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Predictors of Global Scientific Literacy of Pre-Service Teachers: A Structural Equation Modeling Study*

Öğretmen Adaylarının Evrensel Fen Okuryazarlığının Yordayıcıları: Bir Yapısal Eşitlik Modellemesi Çalışması

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ABSTRACT: The purpose of this study was to examine the relationship among pre-service science teachers' global scientific literacy and various variables within the scope of the structural equation model. Since the relations among the variables were investigated in the structural model established for this study, correlational research methodology was applied. The application was carried out with 294 pre-service teachers studying in the departments of chemistry, physics, biology and elementary science education of a state university. The data of the study were obtained with the scales of global scientific literacy, the perception of science process skills, the inquiry skills, the self-directed learning readiness in laboratory, the attitude scale towards the laboratory and the personal information questionnaire. Within the framework of structural equation modeling, the causal and relational analyses of the data were examined. The results showed that the proposed model of the relationship among global scientific literacy and the variables predicting global scientific literacy was also found to be compatible with the data, and the entire model was confirmed except for the attitude towards the laboratory. In this context, it can be claimed that these variables play an essential role in pre-service teachers' being global scientifically literate.

Keywords: Global scientific literacy, inquiry skills, perception of science process skills, self-directed learning readiness in laboratory, pre-service science teachers.

ÖZ: Bu araştırmanın amacı fen alanları öğretmen adaylarının evrensel fen okuryazarlıklarının çeşitli değişkenlerle olan ilişkisini yapısal eşitlik modeli kapsamında incelemektir. Çalışmanın amacı kapsamında ortaya konan yapısal modelde ele alınan değişkenler arasındaki ilişkiler incelendiği için araştırmada korelasyonel araştırma yöntemi kullanılmıştır. Uygulama bir devlet üniversitesinin kimya, fizik, biyoloji ve fen bilgisi eğitimi anabilim dallarında öğrenimine devam eden 294 öğretmen adayı ile gerçekleştirilmiştir. Araştırmada veriler evrensel fen okuryazarlık ölçeği, bilimsel süreç becerileri algı ölçeği, sorgulama becerileri ölçeği, laboratuvarda kendi kendine öğrenme hazırbulunuşluk ölçeği, laboratuvara yönelik tutum ölçeği ve kişisel bilgi anketi ile elde edilmiştir. Toplanan verilere ilişkin nedensel ve ilişkisel analizler yapısal eşitlik modellemesi kapsamında incelenmiştir. Araştırma sonuçlarına göre evrensel fen okuryazarlığı ile evrensel fen okuryazarlığını yordayıcı değişkenler arasındaki ilişkiye ait önerilen modelin veri ile uyumlu olduğu belirlenmiş ve tüm model laboratuvara yönelik tutum değişkeni dışında doğrulanmıştır. Bu bağlamda öğretmen adaylarının evrensel fen okuryazarı olmalarında söz konusu değişkenlerin önemli bir role sahip olduğu söylenebilir.

Anahtar kelimeler: Evrensel fen okuryazarlığı, sorgulama becerileri, bilimsel süreç becerileri algısı, laboratuvarda kendi kendine öğrenme hazırbulunuşluğu, fen alanları öğretmen adayları.

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The fact that the world is in constant development and change brings along technological innovations, and these innovations reshape the world we live in. While globalization and competition between countries continue unceasingly, they aim to keep up with economic, scientific and technological developments. It is crucial for accomplishing this goal that the individuals who make up the society are educated, creative, well-equipped, capable of solving problems, able to adjust to advances in science and technology, and able to assimilate scientific knowledge, use and transfer it effectively. It is possible for individuals to acquire these qualities if they get reach scientific literacy (Lieskovský & Sunyík, 2022; Putra et al., 2016). Accordingly, it is essential for civilizations to be scientifically literate so that they can follow the ever-increasing developments and be involved in the innovation process (Zainuri et al., 2020).

