Code	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Yes	Role of Teachers	By giving simulation link	2	4
		By asking research questions	1	3
		By gathering attention	1	-
		By giving feedback to students' assignment	-	2
	Role of Students	By being active	-	5
		By following Instructions	2	4
		By listening and watching the teacher	-	2
		Listening to the lesson several times	-	1

Table 5.7. Categories and codes identified in preservice science teachers' pre- and post-descriptions about inclusion of simulations in asynchronous learning environments (cont.).

Statement	Category	Code	Frequency in Pre-descriptions	Frequency in Post-Descriptions
Not Sure	Role of Teachers	Lecturing	1	
	Role of Students	Not sure whether students		
		use simulation	-	2
		Not sure whether students listen to lesson	-	2
		No interaction	1	-
No	Role of Teachers	-	-	-
	Role of Students	Watching simulations is not proper	2	-
		passive	1	-
		not asking questions to the teacher	1	-

The considerable change from preservice science teachers' pre-descriptions to the post-descriptions was the increasing number of codes in both *role of teachers* and *role of students* categories for the yes statement. Also, in the post-descriptions, all the codes in the *not sure* statement were related with the category of the *role of students*, with two codes. These two codes revealed that they were *not sure whether students listen to the lesson* and *students use simulations*. Also, in the pre-descriptions all codes in the no statement were related to the *role of students* category with three codes which *were watching simulation is not proper, students are passive*, and *students cannot ask questions to the teacher*. However neither of these codes emerged in the post-descriptions. Exemplified quotations identified *how simulations can be used in asynchronous learning environments* or *why simulations cannot be used in asynchronous learning environments* are given below. Example quotations also demonstrated how example preservice science teachers' thoughts changed.

> I think that simulations cannot be used in asynchronous. I mean, the teacher uses but students only watch passively like watching a video. This is not an effective

use of simulations (No, Ezgi, pre-description).

> Simulation is a right tool for asynchronous [lessons]. I mean a student not only watch like a video ... I think that a student actively uses a simulation. (Yes, Ezgi, post-description). I think so. I just gave the instructions to the children and explained mmm... after that I told them how to use it, I think it can be this way. Because they will only follow these instructions, well, they will use according to my explanations. (Yes, Jale,pre-description) I think that using simulations in asynchronous learning environments is actually the best thing, because we cannot interact with students, but they can directly experience with the applications ... well I think it will be effective to use application, I mean, simulations that can be used at home (Yes, Jale, post-description).

> It seems, ineffective to me. It [Simulation] will be in the video, right? The teacher shoots a video and send it to students, but students will not be able to ask questions to the teacher and maybe they will not even use (No, Işıl, pre-description).

5.2.2. Analysis of Inclusion of an Inquiry-based Science Education in Asynchronous Learning Environments

Research question 2B was "How do preservice science teachers describe inclusion of an inquiry-based science education in asynchronous learning environments before and after the intervention on professional development module?". The first analysis performed for the research question 2B was the analysis of preservice science teachers' descriptions of inclusion of inquiry-based science education in asynchronous learning environments from pre- and post-interviews. From a total of 20 verbatim transcripts, preservice science teachers' statements classified into *yes, no*, and *not sure* about inclusion of simulations in asynchronous learning environments. This transformation in preservice science teachers' statements demonstrated in Figure 5.3 which indicates the changing frequencies of number of preservice science teachers' statements about inclusion of inquiry-based science education in asynchronous learning environments.

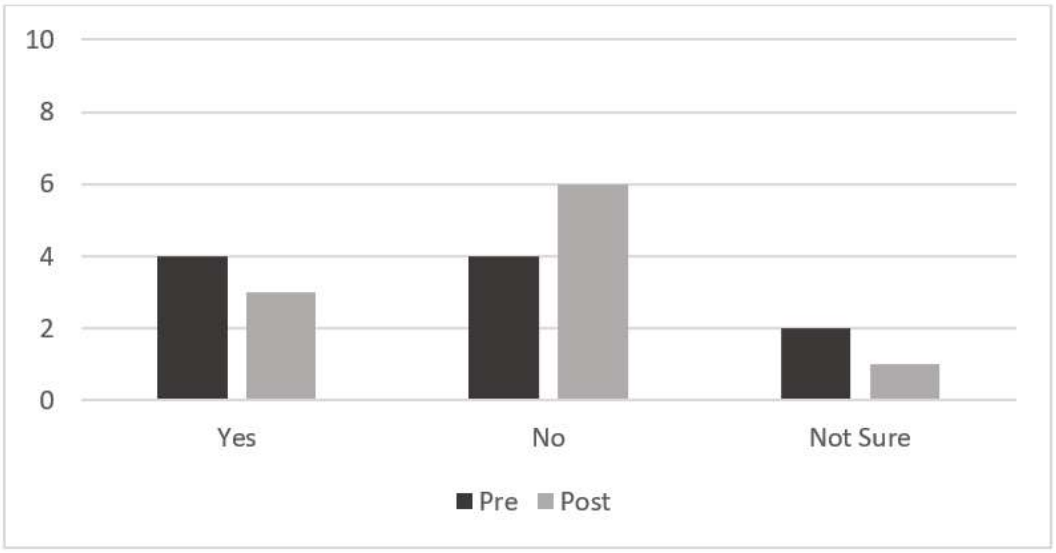


Figure 5.3. The Number of Preservice Science Teachers' Statements About Inclusion of Inquiry in Asynchronous Learning Environments.

The analysis of descriptions showed that there was an unexpected decrease in the number of yes statement about the inclusion of inquiry in asynchronous learning environments. In other words, after the SIMINA module, less number of preservice teachers thought that they could integrate inquiry into asynchronous learning environments. According to the post-descriptions six out of ten preservice teachers stated that inquiry-based science education could not be used in asynchronous learning environments.

Then, preservice science teachers' statements about how simulations could be used in asynchronous learning environments or why simulations could not be used in asynchronous learning environments were obtained and clustered into two categories which were the *role of teachers* and *the role of students*. From these two categories, a total of 35 statement revealed 17 important codes which were obtained from pre-descriptions and the post- descriptions, as shown in Table 5.8.

Table 5.8. Categories and codes identified in preservice science teachers' pre- and post-descriptions about inclusion of inquiry-based science education in asynchronous learning environments.

Statement	Category	Code	Frequency in Pre-descriptions	Frequency in post-descriptions
Yes	Role of Teachers	giving instructions	1	2
		data collection and analysis through simulation	-	1
		increasing curiosity	1	-
		preparing to the lesson	1	-
	Role of Students	trying experiments at home	2	-
		collecting data to answer research question	1	2
Not Sure	Role of Teachers	not sure assigning research questions as homework is enough	1	-
	Role of Students	not sure whether guiding students is enough the instructions	2	1
No	Role of Teachers	not guiding students	-	3
		not asking questions	-	2
		lecturing	1	-
	Role of Students	might not listen to the teacher	-	3
		not asking questions	2	3
		only watching the video	-	2
		might not follow instructions	-	2
		participating lesson to different time	1	-

A considerable change from preservice science teachers' pre-descriptions to the post-descriptions was the increasing number of codes both in the categories of the *role of teachers* and the *role of students* in all the statements. While there were 10 codes from 13 statements in the pre-descriptions, there were 11 codes from 22 statements, in the post-descriptions. Comparison of pre-descriptions and post-descriptions revealed that while in the pre-descriptions there were more codes in yes statement, in the post-descriptions there were more codes in the *no* statement. Regarding the yes statement, while there were 5 codes in the pre-descriptions, there were 3 codes in the post-descriptions. Similarly, regarding the *no* statement, while in the pre-descriptions there were 3 codes, there were 6 codes in post-descriptions.

Exemplified quotations identified how inquiry-based science education could be used in asynchronous learning environments or why inquiry-based science education could not be used in asynchronous learning environments, are given below. Example quotations also demonstrated how example preservice science teachers' thoughts changed. In the pre-description, Jale was not sure about how inquiry-based science education could be used in asynchronous learning environments, but in post-description she explained how it could be.

> A problem is defined, and it is asked children to do research for this problem. But I'm not sure if that would be exactly an inquiry-based. So, I don't know if it can be done. (Not Sure, Jale, pre-description).

> In the asynchronous learning environments, there is no interaction, but with our mmm... little clues, we can encourage students to investigate through research questions. With these questions, I think it's like this, children find out by questioning themselves without telling the problem directly. (Yes, Jale, post-description).

On the contrary, in the pre-description Deniz stated that inquiry-based science education could be used in asynchronous learning environments, however in the post-descriptions she did not think that way.

> I think so. The teacher gives questions to the students and can wait for the answers from the students. (Yes, Deniz, pre-description).

> Because I think that most of the students do not listen to the lesson, do not take the lesson into consideration. Lets say I gave research question to the students but most of them did not do, only listen to the lesson (Not Sure, Deniz, post-description).

> It is asked students to have prepare to the subject and do research on a subject before coming to the class. Well, in other words, I would say, they can do simple experiments in their home, so they can also do these inquiry-based simple experiments in asynchronous environment. (Yes, Buse, post-description).

5.3. Analysis of Progression on Designing a Simulation-enhanced Inquiry-based Science Lesson for Asynchronous Learning Environments

Research question 3 was "How are preservice science teachers' progressions on designing a simulation-enhanced inquiry-based science lesson design for asynchronous learning environments?". This research question had three sub-questions which focus on: progression on designing inquiry-based science lesson, progression on designing simulation-enhanced science lesson, and progression on designing science lesson for asynchronous learning environments, respectively. Data for this research question came from 1^{st} lesson plans 2^{nd} lesson plans, and the teaching videos preservice science teachers recorded. Each sub-question was analysed, compared, and contrasted with each other separately.

Preliminary findings of the analysis of first of the lesson plans indicated that while nine preservice science teachers prepared their lesson plans by using the 5E instructional model, one preservice science teacher, Hilal, did not use the 5E instructional model. She said in her pre-interview that "*There are lots of topics that I do not know related to science teaching and 5E instructional model is one of them*". In addition to that, comparison of the 1^{st} and the 2^{nd} lesson plans in terms of the instructional objectives demonstrated that six preservice science teachers used the same objective in both the 1^{st} and 2^{nd} lesson plans, whereas four of them changed their objectives. Ceren, Deniz, and Hilal said in their post-interviews that they changed their objectives because they did not find proper simulation for their objectives. All three preservice science teachers' first objectives related to biology topics. Ceren selected physics topic whereas Deniz and Hilal selected chemistry topic for their second of lesson plans. In addition, Jale said that she changed her objective because she was not able to use Algodoo simulation as she would like to use. Jale's first objective was simple machine (physics topic) and second objective was acids and bases (chemistry topic).

5.3.1. Analysis of Progression on Designing Inquiry-based Science Lesson

Research question 3A was "How are preservice science teachers' progression on designing inquiry-based science lesson?". The first analysis performed for the research question 3A was the analysis of the 1^{st} and the 2^{nd} lesson plans with respect to the inquiry-based science education. Then, how the inquiry-based science education was represented in their teaching videos was analysed. *Inquiry Scoring Rubric for Lesson Plans* (see Table 5.1) developed by Forbes and Davis (2010) was used for analyzing inquiry-based science education conveyed in the lesson plans. This rubric has 5 dimension which are 1) *scientifically oriented questions*, 2) *gathering, organizing and analyzing data*, 3) *formulating explanations from evidence to address scientifically oriented questions, 4) evaluating their explanations in light of alternative explanations, and 5) communicating and justifying their explanations.* The maximum score of this rubric was fifteen. Firstly, the average scores were calculated for the 1^{st} and 2^{nd} lesson plans. The average score of 1st lesson plan was 5,6 whereas the average score of 2^{nd} lesson plan was 8,8. Firstly, each preservice science teacher's total score for inquiry-based science education was calculated and demonstrated at Figure 5.4.

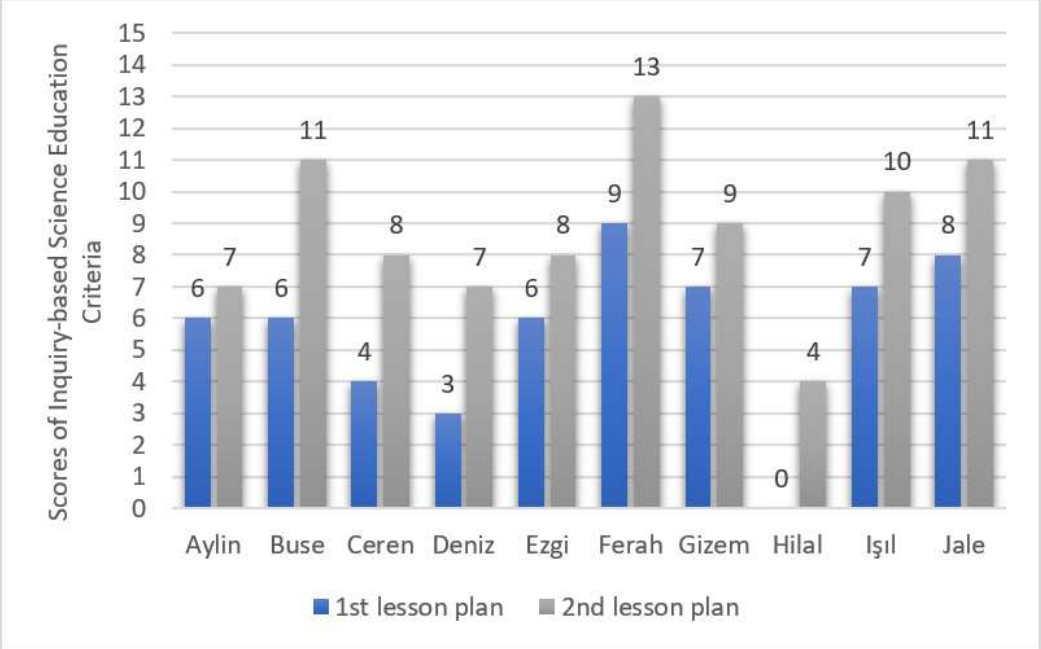


Figure 5.4. Total Inquiry Scores of the First and the Second of Lesson Plans.

As seen in the Figure 5.4 all preservice science teachers second lesson plans gained higher score compared to first lesson plans on inquiry-based science education criteria. While Aylin had the least increase with only 1-point, Buse had the most increase with 5-points. In addition, Ferah had the highest points both the first and the second lesson plans; nine points at the 1^{st} lesson plan and thirteen at the 2^{nd} lesson plan. On the contrary, Hilal had the lowest point both the first and second of her lesson plans; zero-point at 1^{st} lesson plan and four points at 2^{nd} lesson plan according to the inquiry-based science education criteria. Then, each preservice science teacher's inquiry scores for each dimension of the rubric were analysed, 1st and 2nd lesson plan scores are compared and demonstrated at Table 5.9.

Table 5.9. Each preservice science teacher's 1^{st} and 2^{nd} lesson plan scores for inquiry-based science education criteria.

IBSE	Scientifically...		Gathering....		Formulating...		Evaluating...		Communicating...	
Student	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the 1^{st} LP	Score in the 2^{nd} LP
Aylin	2	2	1	1	1	2	1	1	1	1
Buse	2	3	2	3	2	3	0	1	0	1
Ceren	1	3	0	2	1	2	1	0	1	1
Deniz	1	2	1	2	1	2	0	0	0	1
Ezgi	1	2	2	2	2	2	0	1	1	1
Ferah	2	3	2	3	2	3	2	2	1	2
Gizem	1	2	1	2	1	2	2	1	1	2
Hilal	0	1	0	2	0	1	0	0	0	0
Işıl	1	3	2	3	2	3	1	1	1	1
Jale	2	2	2	3	2	3	1	1	1	2
Average	1.3	2.3	1.3	2.3	1.4	2.3	0.8	0.8	0.7	1.2

One considerable fact that can be deduced from Table 5.9 was that none of the 1st of lesson plans gained 3-points from any dimension. Also, none of the second of lesson plans gained 3-points on *evaluating their explanations in light of alternative explanations* and *communicating and justifying their explanations* dimensions. In addition to that, Hilal did not include inquiry-based science education on her 1^{st} of lesson plan, therefore she gained zero point. In other words, Hilal's 1^{st} of lesson plan did not include any of these five dimensions. Following paragraphs demonstrates how each dimension

represented in preservice science teachers' lesson plans with explanations. Following paragraphs indicates each dimension's separate analyses.

For *scientifically oriented question* dimension, none of the first lesson plans gained 3-points from this dimension. In the first of lesson plans, five preservice science teachers' lesson plans got 1-point, four preservice science teachers' lesson plans got 2-points, and Hilal got zero-point. However, in the second lesson plans four preservice science teachers got 3-points, five preservice science teachers got 2-points, and Hilal got 1-point. While Aylin's and Jale's scores for this dimension did not change from first lesson plan to second lesson plan, Ceren's and Işıl's scores were increased 2-points, other preservice science teachers' scores increased 1-point.

For *gathering, organizing, and analyzing data* dimension, none of the first lesson plans gained 3-points from this dimension. In the first lesson plans, two preservice science teachers' lesson plans got zero-point, one preservice science teacher's lesson plan got 1-point and six preservice science teachers' lesson plans got 2-points. In the second lesson plans, four preservice science teachers got 3-points, five preservice science teachers got 2-points, and Aylin got 1-point. One considerable shift from the first to second lesson plan was occurred Ceren's research question. Ceren's first of lesson plan had no *gathering, organizing, and analyzing data dimension.* In the first of Ceren's lesson plan, she stated that students were only watching the video. However, in the second of Ceren's lesson plan, she described that student collected and analysed data through research question. Therefore, her score increased in 2-points.

For *formulating explanations from evidence to address scientifically oriented* questions dimension, none of the first lesson plans gained 3-points from this dimension. In the first lesson plans, five preservice science teachers' lesson plans got 1-point and four preservice science teachers' lesson plans got two-points. In the second lesson plans, four preservice science teachers got 3-points, five preservice science teachers got 2-points, and Hilal got 1-points. Nine preservice science teachers' lesson plans increased one point which was a slight increase. However, Ezgi's score for this dimension since she did not change this part of her lesson plan.

For *evaluating their explanations in light of alternative explanations* dimension, none of the lesson plans got 3-points from this dimension. In the first of lesson plans, four preservice science teachers' lesson plans got zero-point, four preservice science teachers' lesson plans got 1-point, and two preservice science teachers' lesson plans got 2-points. In the second of lesson plans, three preservice science teachers' lesson plans got zero-point, six preservice science teachers' lesson plans got 1-point, and one preservice science teacher's lesson plan got two points. Comparison of the first and the second lesson plans on *evaluating their explanations in light of alternative explanations* dimension revealed that Buse and Ezgi's lesson plans score increase in one point. For example; Buse, in her second of lesson plan, created a virtual classroom where students post their explanations and discuss alternative explanations. In addition, Ceren's second lesson plan score decrease in one point. Ceren's first of lesson plan scored 1-point in this dimension, there was no statement about alternative explanations in Ceren's second of lesson plan, so she scored zero for this dimension in second lesson plan.

For *communicating and justifying their explanations* dimension, none of the lesson plans got 3-points from this dimension. In addition to that none of the first lesson plans got 2-points in this dimension, either. In the first lesson plans; three preservice science teachers got zero-point and those of seven preservice science teachers got one point. On the contrary, one preservice science teacher got zero-point, those of six preservice science teachers got 1-point, and those of three preservice science teachers got two points from second lesson plans. Comparison of the first and second of lesson plans' dimension revealed that *communicating and justifying their explanations* dimension five preservice science teachers' scores increased one point. Following Table 5.10 demonstrates average scores of first and second lesson plans with concrete examples from lesson plans.

Table 5.10. Average of 1^{st} and 2^{nd} lesson plan scores for dimensions of inquiry-based science education with example quotes.

IBSE	Average score in the 1^{st} LP	Example from the 1^{st} LP	Average score in the 2^{nd} LP	Example from the 2^{nd} LP
Scientifically ...	1,3	Why are our clothes in different colours? (Işıl, 1^{st} lesson plan, 1-point)	2,3	How white light is formed? (Işıl, 2^{nd} lesson plan, 3-points)
Gathering ...	1,3	The video is watched by the students. The video is paused where necessary and the teachers explains the concept. (Ceren, 1st lesson plan, 1-pointt)	2,3	Before simulation, the teacher gave research questions to the students. Teacher said students to answer research questions through simulation. Students will collect data for each research question and write their explanations on worksheet (Ceren, 2^{nd} lesson plan, 2-points).
Formulating ...	1,4	By keeping simple machines in mind, please write how force output change. You can also explain through the video (Jale 1^{st} lesson plan, 2-points)	2,3	Now by considering collected data, write your claims which is acid which is base. Please support your claim with your investigation! (Jale, 2nd lesson plan, 3-points)
Evaluating ...	0,8	The teacher expects students to comprehend different results can be found from the same experiments (Gizem, 1^{st} lesson plan, 2-points).	0,8	Then teacher wants students to compare their findings with the accepted scientific knowledge. (Gizem, 2^{nd} lesson plan, 1 point)
Communicating ...	0,7	Share your ideas with your classmates (Ferah, 1^{st} lesson plan, 1-point)	1,2	Please write your ideas about energy saving strategies in the forum and discuss with your classmates. (Ferah, 2^{nd} lesson plan, 2-points)

As seen in the Table 5.10; for all dimensions, except from *evaluating their explanations in light of alternative explanations* dimension, scores in the second lesson plan were higher than scores in the first lesson plan. For *evaluating their explanations in light of alternative explanations* dimension average score was remained same.

Accordingly, the most increase happened in the *scientifically oriented questions* and *gathering, organizing and analyzing data* dimensions with 1,0 point. In addition to that *formulating explanations from evidence to address scientifically oriented questions* had the highest first lesson plan average point with 1,4 whereas *communicating and justifying their explanations dimension* had the least first lesson plan average point.