People who are scientifically literate conduct research, ask probing questions, offer constructive criticism, are curious about the world they live in, have values, attitudes, understanding and skills related to science, are equipped with knowledge, and consider lifelong learning (Ministry of National Education [MoNE], 2018). Considering the revised curriculum, individuals who are scientifically literate have science process skills, life skills, inquiry skills, engineering and design abilities, and a positive attitude towards science (MoNE, 2018). The process of educating individuals to be scientifically literate begins in the primary school period, when the individual learns to read and write, and experiences science lessons for the first time, and continues throughout their lives. It is feasible to raise these people through science education so that they have embraced modern scientific ideas and are capable of approaching challenges from a variety of disciplinary perspectives (Derman, 2014). Science education aims to know the basic concepts, theories, laws and principles of science, to use scientific process skills and scientific concepts, to produce knowledge by questioning (Chin & Osborne, 2008; Karapınar, 2016). In addition, it seeks to develop scientifically literate people who are aware of their scientific life and employ their minds (Oliver & Adkins, 2020). In this context, one of the primary objectives of science education is to promote scientific literacy.

In addition to the universality of science, education systems also have a global character. Regardless of the society they are a part of, each person acquires a universal quality. From this point of view, Choi et al. (2011) renamed the concept of scientific literacy and introduced it to the literature as global scientific literacy. The reason for the renewal of the concept in this way is that the individuals who make up the societies are seen as global citizens (Choi et al., 2011). When we look at the characteristics of individuals who are global scientifically literate, they can be described as those who understand scientific ideas, appreciate diversity of cultures and values, feel responsible for global issues related to science, and develop character and values as a member of a global society (Choi et al., 2011). In summary, global scientific literacy encompasses the definition of scientific literacy, and the only distinction between this idea and scientific literacy is the view of people as global citizens. Due to this, the study's definition of "global scientific literacy"—which includes concepts like "scientific literacy"—indicates that everyone is aware of how their environment is changing as well as how much of a degree they have in terms of scientific knowledge, abilities, attitudes, and values (Choi et al., 2011; Čipková et al., 2018).

The Laboratory's Contribution to the Development of Global Scientific Literacy

The ability to retrieve information rather than memorize it are provided by science classes taught within the context of science education, which increases the persistence of knowledge (Athuman, 2017; Wahyuni et al., 2017). By investigating and questioning in science lessons, it becomes easier to establish a connection between the knowledge that goes through the mental process and life (Karapınar, 2016; Wahyuni et al., 2017). One of the best settings for acquiring the skills that people with a scientific literacy should have is in laboratories, which are like the kitchen of science classes. Laboratories can be thought as a way that enables individuals to comprehend scientific knowledge, learn by practicing science, and participate in the development of science (Surpless et al., 2014). Laboratories are a complementary way of science education that promote inquiry and also provide skills including observation, data collection, classification, and experimentation (Keskin Geçer, 2018; Wenning, 2011). Because of this, laboratories are an essential part of raising scientifically literate citizens of the world. While laboratories play an active role in providing permanent learning, they also give the global scientifically literate individual the skills, attitudes and values that should be. This shows that global scientific literacy is related to various factors.

When the literature is examined, Çepni et al. (2012, pp.40-42) point out that being a scientifically literate individual requires the skills to question, solve problems, apply science process skills successfully, and have a positive attitude towards laboratory and science. Similarly, the National Research Council [NRC] (1996, p.22) defined scientific literacy as a concept that includes various skills such as understanding scientific concepts, questioning and using science process skills. In this regard, investigating the relationship among scientific literacy and numerous variables is critical for developing globally skilled individuals with scientific literacy skills. Pre-service teachers who will be practitioners of formal education in their professional lives have the most responsibility for developing scientifically literate people, which is a crucial need of our time (Pahrudin et al., 2019). Due to the fact that the qualities of pre-service teachers would immediately affect their students and the effectiveness of the teaching process (Atikoh & Prasetyo, 2018). In line with this significance, it is critical to investigate the relationship among global scientific literacy and various characteristics of pre-service teachers who would perform the teaching profession in science courses.

The Relationship Between Global Scientific Literacy and Inquiry Skills

One of the fundamental characteristics of a scientifically literate individual is the ability to question (Lederman et al., 2014; Wen et al., 2020). Because scientifically literate people are defined as individuals who are sensitive to the events related to science, go down to the source of the events, identify possible problems, reach information, make explanations and therefore have the ability to question (MoNE, 2018). Because scientifically literate individuals are described as those who are sensitive to scientific events, investigate the events in depth, recognize potential difficulties, obtain knowledge, make explanations, and thus have the ability to question. It is very critical to acquire inquiry skills in laboratory studies. Science laboratories, which incorporate inquiry-based activities, allow people to develop their ideas while also teaching them investigation, questioning, and scientific thinking skills (Hofstein &

Lunetta, 2004). Inquiry is a critical component of science programs at all levels and in all areas of science (NRC, 1996). Inquiry-based science teaching is used as a strategy to improve individuals' scientific literacy competencies (Gormally et al., 2009; Khumraksa & Phengkampang, 2021). Inquiry skills enable the individual to come to a conclusion by developing alternate thoughts and giving numerous solutions in the face of new problems. Thus, in the developing world, he advances on his path to become a scientifically knowledgeable individual. In this regard, inquiry skill is one of the basic skills that scientifically literate pre-service teachers should have (Balbağ & Aynur, 2020; Imaduddin & Hidayah, 2019).

The Relationship Between Global Scientific Literacy and Science Process Skills

Science process skills are among the skills that science education aims to gain individuals. Scientifically literate person uses scientific knowledge and apply science process skills while solving the problem they encounter and making decisions to find a solution (Fives et al., 2014; Khaeroningtyas et al., 2016; MoNE, 2018). Thus, people develop towards becoming scientifically literate at every stage of their lives. Science process skills that enable them to question, analyze and make decisions are critical for an effective science education. Because science process skills are intellectual skills used to create knowledge, solve problems scientifically, develop thinking skills as well as a crucial component of the inquiry process and also contribute to scientific literacy (Nugraha et al., 2018). In this regard, pre-service teachers need to have developed themselves in terms of science process skills in order to become lifelong learners who are scientifically literate (Dewi et al., 2021; Zainuri et al., 2020). Because there is a positive relationship between scientific literacy and science process skills.

The Relationship Between Inquiry Skills and Science Process Skills

Science education aims to train individuals who can integrate theory with daily life. This goal can be achieved with the help of inquiry and science process skills (Çolak, 2014). Inquiry and scientific process skills can be acquired through education in which individuals actively participate. According to Akkuzu Güven and Uyulgan (2019), science process skills involve the utilization of both physical and cognitive skills in order to acquire knowledge. On the other hand, inquiry includes cognitive skills such as gathering data based on varied facts, establishing connections between existing knowledge and data, developing hypotheses, and reasoning (Chen et al., 2018). When people inquire, their cognitive and scientific process skills are both also engaged (García-Carmona et al., 2017). Permanent learning occurs when inquiries are made during education. In particular, some studies in the literature reveal that individuals who can actively engage their science process skills during the inquiry process can achieve effective, easy and permanent learning by their own efforts (Akkuzu Güven & Uyulgan, 2019; Duschl et al., 2007; NRC, 2012). Settlage and Southerland (2007) emphasize that science process skills form a basis for inquiry. At this point, it may be claimed that inquiry skills and science process skills cannot be separated.

The age we live intends to provide individuals with lifelong learning skills rather than transferring existing knowledge (Marta-Lazo et al., 2019). Therefore, pre-service teachers should have met the requirements of the age (Akkuzu, 2012; Sandra, 2021). At this point, it is extremely important for pre-service science teachers to be scientifically literate, to develop their inquiry skills and science process skills that they will use in the lifelong learning process (Koyunlu Ünlü, 2020).