5.3.2. Analysis of Progression on Designing Simulation-enhanced Science Lesson

Research question 3B was "How are preservice science teachers' progression on designing simulation-enhanced science lesson?". The first analysis performed for the research question 3B was the analysis of preservice science teachers' the first and the second of their lesson plans according to the integration of simulations in their lessons. Then how they integrated simulation in their asynchronous teaching video was analysed. The analysis of lesson plans and teaching videos revealed following categories; *the phase of 5E instructional model where the simulations were integrated, introduction of simulations*, and *simulation-enhanced inquiry-based science education.* Preliminary findings related to simulation-enhanced science lesson revealed that 4 preservice science teachers, Aylin, Ceren, Gizem and Hilal, did not include simulations in their first lesson plans. However, all the preservice science teachers included simulations in the second lesson plans. Table 5.11 demonstrates preservice science teachers' simulation integration of lesson plans and teaching videos.

Table 5.11. Simulation integration into 1st lesson plan, 2nd lesson plan, and teaching video.

Simulation Criteria	Phase of 5E Instructional Model			Introduction of Simulations			Simulation-enhanced Inquiry		
Student	1^{st} LP	2^{nd} LP	Teaching Video	1^{st} LP	2^{nd} LP	Teaching Video	1^{st} LP	2^{nd} LP	Teaching Video
Aylin	-	Explore Explain	Explain	-	Yes	No	-	Yes	Yes
Buse	Explore	Explore Explain	Explore, Explain	Yes	yes	Yes	No	Yes	Yes
Ceren	-	Explore Explain	Explore, Explain	-	Yes	Yes	-	Yes	Yes
Deniz	Elaborate	Explore Explain	Explore, Explain	No	No	No	No	No	No
Ezgi	Explore	Explore Explain	Explore, Explain	No	Yes	Yes	No	No	No
Ferah	Explore Explain	Explore Explain	Explore, Explain	Yes	Yes	Yes	Yes	Yes	Yes
Gizem	-	Explore Explain	Explore, Explain	-	Yes	Yes	-	Yes	Yes
Hilal	-	Explore Explain	Explain	-	No	No	-	No	No
Işıl	Explore Explain	Explore Explain	Explore, Explain	Yes	Yes	Yes	Yes	Yes	Yes
Jale	Explain	Explore Explain	Explore, Explain	yes	yes	yes	No	Yes	Yes

The first category was *the phase of 5E instructional model where the simulations was integrated.* In the first of lesson plans, six preservice science teachers used simulations. While two of them, Işıl and Ferah, used simulation in both exploration and explanation stages, two of them, Buse and Ezgi, used only in exploration stage, one of them, Jale, used only in explanation stage, and one of them, Deniz, used only in elaboration stage. On the other hand, in the second lesson plans all preservice science teachers used simulations in both exploration and explanation stages. Even though preservice science teachers recorded second lesson plans as a teaching video, analysis of teaching videos revealed that Aylin and Hilal only used simulations to explain.

The second category *was Introduction of simulations.* In the first lesson plans, four preservice science teachers introduced simulation environment before using it to

the students while two of them, Deniz and Ezgi, did not introduce. In the second lesson plans, eight preservice science teachers introduced simulation environment to the students however, Deniz and Hilal did not introduce. These two preservice science teachers also did not introduce simulation environment to students at teaching videos. In addition to that, even though Aylin's second lesson plan stated that she will introduce simulation to students, in her teaching video she did not introduce. Example quotations demonstrate how preservice science teachers introduced simulations in their lesson plans and teaching videos;

> In the simulation application, I demonstrated what were the variables and gave time to get to know the environment. (Buse, 1st lesson plan, introduction)

> The respiratory system simulation link ..... was given to the students demonstrated to the students to observe changes in lung during breathing. (Ezgi, 1^{st} lesson plan, did not introduce)

> The variables in the simulation are introduced to the students and it is asked to observe the changes. (Ezgi, 2^{nd} lesson plan, introduce)

> Let's get to know simulation environment. On the left side you will see pH scale. On the top you can change matter that you would like to see it's pH. Let me show you an example. (Jale, teaching video, introduce)

The third theme was; simulation-enhanced inquiry-based science education. In the first lesson plans only Işıl and Ferah used simulation-enhanced inquiry-based science education. In the second lesson plans, seven preservice science teachers used simulation-enhanced inquiry-based science education however three of them, Deniz, Ezgi, and Hilal did not use simulations-enhanced inquiry-based science education. These three preservice science teachers still did not use simulation-enhanced inquiry-based science education on their teaching videos. Example quotations demonstrate how preservice science teachers used simulation-enhanced inquiry-based in their lesson plans;

> It is asked students to "Which electrical device in your home consume the most energy?" and students write their predictions. Then they see which device consumes how much energy in the given simulation link ... Then they compare their predictions. (Ferah, 1^{st} of lesson plan, simulation-enhanced inquiry-based)

> It is asked to collect data by simulation to explore for an answer to the question "What is the effect of increased food on rabbits?" ... Students test their hypothesis by using simulation. (Gizem, 2^{nd} of lesson plan, simulation-enhanced inquiry-based)

5.3.3. Analysis of Progression on Designing Science Lesson for Asynchronous Learning Environments

Research question 3C was "How are preservice science teachers' progression on designing science lesson for asynchronous learning environments?". The first analysis performed for the research question 3C was the analysis of the first and the second of preservice science teachers' lesson plans with respect to the asynchronous learning environments. Accordingly, their asynchronous teaching video was analysed. Preliminary findings related to science lesson for asynchronous learning environments revealed that 5 preservice science teachers, Aylin, Ceren, Ferah, Gizem and Hilal, did not plan their lessons for asynchronous learning environments in their first of lesson plans. In the post interviews, all of them said that they did not prepare 1^{st} of lesson plans according to the asynchronous learning environments because they did not know. They also stated during the module. In second of lesson plans while nine preservice science teachers planned their lesson plans for asynchronous learning environments, Hilal still did not plan her lesson plans for asynchronous learning environments. It was understood their 2^{nd} of lesson plans.

An asynchronous lesson evaluation rubric had eighteen questions with 3-point scale. The lowest point can be gained is zero and the highest point can be gained is fifty-one. The rubric had three dimensions which are *asynchronous lesson, simulation, and inquiry.* At first, Table 5.12 demonstrates preservice science teachers' scores for asynchronous dimension.

Table 5.12. Scores for Inquiry, Simulation, and Asynchronous Dimensions for 1^{st} lesson plans, 2^{nd} lesson plans, and teaching videos.

Asynchronous	Inquiry			Simulation			Asynchronous		
Student	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the video	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the video	Score in the 1^{st} LP	Score in the 2^{nd} LP	Score in the video
Aylin	2	5	9	0	3	7	7	14	20
Buse	3	10	11	2	14	13	10	22	20
Ceren	1	4	14	0	3	13	8	16	21
Deniz	1	3	9	1	3	8	10	13	22
Ezgi	2	5	9	4	4	7	10	14	18
Ferah	4	10	10	2	9	10	10	17	23
Gizem	2	5	13	0	4	10	8	12	16
Hilal	0	3	4	0	1	6	4	8	13
Işıl	3	9	11	4	10	5	11	19	19
Jale	3	9	14	2	8	13	10	21	19
Average	2.1	6.3	10.4	1.5	5.9	9.2	8.8	14.1	19.1

For inquiry and simulation themes, there were five questions for each; the maximum point was twenty-four for these dimensions. However, there were eight questions for asynchronous dimension and the maximum point for this dimension was twenty-four. As seen in the Table 5.12; neither of lesson plans nor teaching videos got the highest point from any dimension. In addition to that, for all dimensions average scores of 1^{st} lesson plans lower than average scores of 2^{nd} lesson plans. Although preservice science teachers recorded their 2^{nd} lesson plans, average of teaching video scores were higher than average of 2^{nd} lesson plan scores. Also, none of the preservice science teachers got full points from any dimension. Following paragraphs identifies deeper analysis for each dimension.

The first dimension was *inquiry* for asynchronous theme. For *inquiry* dimension whether inquiry-based science education was appropriate to asynchronous learning environments was investigated. For inquiry dimension, there were five questions related to inquiry, and the maximum point was fifteen. Table 5.12. demonstrates each preservice science teachers' integration of inquiry in their first and second lesson plans. The average score of first lesson plans was 2,1 whereas the average score of second

lesson plans was 6,3 and average scores of teaching videos was 10,4. As seen in Table 5.12 none of the preservice science teachers got full points on this dimension. In addition, comparison of first and second lesson plans revealed that, while Hilal's first of lesson plan gained zero point, Buse's and Ferah's second of lesson plans gained the highest points with ten points. Ferah's first of lesson plan has the highest score with four points within the first lesson plans. Comparison of the first and the second of lesson plans revealed that Buse's lesson plan has the most increase with seven points, whereas Deniz's lesson plan has the least increase with two points. In addition to that, all preservice science teachers' teaching video scores on inquiry dimension was higher than their lesson plan scores. A remarkable difference was observed in Ceren's second lesson plan and teaching video score. Ceren's second lesson plan score was four however her teaching video score was fourteen. Ceren and Jale had the highest scores on teaching videos with fourteen whereas Hilal's teaching video score was the lowest with four-points.

The second dimension was *simulation* for asynchronous theme. For the *simulation* dimension, the integration of the simulation into asynchronous learning environments was investigated. In the rubric, there were five questions related to *simulation* dimension, and the maximum point was fifteen. Table 5.12. demonstrates that each preservice science teachers' score of first lesson plan, second lesson plan, and teaching video for simulation dimension. Firstly, none of the preservice science teachers got full points (fifteen) from neither lesson plans nor teaching videos. The average score of first lesson plans was 1,5 whereas the average score of second lesson plans was 5,9 and average scores of teaching videos was 9,2. As stated above, since Aylin, Ceren, Gizem and Hilal did not know simulations, they did not use simulations in their first lesson plans. For this reason, they also got zero point for this dimension. Işıl's first lesson plan has the highest score with four points within the first lesson plans. On the other hand, Buse's second lesson plan had the highest score with eleven points within the second lesson plans. Comparison of the first and the second of lesson plans revealed that Buse's lesson plan had the most increase with nine points. However, Ezgi's score for the integration of simulation into her lesson plan did not change therefore she got four points for both the first and the second of her lesson plans. Also, Hilal's simulation

score from first lesson plan to second lesson plan was increased 1-point which is the lowest increase score.

Furthermore, as seen in the Table 5.12; Buse, Ceren and Jale got the highest score on teaching video with thirteen whereas Işıl got the lowest score with five. Comparison of scores of second lesson plans and teaching videos identified that Buse's and Işıl's teaching video scores was lower than second lesson plan score. On the contrary, Ceren's score from second lesson plan to teaching video had the highest increase with ten-points.

The third and the last observed category was *asynchronous*. In the rubric, there were eight questions related to *asynchronous* dimension, and the maximum point was twenty-four. Table 5.12 demonstrates that each preservice science teachers' score of first lesson plan, second lesson plan, and teaching video for *asynchronous* dimension. None of the preservice science teachers got full points from neither lesson plans nor teaching videos. The average score of first lesson plans was 8,8 whereas the average score of second lesson plans was 14,1 and average scores of teaching videos was 19,1. As seen in the Table 5.12, all preservice science teachers' scores of second lesson plans were higher than the scores they had in their first lesson plans. When looking separately to each preservice science teachers' first and second lesson plan scores, it revealed that Hilal's first lesson plan gained the lowest score with four points, Buse's second lesson plan gained the highest point with twenty-two points. Comparison of the first and the second lesson plans revealed that Buse's lesson plan had the most increase with twelve points, whereas Deniz's lesson plan had the least increase with three points. In addition to that, analysis of teaching videos identified that Ferah gained the highest score with twenty-three and Hilal got the lowest score with thirteen. Also, comparison of scores of second lesson plan and teaching videos revealed that except from Buse and Işıl, other preservice science teachers' scores of second lesson plans were higher than the scores they obtained in their teaching video. Deniz's teaching video had the highest increase with nine-points compared to her second lesson plan score. Following Table 5.13 demonstrates average scores of first and second lesson plans and teaching videos with concrete examples from them.

For *inquiry* dimension of the rubric, whether writing a research question and data usage appropriate for asynchronous learning environments or not was analysed. In the first lesson plans, only three preservice science teachers (Aylin, Ferah, and Işıl) referred research question and data. On the contrary, in the second lesson plans, except from Deniz and Hilal, eight preservice science teachers referred research question and data. In the teaching videos, only Hilal did not refer research question or data, other preservice science teachers applied inquiry-based science education.

For *simulation* dimension of the rubric, a considerable transition in the lesson plans was the purpose of simulation transformed from explanation to exploration. While four preservice science teachers (Buse, Deniz, Ezgi, Ferah, and Jale) used simulations to explain, only Işıl used simulations to explore in the first lesson plans. In the second lesson plans, seven preservice science teachers used simulations to explore whereas three of them (Deniz, Ezgi, and Hilal) used simulations to explain. Also, except from Ezgi, Hilal, and Işıl, all preservice science teachers introduce simulation environment to students.

For *asynchronous* dimension of the rubric, *learning, communication, assessment*, and *resources and technics* categories revealed. However, *resources* and *technics* categories did not observe in neither 1^{st} nor 2^{nd} lesson plans. These two categories were only seen on the teaching videos.

Table 5.13. Average scores of first and second lesson plans and teaching videos.

Asynchronous	Average score in the 1st LP	Example from the 1st LP	Average score in the 2nd LP	Example from the 2nd LP	Average Score in Teaching Video	Example from the Teaching Video
Inquiry	2,1	Today we will learn types of bones. Do you know "how many bones you have?" (Hilal, zero-point)	6,3	It is asked to collect data by simulation to explore for an answer to the question "What is the effect of increased food on rabbits?" (Gizem, 2-points	10,4	We will now collect data by simulation to observe our first research question, Let's observe how the number of rabbits will change. (Gizem, 3-points).
Simulations	1,5	Now I want you to click on the link and observe how we see colours, what are primary colours and then how secondary colours formed (Işıl,2-points). By Algodoo, a video is shouted for how to reduce effort. This video will share with students to teach how to reduce effort ins simple machines. (Jale, 1-point)	5,9	The teacher demonstrates the simulation for volume and mass relationship then explain this relationship with simulation and want students to take notes on notebooks. (Aylin,1-point) With the simulation, the pH of different substances is measured, and it is aimed to explore whether these substances are acid or base. (Jale, 3-points	9,2	Let's start the simulation by pressing intro. What do you see? As you see, there are rabbits and food around. You can reduce food by pressing the limited food button. Please write your observations. Let's wait a while? What did you observe? Continue to take notes. (Buse, 3-point)
Asynchronous	8,8	In the asynchronous learning environments, first the teacher greets the students and introduces today's topic as destructive natural events. (Deniz, 1-point)	14,1	The teacher greets the students and introduces today's subject. The teacher asks students to briefly comment on what they know about matter and think about what a particle is. Students can write their ideas on their science notebooks. (Deniz, 2-points)	19,1	Hello guys! We will learn the particulate nature of matter. But before we starting to the subject, I want you to write down the phase changes you have already known and write what you think about the particulate structure. (Deniz, 2-points)

The first category of asynchronous theme was *learning*. In both first and second lesson plans and teaching videos these categories observed. In the lesson plans, learning goals and objectives were written and shared with students at the very beginning of the preservice science teachers' lesson plans. In addition, in the very beginning of teaching videos all preservice science teachers stated what students were going to learn from the video. The second category was *communication*. In the first lesson plans, there is no mention of *communication* category for asynchronous learning environments. However, in the second lesson plans, three preservice teachers (Buse, Ferah, and Jale) created a virtual classroom to communicate with students. Figure 5.5 demonstrated that how Buse added an example screenshot from her virtual classroom at the second of lesson plan.

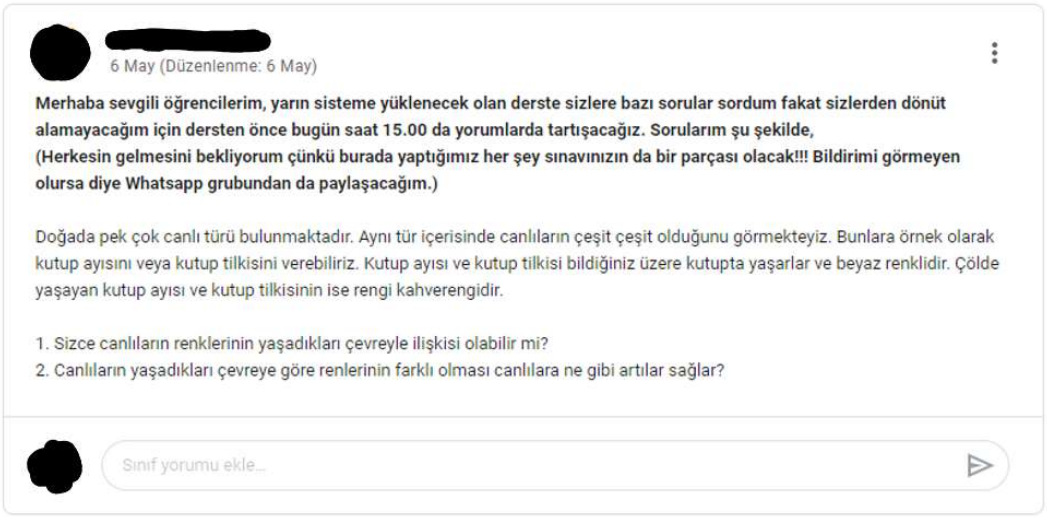


Figure 5.5. An Example Screenshot from Virtual Classroom from Buse's Second of Lesson Plan..

As seen in the Figure 5.5. Buse added an example screenshot to her lesson plan to demonstrate how she planned to interact with students. Likewise in her teaching video she said, "*When I ask a question in this teaching video, I want you to pause the video and write your answers on the discussion panel in our virtual classroom*". to interact with students. This was also an example for hybrid learning environments where asynchronous and synchronous used together.

The third category was *assessment* for asynchronous theme. All preservice science teachers' first lesson plans focused on summative assessment for the evaluation stage of 5E instructional model. As formative assessment, only two preservice science teachers, Gizem and Ferah, used formative assessment strategies in the first lesson plans. Both used worksheets as a formative assessment tool. In addition, in the second lesson plans, except from Deniz and Hilal, all preservice science teachers used formative assessment strategies such as worksheet, questions, or virtual discussions, too. Similarly for teaching videos, while Deniz and Hilal only used summative assessment such as quizzes, other preservice science teachers used both formative and summative assessment. Example quotations from formative and summative assessment strategies from lesson plans and how they are state formative and summative assessment strategies in their teaching videos.

> Please fill the worksheet through the lesson and send it to me at the end of the lesson (Gizem, formative assessment, 1st lesson plan)

> The following questions are posted to students and wanted them to solve. (Deniz, summative assessment first and 2nd lesson plan)

> Please do the evaluation activities below. (Işıl, summative assessment, 1st lesson plan) I would like you to do the activity through the lesson. At the end of the lesson please send it to me. (Işıl, formative assessment, 2nd lesson plan)

> "What is the relationship between light and colors coming into objects?" I want you to write your hypotheses for this question and other questions in your worksheet. Now I will answer some questions with simulation. Then you pause the video and try to do it yourself. Write the results you find. Don't forget to send it to me at the end of the lesson. (Işıl,teaching video, formative assessment)

> I want to solve some questions. [.....] "What is the name of the substances that give hydroxide ions when they dissolved in water?" [.....] Did you write the answers? What was it? Base. Next question. (Hilal, summative assessment, teaching video)

The fourth category was *resources* for asynchronous theme. This category was only seen in teaching videos. All preservice science teachers used Microsoft Teams

program to videotape their lessons. In addition, Aylin also used EIN (Education Information Network) platform. For this category there was not example quotation from teaching videos. The fifth category was *technics* for asynchronous theme. This category was only seen in teaching videos. All preservice science teachers edited their teaching videos before they uploaded. Since the last two categories cannot be demonstrated by concrete examples, there were no direct quotations or screenshots for this category.

The last but not the least findings related to research question 3C is total scores for designing a simulation-enhanced inquiry-based science lesson for asynchronous learning environments. Figure 5.6 identifies total scores of preservice teachers obtained for the asynchronous learning environments rubric.

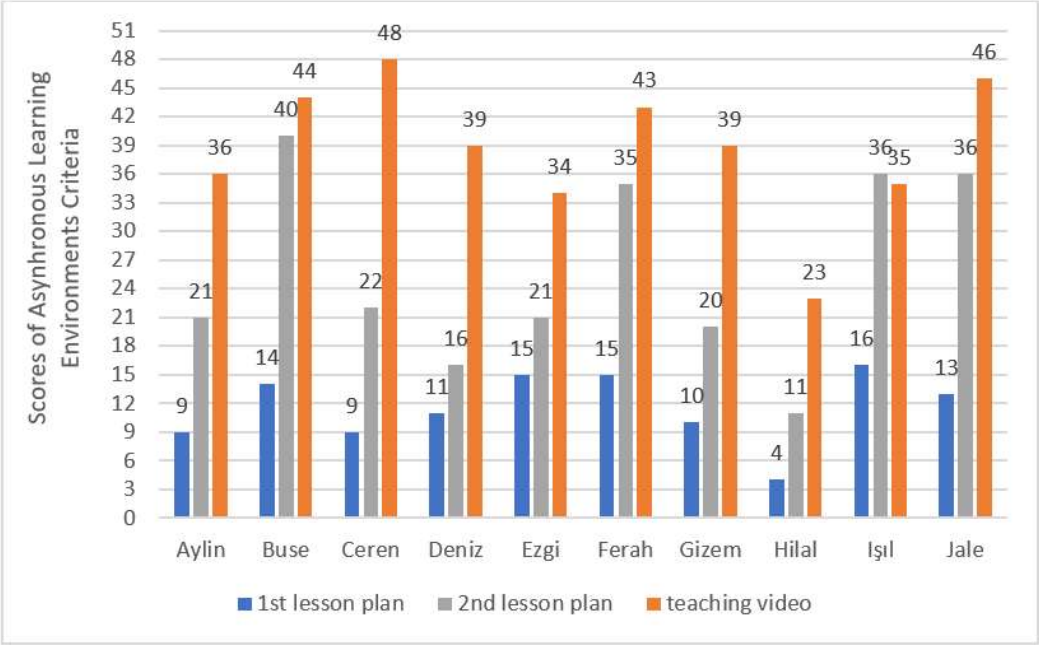


Figure 5.6. Total scores of preservice teachers obtained for the asynchronous learning environments.