The Relationship Between Science Process Skills and Self-Directed Learning Readiness in Laboratory

In general, education aims to change the behavior of individuals in the desired manner. This desired change is related to the readiness of individuals (Aktaş, 2019). Readiness is the prerequisite that an individual must have while new learning occurs (Aydın, 2001). Particularly in laboratories, readiness is critical for acquiring knowledge and skills. In laboratories, knowledge and skills are gained by doing and experiencing. People who learn by themselves in labs through hands-on experiences develop skills such as observation, problem-solving, inquiry, and questioning, and take responsibility for their own learning process. This process is defined as individuals' self-directed learning readiness (Alkan, 2012). Scientific process skills enable individuals to comprehend laboratory work, develop their responsibilities, make them active learners, and help them find ways of learning and discovery (Irwanto et al., 2019). For this reason, it can be said that there is a relationship between self-directed learning readiness in laboratory and science process skills. Because self-directed learning readiness requires having cognitive and psychomotor behaviors for a behavior to be acquired (Özbek, 2005; as cited in Önal, 2009). When pre-service teachers perform their responsibilities in laboratories, their science process skills improve and they can have sufficient knowledge and necessary equipment in the lifelong learning process (Akkuzu Güven & Uyulgan, 2019; Taylor et al., 2009). At the same time, pre-service teachers can participate in research as part of the self-directed learning process, make suggestions, be open to innovations, and evaluate the outcomes. Based on all these, it is necessary to reveal the relationship between pre-service teachers' self-directed learning readiness in laboratory and their science process skills.

The Relationship Between Science Process Skills and Attitude Towards Laboratory

Learning Science is a complex activity that requires to acquire scientific attitudes as well as scientific knowledge and science process skills. Gunawan et al. (2019) state that the method of learning and teaching science process skills is one that is aimed to help students comprehend facts, concepts, and apply them to their own attitudes. Zeidan and Jayosi (2015) emphasize that individuals with positive attitudes focus more on the scientific process. The researchers believe that the positive attitudes toward science makes the students more interested in focusing on science process. To put it another way, when students grasp the science process skills, science becomes more significant to them, leading to more positive attitudes toward learning. The feelings that individuals have while solving the problems they encounter are reflected in their behaviors. Ajzen (2001) state that attitudes play an important role in predicting behaviors. From this, it can be concluded that individuals' attitudes toward science-related activities increase their science process skills. Through hands-on experiences in laboratories, people can improve their science process skills, but they can also improve their attitudes towards the laboratory (Juhji & Nuangchalerm, 2020). Irwanto et al. (2019) state that the attitude towards the laboratory is an integral part of science laboratory activities. According to Juhji and Nuangchalerm (2020), people with positive attitudes are more successful and develop better science process skills. Tinapay et al. (2021) state that individuals who have positive attitude towards science and enhance their science process skills will learn effectively and permanently. Individuals with science process skills, on the other hand, can alter their attitudes and values through comprehending facts and concepts more easily (Ogunleye, 2012). Scientifically literate pre-service teachers are expected to have adequate science process skills and positive attitudes in order to improve student performance and success in science fields. Because, being able to teach well in learning activities is related to the attitudes and science process skills of pre-service teachers (Zeidan & Jayosi, 2015).

When the aforementioned variables are taken into consideration, as well as the relationship among global scientific literacy and these variables, it is clear that global scientific literacy plays a critical role in science education. One of the primary considerations in selecting such a study subject has been the growing significance of global scientific literacy, which plays a significant role in the advancement of science education. In the current world, where scientific literacy is becoming increasingly important, educators who will teach scientific literacy to their students in accordance with the revised curricula bear enormous responsibility (Göktepe, 2019). Teachers, who are the implementers of the courses, are expected to have various knowledge, skills and positive attitudes. These characteristics will affect the scientific literacy levels of teachers who aim for their students to become strong scientifically literate individuals (Çepni et al., 2012). Because the scientific literacy levels of pre-service science teachers directly affect the students they will educate. In this regard, it is necessary to investigate the relationship among global scientific literacy and inquiry skills, science process skills, self-directed learning readiness in laboratory and attitudes towards the laboratory of pre-service chemistry, physics, biology and science teachers before graduating from university.