It can be referred from Figure 5.6 was that the average score for 1^{st} lesson plans were11,6 whereas the average score for 2^{nd} lesson plans were 25,8 and the average score for teaching videos were 38,7. The first remarkable change that can be deduced from Figure 5.6 was that all preservice science teachers' second lesson plans gained higher score than the first of lesson plans on asynchronous learning environments. While Deniz

had the least increase with 5 points, Buse had the most increase with 26 points in total. In addition, Işıl had the highest point on the first of her lesson plan whereas Buse had the highest point on the second of her lesson plan. In addition, Hilal had the lowest point both the first and the second of her lesson plans according to the asynchronous learning environments criteria. On the other hand, Ceren's teaching video gained the highest score on the rubric with forty-eight points whereas Hilal's video gained the lowest score with twenty-three points. Except from Işıl, all preservice science teachers' teaching video scores were higher than their second lesson plans.

All in all, the first remarkable fact that can be deduced from this research question was that preservice science teachers' second lesson plans gained higher scores compared to the first lesson plans for all dimensions which means that preservice science teachers improve their lesson plans according to inquiry-based science education, simulations, and asynchronous learning environments. As stated above, some preservice science teachers did not use inquiry-based science education, simulation, or asynchronous learning environments in their lesson plans. However, they used all of these in their second lesson plans. In addition, teaching videos demonstrated how preservice science teachers recorded their lessons for students. All of teaching videos also had inquiry-based science education, simulation, and asynchronous learning environments dimension. Also, eight preservice science teachers' teaching video got higher score compared to first and second of lesson plans.

5.4. Analysis of the Strengthens and Limitations of Designing Simulation-enhanced Inquiry-based Lesson for Asynchronous Learning Environments

Research question 4 was "What are the strengthens and limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments?". This research question aims to explore strengthens and limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments. The analysis of lesson design was explored in two stages; *a lesson plan* design and *a teaching video*. For both a lesson plan and a teaching video it was asked preservice science teachers

to explain advantages and limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments.

5.4.1. Analysis of Strengthens of Designing Simulation-Enhanced Inquiry-based Lesson for Asynchronous Learning Environments

The first analysis conducted for the research question 4a was the analysis of strengthens of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments. In the first stage preservice science teachers' explanations of a lesson plan were analyzed. From the transcripts of 10 post-interviews', a total of 21 statements revealed 7 codes which were classified into 4 categories which were features of *lesson plan, inquiry, simulation, and asynchronous environment* explained and exemplified in Table 5.14.

Table 5.14. Categories and codes identified in preservice science teachers' descriptions about strengthens of designing simulation-enhanced inquiry-based lesson plan for asynchronous learning environments.

Category	Code	Frequency in Post-Descriptions	Example Quote
Features of Lesson Plan	More structured lesson plans	5	It was more structured compared to face-to-face lessons (Ezgi)
	Giving clear instructions	2	I tried to explain that every student can understand. I also wrote everything I said on the screen. (Ferah)
Features of Inquiry	Giving research questions	4	I prepared and gave research question to the students (Buse)
	Data collection and analysis	4	Data collection and analysis through simulation (Işıl)
Features of Simulation	Observation of hypothetical situations	3	Students observed different situations through simulation (Jale)
Features of Asynchronous	Creating virtual classroom	3	I created virtual classroom for the lesson (Ferah)

The data analysis showed that preservice science teachers' descriptions about strengthens of designing simulation-enhanced inquiry-based lesson plan for asynchronous learning environments focused all three focused of SIMINA Module which were *inquiry, simulation*, and *asynchronous lesson plan.* While most of the statements were found in *inquiry*, with eight statements, seven statements were related to the *lesson plan*, and six statements were related to the *asynchronous learning environments.*

In the second stage, preservice science teachers' explanations of a teaching video were analyzed. Out of ten post-interviews' transcripts, a total of 21 statements revealed 8 codes which were classified into 3 categories: features of *inquiry, simulation*, and *asynchronous learning environments* explained and exemplified in Table 5.15.

Table 5.15. Categories and codes identified in preservice science teachers' descriptions about strengthens of designing simulation-enhanced inquiry-based teaching video for asynchronous learning environments.

Category	Code	Frequency in Post-Descriptions	Example Quote
Features of Inquiry	Data collection and analysis	3	I want students to observe their breathing to count how many times (Ezgi)
Features of Simulation	Multiple representations	4	Enriching the video through text, image, and simulation (Jale)
	Students use simulations	2	I gave the simulation link to students use on their own (Buse)
	Observation of hypothetical situations	2	Students may observe or explore many different situations (Buse)
Features of Asynchronous	Individualized learning	4	Students can watch until they learn (Gizem)
	No time and place restrictions	3	They can watch my lesson whatever they want (Jale)
	Fewer social obstacles	2	They can focus easily, there are no distractions (Ceren)
	Seeing the teacher and the screen simultaneously	1	They see me and my screen at the same time (Ezgi)

Preservice science teachers' descriptions about strengthens of designing simulation-enhanced inquiry-based teaching video for asynchronous learning environments were found to focus all three aspects of SIMINA Module which were *inquiry, simulation*, and *asynchronous learning environment*. While the most statements found in *asynchronous learning environments* with ten statements, eight statements were related to *simulation*, and three statements were related to inquiry.

5.4.2. Analysis of Limitations of Designing Simulation-enhanced Inquiry-based Lesson for Asynchronous Learning Environments

The first analysis conducted for the research question 4b was the analysis of limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments. In the first stage, preservice science teachers' explanations of a lesson plan were analyzed. out of 10 transcribed post-interviews, a total of 13 significant statements revealed 5 significant codes which were classified into 3 categories: *lesson plan, asynchronous learning environments* and *teacher related issues*, as demonstrated and explained in Table 5.16.

Table 5.16. Categories and codes identified in preservice science teachers' descriptions about limitations of designing simulation-enhanced inquiry-based lesson plan for asynchronous learning environments.

Category	Code	Frequency in Post-Descriptions	Example Quote
Lesson Plan Related	Teacher-centered	4	My lesson plans were teacher centered (Deniz)
	No formative assessment	3	I did not assess their understanding during the lesson (Işıl)
Asynchronous Related	Lack of interactivity	4	Exploration and explanation was hard because I didn't get answer to my questions (Hilal)
Preservice Teacher Related	Inability to use simulations	4	I did not activate simulation on my c omputer, therefore I only show it (Aylin)

The analysis of data revealed that preservice science teachers' descriptions about strengthens of designing simulation-enhanced inquiry-based lesson plan for asynchronous learning environments focused only asynchronous part of the SIMINA module. According to their statements, other two limitations were related to *lesson plan and teacher related issues*. Specifically, while 7 statements were related to the lesson plan, 4 statements were related to the *asynchronous learning environments*, and 4 statements were related to the *teacher related issues herself*.

In the second stage, preservice science teachers' explanations of a teaching video were analyzed. Out of 10 transcribed post-interviews, a total of 27 statements revealed 5 codes which were *asynchronous learning environments*, and *preservice teacher related issues* related classified into 2 categories as shown in Table 5.17.

Table 5.17. Categories and codes identified in preservice science teachers' descriptions about limitations of designing simulation-enhanced inquiry-based teaching video for asynchronous learning environments.

Category	Code	Frequency in Post-Descriptions	Example Quote
Asynchronous learning environments	Teacher-centered video	8	I asked and I answered, only I talked (Aylin)
	Lack of interactivity	7	I did not interact with students (Işıl)
Preservice Teacher Related Issues	Lack of knowledge about technology	6	I am not technology-literate, I had difficult in using camera (Ceren)
	Word mistakes, slip of tongue, diction	4	I stopped and recorded so many times. It was hard to speak fluently (Buse)
	Lack of whiteboard at home	2	I don't have whiteboard at home (Gizem)

Based on data analysis, it was observed that preservice science teachers' descriptions about strengths of designing a simulation-enhanced inquiry-based lesson plan for asynchronous learning environments focused only asynchronous part of the SIMINA module. According to their statements, the other limitations were related to the preservice teacher. In addition, while 15 statements are related to *asynchronous learning environments*, 12 statement related to *preservice teacher herself.*

5.5. Analysis of Instructor Feedbacks, Peer Feedbacks and Reflections

Research question 5 was "How do preservice science teachers reflect on feedback while they are progress their lesson?". This research question aims to explore preservice science teachers' feedbacks and reflections while they progress their lessons. The analyses of feedbacks analzyed in two stages; *feedback from the instructor* and *feedback from a peer*. For both instructor feedbacks and peer feedbacks, it was asked preservice science teachers to describe their effectiveness as they progress their lesson. Preservice science teachers either explained how instructor or peer feedbacks were effective for progress their lesson or why instructor or peer feedbacks were not effective for progress their lesson. Furthermore, analyses of reflections explored in four stages; reflection on asynchronous part of the lesson plan, reflection on inquiry-based science education part of the lesson plan, reflection on simulation part of the lesson plan, and reflection on teaching video.

5.5.1. Analysis of Feedback from the Instructor

The first analysis conducted for the research question 5A is the analysis of the instructor feedback. The instructor gave separate feedbacks to asynchronous, inquiry, and simulation components to the lesson plan and gave feedback to the teaching video. From 10 verbatim post-interview transcripts, preservice science teachers' descriptions about each of the instructor feedback were analyzed. In the first stage, preservice science teachers' statements about each of the instructor feedback's effectiveness were classified as, effective, not effective, and not remember the feedback as shown in Figure 5.7.

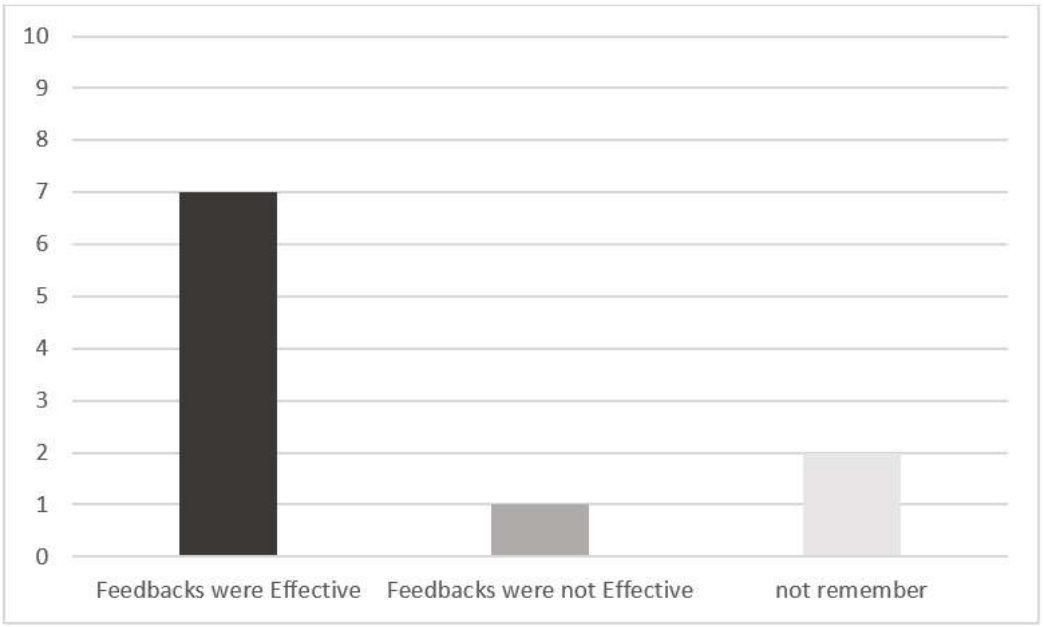


Figure 5.7. Effectiveness of the Instructor Feedback.

Then, preservice science teachers' explanation about statements how instructor feedback was effective or why instructor feedback was not effective obtained from post-descriptions. From a total of 24 statements, 8 codes revealed and were classified into 3 categories: *reflectiveness, timing, and content* presented in Table 5.18.

Preservice science teachers' descriptions of how instructor feedback was effective had three categories which *reflectiveness, timing, and content.* Most of the statements found in *reflectiveness* category with nine statements, eight statements found in *content* category, and four statements found in timing category. Preservice science teachers' descriptions of why instructor feedback was not effective had two categories which *reflectiveness* and *timing.* While two statements found in *reflectiveness* category, one statement found in *timing* category.

Table 5.18. Categories and codes identified in preservice science teachers' descriptions of how instructor feedback was effective or why instructor feedback was not effective obtained from post-descriptions.

Statement	Category	Code	Frequency in Post-Descriptions	Example Quote
How instructor feedback was effective	Reflectiveness	Drive to think differently about assignment	7	I judged my own work. You said for example, while using simulations what students should pay attention to. Then I thought again. (Ezgi)
		Enhances viewpoint	2	In my first draft of lesson plan, I didn't do anything about interacting with students in an asynchronous environment, with your feedback, I realized this. (Işıl)
	Timing	Immediate	4	You send feedback right after the lesson, it was good. (Gizem)
	Content	Shows strengthens and weaknesses	3	You both wrote good and bad things about my lesson plan. (Ezgi)
		Detailed and specific	3	You thought of every single detail and wrote it to us. (Ferah)
		Giving guidance or clue	2	Because you asked questions and gave hints, which helped me think and decide. (Aylin)
Why instructor feedback was not effective	Reflectiveness	Lack of knowledge what to do	2	You want me to think about my research questions, but I cannot think of new ideas. (Buse)
	Timing	Late	1	Because I already shoot my video and send it to you. (Işıl)

5.5.2. Analysis of Feedback from the Peer

The first analysis conducted for the research question 5B was the analysis of the peer feedback. Peers gave separate feedbacks to *asynchronous learning environment, inquiry*, and *simulation* components to the lesson plan and gave feedback to the teaching video. From 10 verbatim post-interview transcripts, preservice science teachers'

descriptions about each of the peer feedback were analyzed. In the first stage, preservice science teachers' statements about each of the peer feedback's effectiveness were classified as: *effective, not effective*, and *not remember* the feedback as shown in Figure 5.8.

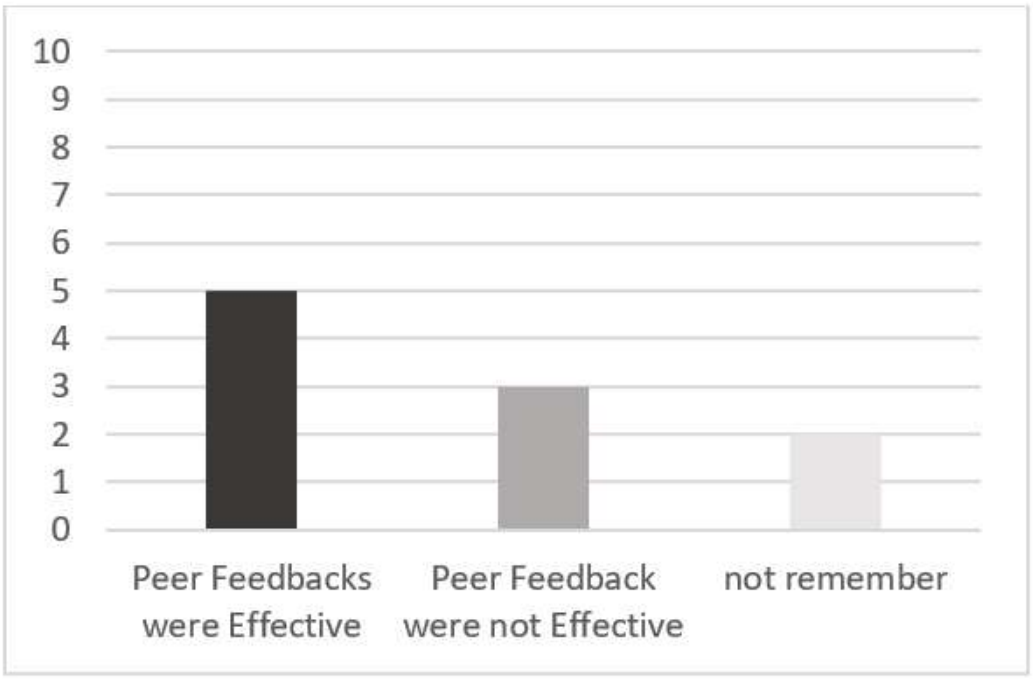


Figure 5.8. Effectiveness of the Peer Feedback.

Then, preservice science teachers' explanation about statements how peer feedback was effective or why peer feedback was not effective obtained from post-descriptions. From a total of 14 statements, 7 codes revealed which were classified into 4 categories: *reflectiveness, content, timing*, and accuracy, as presented in Table 5.19.

Table 5.19. Categories and codes identified in preservice science teachers' descriptions of how peer feedback was effective or why peer feedback was not effective obtained from post-descriptions.

Statement	Category	Code	Frequency in Post-Descriptions	Example Quote
How peer feedback was effective	reflectiveness	Enhances viewpoint	1	She (peer) made me realize things I couldn't. (Ceren)
	content	Giving guidance or example	3	She (peer) was said you did not write a research question, then gave me an example research question. (Hilal)
	timing	Immediate	2	It was good that you and she wrote it separately for each part and feedbacks was on time for each of them (Aylin)
Why peer feedback was not effective	accuracy	Not agree with the feedback	3	She (peer) said this is not inquiry-based. But I can't do what she said in asynchronous (Deniz)
	Content	Positive	2	Did she not see a negative thing or did she not want to criticize me? She didn't say anything that I would correct. (Jale)
		General	1	She said this lesson plan was not appropriate for asynchronous, so how did not appropriate, which part did not appropriate? (Ceren)
	Timing	Late	2	She always send me late. (Jale)

Preservice science teachers' descriptions of how peer feedback was effective had three categories which were *reflectiveness, content, and timing.* Compared to *reflectiveness* category, there were more statements found in *content* and *timing* categories. *Reflectiveness* category had only one statement which focused on how feedbacks enhanced a preservice science teacher's viewpoint. Preservice science teachers' descriptions of why peer feedback was not effective had three categories which *accuracy, content*, and *timing.* While three statements found in *accuracy* category, two statements found in content category and two statements found in *timing* category.

5.5.3. Analysis of Reflections

The analysis conducted for the research question 5C was the analysis of reflections. Preservice science teachers wrote separate reflections for *asynchronous lesson, inquiry-based science education*, and *simulation* components of their lesson plans and the teaching videos. In other words, each preservice science teachers wrote 4 reflections. These reflections were read, reread, and coded according to Oner and Adadan's (2011) reflective thinking indicators (see Table 4.2). They were grouped into two categories: high-level thinking indicators consisting of Claim-evidence (C-E), Reflection-in-action (RNA), Recognizing and stating discrepancies (RECD), and Reflection-on-action (ROA), whereas low-level thinking indicators including Goal-experience discrepancy (GED) and Describing experience (DE). To confirm the inter-rater reliability for the coding, 2 randomly selected reflections from each theme (asynchronous lesson, inquiry-based science education, and simulation and the teaching videos), a total 8 reflections, were sent to a science education expert. The inter-rater reliability for the coding of reflections was found to be 85.0%, based on Miles and Huberman's (1994) formula for qualitative research. Following paragraphs represent the distribution of reflective thinking indicators for each theme.

5.5.3.1. Analysis of Reflections for Asynchronous Lesson Environments. The first theme determined in the reflections was the asynchronous learning environments. Firstly, preservice science teachers wrote one reflection for asynchronous learning environments. Table 5.20 represents the distribution of each preservice science teachers' reflective thinking indicators with example quotation.

Table 5.20. Distribution of each preservice science teachers' reflective thinking indicators for the theme asynchronous learning environments with sample quote.

Reflective Thinking Indicators (RTI)		Students who have the RTI	Example quote
High-level of Reflective Thinking Indicators	C-E	Buse, Ezgi, Ferah, Gizem, and Işıl	I thought that the learning process should base on interaction. I thought about how I can interact in the asynchronous learning environments. I created virtual classroom and added discussion forums there. That way I can interact with students (Jale)
	RNA	-	-
	RECD	-	-
	ROA	Ferah and Işıl	I did not know the difference between synchronous and asynchronous. For this reason, students work collaboratively. However, I know what is asynchronous now. I changed my activity design (Ferah)
	Total	7	
Low-level Thinking Indicators	GED	Aylin, Buse, Ceren, Hilal, and Jale	I wanted students to take notes during whole class. However, I do not believe it is realistic. (Aylin)
	DE	Aylin, Ceren, Deniz, Ezgi, Ferah, Gizem, and Jale	Before the class I sent pre-test to test students' prior knowledge and possible misconceptions. (Ezgi)
	Total	12	

As seen in the Table 5.20, a total of 19 reflective thinking indicators were determined in each preservice science teachers' reflections on asynchronous learning environments and each preservice science teacher had at least one reflective thinking indicator. From a total of 19 reflective thinking indicators; twelve of them were at low-level (GED and DE) and seven of them were at high-level (C-E and ROA). Aylin and Işıl had only high-level reflective thinking indicators, whereas Ceren, Deniz, Hilal and Jale only had low-level of reflective thinking indicators. Other preservice science teachers; Buse, Ezgi, Ferah, and Gizem had both low and high-level of reflective thinking indicators. There were no RNA (Reflection-on-action) and RECD (Recognizing and stating Discrepancies (RECD) indicators on asynchronous learning environments theme.

5.5.3.2. Analysis of Reflections for Inquiry-based Science Education. The second theme was the inquiry-based science education. Preservice science teachers wrote reflection for inquiry-based science education part of their lesson plan by considering feedbacks that they received from the instructor and a peer. indicates the distribution of each preservice science teachers' reflective thinking indicators for inquiry-based science education with example quotation.

Table 5.21. Distribution of Each Preservice Science Teachers' Reflective Thinking Indicators for the theme Inquiry-based Science Education with Example Quotations.

RTI		Students who have the RTI	Example quote
High-level of RTI	C-E	Buse, Ezgi, Ferah, Gizem, and Işıl	I learned that, if I would like to use inquiry-based science education, I should design student centered learning environment. For this reason, students collect their own data via simulations. (Buse)
	RNA	-	-
	RECD	Ferah	Throughout the process, I received feedback from the instructor and my feedback peer. I improved my lesson plan by considering these feedbacks and the module. For example, my first draft of lesson did not include researchable questions. Then you (the instructor) suggested to include "how" and "why" questions to collect data. It made sense to me and I prepared research questions so that students explore on their own. Then I wanted students to draw tables and graphs. Because I believe that their learning will be more permanent in this way (Ferah).
	ROA	Ferah and Işıl	I compared my first draft of lesson plan and our discussions during the class. Then I realized that there was no inquiry in my lesson plan. I will write research questions in order students to explore simple machines.
	Total	8	
Low-level of RTI	GED	Aylin, Buse, Ceren, Deniz, Hilal, and Jale	I had planned to prepare research questions with students. However, this lesson was asynchronous. Therefore, I gave already prepared questions to them (Deniz).
	DE	Aylin, Ceren, Deniz, Ezgi, Ferah, Gizem, and Jale	I gave questions to students, and I wanted them to solve it. (Hilal)
	Total	13	

As seen in the Table 5.21, a total of 21 reflective thinking indicators were found in each preservice science teachers' reflections on inquiry-based science education and

each preservice science teacher had at least one reflective thinking indicator. From a total of 21 reflective thinking indicators; thirteen of them were low-level (GED and DE) indicated by nine preservice science teachers and eight of them were high-level (C-E, RECD and ROA) indicated by five preservice science teachers. Işıl had only high-level reflective thinking indicators whereas Buse, Ceren, Deniz, and Hilal had only low-level of reflective thinking indicators. Other preservice science teachers; Aylin, Ezgi, Ferah, Gizem, and Jale had both low and high-level of reflective thinking indicators. There was no RNA (Reflection-on-action) indicator and RECD (recognizing and stating discrepancies) was firstly seen on inquiry-based science education theme.

5.5.3.3. Analysis of Reflections for Simulations. The third theme was the simulations. Preservice science teachers wrote reflection for simulation part of their lesson by considering the feedbacks they received from the instructor ans a peer. Table 5.22 indicates the distribution of each preservice science teachers' reflective thinking indicators for simulation with example quotation.

Table 5.22. Distribution of each preservice science teachers' reflective thinking indicators for the theme simulations.

RTI		Students who have the RTI	Example quote
High-level Thinking Indicators	C-E	Aylin, Ceren, Deniz, Ezgi, Ferah, Işıl, and Jale	I used simulations for inquiry. First, I deeply investigated the simulation and wrote my research questions according to the simulation. Then, students will collect data through simulation. I think this was the way for simulation-enhanced inquiry. (Ceren)
	RNA	-	-
	RECD	-	-
	ROA	Aylin, Ferah, Işıl and Jale	I would encourage students to use simulation on their own. If I did this way, students would explore on their own. With this way my lesson will become more student-centered. (Jale)
	Total	11	
Low-level Thinking Indicators	GED	Buse, Ezgi, Gizem, Işıl,	I used simulation to help them (students) better understand respiratory system organs and their working mechanisms. But this way was teacher-centered. I need to think and revise (my lesson plan) by including simulations in an asynchronous lesson. (Ezgi)
	DE	Buse, Ceren, Deniz, Ferah, Gizem, Hilal, Işıl, Jale	By using simulations, I aimed permanent learning. In addition to that when a student changed a variable, s/he instantly observes what happens. (Gizem)
	Total	12	

Analysis of Table 5.22 indicated that a total of 23 reflective thinking indicators were found in each preservice science teachers' reflections on simulation. Except Hilal, all the preservice science teacher had at least two reflective thinking indicators. From a total of 23 reflective thinking indicators; twelve of them were at low-level (GED and DE) and eleven of them were at high-level (C-E and ROA). Aylin had only high-level reflective thinking indicators, while Buse, Gizem and Hilal only had low-level of reflective thinking indicators. Other preservice science teachers; Ceren, Ezgi, Ferah, Işıl and Jale had both low and high-level of reflective thinking indicators.

Lastly, preservice science teachers' reflections for the teaching video were analyzed. They wrote this reflection after they received feedback from the instructor

and their peer for their teaching video. Table 5.23 demonstrates the distribution of each preservice science teachers' reflective thinking indicators for teaching video with example quotations.

Analysis of Table 5.23 indicated that a total of 26 reflective thinking indicators were found in each preservice science teachers' reflections on teaching video. While Hilal only had one reflective thinking indicator, others had at least two reflective thinking indicators. From a total of 26 reflective thinking indicators; twelve of them was low-level (GED and DE). and fourteen of them was high-level (C-E, RNA, and ROA). While Ferah had only high-level reflective thinking indicators with three, Hilal only had one low-level of reflective thinking indicator. Other preservice science teachers had both low and high-level of reflective thinking indicators. RNA (Reflection on action) was only seen in Aylin's reflection for teaching video.

In short, the total number of reflective thinking indicators increased from 19 to 26, as moving from the theme of asynchronous to the theme of teaching video. Following sub-section represents general analyses for total number of reflective thinking indicators.

Table 5.23. Distribution of each preservice science teachers' reflective thinking indicators for teaching video.

Thinking Indicators (TI)		Students who have the TI	Example quote
High-level Thinking Indicators	C-E	Aylin, Ceren, Deniz, Ezgi, Ferah, Gizem, Işıl, Jale	I can say that my teaching video was suitable to inquiry and asynchronous. After the part that students collected data, I wanted to explain all research questions to the students. With this way students can compare and discuss about their findings. I prepared an worksheet for it. (Jale)
	RNA	Aylin	I tried to speak more fluently with the sentences that I had planned beforehand, but I realized that I am acting, and it didn't look natural. Then, I ignored slip of my tongue and continued my lesson. So, I think the video is more natural and warmer for students (Aylin).
	RECD	Ferah	Before recording my teaching video, I reread all feedbacks that I took and notes that I took during our classes. I aimed to give all lesson notes to students. You said that students became audience. Then I realized that you were right. They must be participant. Iasked students to take notes, wrote questions for further. With this way they might participate my asynhronous lesson. (Ferah)
	ROA	Aylin, Buse, Ferah, Gizem, Işıl	I watched the video from the student's point of view before sending it to you (the instructor). To be honest, I realized it was a little boring. Asynchronous environments also need to be fun to gather students' attention. I should have put music or gif in the background, or I would prepare funnier presentation (Işıl).
	Total	15	
Low-level Thinking Indicators	GED	Buse, Işıl	I got excited in front of camera, and I had many slipped of tongues and slangs. Maybe I edited my videos however I am not comfortable in using technology. (Buse)
	DE	Aylin, Buse, Ceren, Deniz, Ezgi, Gizem, Hilal, Işıl, Jale	Even if I could not interact with the students at that moment, I stated that I wanted them to stop the video, when necessary, think and take notes in their notebooks to gather their attention. I also made an evaluation using web 2.0 tools. I aimed to follow all these interactions included in the classroom environment (Ezgi).
	Total	11	

5.5.3.4. General Analyses for Reflections. This section has three foci: the total number of high and low-level of reflective thinking indicators observed in each theme, total number of reflective thinking indicators and and each preservice science teachers' total number of high and low-level of reflective thinking indicators. Firstly, the total number of high and low-level of reflective thinking indicators was found for each theme and represented in Figure 5.9.

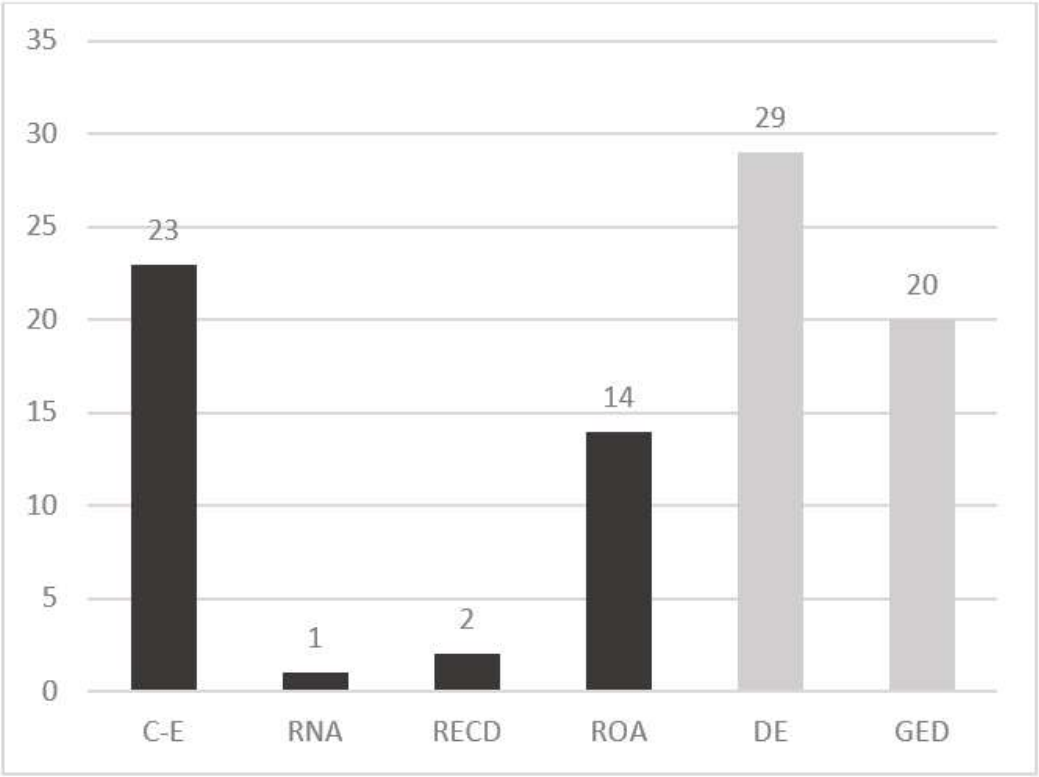


Figure 5.9. Distribution of Total High and Low-Level of Reflective Thinking Indicators Conveyed in the Reflections.

As seen in the Figure 5.9, in preservice science teachers' reflections there were both high (C-E, RNA, RECD, and ROA) and low (DE and GED) level reflective thinking indicators. There were more number of low-level of reflective thinking indicators compared to the number of high-level of reflective thinking indicators. In other words, while there were forty-nine low-level reflective thinking indicators, there were forty high-level reflective thinking indicators. In addition, a remarkable fact that can be deduced from Figure 5.9 is that there was only one indicator in both RNA (reflection-in-action) and RECD (recognizing discrepancies) which are high-level of reflective thinking indicators.

Then, each preservice science teacher's individualistic analysis conducted. Figure 5.10 indicates each preservice science teachers' total number of reflective thinking indicators.

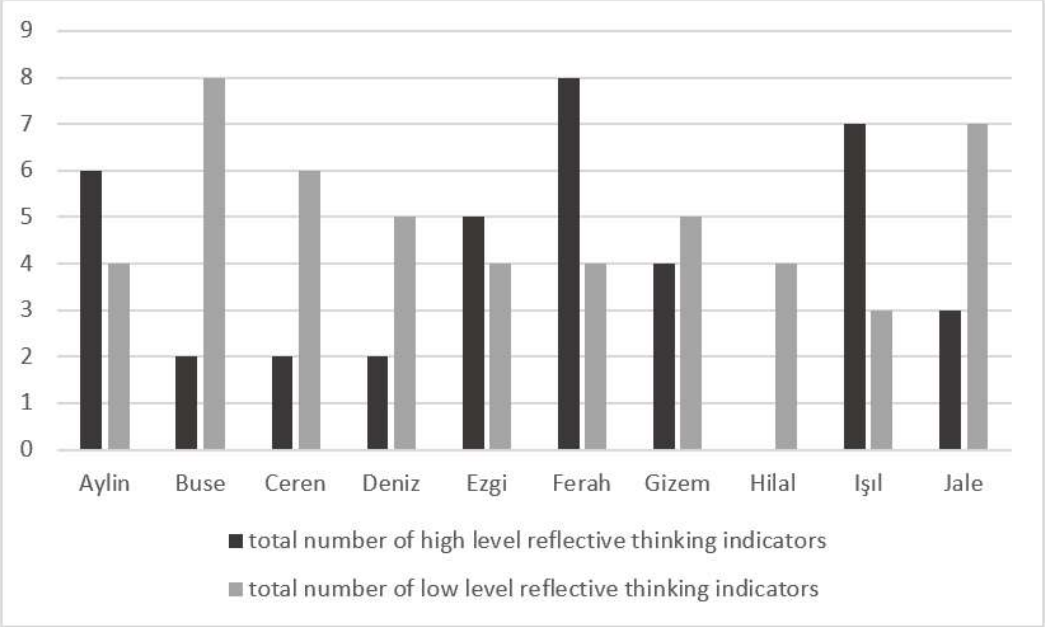


Figure 5.10. Each Preservice Science Teachers' Total Low and High-Level of Reflective Thinking Indicators.

As seen in the Figure 5.10, except from Hilal, all preservice science teachers had both high and low-level of reflective thinking indicators. In other words Hilal only had low-level of reflective thinking indicators. While six preservice science teachers had more low-level of reflective thinking indicators, four preservice science teachers had more high-level of reflective thinking indicators. Furthermore, while Ferah had the greatest number of reflective thinking indicators with twelve (nine of them were high, and three of them were low), Hilal has the least number of reflective thinking indicators with four (all of them were low).

All in all, the aim of this research question was to analyze the effectiveness of peer and the instructor feedbacks, and to analyze preservice science teachers reflective thinking indicators according to their reflections. The general findings related to feedbacks indicated that preservice science teachers thought that instructor feedbacks were more effective than peer feedback. They stated that instructor feedbacks were re-

flective, whereas peer feedbacks were all positive. Regarding the reflections, preservice science teachers demonstrated both high and low-level of reflective thinking indicators. While three preservice science teachers; Ezgi, Ferah and Işıl had more high-level of reflective thinking indicators, other seven preservice science teachers had more low level of reflective thinking indicators.

6. DISCUSSION

Online education was the only alternative in response to unexpected COVID-19 pandemic for K-12 and universities. However, neither teachers nor teacher educators had taught or prepared a lesson for online education up to the pandemic. During the pandemic preservice teachers got their lessons online, either synchronously or asynchronously, and prepared lessons as a part of science teaching and learning courses. Although, lessons taught online, a limited number of studies have examined online lesson preparation in preservice science teacher education (Wang and Wang, 2020). Previous online education studies in science education mostly cover synchronous (Scull *et al.*, 2020; Tallent-Runnels *et al.*, 2006) or hybrid environments (Burns *et al.*, 2020; Jang, 2008). Therefore, in the literature there was a limited number of studies which relied on asynchronous lesson preparation in science education. Therefore, the purpose of this study was to explore the progression of preservice science teachers on designing a simulation enhanced inquiry-based instruction for asynchronous learning environments. By this aim, this study emphasized on three themes: (i) inquiry-based science education, (ii) inclusion of simulations into inquiry-based science education, (iii) inclusion of simulations into inquiry-based science education via asynchronous learning environments. With this purpose, the data were collected from ten volunteer preservice science teachers through pre- and post-interviews, first and second lesson plans, teaching videos, instructor's field notes, peer feedbacks, instructor feedbacks and reflections. This section was organized around discussion of five research questions.

6.1. Discussion Regarding Preservice Science Teachers' Descriptions of Simulation-enhanced Inquiry-based 5E Lesson Plan for Asynchronous Learning Environments

Research question 1 was "How do preservice science teachers describe simulation-enhanced inquiry-based 5E lesson plan for asynchronous learning environments before and after the intervention on professional development module?". The aim of this question was to compare preservice science teachers' descriptions of lesson plan, in terms of

5E instructional model, inquiry-based science education, simulations, and asynchronous learning environments before and after attending the SIMINA Module. Analysis of the data revealed that preservice science teachers' descriptions comprised of the following categories: *purpose, tool (resource), process, product learning and assessment, aspect, communication*, and technic in various ways.

Firstly, preservice science teachers' descriptions of lesson plan were analyzed. Preservice science teachers learn how to prepare lesson plans in their science teaching method courses during their undergraduate years. However, literature conveyed that they might have problems in preparing effective lesson plans by using various science teaching methods (Gungoren *et al.*, 2020; Mesci *et al.*, 2020; Namdar and Kucuk, 2018). In accordance with the literature, in this study, preservice science teachers stated they had difficulties in preparing lesson plans in their pre-descriptions. They listed these difficulties while they were describing lesson plan in pre-interviews, reflections, and during the module implementation. In the pre-descriptions they mostly stated difficulties related to time management and how to guide students stated in the pre-interviews by four and five preservice science teachers, respectively. These findings were also stated in previous studies who found that preservice science teachers had difficulties in time management (Capps and Crawford, 2012) and guidance (Bansal, 2020; Namdar and Kucuk, 2018). Further, revealed categories related to lesson plan were *purpose, process*, and *product*. From pre-descriptions to post-descriptions preservice science teachers' descriptions changed from *product* to *process*. In the pre-descriptions there were 12 codes in *product* and six codes in *process* categories. However, in the post-descriptions, there were only one code in product category and eight codes in process category. The reason for this change might be the fact that during the module they improved their lesson plans, continuously. Accordingly, they started to seem lesson plan development is a continuing process. This finding is also consistent with the literature; Bergeson and Beschorner (2020) argued that preservice teachers started to seem lesson planning is a process since they continue to prepare and revise lesson plans.

The second theme was 5E instructional model which is a well-known lesson plan model for designing science lessons. Even though preservice science teachers prepared

various lesson plans by using 5E instructional model, they might still have problems (Goldston *et al.*, 2010; Namdar and Kucuk, 2018). In this present study, the revealed categories related to 5E instructional model were *purpose, tool, process, product, and aspect.* While in the pre-interviews, half of the preservice science teachers focused *purpose* of 5E instructional model and 5E instructional model as a product, seven of them focused more on the *process* of 5E instructional model and inquiry-based science education in the post-interviews. This shift infers that preservice science teachers started to see 5E instructional model as a *process.* This finding is supported by Lotter *et al.* (2007) who claimed that preservice science teachers' beliefs related to 5E instructional model were subject to change and it took time to internalize 5E instructional model as a process. The other striking finding related to 5E instructional model is related to the explanation stage of 5E instructional model. As reported in the previous studies, even though researchers stated that students should explain what they explored, and the teacher should guide them (Bell *et al.*, 2005; Bybee, 2006) preservice or inservice teachers explain concepts in a teacher-centered way (Jun *et al.*, 2013; Namdar and Kucuk, 2018; Mesci *et al.*, 2020). For example, in Namdar and Kucuk's (2018) study preservice science teachers mostly critiqued about the explanation stage. The reason of this situation might be the fact that preservice science teachers unsure of who is going to explain (Gungoren *et al.*, 2020). Similarly, in this study preservice science teachers mentioned about who is going to explain dilemma both pre- and post-interviews and during the implementation of the module.

The third theme of the module was inquiry-based science education and the revealed categories related to this dimension were *purpose, tool*, and *process.* As reported in the literature, inquiry-based science education is challenging for inexperienced science teachers (McBride *et al.*, 2004; Lehtinen *et al.*, 2016). Pajares (1992) and Luft (2001) stated that inexperienced science teachers' inquiry beliefs might change with more practice and experience. Accordingly, in this study, preservice science teachers' descriptions related to inquiry-based science education moved from *purpose* to *process* and *tool.* While in the pre-interviews there were seven codes in the purpose category, there were fourteen codes in *tool* category and seven codes in the *process* category. This finding was consisted with Nhlengethwa, Govender and Sibanda's (2020) study,

since the authors reported that preservice science teachers' inquiry orientations focused on how to conduct the inquiry process through research question and data which are stated in *process* and *tool* categories. In this present study, preservice science teachers' also mentioned in the post-interviews about their research questions, data collection, data analysis, and interpreting results for inquiry-based science education which is aligned with the findings of Bybee (2006) and Bell and colleagues (2005).

The fourth theme included in the module was the simulation and the revealed categories related to this dimension were *purpose, process, learning, aspects, and resource.* One significant finding related to this dimension was that *resource* and *aspect* categories were only found in post-descriptions. In the post-interviews all preservice science teachers stated at least one simulation resource and four of them stated aspects of simulations. The reason might behind this trend might be that they did not know simulation *resources* (PhET, Algodoo, WISE, and Condord Consortium) and *aspects* of simulations before attending the module according to their statements in the pre-interviews. This finding showed that simulations can be integrated into preservice science teachers' science teaching and learning method courses so that learning and using simulations in their future lessons (Gonczi *et al.*, 2016). Further, Lehtinen and colleagues (2016) and Chen (2010) claimed that preservice science teachers' orientations and descriptions about simulation directly affect their integration of simulations into their lessons. Since preservice science teachers' descriptions changed, it is believed that they use simulations more in their future science lessons. In addition, only in the post-descriptions four preservice science teachers explained how to use simulations in inquiry-based science education by stating aspects of simulation such as changing variables, making invisible to visible, and interactive learning environments. Preservice science teachers' descriptions related to features of simulation revealed that simulation-enhanced inquiry-based science education allow students to learn by doing in the student-centered environments. This finding was aligned with the previous studies which integrated simulations into inquiry-based science education (Dunn and Ramnarain, 2020; Jones *et al.*, 2011).

The fifth theme of the module was asynchronous learning environments. All preservice science teachers stated in the pre-interviews that they had no experience in preparing a lesson for asynchronous learning environments. This situation might explain their lack of knowledge and limited information provided with the descriptions about asynchronous learning environments. The revealed categories for this theme were *learning, communication, resource, assessment*, and *technic* for this category. One considerable shift occurred in *communication* category. Preservice science teachers argued in their pre-descriptions that there was no interaction neither between the teacher nor the peers whereas in their post-descriptions they explained how to communicate in asynchronous learning environments. Wang and Wang (2020) highlighted the importance of interaction and communication in asynchronous lessons through discussion forums or synchronous sections. Similarly, in this study preservice science teachers included the interaction and communication strategies via hybrid education, virtual classrooms, and discussion forums. Huang and colleagues (2020) suggested to use different communication strategies including synchronous discussions or designing hybrid lessons. Another considerable shift occurred in the technic category. In the pre-descriptions two preservice science teachers only said that there might be technical problems without stating any specific problem. However, in the post-descriptions, three of them discussed about technical problems. One notable problem was lack of knowledge about technology. Hence, they said they did not know how to edit the video some of the videos had grammar mistakes or slip of the tongue. Lowenthal (2021) and Severino and colleagues (2021) discussed the importance of editing videos before submitting to the students. In that way, teaching videos might seem more professional and interesting for learners.

In addition, as Lowenthal (2021) reported, the opportunity of pausing and rewinding while watching the same video facilitates learning in online video-based learning environments. In this study, preservice science teachers stated the importance of reminding students to pause or rewind the video and take notes while watching the teaching videos. However, preservice science teachers also mentioned their concerns for effectiveness of asynchronous video as students being passive listeners, they might not watch the video, or their attention span can decrease. Similarly, Saego, Koellner

and Jacobs (2018) argued that watching video did not guarantee learning from the video. In order to increase students' learning from a video, Lowenthal (2021) suggested to integrate audiovisual elements into teaching videos. In this study, preservice science teachers' post-descriptions of asynchronous learning environments concentrated on using multiple representations including image, audio, gif, or simulation to gather students' attention and enhance students' learning.

Finally, since preservice science teachers experienced lesson plans, 5E instructional model, inquiry-based science education, simulations, and asynchronous learning environments throughout the SIMINA, their post-descriptions was different compared to pre-descriptions. This finding was supported by Pajares (1992) who argued that preservice teachers' beliefs and orientations about their teaching practice was subject to change through experience and practice. It should be noted that preservice science teachers' post-descriptions regarding to lesson plan, 5E instructional model, inquiry-based science education, simulation, and asynchronous learning environments were more integrated compared to their pre-descriptions since there were more codes and categories in the post-descriptions. In other words, they only described the specific theme that asked in the pre-descriptions. However, they included lesson plan, simulation, and inquiry-based science education themes together in the post-descriptions. This may represent preservice science teachers integrate these concepts.

6.2. Discussion Regarding Preservice Science Teachers' Inclusion of a Simulation-enhanced Inquiry-based Science Education for Asynchronous Learning Environments

Research question 2 was "How do preservice science teachers describe inclusion of a simulation-enhanced inquiry-based science education for asynchronous learning environments before and after the intervention on professional development module?". The aim of RQ2 was to examine inclusion of a simulations and an inquiry-based science education in asynchronous learning environments. In this research question, preservice science teachers either explained how to include simulations or inquiry-based science education in asynchronous learning environments or explained why they did not in-

clude them. Analysis of the data revealed that preservice science teachers stated their explanations by focusing either role of teacher or *role of students in* various ways.

First, the inclusion of simulations in asynchronous learning environments was investigated. In the post-descriptions eight preservice science teachers stated that simulations can be included in asynchronous learning environments whereas six of them was said simulations can be included in asynchronous learning environments in the pre-descriptions in the interviews. Student-centered nature of simulations might be the reason for this increase. Since simulations provide students with flexible and student-centered learning environments, they are also suitable for asynchronous learning environments (Beckhem, 2012). In addition to that, out of four simulation resources (PhET, Algodoo, Concord Consortium, and WISE) that were used in the SIMINA, all preservice science teachers used PhET. This finding was unexpected because it was believed that preservice science teachers used different simulation sources in their lesson plans and teaching videos. The reason might behind this finding was that their language barrier since Concord Consortium and WISE have no Turkish resources which stated during the module and post-interviews. According to the preservice science teachers, the reason for not using Concord Consortium and WISE was that these resources were English which is said in the post-interviews. This finding was also supported by Ceylan and Gundogdu (2017) who claimed that teachers' language barrier might limit their use of technology in classrooms. Further, two preservice science teachers stated in their post-interview that they did not use Algodoo because designing in this simulation was hard. This reason was also observed in Akdag and Gunes's (2015) findings who reported that designing simulation environment was time consuming and challenging process according to the preservice and inservice teachers' views. Also, the reason for preservice science teachers' selection of PhET simulation was compatible with the previous studies reporting that PhET simulations were suitable to middle school science (Perkin *et al.*, 2012; Wieman *et al.*, 2009) and inquiry-based science education (Moore *et al.*, 2014; Yuliati *et al.*, 2018).

Second, inclusion of an inquiry-based science education in asynchronous learning environments was examined. Interestingly, compared to pre-descriptions, in the post-

descriptions less number of preservice science teachers stated that inquiry-based science education could be included in asynchronous learning environments. While in the pre-interviews four preservice science teachers said that inquiry-based science education could be included in asynchronous learning environments, three of them stated in the post-interviews. However, seven preservice science teachers actually integrated inquiry-based science education into asynchronous learning environments in their second of lesson plans and teaching videos. The reason might behind this trend might be the fact that preservice science teachers' statements do not always meet their practices such as lesson plans or teaching videos. Moreover, as stated in the literature, inquiry-based science education was not implemented well by preservice science teachers due to lack of knowledge and practice. Since it is hard to teach inquiry-based science for preservice science teachers (Eick and Reed, 2002; Hanuscin, Lee, and Akerson, 2011; Meyer *et al.*, 2013; Namdar and Kucuk, 2018) it would be harder to teach inquiry-based science in asynchronous learning environments.

Although there are variety of study about the usage of simulations, a limited number of them concentrated on design and implementation of simulation-enhanced inquiry-based science education (Chabalengula ,2016). This study focused on the design of asynchronous learning environments by using simulations and inquiry-based science education. Previous studies have agreed on simulation-enhanced inquiry-based science education was beneficial for students' understanding and learning science (Golston *et al.*, 2010; 2013). However, this study also had asynchronous learning environments dimension. According to the findings of this study, implementation of inquiry-based science education was challenging in asynchronous learning environments. On the contrary, simulation integration into asynchronous learning environments was an effective strategy which facilitates individualized learning. In short, findings of this research question implied that lesson plan and asynchronous video development were progressive processes, suggesting that preservice science teachers would need more time and experience to perfect their science lessons.

6.3. Discussion Regarding Preservice Science Teachers' Progression on Designing a Simulation-enhanced Inquiry-based Lesson for Asynchronous Learning Environments

Research question 3 was "How are preservice science teachers' progressions on designing a simulation-enhanced inquiry-based science lesson design for asynchronous learning environments?". The aim of RQ3 was to examine preservice science teachers' progression on designing a simulation-enhanced inquiry-based science lesson for asynchronous learning environments. This research question had three foci: *progression on designing inquiry-based science lesson, progression on designing simulation-enhanced science lesson, and progression on designing science lesson for asynchronous learning environments.*

Preliminary findings were brought out that four of the preservice science teachers changed their objectives from biology to chemistry or physics. The reason of this change was there is limited number of simulations in biology topics and biology topics are not suitable to inquiry-based science education stated in the post-interviews. This finding is supported by Smetana and Bell (2012) who found the simulations widely prepared for physics and chemistry topics. Besides, results of the Rutten and colleagues' (2015) identified that finding a simulation which was suitable for each learning objective is one of the drawbacks of simulations. Further, most of the inquiry-based science education research conducted in teaching or learning physics (Celik *et al.*, 2015; Tasoobshirazi *et al.*, 2006; Wieman *et al.*, 2009; Yuliati *et al.*, 2018) and chemistry (Fang *et al.*, 2016; Moore *et al.*, 2014; Ryoo and Linn, 2011;) topics. Therefore, the reason of changing biology objectives might be the fact that not finding a proper simulation for that objective.

Comparison of the first and second lesson plan scores found out that the most increase observed in asynchronous learning environments, simulations, and inquiry-based science education respectively. The reason for this trend might be the fact that; preservice science teachers did not know anything about asynchronous learning environments before this study. For this reason, the most increase observed in asynchronous learning

environments hence they did not adapt their first lessons. Moreover, simulation and inquiry integration were challenging for preservice science teachers (Goldston, 2013; Meyer *et al.*, 2013). Half of the preservice science teachers did not know neither simulations nor inquiry before this study. During the study, they experienced both. Lack of technological knowledge might be the reason for not adapting simulation (Ertmer, 2005; Lehtinen *et al.*, 2016) Accordingly, preservice science teachers' lack of experience in inquiry and their teaching orientations (Eick and Reed, 2002; Namdar and Kucuk, 2018) might be the reason for not adapting inquiry-based science education in their first lesson plans. Following paragraphs discuss the progression on each dimension separately by referring to the previous literature.

First, progression on designing inquiry-based science lesson analyzed according to Forbes and Davis's (2010) *Inquiry Scoring Rubric for Lesson Plans which has* 5 dimension which are 1) *scientifically oriented questions*, 2) *gathering, organizing and analyzing data*, 3) *formulating explanations from evidence to address scientifically oriented questions*, 4) *evaluating their explanations in light of alternative explanations, and* 5) *communicating and justifying their explanations* (see Table 4.1.). It was found that preservice science teachers' scores for each dimension were increased. The reason behind this trend might be that throughout the study they became more experienced in designing lesson plans for inquiry-based science education. This finding is supported by Namdar and Kucuk (2018) and Gungoren *et al.* (2020) who argued that increasing the experiences might cause better performance in designing inquiry-based science lessons. A significant increase was observed in the *scientifically oriented questions* dimension. Similarly, Pringle and colleagues (2017) studied with in-service science teachers and in their study while the highest progression was observed in *scientifically oriented questions*, the least progression was observed *in communicating and justifying their explanations* dimension. These findings can be explained by Forbes and Davis's (2010) arguement which integration of communication requires more experience and teaching practice.

Second, progression on designing simulation-enhanced science lesson was analyzed according to following dimensions which found on lesson plans and teaching

videos: the phase of 5E instructional model where the simulations was integrated, introduction of simulations, and simulation-enhanced inquiry-based science education. For all the dimensions, preservice science teachers' teaching video scores were higher than their second of lesson plan scores. Nhlengethwa and colleagues (2020) found similar results that preservice science teachers' lesson plan scores lower than their lesson implementation scores. Moreover, all preservice science teachers used simulations at the Explore and Explain stages of 5E instructional model. Similarly, previous studies suggested that exploration through simulations might contribute to better implementation of inquiry-based science education (Gonczi *et al.*, 2016; Rutten *et al.*, 2015). This study has pointed to previous findings that middle school students need guidance while using simulations Huang *et al.*, 2016; Kukkonen *et al.*, 2014). In Huang and colleagues' (2016) study, middle school students who got scaffolds in the simulation-based learning environments outperformed students who used simulations on their own. In this present study, preservice science teachers discussed the importance of introducing simulation environments and explaining how to use simulations in detailed. These findings imply that teachers should introduce and explain simulation learning environments to students. Simulation-enhanced inquiry-based science education was deliberate practice of this study. Therefore, whether simulation-enhanced inquiry-based science education was used or not investigated. Preservice science teachers' second of lesson plans and teaching videos were more appropriate for simulation-enhanced inquiry-based science education according to second lesson plan and teaching video scores. These findings can be explained by Rutten and colleagues' (2015) and Gonczi and colleagues' (2016) suggestions; preservice science teachers need extra practice for simulation and inquiry for effective integration of their lessons.

Third, progression on designing science lesson for asynchronous learning environments analyzed according to following categories: *asynchronous, simulation* and inquiry. Preservice science teachers' teaching video scores were mostly higher than the second draft of lesson plan scores. The reason for this trend might be that while some preservice science teachers indicated asynchronous dimension was better in lesson plans, others indicated that it was better in teaching videos. In support of this finding, Lim *et al.* (2018) found that planning and implementation were compatible,

but not always the same. Wang and Wang (2020) and Verma and colleagues (2020) suggested to integrate online learning environments into preservice science teachers' undergraduate course after the pandemic. With this way, preservice science teachers prepare themselves for different learning environments to teach science. Similarly in this study, all preservice science teachers also argued that learning to teach science for asynchronous learning environments was necessary and they needed more practice for progression.

All in all, increasing experience might cause progression on designing a simulation-enhanced inquiry-based instruction design for asynchronous learning environments. However, not only increasing experience but also giving and receiving feedback, implementation of SIMINA and in-class discussions during SIMINA had to be affected progression. The implication of these findings is that preservice science teachers are supposed to experience more at designing, implementing lessons through giving and receiving feedbacks which support progression in lessons.

6.4. Discussion with Respect to the Strengthens and Limitations of Designing Simulation-enhanced Inquiry-based Lesson for Asynchronous Learning Environments

Research question 4 was "What are the strengthens and limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments?". The aim of RQ4 was to explore the strengths and limitations of designing simulation enhanced inquiry-based lesson for asynchronous learning environments. Analysis of post-interview and field notes data indicated that for both strengths and limitations comprised of following categories: lesson plan, inquiry, simulation and asynchronous.

First, the strengths of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments was discussed. One of the mostly stated strengths was preparing more structured lesson plan compared to face-to-face lessons in the post-interviews stated by post-interviews. According to the Hrantinski (2008), asynchronous lessons were more planned, structured, and step-by-step processes compared to syn-

chronous lessons. Thus, this study's findings were aligned with the previous literature. Furthermore, asynchronous learning environment design was mostly related to the individualized learning due to time and space barriers which is an advantage. Wang and Wang (2020) suggested to use asynchronous learning environments when students need individualized time and space to learn. Therefore, asynchronous learning environments give more time to students to explore, explain and discuss; hence simulations can easily be integrated.

Accordingly, preparing a simulation-enhanced science lesson for asynchronous learning environments was another mostly stated advantage by four preservice science teachers. In other words, simulations allow students to learn individually by exploring hypothetical situations continuously. This finding also supported by meta-analyses of Rutten *et al.* (2012) and Smetana and Bell (2012) who found simulations supported individualized and dynamic learning environment for students. These features of simulations also enable using simulations with inquiry-based science education (Chang and Linn 2013; Jones *et al.*, 2011). Therefore, researchers suggested to use simulations in inquiry-based science education since simulations facilitate exploring various situations through data collection and analysis (Gonczi *et al.*, 2016; Klahr and Nigam, 2004: McElhaney and Linn, 2010). Findings of this study also indicated that simulation-enhanced inquiry-based science education was an effective approach for science lessons. Since both simulations and asynchronous learning environments support individualized learning, they can be used together.

Second, limitations of designing simulation-enhanced inquiry-based lesson for asynchronous learning environments were stated in the post-interviews. Structured lesson plan and teacher-centered teaching video were the mostly stated limitation by preservice science teachers. As stated by Burns and colleagues (2020), structured nature of asynchronous learning environments causes teacher-centered course design. In addition to that, there is lack of communication and interaction with peers or the teacher in asynchronous learning environments which was stated in the post-interviews as a limitation. This is also confirmed by Wang and Woo (2007) who argued that lack or late feedbacks were one of the most significant shortcomings of asynchronous

discussions. Limitations regarding to inquiry-based science education were also due to asynchronous learning environments.

According to Lim (2004) and Windschitl (2000) students need to work collaboratively, engage in discussions through teacher guidance. Yet, neither of them was possible in asynchronous learning environments. This can be a reason for not effectively integrating inquiry-based science education into asynchronous learning environments. There was no limitation stated with using simulation-enhanced inquiry-based science education or using simulations in asynchronous learning environments. On the contrary, preservice science teachers argued that simulations were suitable for inquiry-based science education and asynchronous learning environments. The only stated limitation regarding the simulations was preservice science teacher related. In other words, some of the preservice teachers said that they did not use simulations appropriately. As stated in the literature, teachers' knowledge and skills related to technology directly affect technology integration into their lessons (Ertmer, 2005).

6.5. Discussion Regarding Preservice Science Teachers' Reflections and Feedbacks While They Progress Their Lesson

Research question 5 was "How do preservice science teachers reflect on feedback while they are progress their lesson?". The aim of RQ5 was to explore preservice science teachers' feedbacks and reflections while they are progress their lessons. Both feedback and reflection are ongoing processes in teachers' life cycle (Fuller and Bown, 1975; O'Brien, 1992). The feedbacks were analyzed in two stages: feedback from the instructor and feedback from a peer. Analyses of feedbacks revealed following categories; *reflectiveness, timing, content, and accuracy.* In addition to that, the analyses of reflections focused on preservice science teachers' high level of reflective thinking indicators [Claim-Evidence (C-E), Reflection-in-action (RNA), Recognizing and stating Discrepancies (RECD), and Reflection-on-action (ROA)] and low level of reflective thinking indicators [Goal-experience discrepancy (GED) and Describing experience (DE)]. Following paragraphs discuss the findings of this study referring to the literature in terms of the instructor feedback, peer feedback and reflection.

Firstly, seven preservice science teachers stated in the post-interviews that instructor feedback was effective for progressing their lesson plan. According to Carless and Boud (2018) effective feedback, should be reflective, task-oriented, and timely. Similarly, Thurlings and colleagues (2013) stated that instructor feedback should be personalized and task oriented. In this study, the analysis of instructor's feedbacks revealed following categories: *reflectiveness, timing*, and *content*. These categories are consistent with previous studies' (Carles and Boud, 2018; Thurlings *et al.*, 2013) results about preservice teachers' need for effective instructor feedback to improve their teaching practices. Literature also suggests to give and receive feedback from peers so that raising awareness about assessment procedure (Strijbos and Sluijmans, 2010). For this reason, preservice science teachers gave feedbacks to one of their peers and received feedbacks from another peer.

However, preservice science teachers stated that peer feedbacks did not as effective as instructor feedback. The analysis of why peer feedbacks were not effective revealed following categories: *timing, content*, and *accuracy*. According to the literature there are various reason for peer feedback is not effective (Alqassab *et al.*, 2019; Lynch *et al.*, 2012). Half of the preservice science teachers found peer feedback less accurate and too general. This finding is supported by Lynch and colleagues (2012) who found that peer feedbacks did not focus on performance or improvement of performance. Moreover, it is continuously stated in the literature that preservice teachers sometimes reject feedback due to several reasons (Anker-Hansen and Andree, 2019; Topping, 1998). One reason for this situation is that feedback might not fit into their teaching strategies or beliefs. Researchers suggest stating reason for rejecting feedback to overcome this situation. Writing only negative statements without explaining reason is another cause for rejecting peer feedback (Alqassap, 2019). Contrary to the literature, in this study only positive statements were written by three preservice science teachers. This situation also decreased the accuracy of peer feedback. Therefore, it can be said that neither positive nor negative statements are called as feedbacks. In other words, feedbacks need an explanation and reason (Topping, 1998). Thus, in this study it was expected preservice science teachers to verify their feedbacks through concrete examples from the task.

On the one hand feedbacks enable to look someone's work from different perspective, on the other hand; reflections enable to think deeply about one's own task. Reflections are as essential as feedbacks in preservice teacher education (Korkko *et al.*, 2016). The frequency and the nature of *reflective thinking indicators* developed by Oner and Adadan (2011) was utilized for analyzing their reflections. Parallel to this framework, in their reflections, preservice science teachers wrote their discrepancies among their goals, experiences, and observations. The analysis of reflections indicated that preservice science teachers have both high (C-E, RNA, RECD, and ROA) and low (DE and GED) level reflective thinking indicators. The number of high-level of reflective thinking indicators increased from first reflection task to last reflection task from seven to fifteen. Similarly, Oner and Adadan (2011; 2016) was found a statistically significant increase in the number of high-level of reflective thinking indicators from first reflection tasks to second.

In this present study, RNA was observed once in reflection for teaching video by one preservice science teacher. The reason of this trend might be the fact that teaching video was the only opportunity to implement their lesson plans. Similarly, according to the Schön (1983), extensive experience is needed to develop RNA (reflection-in-action). This finding is supported by Oner and Adadan (2011; 2016) who found a limited number of RNA reflective thinking indicators in preservice teachers' reflection tasks. The reason for a few numbers of RNA may be the feedbacks given by the instructor or peers were not sufficient. Further, RECD was observed twice. This reflective thinking indicator observed when a preservice science teacher discussed discrepancies among her goals and experiences. According to Oner and Adadan (2016) the reason of less observation of RECD indicates preservice science teachers were not totally aware of feedbacks that they received.

Besides, from low-level of reflective thinking indicators DE decreased from first reflection task to last. According to Oner and Adadan (2016) this situation represented the progress in reflective thinking. In this study DE indicators transformed to ROA which represents preservice science teachers' awareness of teaching experiences (Fuller and Bown, 1975). For this reason, this finding might refer that preservice science teach-

ers aware of discrepancies and expressed more on their teaching experiences through the process.

6.6. Limitations

This study was intentionally situated in a simulation-enhanced inquiry-based science lesson for asynchronous learning environments due to the increasing interest in simulation-enhanced inquiry and due to the increasing need of asynchronous lesson development because of unexpected COVID-19 pandemic. Yet, the unique nature of this study accompanied by some limitations. These limitations should be taken into consideration after presenting the findings of this study. This study was exploratory in nature. Its findings came from preservice science teachers' pre- and post-interviews, first and second of lesson plans, the researcher's field notes, instructor and peer feedbacks, and teaching videos. This qualitative data collection tools provided rich and in-depth information but still it was restricted to qualitative methodology, data collection tools that used, preservice science teachers who participated, and the SIMINA module which applied.

First, qualitative nature of this present study limits generalizability of the findings. Data collection tools were either selected or prepared by considering the study's aim. Like other qualitative studies, the analysis of data might depend on the researcher's interpretation, experiences, and possible biases. To overcome this situation, the researcher explained her role and background to the participants and readers. Further, randomly selected 20% of qualitative data from each data source was coded by other science education experts to provide inter-rater reliability of findings.

Second, the study conducted with ten senior year preservice science teachers. Since the study was conducted in the conveniently selected university, participants were limited to preservice science teachers who studied in that university. Yet, all participants were voluntarily participated to this study which increased validity of the findings. Although findings of this study were limited to participants, it provided triangulated and detailed investigation of study phenomenon.

Third, the SIMINA module was developed specifically for this study by considering previous findings and suggestions from the current literature. Even though preservice science teachers developed their lesson plans through the SIMINA Module and through feedbacks and reflections, they videotaped their lesson only once. Thus, the limitation of this situation was that they had no opportunity to improve their teaching video by considering feedbacks and reflections. If they had opportunity to videotape their lesson one more time, more progression might be observed.

6.7. Implications and Recommendations for Future Research

There is no doubt that designing and implementing a simulation-enhanced inquiry-based science education for asynchronous learning environments was a challenging process for preservice teachers. Since the aim of this study was to explore the progression of pre-service science teachers on designing a simulation enhanced inquiry-based instruction for asynchronous learning environments, it is recommended that preservice science teachers would experience it via undergraduate science teaching courses, extra professional development modules, or trainings. These would allow for better preparation and implementation of a simulation-enhanced inquiry-based science lesson for asynchronous learning environments.

Findings of this study shed light on the increasing need of designing research on asynchronous learning environments for science education. Thus, not only preservice but also inservice science teachers' current situation and future progression on designing science lesson for asynchronous learning environments would be investigated. This is especially true in preparing science lesson by considering todays and future's needs for education. Integrating effective science teaching media and methods, simulations, and inquiry-based science education for this present study, might also increase effectiveness of science lessons for asynchronous learning environments. This study revealed that there is a limited study on inquiry-based science education for asynchronous learning environments. Thus, it can be suggested that science education researchers may conduct research to investigate inquiry-based science education for asynchronous learning environments.

Besides, instead of asking preservice science teachers to plan and teach simulation-enhanced inquiry-based science lesson for asynchronous learning environments, it may be expected preservice science teachers to improve their teaching videos through feedback and reflection just as what they did in lesson plans. Preservice science teachers had only one chance for giving and receiving feedback to their teaching videos and then writing reflection. This study revealed that both feedbacks and reflections may help preservice teachers perceive lesson plans and teaching videos from different perspectives which promote progression of lesson. In this study, the aim of feedbacks and reflections were to improve the lesson plans and teaching videos through feedbacks and reflections. Future research may focus on detailed and specific focus on enhancement of feedbacks and reflections for observing their impact and effectiveness.

All in all, the findings of this study were non-generalizable but applicable for other situations. Thus, future studies might conduct with a different sample including either preservice or inservice science teachers for the same purpose to compare and contrast their findings with this study's findings. Further, future studies might conduct with longer interventions, or longitudinal progression might investigate, particularly the implications for designing simulation-enhanced inquiry-based science lessons for asynchronous learning environments.

REFERENCES

Abd-El-Khalick, F., S. BouJaoude, R. Duschl, N.G. Lederman, R. Mamlok-Naaman, A. Hofstein, *et al.* 2004, "Inquiry in Science Education: International Perspectives", *Science Education*, Vol. 88, No. 3, pp. 397-419.

Adams, W.K., S. Reid, R. LeMaster, S. McKagan, K. Perkins, M. Dubson, C.E. Wieman, 2008, "A Study of Educational Simulations Part II-Interface Design", *Journal of Interactive Learning Research*, Vol. 19, No. 4, pp. 551-577.

Ainsworth, S., and N. VanLabeke, 2004, "Multiple Forms of Dynamic Representation", *Learning and Instruction*, Vol. 14, No. 3, pp. 241-255.

Akdağ, F.T., and T. Güneş, 2015, "Kuvvet Ve Hareket Ünitesinin Bilgisayar Destekli Öğretiminde Algodoo Kullanımı", *International Journal of Social Sciences and Education Research*, Vol. 4, No. 1, pp. 138-149.

Akpan, J.P., 2001, "Issues Associated With Inserting Computer Simulations Into Biology Instruction: A Review Of The Literature", *The Electronic Journal for Research in Science and Mathematics Education.*

Akerlind, G., 2005, "Variation and Commonality in Phenomenographic Research Methods", *Higher Education Research and Development*, Vol. 24, No. 1, pp. 321-334.

Alqassab, M., J.W. Strijbos, and S. Ufer, 2019, "Preservice Mathematics Teachers' Beliefs About Peer Feedback, Perceptions of Their Peer Feedback Message, and Emotions as Predictors of Peer Feedback Accuracy and Comprehension of the Learning Task", *Assessment and Evaluation in Higher Education*, Vol. 44, No. 1, pp. 139-154.

Anderson, R.D. (2002), "Reforming Science Teaching: What Research Says About Inquiry", *Journal of Science Teacher Education*, Vol. 13, No. 1, pp. 1-12.

Anker-Hansen, J., and M. Andrée, 2019, "Using and Rejecting Peer Feedback in the Science Classroom: A Study of Students' Negotiations on How to Use Peer Feedback When Designing Experiments", *Research in Science and Technological Education*, Vol. 37, No. 3, pp. 346-365.

Banks, J.L., H.S. Beard, Y. Cao, A.E Cho, W. Damm, R. Farid, and R.M. Levy, 2005, "Integrated Modeling Program, Applied Chemical Theory (IMPACT)", *Journal of Computational Chemistry*, Vol. 26, No. 16, pp. 1752-1780.

Bansal, G., 2021, "Indian Pre-Service Teachers' Conceptualisations and Enactment of Inquiry-Based Science Education", *Education*, 3-13, Vol. 49, No. 3, pp. 275-287.

Baran, B., and E. Keles, 2011, "Case Study Discussion Experiences of Computer Education and Instructional Technologies Students about Instructional Design on an Asynchronous Environment", *Turkish Online Journal of Educational Technology*, Vol. 10, No. 1, pp. 58-70.

Beckem, J.M., 2012, "Bringing Life to Learning: Immersive Experiential Learning Simulations for Online and Blended Courses", *Journal of Asynchronous Learning Networks*, Vol. 16, No. 5, pp. 61-70.

Bell, R.L., L. Smetana, and I. Binns, 2005, "Simplifying Inquiry Instruction", *The Science Teacher*, Vol. 72, No. 7, pp. 30-33.

Bell, R.L., J.L. Maeng, and I.C. Binns, 2013, "Learning In Context: Technology Integration in a Teacher Preparation Program Informed By Situated Learning Theory", *Journal of Research in Science Teaching*, Vol. 50, No. 3, pp. 348-379.

Berg, B.L. and H. Lune, 2017, *Qualitative Research Methods for the Social Sciences*, Ninth Edition, Boston, MA: Pearson.

Bergeson, K., and B., Beschorner, 2020, "Modeling and Scaffolding the Technology Integration Planning Cycle for Pre-Service Teachers: A Case Study", *International*

Journal of Education in Mathematics, Science and Technology, Vol. 8, No. 4, pp. 330-341.

Beyer, C.J., and E.A. Davis, 2009, "Using Educative Curriculum Materials to Support Preservice Elementary Teachers' Curricular Planning: A Comparison between Two Different Forms of Support", *Curriculum Inquiry*, Vol. 39, No. 5, pp. 679-703.

Blake, C., and E. Scanlon, 2007, "Reconsidering Simulations in Science Education at a Distance: Features of Effective Use", *Journal of Computer Assisted Learning*, Vol. 23, No. 6, pp. 491-502.

Boud, D., and E. Molloy, 2013, "Rethinking Models of Feedback for Learning: The Challenge of Design", *Assessment and Evaluation in Higher Education*, Vol. 38, No. 6, pp. 698-712.

Bradley, E.G., and B. Kendall, 2014, "A Review of Computer Simulations in Teacher Education", J*ournal of Educational Technology Systems*, Vol. 43, No. 1, pp. 3-12.

Bransford, J.D., A.L. Brown, and R.R. Cocking, 2000, "How People Learn, Washington", *DC: National Academy Press*, Vol. 11.

Brierton, S., E. Wilson, M. Kistler, J. Flowers, and D. Jones, 2016, "A Comparison of Higher Order Thinking Skills Demonstrated in Synchronous and Asynchronous Online College Discussion Posts", *Nacta Journal*, Vol. 60, No. 1, pp. 14-21.

Bunterm, T., K. Lee, J. Ng Lan Kong, S. Srikoon, P. Vangpoomyai, J. Rattanavongsa, and G. Rachahoon, 2014, "Do Different Levels of Inquiry Lead to Different Learning Outcomes? A Comparison between Guided and Structured Inquiry", *International Journal of Science Education*, Vol. 36, No. 12, pp. 1937-1959.

Burns, A., P. Holford, and N. Andronicos, 2020, "Enhancing Understanding of Foundation Concepts ın First Year University STEM: Evaluation of an Asynchronous

Online Interactive Lesson", *Interactive Learning Environments*, pp. 1-13.

Bybee, R., and N.M. Landes, 1990, "Science for Life and Living: An Elementary School Science Program From Biological Sciences Improvement Study (BSCS)", *The American Biology Teacher*, Vol. 52, No. 2, pp. 92-98.

Bybee, R.W., 2006, "Scientific Inquiry And Science Teaching, In Scientific Inquiry and Nature of Science", *Springer*, Dordrecht, pp. 1-14.

Bybee, R.W., J. Taylor, A. Gardner, van A. Scotter, van P. Scotter, J. Powell, A. Westbrook, and N. Landes, 2006, *The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications*, Colorado Springs, CO: BSCS.

Bybee, R.W., J.A. Taylor, A. Gardner, P. Van Scotter, J. Carlson Powell, A. Westbrook, and N. Landes, 2006, *The BSCS 5E Instructional Model: Origins, Effectiveness and Applications, Retrieved from* 2006 http://www.bscs.org/bscs-5e-instructional-model, accessed in April 2020.

Capps, D.K., B.A. Crawford, and M.A. Constas, 2012, "A Review of Empirical Literature on Inquiry Professional Development: Alignment With Best Practices and a Critique of the Findings", *Journal of Science Teacher Education*, Vol. 23, No. 3, pp. 291-318.

Carless, D., and D. Boud, 2018, "The Development of Student Feedback Literacy: Enabling Uptake of Feedback", *Assessment and Evaluation in Higher Education*, Vol. 43, No. 8, pp. 1315-1325.

Celik, H., U. Sarı, and U.N. Harwanto, 2015, "Developing And Evaluating Physics Teaching Material With Algodoo (Phun) In Virtual Environment: Archimedes' Principle", *International Journal of Innovation in Science and Mathematics Education*, Vol. 23, No. 4.

Ceylan, V.K. ve K. Gundogdu, 20019, "Oğretmenlerin E-Içerik Geliştirme Becerileri:

Bir Hizmet İçi Eğitim Deneyimi", *Eğitim ve İnsani Bilimler Dergisi*, Vol. 8, No. 15.

Chabalengula, V., R. Fateen, F. MuMba, and L.K. Ochs, 2016, "Effect of Inquiry-Based Computer Simulation Modeling on Pre-Service Teachers' Understanding of Homeostasis and Their Perceptions of Design Features", *Journal of Computers in Mathematics and Science Teaching*, Vol. 35, No. 3, pp. 225-248.

Chang, H.Y., and M.C. Linn, 2013, "Scaffolding Learning From Molecular Visualizations", *Journal of Research in Science Teaching*, Vol. 50, No. 7, pp. 858-886.

Chao, J., C. Xie, S. Nourian, G. Chen, S. Bailey, M.H. Goldstein, and M.S. Tutwiler, 2017, "Bridging the Design-Science Gap with Tools: Science Learning and Design Behaviors in a Simulated Environment for Engineering Design", *Journal of Research in Science Teaching*, Vol. 54, No. 8, pp. 1049-1096.

Chen, R., 2010, "Investigating Models for Preservice Teachers' Use of Technology to Support Student-Centered Learning", *Computers and Education*, Vol. 55, No. 1, pp. 32-42.

Chen, S., 2010, "The View of Scientific Inquiry Conveyed by Simulation-Based Virtual Laboratories", *Computers and Education*, Vol. 55, No. 3, pp. 1123-1130.

Choi, B., 2016, "How People Learn in an Asynchronous Online Learning Environment: The Relationships Between Graduate Students' Learning Strategies and Learning Satisfaction", *Canadian Journal of Learning and Technology*, Vol. 42, No. 1.

Clara?, M., T. Mauri, R. Colomina, and J. Onrubia, 2019, "Supporting Collaborative Reflection In Teacher Education: A Case Study", *European Journal of Teacher Education*, Vol. 42, No. 2, pp. 175-191.

Creswell, J.W., 2014, *Research Design: Qualitative, Quantitative and Mixed Method Approaches*, 4^{th} Edition, SAGE Publications, Los Angeles, CA.

Creswell, J.W., and C.N. Poth, 2016, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, Sage Publications.

d'Alessio, M.A., 2018, "The Effect of Microteaching on Science Teaching Self-Efficacy Beliefs in Preservice Elementary Teachers", *Journal of Science Teacher Education*, Vol. 29, No. 6, pp. 441-467.

De Jong, T., and W.R. Van Joolingen, 1998, "Scientific Discovery Learning With Computer Simulations of Conceptual Domains", *Review of Educational Research*, Vol. 68, No. 2, pp. 179-201.

De Jong, T., M.C. Linn, and Z.C. Zacharia, 2013, "Physical and Virtual Laboratories in Science and Engineering Education", *Science*, Vol. 340, No. 6130, pp. 305-308.

Dunn, J., and U. Ramnarain, 2020, "The Effect of Simulation-Supported Inquiry on South African Natural Sciences Learners' Understanding of Atomic and Molecular Structures", *Education Sciences*, Vol. 10, No. 10, pp. 280.

Edelson, D.C., 2001, "Learning-For-Use: A Framework for the Design of Technology-Supported Inquiry Activities", *Journal of Research in Science Teaching*, Vol. 38, No. 3, pp. 355-385.

Eick, C., and C. Reed, 2002, "What Makes An Inquiry-Oriented Science Teacher? The Influence of Learning Histories on Student Teacher Role Identity and Practice", *Science Education*, Vol. 86, pp. 401-416.

Ellis, N.J., and T. Loughland, 2017, "Where to Next? 'Examining Feedback Received By Teacher Education Students", *Issues in Educational Research*, Vol. 27, No. 1, pp. 51-63.

Ertmer, P., 2003, "Transforming Teacher Education: Visions and Strategies", *Educational Technology Research and Development*, Vol. 51, No. 1, pp. 124-128.

Ertmer, P.A., 2005, "Teacher Pedagogical Beliefs: The Final Frontier in Our Quest

for Technology Integration?", *Educational Technology Research and Development*, Vol. 53, No. 4, pp. 25-39.

Evans, C., 2013, "Making Sense of Assessment Feedback in Higher Education", *Review of Educational Research*, Vol. 83, No. 1, pp. 70-120.

Fang, S.C., Y.S. Hsu, H.Y. Chang, W.H. Chang, H.K. Wu, and C.M. Chen, 2016, "Investigating the Effects of Structured and Guided Inquiry on Students' Development of Conceptual Knowledge and Inquiry Abilities: A Case Study in Taiwan", *International Journal of Science Education*, Vol. 38, No. 12, pp. 1945-1971.

Ferguson, P., 2011, "Student Perceptions of Quality Feedback in Teacher Education", *Assessment and Evaluation in Higher Education*, Vol. 36, No. 1, pp. 51-62.

Forbes, C.T., and E.A. Davis, 2010, "Curriculum Design For Inquiry: Preservice Elementary Teachers' Mobilization And Adaptation Of Science Curriculum Materials", *Journal of Research in Science Teaching*, Vol. 47, No. 7, pp. 820-839.

Fu, X., and E. Liu, 2016, "Using WISE Materials To Design An Inquiry-Based Curriculum With The 5E Instructional Model", *The American Biology Teacher*, Vol. 78, No. 3, pp. 208-219.

Fuller, F.F., and O. Bown, 1975, "Becoming a Teacher. In K. Ryan (Ed.), Teacher Education, 74th yearbook of the National Society for the Study of Education", *Chicago: University Of Chicago Press*, pp. 25-52.

Gay, L.R., G.E. Mills, and P.W. Airasian, 2009, *Educational Research: Competencies for Analysis and Applications*, Merrill/Pearson.

Gibbs, G., and C. Simpson, 2005, "Conditions Under Which Assessment Supports Students' Learning", *Learning and Teaching in Higher Education*, No. 1, pp. 3-31.

Gielen, S., E. Peeters, F. Dochy, P. Onghena, K. and K. Struyven, 2010, "Improving

the Effectiveness of Peer Feedback for Learning", *Learning and Instruction*, Vol. 20, No. 4, pp. 304-315.

Glaser, B., and A. Strauss, 1967, *The Discovery of Grounded Theory*, Chicago: Aldine.

Gonczi, A.L., J.L. Maeng, R.L. Bell, and B.A. Whitworth, 2016, "Situating Computer Simulation Professional Development: Does it Promote Inquiry-Based Simulation Use?", *Computers in the Schools*, Vol. 33, No. 3, pp. 133-152.

Goldston, M.J., J.B. Day, C. Sundberg, and J. Dantzler, 2010, "Psychometric Analysis of A 5E Learning Cycle Lesson Plan Assessment Instrument", International *Journal of Science and Mathematics Education*, Vol. 8, No. 4, pp. 633-648.

Goldston, M.J., J. Dantzler, J. Day, and B. Webb, 2013, "A Psychometric Approach to the Development of A 5E Lesson Plan Scoring Instrument for Inquiry-Based Teaching", *Journal of Science Teacher Education*, Vol. 24, No. 3, pp. 527-551.

Griffiths, M., and C. Graham, 2010, "Using Asynchronous Video to Achieve Instructor Immediacy and Closeness in Online Classes: Experiences From Three Cases", *International Journal on E-Learning*, Vol. 9, No. 3, pp. 325-340.

Güneş, T., and F.T. Akdağ, 2016, "Determination of Perceptions of Science High School Students On Energy And Their Levels Of Interdisciplinary Association", *International Journal of Social Sciences and Education Research*, Vol. 2, No. 2, pp. 625-635.

Gungoren, S.Ç., F.Y. Hasancebi, and G. Mesci, 2020, "The Effect of Teacher Evaluation and Self-Evaluation on Pre-Service Teachers' Inquiry-Based 5E Lesson Plan Design and Teaching Practice", *Educational Policy Analysis and Strategic Research*, Vol. 15, No. 4, pp. 367-388.

Haefner, L.A., and C. Zembal-Saul, 2004, "Learning by Doing? Prospective Elementary Teachers' Developing Understandings of Scientific Inquiry and Science Teaching

and Learning", *International Journal of Science Education*, Vol. 26, No. 13, pp. 1653-1674.

Haney, J.J., and J. McArthur, 2002, "Four Case Studies of Prospective Science Teachers' Beliefs Concerning Constructivist Teaching Practices", *Science Education*, Vol. 86, No. 6, pp. 783-802.

Hanuscin, D.L., M.H. Lee, and V.L. Akerson, 2011, "Elementary Teachers' Pedagogical Content Knowledge for Teaching the Nature of Science", *Science Education*, Vol. 95, No. 1, pp. 145-167.

Hasselgren, B., and D. Beach, 1997, "Phenomenography-A Good-ForNothing Brother of Phenomenology? Outline of an Analysis", *Higher Education Research and Development*, Vol. 16, No. 2, pp. 191-202.

Haughney, K., S. Wakeman, and L. Hart, 2020, "Quality of Feedback in Higher Education: A Review of Literature", *Education Sciences*, Vol. 10, No. 3, pp. 60.

Haythornthwaite, C., and B. Wellman, 2002, "The Internet in Everyday Life", *Oxford: Blackwell*, pp. 3-41.

Hiltz, S.R., 2000, "Measuring the Importance of Collaborative Learning for Effectiveness of ALN: A Multi-Measure, Multi-Method Approach", *Journal of Asynchronous Learning Network*, Vol. 4, No. 3, pp. 140-151.

Howes, E., M. Lim, and J. Campos, 2008, "Journeys into Inquiry-Based Elementary Science: Literacy Practices, Questioning, and Empirical Study", *Science Education*, Vol. 93, No. 2, pp. 189-221.

Huang, K., X. Ge, and D. Eseryel, 2017, "Metaconceptually-Enhanced Simulation-Based Inquiry: Effects on Eighth Grade Students' Conceptual Change and Science Epistemic Beliefs", *Educational Technology Research and Development*, Vol. 65, No. 1, pp. 75-100.

Hrantinski, S., 2008, *Asynchronous and Synchronous E-Learning. EDUCAUSE Quarterly*, 2008, Retrieved from https://er.educause.edu/articles/2008/11/asynchronous-and-synchronous-elearning, Vol. 31, No. 4, accessed in April 2021.

Jang, S.J., 2008, "The Effects of Integrating Technology, Observation and Writing Into A Teacher Education Method Course", *Computers and Education*, Vol. 50, No 3, pp. 853-865.

Jun, W.H., J.-W. Lee, H.J. Park, A. Chang, and M.J. Kim, 2013, "Use of the 5E Learning Cycle Model Combined With Problem-Based Learning for A Fundamentals of Nursing Course", *Journal of Nursing Education*, No. 52, pp. 681-689.

Jones, L.L., J.R. MacArthur, and S. Akaygun, 2011, "Using Technology to Engage Preservice Elementary Teachers in Learning About Scientific Inquiry", *CEPS Journal*, Vol. 1, No. 1, pp. 113-131.

Kanuka, H., and D. Conrad, 2003, "The Name of the Game", *Quarterly Review of Distance Education*, Vol. 4, No. 4.

Kaufman, D., and A. Ireland, 2016, "Enhancing Teacher Education With Simulations", *TechTrends*, Vol. 60, No. 3, pp. 260-267.

Klahr, D., L.M. Triona, and C. Williams, 2007, "Hands on What? The Relative Effectiveness of Physical versus Virtual Materials in an Engineering Design Project by Middle School Children", *Journal of Research in Science Teaching*, Vol. 44, No. 1, pp. 183-203.

Kirschner, P.A., J. Sweller, R.E. and Clark, 2006, "Why Minimal Guidance during Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery", *Problem-Based, Experiential and Inquiry-Based Teaching, Educational Psychologist*, Vol. 41, No. 2, pp. 75-86.

Kukkonen, J.E., S. Kärkkäinen, P. Dillon, and T. Keinonen, 2014, "The Effects of

Scaffolder Simulation-Based Inquiry Learning on Fifth-Graders' Representations of the Greenhouse Effect", *International Journal of Science Education*, Vol. 36, No. 3, pp. 406-424.

Kumar, D.D., and R.D. Sherwood, 2007, "Effect of A Problem Based Simulation on the Conceptual Understanding of Undergraduate Science Education Students", J*ournal of Science Education and Technology*, Vol. 16, No. 3, pp. 239-246.

Klahr, D., and M. Nigam, 2004, "The Equivalence of Learning Paths in Early Science Instruction: Effects of Direct Instruction and Discovery Learning", *Psychological Science*, Vol. 15, o. 10, pp. 661-667.

Klahr, D., L.M. Triona, and C. Williams, 2007, "Hands on what? The Relative Effectiveness of Physical versus Virtual Materials in an Engineering Design Project by Middle School Children", *Journal of Research in Science Teaching*, Vol. 44, No. 1, pp. 183-203.

Koehler, M.J., and P. Mishra, 2005, "What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge", *Journal of Educational Computing Research*, Vol. 32, No. 2, pp. 131-152.

Korkko, M., O. Kyro-Ämmälä, and T. Turunen, 2016, "Professional Development through Reflection in Teacher Education", *Teaching and Teacher Education*, No. 55, pp. 198-206.

Kyza, E.A., 2009, "Middle-School Students' Reasoning About Alternative Hypotheses in a Scaffolded, Software-Based Inquiry Investigation", *Cognition and Instruction*, Vol. 27, No. 4, pp. 277-311.

Lazonder, A.W., and R. Harmsen, 2016, "Meta-Analysis of Inquiry-Based Learning: Effects of Guidance", *Review of Educational Research*, Vol. 86, No. 3, pp. 681-718.

Lederman, N.G., J.S. Lederman, and A. Antink, 2013, "Nature of Science and Scientific Inquiry as Contexts for the Learning of Science and Achievement of Scientific Literacy, International Journal of Education in Mathematics", *Science and Technology*, Vol. 1, No. 3.

Lehtinen, A., P. Nieminen, and J. Viiri, 2016, "Preservice Teachers' TPACK Beliefs and Attitudes Toward Simulations", *Contemporary Issues in Technology and Teacher Education*, Vol. 16, No. 2, pp. 151-171.

Levin, O., and H. Flavian, 2020, "Simulation-Based Learning In The Context Of Peer Learning From The Perspective Of Preservice Teachers: A Case Study", *European Journal of Teacher Education*, pp. 1-22.

Lewis-Beck, M., A.E. Bryman, and T.F. Liao, 2003, *The Sage Encyclopedia Of Social Science Research Methods*, Sage Publications.

Lim, W., J.W. Son, and D.J. Kim, 2018, "Understanding Preservice Teacher Skills To Construct Lesson Plans", *International Journal of Science and Mathematics Education*, Vol. 16, No. 3, pp. 519-538.

Lin, N., 1976, *Foundations of Social Research*, McGraw-Hill Companies.

Lincoln, Y.S., and E.G. Guba, 1985, *Naturalistic Inquiry*, Sage.

Lotter, C., W.S. Harwood, and J.J. Bonner, 2007, "The Influence of Core Teaching Conceptions on Teachers' Use of Inquiry Teaching Practices", *Journal of Research in Science Teaching*, Vol. 44, No. 9, pp. 1318-1347.

Loughran, J.J., 2002, "Effective Reflective Practice: In Search of Meaning in Learning About Teaching", *Journal of Teacher Education*, Vol. 53, No. 1, pp. 33-43.

Lowenthal, P.R., L.O. and Cavey, 2021, "Lessons Learned From Creating Videos For Online Video-Based Instructional Modules in Mathematics Teacher Education", *TechTrends*, Vol. 65, No. 2, pp. 225-235.

Luft, J.A., 2001, "Changing Inquiry Practices and Beliefs: The Impact of an Inquiry-Based Professional Development Programme on Beginning and Experienced Secondary Science Teachers", *International Journal of Science Education*, Vol. 23, No. 5, pp. 517-534.

Lynch, R., P.M. McNamara, and N. Seery, 2012, "Promoting Deep Learning in A Teacher Education Programme Through Self-And Peer-Assessment and Feedback", *European Journal of Teacher Education*, Vol. 35, No. 2, pp. 179-197.

Marshall, J.C., J.B. Smart, and D.M. Alston, 2017, "Inquiry-Based Instruction: A Possible Solution to Improving Student Learning of Both Science Concepts and Scientific Practices", *International Journal of Science and Mathematics Education*, Vol. 15, No. 5, pp. 777-796.

Marton, F., 1981, "Phenomenography-Describing Conceptions of the World Aroundus", *Instructional Science*, Vol. 10, No. 2, pp. 177-200.

Marton, F., 1986, "Phenomenography-A Research Approach to Investigating Different Understandings of Reality", *Journal of Thought*, pp. 28-49.

Mayadas, F., 1997, "Asynchronous Learning Networks: A Sloan Foundation Perspective", *Journal of Asynchronous Learning Networks*, Vol. 1, No. 1, pp. 1-16.

McBride, J.W., M.I. Bhatti, M.A. Hannan, and M. Feinberg, 2004, "Using an Inquiry Approach to Teach Science to Secondary School Science Teachers", *Physics Education*, Vol. 39, No. 5, pp. 434.

McElhaney, K., and M. Linn, 2010, "Helping Students Make Controlled Experiments More Informative, In K. Gomez, L. Lyons, And J. Radinsky, Learning in the disciplines: Proceedings of the 9^{th} International Conference of the Learning Sciences (ICLS 2010): Vol. 1. Full papers", *Chicago, IL: International Society of the Learning Sciences*, pp. 786-793.

McCarthy, J., 2015, "Evaluating Written, Audio and Video Feedback in Higher Education Summative Assessment Tasks", *Issues in Educational Research*, Vol. 25, No. 2, pp. 153-169.

Mesci, G., S. Çavuş-Güngören, and F. Yesildag-Hasancebi, 2020, "Investigating the Development of Pre-Service Science Teachers' NOSI Views and Related Teaching Practices", *International Journal of Science Education*, Vol. 42, No. 1, pp. 50-69.

Meyer, K.A., 2003, "Face-To-Face Versus Threaded Discussions: The Role of Time and Higher-Order Thinking", *Journal of Asynchronous Learning Networks*, Vol. 7, No. 3, pp. 55-65.

Meyer, D. Z., A.A. Meyer, K.A. Nabb, M.G. Connell, and L.M. Avery, 2013, "A Theoretical and Empirical Exploration of Intrinsic Problems in Designing Inquiry Activities", *Research in Science Education*, No. 43, pp. 57-76.

Minner, D.D., A.J. Levy, and J. Century, 2010, "Inquiry-Based Science Instruction-What Is it And Does It Matter? Results from a Research Synthesis Years 1984 to 2002", *Journal of Research in Science Teaching*, Vol. 47, No. 4, pp. 474-496.

Miles, M.B., and A.M. Huberman, 1994, *Qualitative Data Analysis: An Expanded Sourcebook*, Sage.

Miles, M.B., A.M. Huberman, and J. Saldaña, 2018, *Qualitative Data Analysis: A Methods Sourcebook*, Sage Publications.

Ministry of National Education, 2018, *Fen Bilimleri Dersi Öğretim Programı*, Ankara.

Moore, E.B., J.M. Chamberlain, R. Parson, and K.K. Perkins, 2014, "PhET Interactive Simulations: Transformative Tools for Teaching Chemistry", *Journal of Chemical Education*, Vol. 91, No. 8, pp. 1191-1197.

Moore, M.G., and G. Kearsley, 2012, *Basic Concepts, In Distance Education: A Systems View of Online Learning (3rd ed.), Belmont*, CA: Wadswort.

Moorhouse, B.L., 2020, "Adaptations to a Face-To-Face Initial Teacher Education Course Forced Online Due To the COVID-19 Pandemic", *Journal of Education for Teaching*, pp. 1-3.

Mortari, L., 2012, "Learning Thoughtful Reflection in Teacher Education", *Teachers and Teaching*, Vol. 18, No. 5, pp. 525-545.

Munby, H., and T. Russell, 1990, "Metaphor in the Study of Teachers' Professional Knowledge", *Theory Into Practice*, Vol. 29, No. 2, pp. 116-121.

Namdar, B., and M. Kucuk, 2018, "Preservice Science Teachers' Practices of Critiquing and Revising 5E Lesson Plans", *Journal of Science Teacher Educatio*n, Vol. 29, No. 6, pp. 468-484.

National Research Council (NRC), 2000, *Inquiry and the National Science Education Standards*, Washington, DC: National Academies Press.

Nhlengethwa, K.B., N. Govender, and D. Sibanda, 2021, "Primary School Pre-Service Teachers' Enactment of Inquiry-Based-Science Teaching", *Education 3-13*, Vol. 49, No. 3, pp. 288-301.

Olympiou, G., Z. Zacharias, and T. Dejong, 2013, "Making the Invisible Visible: Enhancing Students' Conceptual Understanding by Introducing Representations of Abstract Objects in a Simulation", *Instructional Science*, Vol. 41, No. 3, pp. 575-596.

Oner, D., and Adadan, E., 2011, "Use Of Web-Based Portfolios as Tools for Reflection in Preservice Teacher Education", *Journal of Teacher Education*, Vol. 62, No. 5, pp. 477-492.

Oner, D., and E. Adadan, 2016, "Are Integrated Portfolio Systems the Answer? An Evaluation of a Web-Based Portfolio System to Improve Preservice Teachers' Reflective Thinking Skills", *Journal of Computing in Higher Education*, Vol. 28, No.

2, pp. 236-260.

Ornstein, A.C., and F.P. Hunkins, 1988, "Curriculum Design, In Curriculum: Foundations, Principles, and Issues", *Englewood Cliffs, NJ: Prentice Hall*, pp. 234-270.

Owens, R.F., J.L. Hester, and W.H. Teale, 2002, "Where Do you want to Go Today? Inquiry-Based Learning and Technology Integration", *The Reading Teacher*, Vol. 55, No. 7, pp. 616-625.

Ozkaral, T.C., and R. Bozyigit, 2020, "Social Studies and Geography Teacher Candidates' Views on Coronavirus (Covid 19) and Online Education Process", *Review of International Geographical Education Online*, Vol. 10, No. 3, pp. 467-484.

Pajares, M.F., 1992, "Teachers' Beliefs And Educational Research: Cleaning Up A Messy Construct", *Review of Educational Research*, Vol. 62, No. 3, pp. 307-332.

Pekbay, C., and Ö. Koray, 2020, "Alternative Assessment Tools Based on a Feedback Process: Perceptions of Pre-Service Science Teachers", *Malaysian Online Journal of Educational Sciences*, Vol. 8, No. 1, pp. 50-63.

Perkins, K., E. Moore, N. Podolefsky, K. Lancaster, and C. Denison, 2012, "Towards Research-Based Strategies For Using Phet Simulations In Middle School Physical Science Classes, In AIP Conference Proceedings", *American Institute of Physics*, Vol. 1413, No. 1, pp. 295-298.

Pringle, R.M., J. Mesa, and L. Hayes, 2017, "Professional Development For Middle School Science Teachers: Does an Educative Curriculum Make a Difference?", *Journal of Science Teacher Education*, Vol. 28, No. 1, pp. 57-72.

Ryoo, K., and M.C. Linn, 2012, "Can Dynamic Visualizations Improve Middle School Students' Understanding of Energy In Photosynthesis?", *Journal of Research in Science Teaching*, Vol. 49, No. 2, pp. 218-243.

Rodriguez, J., T. McKinney, S. Powell, Z. Walker, and K. Vince Garland, 2018, "Was

This Feedback Useful? Examining the Observation and Feedback Process for Pre-Service Teachers", *Teaching Education*, Vol. 31, No. 2, pp. 144-161.

Rutten, N., W.R. Van Joolingen, and J.T. Van Der Veen, 2012, "The Learning Effects of Computer Simulations in Science Education", *Computers and Education*, Vol. 58, No. 1, pp. 136-153.

Rutten, N., J.T. van der Veen, and W.R. van Joolingen, 2015, "Inquiry-Based Whole-Class Teaching with Computer Simulations in Physics", *International Journal of Science Education*, Vol. 37, No. 8, pp. 1225-1245.

Seago, N., K. Koellner, and J. Jacobs, 2018, "Video in the Middle: Purposeful Design of Video-Based Mathematics Professional Development", *Contemporary Issues in Technology and Teacher Education*, Vol. 18, No. 1, pp. 29-49.

Sargeant, J.M., K.V. Mann, C.P. Van der Vleuten, and J.F. Metsemakers, 2009, "Reflection: A Link between Receiving and Using Assessment Feedback", *Advances in Health Sciences Education*, Vol. 14, No. 3, pp. 399-410.

Schön, D., 1983, *The Reflective Practitioner*, New York, NY: Basic Books.

Scull, J., M. Phillips, U. Sharma, and K. Garnier, 2020, "Innovations in Teacher Education at the Time of COVID19: An Australian Perspective", *Journal of Education for Teaching*, pp. 1-10.

Settlage, J., 2007, "Demythologizing Science Teacher Education: Conquering the False Ideal of Open Inquiry", *Journal of Science Teacher Education*, Vol. 18, No. 4, pp. 461-467.

Severino, L., M. Petrovich, S. Mercanti-Anthony, and S. Fischer, 2021, "Using a Design Thinking Approach for an Asynchronous Learning Platform during COVID-19", *IAFOR Journal of Education*, Vol. 9, No. 2, pp. 145-162.

Simonson, M., S. Smaldino, and S. Zvacek, 2015, *Teaching and Learning at a Distance*

Foundations of Distance Education, Charlotte, North Carolina: Information Age Publishing, Inc.

Smetana, L.K., and R.L. Bell, 2012, "Computer Simulations to Support Science Instruction and Learning: A Critical Review of the Literature", *International Journal of Science Education*, Vol. 34, No. 9, pp. 1337-1370.

Slotta, J.D., and M.C. Linn, 2009, *WISE Science: Web-based Inquiry in the Classroom. Technology*, Education-Connections, Teachers College Press. 1234 Amsterdam Avenue, New York, NY 10027.

Stake, R.E., 1995, *The Art of Case Study Research*, Sage.

Stavroulia, K.E., E. Makri-Botsari, S. Psycharis, and G. Kekkeris, 2016, "Emotional Experiences in Simulated Classroom Training Environments", *International Journal of Information and Learning Technology*, Vol. 33, No. 3, pp. 172-185.

Strijbos, J.W., and Sluijsmans, D.M.A., 2010, "Unravelling Peer Assessment through (Quasi) Experimental Research", *Learning and Instruction*, Vol. 20, No. 4, pp. 265-269.

Strijbos, J.W., S. Narciss, K. Dunnebier, 2010, "Peer Feedback Content and Sender's Comptence Level in Academic Writing Revision Tasks: Are They Critical for Feedback Perceptions and Efficiency?", *Learning and Instruction*, Vol. 20, No. 4, pp. 291-303.

Swanson, R.A., and E.F. Holton, 2005, *Research in Organizations: Foundations and Methods in Inquiry*, Berrett-Koehler Publishers.

Tallent-Runnels, M.K., J.A. Thomas, W.Y. Lan, S. Cooper, T.C. Ahern, S.M. Shaw, and X. Liu, 2006, "Teaching Courses Online: A Review of the Research", *Review of Educational Research*, Vol. 76, No. 1, pp. 93-135.

Tao, P.K., and R.F. Gunstone, 1999, "The Process of Conceptual Change in Force and

Motion During Computer-Supported Physics Instruction", *Journal of Research in Science Teaching: Journal of Research in Science Teaching*, Vol. 36, No. 7, pp. 859-882.

Taylor, S.J., R. Bogdan, and M. DeVault, 2015, *Introduction to Qualitative Research Methods: A Guidebook and Resource*, John Wiley and Sons.

Theelen, H., A. Van den Beemt, and P. den Brok, 2019, "Classroom Simulations in Teacher Education to Support Preservice Teachers' Interpersonal Competence: A Systematic Literature Review", *Computers and Education*, Vol. 129, pp. 14-26.

Thurlings, M., M. Vermeulen, T. Bastiaens, and S. Stijnen, 2013, "Understanding Feedback: A Learning Theory Perspective", *Educational Research Review*, No. 9, pp. 1-15.

Tinker, R.F., and Q. Xie, 2008, "Applying Computational Science to Education: The Molecular Workbench Paradigm", *Computing in Science and Engineering*, Vol. 10, No. 5, pp. 24-27.

Topping, K.J., 1998, "Peer Assessment between Students in Colleges and Universities", *Review of Educational Research*, No.68, pp. 249-276.

Toquero, C.M., 2020, "Challenges and Opportunities for Higher Education amid the COVID-19 Pandemic: The Philippine Context", *Pedagogical Research*, Vol. 5, No. 4.

Trumbull, D.J., and P. Kerr, 1993, "University Researchers' Inchoate Critiques of Science Teaching: Implications for the Content of Preservice Science Teacher Education", *Science Education*, Vol. 77, No. 3, pp. 301-17.

Quezada, R.L., C. Talbot, and K.B. Quezada-Parker, 2020, "From Bricks and Mortar to Remote Teaching: A Teacher Education Program'S Response to COVID-19", *Journal of Education for Teaching*, Vol. 46, No. 4, pp. 472-483.

UNESCO, 2020, *Türkiye Millî Komisyonu*, 2020 https://en.unesco.org/covid19/educationresponse , accessed in December 2019.

Xie, C., R. Tinker, B. Tinker, A. Pallant, D. Damelin, and B. Berenfeld, 2011, "Computational Experiments for Science Education", *Science*, Vol. 332, No. 6037, pp. 1516-1517.

Van Joolingen, W.R., T. de Jong, A.W. Lazonder, E.R. Savelsbergh, and S. Manlove, 2005, "Co-Lab: Research and Development of an Online Learning Environment for Collaborative Scientific Discovery Learning", *Computers in Human Behavior*, Vol. 21, No. 4, pp. 671-688.

Walker, K.A., and D.L. Zeidler, 2007, "Promoting Discourse About Socioscientific Issues Through Scaffolded Inquiry", *International Journal of Science Education*, Vol. 29, No. 11, pp. 1387-1410.

Wang, J., and Y. Wang, 2020, "Compare Synchronous and Asynchronous Online Instruction for Science Teacher Preparation", *Journal of Science Teacher Education*, Vol. 1, No. 18, pp. 1-21.

Wang, Q., and H.L. Woo, 2007, "Comparing Asynchronous Online Discussions and Face-To-Face Discussions in A Classroom Setting", *British Journal of Educational Technology*, Vol. 38, No. 2, pp. 272-286.

Wanner, T., and E. Palmer, 2018, "Formative Self-And Peer Assessment for Improved Student Learning: The Crucial Factors of Design, Teacher Participation and Feedback", *Assessment and Evaluation in Higher Education*, Vol. 43, No. 7, pp. 1032-1047.

Wieman, C.E., W.K. Adams, and K.K. Perkins, 2008, "PhET: Simulations That Enhance Learning", *Science*, Vol. 322, No. 5902, pp. 682-683.

Windschitl, M., 2000, "Supporting the Development of Science Inquiry Skills With

Special Classes of Software", *Educational Technology Research and Development*, Vol. 48, No. 2, pp. 81-95.

Williams, E., 1992, "Student Attitudes towards Approaches to Learning and Assessment", *Assessment and Evaluation in Higher Education*, No.17, pp. 45-58.

WHO, 2020, *Director-General's Opening Remarks at the Media Briefing on COVID19*, https://www. who .int/emergencies/diseases/novel-coronavirus-2019, accessed in March 2020.

Welch, W.W., 1981, "The Role of Inquiry in Science Education: Analysis and Recommendations", *Science Education*, Vol. 65, No. 1, pp. 33-50.

Wen, M.L., and C.C. Tsai, 2008, "Online Peer Assessment in an Inservice Science and Mathematics Teacher Education Course", *Teaching in Higher Education*, Vol. 13, No. 1, pp. 55-67.

Yuliati, L., C. Riantoni, and N. Mufti, 2018, "Problem Solving Skills on Direct Current Electricity Through Inquiry-Based Learning With Phet Simulations", *International Journal of Instruction*, Vol. 11, No. 4, pp. 123-138.

Yin, R.K., 2011, *Case Study Research: Design and Methods, 4th Edition*, In United States: Library of Congress Cataloguing-in-Publication Data.

Zhang, M., and C. Quintana, 2012, "Scaffolding Strategies for Supporting Middle School Students' Online Inquiry Processes", *Computers and Education*, Vol. 58, No. 1, pp. 181-196.

APPENDIX A: SEMI STRUCTURED PRE-INTERVIEW QUESTIONS

Yarı Yapılandırılmış Ön-Görüşme Soruları

Merhaba, ben Ilgım Özergun. Boğaziçi Üniversite'sinde matematik ve fen bilimleri eğitimi bölümünde yüksek lisans öğrencisiyim. Aynı zamanda Şubat 2020'den beri ÇOMÜ fen bilgisi eğitiminde araştırma görevlisiyim. Koronadan dolayı yüz yüze tanışamadık. Sen de;

1) Kendinden kısaca bahseder misin?
2) Ders planı nedir?
    a. Ders planı hazırlarken hangi metodu kullanıyorsun?
    b. Ders planı hazırlarken 5E metodunu kullandın mı?
    c. 5E metoduna göre ders planı hazırlamayı nerede ve ne zaman öğrendin?
    d. 5E metoduna göre ders planı hazırlarken neleri göz önünde bulundurursun?
    e. 5E metoduna göre ders planı hazırlarken uyguladığın fen öğretimi metotları nelerdir?
3) Sorgulamaya dayalı fen öğretimi metodu nedir?
    a. Daha önce hiç sorgulamaya dayalı fen öğretimi metodunu kullandın mı?
    b. Sorgulamaya dayalı fen öğretimi metodu için hangi kriterler gereklidir?
    c. Sorgulamaya dayalı fen öğretimi metodu, 5E metoduna göre hazırlanmış bir dersin hangi aşamalarında kullanılabilir?
    d. Sorgulamaya dayalı fen öğretimi metodunu teknoloji ile birlikte kullandın mı? / Hangi teknolojiler ile kullanılabilir?
4) Simülasyon nedir?
    a. Daha önce hiç simülasyon kullandın mı? Evet ise,
        i. Simülasyonu fen bilgisi ders planında hangi öğretim metotlarıyla birlikte kullandın?
        ii. Simülasyonu hiç sorgulamaya dayalı fen öğretiminde ile birlikte kullandın mı?
        iii. Simülasyon ile sorgulamaya dayalı fen öğretimi, 5E metoduna göre hazırlanmış bir dersin hangi aşamalarında kullanılabilir?
    b. Daha önce hiç simülasyon kullandın mı? Hayır ise,

Figure A.1. Semi Structured Pre-Interview Questions.

i. Simülasyonu fen bilgisi dersinde nasıl kullanabilirsin?
ii. Simülasyonu fen bilgisi öğretim metotlarından hangilerinde kullanabilirsin?
iii. Simülasyon sorgulamaya dayalı fen öğretimi, ile birlikte kullanılabilir mi?
iv. Simülasyon ile sorgulamaya dayalı fen öğretimi 5E metoduna göre hazırlanmış bir dersin hangi aşamalarında kullanılabilir?

5) Online (çevrimiçi) öğrenme ortamları ile ilgili neler düşünüyorsun?
   a. Çevrimiçi öğrenme ortamlarının türleri neler olabilir?
   b. Öğretmen ve öğrencinin aynı anda aktif olmadığı çevrim içi öğrenme ortamına ne isim verilir?
   c. Asenkron öğrenme ortamlarında hiç derse girdin mi?
   d. Asenkron öğrenme ortamlarında hiç ders verdin mi? (özel ders vs.)
   e. Asenkron öğrenme ortamları için hiç ders planı hazırladın mı?
   f. Asenkron öğrenme ortamları 5E metoduna göre hazırlanmış bir dersin hangi aşamalarında kullanılabilir?
   g. Sence korona bittikten sonra da asenkron öğrenme ortamları kullanılmaya devam edecek mi?
6) Asenkron öğrenme ortamlarında sorgulamaya dayalı fen öğretimi metodu kullanılabilir mi? Nasıl?
7) Asenkron öğrenme ortamlarında simülasyonlar kullanılabilir mi? Nasıl?

Figure A.2. Semi Structured Pre-Interview Questions 1.

APPENDIX B: SIMINA SELECTED SLIDES

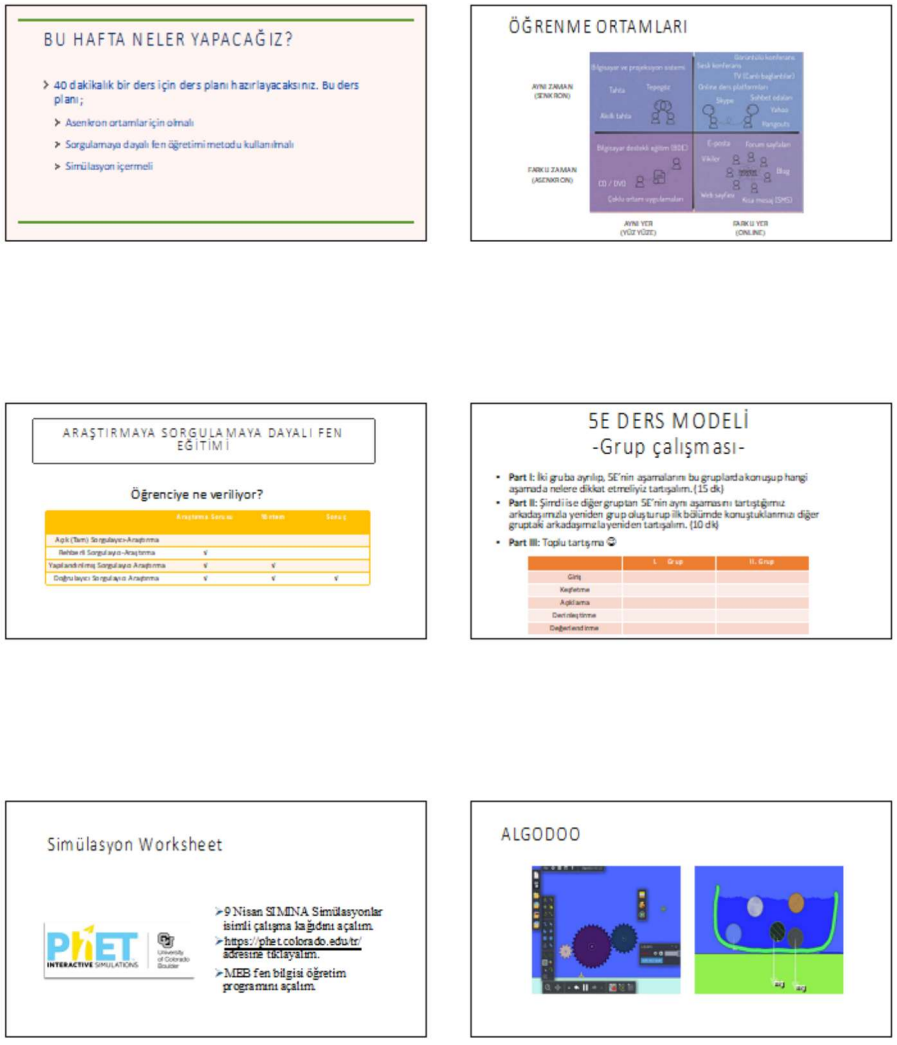


Figure B.1. Simina Selected Slides.

APPENDIX C: SIMINA SELECTED WORKSHEETS

Week 2 - Inquiry Based Science Education
Lecture 4 (22-26 March)

- An example worksheet for inquiry-based & 5E Topics from MEB Objectives.

Ünite/Konu	Kazanım	Araştırma Sorusu (Soruları)	Veri Toplama & Analiz
F.7.7 Elektrik Devreleri / F.7.7.1Ampullerin Bağlanma Şekilleri	F.7.7.1.2. Ampullerin seri ve paralel bağlandığı durumlardaki parlaklıklarını devre üzerinde gözlemleyerek çıkarımda bulunur.	Ampul sayısını arttırmak seri devrelerdeki parlaklığı nasıl etkiler?	Veri Toplama: gerçek dünya ya da simülasyon ile veri toplanabilir. Gözlem Yapılabilir Veri Analizi: Toplanan veriler grafikler yardımıyla analiz edilir.
F.6.4 Madde ve Isı / F.6.4.1 Maddenin Tanecikli Yapısı	F.6.4.1.2. Hâl değişimine bağlı olarak maddenin tanecikleri arasındaki boşluk ve taneciklerin hareketliliğinin değiştiğini deney yaparak karşılaştırır.	Maddenin düzensizliği arttıkça moleküllerin hareketi nasıl değişir?	Veri Toplama: Çıplak göz ile molekül hareketini göremeyiz. O halde video, animasyon ya da simülasyon ile veri toplamamız gerekir. Veri Analizi: Gözlem yaparak topladığımız verileri çizerek ya da sözlü anlatarak/yazarak analiz edilir.
F.8.6 Enerji Dönüşümleri ve Çevre Bilimi / F.8.6.2 Enerji Dönüşümleri	F.8.6.2.2. Fotosentez hızını etkileyen faktörler ile ilgili çıkarımlarda bulunur.	Bitkinin aldığı su miktarı bitkinin fotosentez hızını nasıl etkiler?	Veri Toplama: Işık şiddeti ve sıcaklığın sabit tutulduğu bir ortamda 3-4 farklı bitki ile deney düzeneği kurulur. Her bir bitkiye farklı miktarda su verilerek gelişimi izlenir. Veri Analizi: Bitkinin gelişimi için günlük not tutulabilir, fotoğraf çekilebilir. Veriler tablolaştırılır.
F. 6.3. Kuvvet ve Hareket / 6.3.1 Bileşke Kuvvet	F.6.3.1.2. Bir cisme etki eden birden fazla kuvveti deneyerek gözlemler.		
F.8.4 Madde ve Endüstri / 8.4.4.Asitler ve Bazlar	F.8.4.4.2. Asit ve bazlara günlük yaşamdan örnekler verir.		
F. 8.6. Enerji Dönüşümleri ve Çevre Bilimi / 8.6.1 Besin Zinciri ve Enerji Akışı	F.8.6.1.1. Besin zincirindeki üretici, tüketici, ayrıştırıcılara örnekler verir.		

Figure C.1. Simina Selected Worksheets.

Week 4 – Simulations
Lecture 7 (5-9 April)

- Example simulation learning environments in science education
  - PhET
    - Example simulations from PhET
    - Simulations' relation to MEB's objectives
    - Advantages & Disadvantages of example PhET Simulations
    - PhET Simulations' Integration to inquiry-based science education
    - PheT Simulations' Integration to Asynchronous learning environments
    - An example worksheet;

Link	Kazanım	Fen Dersinde Nasıl Kullanılabilir	Araştırma Sorusu	Veri Toplama ve Analizi
https://phet.colorado.edu/tr/simulation/circuit-construction-kit-dc				
https://phet.colorado.edu/tr/simulation/forces-and-motion-basics				
https://phet.colorado.edu/sims/html/ph-scale/latest/ph-scale_tr.html				
https://phet.colorado.edu/tr/simulation/states-of-matter-basics				

  - Algodoo
    - Example simulations from Algodoo
    - Simulations' relation to MEB's objectives
    - Advantages & Disadvantages of example Algodoo Simulations
    - Algodoo Simulations' Integration to inquiry-based science education
    - Algodoo Simulations' Integration to Asynchronous learning environments

Konu	Kazanım	Fen Dersinde Nasıl Kullanılabilir	Araştırma Sorusu	Veri Toplama ve Analizi
Kuvvet ve Hareket / Basit Makineler	F.8.5.1.1. Basit makinelerin (dişli çarklar ve kasnaklar) sağladığı avantajları örnekler üzerinden açıklar.			
Madde ve Isı / Yoğunluk	F.6.4.2.3. Birbiri içinde çözünmeyen sıvıların yoğunluklarını deney yaparak karşılaştırır.			
Işığın Madde ile Etkileşimi / Işığın Soğurulması	F.7.5.1.2. Beyaz ışığın tüm ışık renklerinin bileşiminden oluştuğu sonucunu çıkarır.			

Figure C.2. Simina Selected Worksheets 1.

Week 5 – Simulations
Lecture 8 (12-16 April)

- Concord Consortium
  - Example simulations from Concord Consortium
  - Simulations' relation to MEB's objectives
  - Advantages & Disadvantages of example Concord Consortium Simulations
  - Concord Consortium Simulations' Integration to inquiry-based science education
  - Concord Consortium Simulations' Integration to Asynchronous learning environments

Link	Kazanım	Fen Dersinde Nasıl Kullanılabilir	Araştırma Sorusu	Veri Toplama ve Analizi
http://has.concord.org/air-pollution.html				
https://concord.org/hioh/build-dam/				

- WISE (Web-based Inquiry Science Environments)
  - Example simulations from WISE
  - Simulations' relation to MEB's objectives
  - Advantages & Disadvantages of example WISE Simulations
  - WISE Simulations' Integration to inquiry-based science education
  - WISE Simulations' Integration to Asynchronous learning environments
  - An example worksheet;

Link	Kazanım	Fen Dersinde Nasıl Kullanılabilir	Araştırma Sorusu	Veri Toplama ve Analizi
https://wise.berkeley.edu/preview/unit/31904/node35				
https://wise.berkeley.edu/preview/unit/33169/node52				

Figure C.3. Simina Selected Worksheets 3.

Week 5 – Simulations
Lecture 9 (12-16 April)

- selected simulations' adaptation to asynchronous learning environments
    - one simulation from PhET will tried to adapt asynchronous learning environments
    - one simulation from Algodoo will tried to adapt asynchronous learning environments
    - one simulation from Concord Consortium will tried to adapt asynchronous learning environments
    - one simulation from WISE will tried to adapt asynchronous learning environments

Link	Kazanım	Sorgulamaya Dayalı Fen Eğitiminde Kullanımı	Asenkron Öğrenme Ortamlarında Kullanımı
https://phet.colorado.edu/tr/simulation/circuit-construction-kit-dc			
Kuvvet ve Hareket (Algodoo)			
https://wise.berkeley.edu/preview/unit/33169/node52			
http://has.concord.org/air-pollution.html			

Figure C.4. Simina Selected Worksheets 4.

APPENDIX D: SEMI STRUCTURED POST-INTERVIEW QUESTIONS

Yarı Yapılandırılmış Son-Görüşme Soruları

1) İşlediğimiz modülde sorgulamaya dayalı fen öğretimi ile ilgili neler deneyimledin?
    a. Sorgulamaya dayalı fen öğretim metodu için hangi kriterleri nelerdir?
    b. Sorgulamaya dayalı fen öğretimi 5E metoduna göre hazırlanmış bir dersin hangi aşamalarında kullanılabilir?
2) İşlediğimiz modülde simülasyonlar ile ilgili neler deneyimledin?
    a. Simülasyonlar ile sorgulamaya dayalı fen öğretimi metodu birlikte nasıl kullanılabilir?
    b. Simülasyonla desteklenmiş sorgulamaya dayalı fen öğretimi metodu 5E metoduna göre hazırlanmış bir dersin hangi aşamalarında kullanılabilir?
3) İşlediğimiz modülde asenkron öğrenme ortamları ile ilgili neler deneyimledin?
    a. Sorgulamaya dayalı öğretimin asenkron öğrenme ortamlarında kullanılmasıyla ilgili ne düşünüyorsun?
    b. Simülasyonların asenkron öğrenme ortamlarında kullanılmasıyla ilgili ne düşünüyorsun?
    c. Simülasyonla desteklenmiş sorgulamaya dayalı fen öğretiminin asenkron öğrenme ortamlarında kullanılmasıyla ilgili ne düşünüyorsun?
4) Asenkron öğrenme ortamlarında simülasyonla desteklenmiş sorgulamaya dayalı fen öğretimi için ders planı hazırlarken neler deneyimledin?
    a. Hazırladığın ders planının asenkron öğrenme ortamlarına göre güçlü ve zayıf yönleri nelerdir?
    b. Hazırladığın ders planında; asenkron öğrenme ortamlarında sorgulamaya dayalı fen öğretimini kullanmanın güçlü ve zayıf yönleri nelerdir?
    c. Hazırladığın ders planında; asenkron öğrenme ortamlarında simülasyonla desteklenmiş sorgulamaya dayalı fen öğretimini kullanmanın göre güçlü ve zayıf yönleri nelerdir?
5) Benden ya da arkadaşlarından aldığın geri bildirimler ders planını iyileştirmede etkili oldu mu?

6) Hazırladığın ders planını videoya çekerken neler deneyimledin?

Figure D.1. Simina Selected Worksheets 1.

a. Çektiğin ders videosunun güçlü ve zayıf yönleri nelerdir?
b. Çektiğin ders videosunun asenkron öğrenme ortamları için uygun olduğunu düşünüyor musun? Neden?
c. Çektiğin ders videosunun simülasyonla desteklenmiş sorgulamaya dayalı fen öğretimine uygun olduğunu düşünüyor musun? Neden?

7) Modül ile ilgili genel deneyimlerin nelerdir?
   a. Modülün öğretmenlik deneyimine faydası olduğunu düşünüyor musun?
   b. Modülün güçlü veya zayıf bulduğun yönleri nelerdir?
   c. Modül ile ilgili eleştirilerin nelerdir?
8) Eklemek istediklerin …

Katılımın için çok teşekkür ediyorum. Başarılar dilerim.

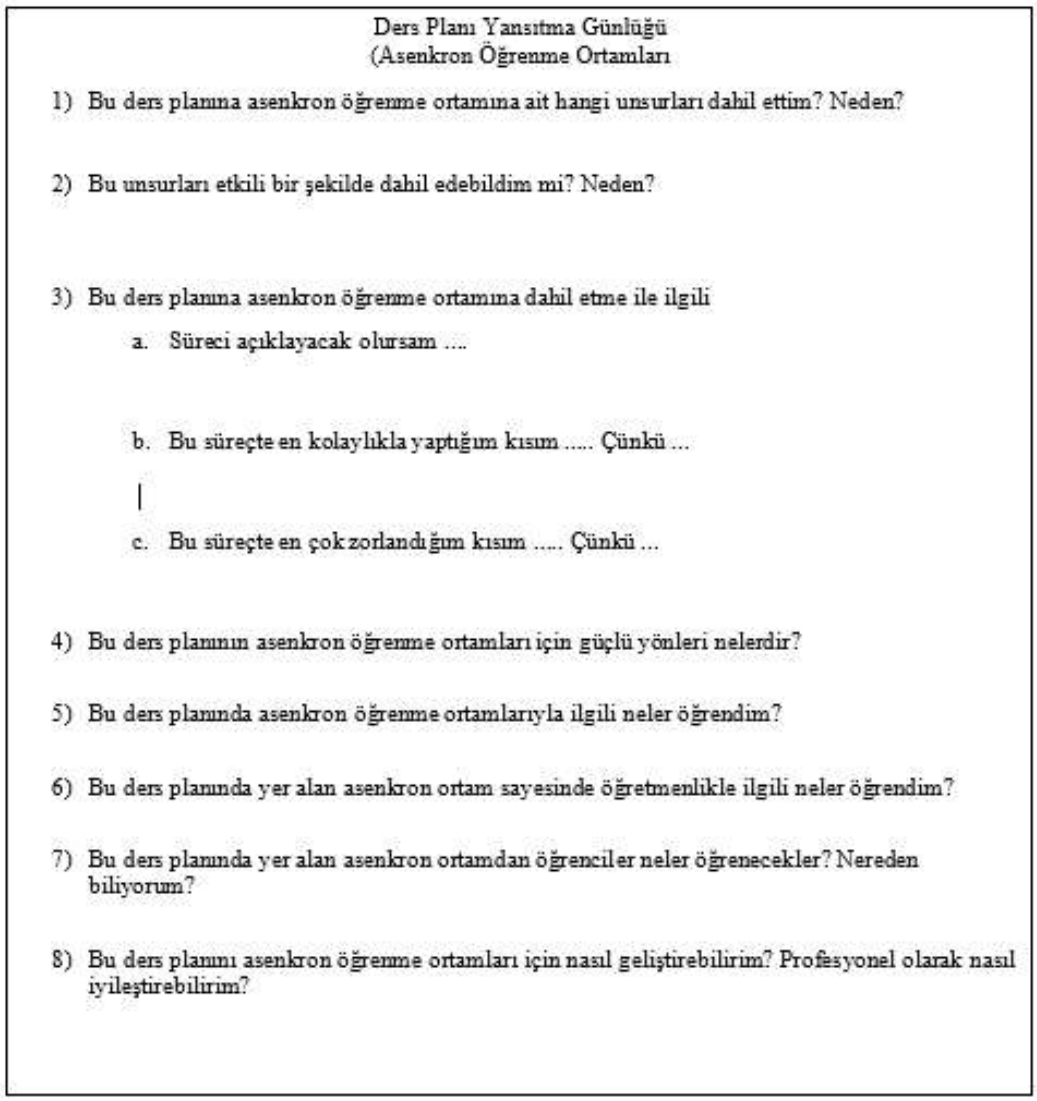
Figure D.2. Simina Selected Worksheets 2.

APPENDIX E: SELECTED FEEDBACK SHEET

Ad: **Geri Bildirim Verilecek Kişinin Adı: Selin** Sorular	**Modülün Adı: Asenkron** Geribildirim
1. Bu ders planında asenkron öğrenme ortamlarına ait hangi unsurları içeriyor? 2. Bu unsurları etkili bir şekilde gerçekleştirmiş mi? Neden?	
3.Bu ders asenkron öğrenme ortamlarına ait güçlü yönleri nelerdir?	
4. Bu ders planında asenkron öğrenme ortamlarına ait geliştirilmesi gereken yönleri nelerdir? 5. Ders planının daha güçlü (etkili) hale getirilmesi için asenkron öğrenme ortamlarına ilişkin ne gibi değişiklikler yapılmasını önerirsin?	

Figure E.1. Simina Selected Worksheets 1.

APPENDIX F: SELECTED REFLECTION SHEET



Ders Planı Yansıtma Günlüğü
(Asenkron Öğrenme Ortamları

1) Bu ders planına asenkron öğrenme ortamına ait hangi unsurları dahil ettim? Neden?

2) Bu unsurları etkili bir şekilde dahil edebildim mi? Neden?

3) Bu ders planına asenkron öğrenme ortamına dahil etme ile ilgili
   a. Süreci açıklayacak olursam ....
   b. Bu süreçte en kolaylıkla yaptığım kısım ..... Çünkü ...
   c. Bu süreçte en çok zorlandığım kısım ..... Çünkü ...

4) Bu ders planının asenkron öğrenme ortamları için güçlü yönleri nelerdir?

5) Bu ders planında asenkron öğrenme ortamlarıyla ilgili neler öğrendim?

6) Bu ders planında yer alan asenkron ortam sayesinde öğretmenlikle ilgili neler öğrendim?

7) Bu ders planında yer alan asenkron ortamdan öğrenciler neler öğrenecekler? Nereden biliyorum?

8) Bu ders planını asenkron öğrenme ortamları için nasıl geliştirebilirim? Profesyonel olarak nasıl iyileştirebilirim?

Figure F.1. Selected Reflection Sheet 1.

Ben, (katılımcının adı) ....., yukarıdaki metni okudum ve katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında soru sorma imkânı buldum. Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi olumsuzluk ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Figure G.3. Consent Form 3.