Significance of the Research

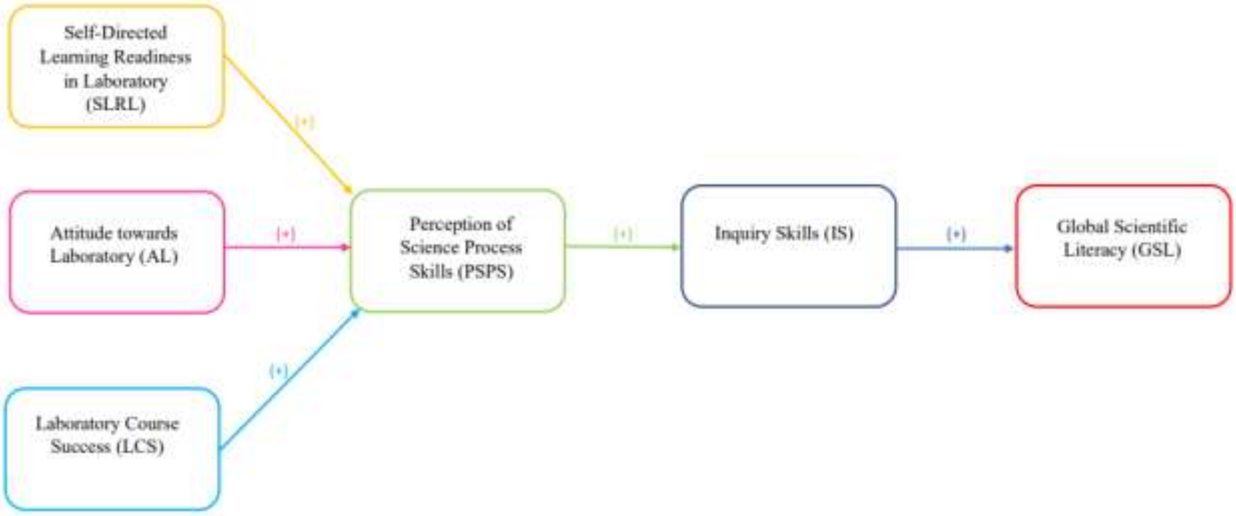
Given the significance of the research in terms of literature, it is clear that many studies shed light on the relationship between science process skills and scientific literacy (Gürses et al., 2015; Handayani et al., 2018; Hartini et al., 2018; Kaya et al., 2012; Sullivan, 2008; Turiman et al.2012; Zainuri et al., 2020). At the same time, we encounter studies on the effects of variables such as inquiry skills, self-efficacy or attitude on science process skills and scientific literacy (Çolak, 2014; Güçlüer, 2012; Shive, 2005). Furthermore, when the relevant studies are examined in terms of the sample group, these subjects are studied on students at different levels (primary, secondary, and university) (Çolak, 2014; Güçlüer, 2012; Gürses et al., 2015; Hartini et al., 2018; Karapınar, 2016; Sullivan, 2008; Usta & Çıkrıkçı-Demirtaşlı, 2014). However, no correlational studies that have addressed how these variables together affecting scientific literacy and identify their causal relationships. Structural Equation Modeling is the method used in multivariate correlational research to explain the theoretical framework by revealing the existence of correlations (Şimşek, 2007, p.43). In this context, our study is considered to be extremely important in regards to the development of scientific literacy, since it is based on the creation and validation of a Structural Equation Modeling (SEM) aimed at revealing the causal relations among various variables and scientific literacy. This study also highlights the significance of laboratory procedures. Because it is possible for scientifically literate individuals to develop their inquiry skills and science process skills by performing laboratory applications. In this context, it is thought that the study has a particular relevance since the data acquired as a consequence of the study provides a broader view on laboratory education.

Purpose of the Research

The aim of this study is to examine the global scientific literacy of the pre-service science teachers (chemistry, physics, biology and science) with regard to various variables, including perceptions of their science process skills, readiness for self-directed learning in laboratory, attitude towards the laboratory and laboratory course success. For this purpose, a structural equation model (see Figure 1) was developed and tested, aiming to reveal the causal link among various variables and global scientific literacy.

Figure 1

The Hypothesized Research Model



In accordance with the aim of the research, answers to the following questions are sought:

1. Do pre-service science teachers' attitudes towards the laboratory, their readiness for self-directed learning in laboratory, and their success in the laboratory course(s) explain their perceptions of science process skills significantly?
2. Do pre-service science teachers' perceptions of science process skills explain their inquiry skills significantly?
3. Do the pre-service science teachers' inquiry skills explain their global scientific literacy significantly?
4. To what extent do the variables of perception of science process skills and inquiry skills mediate the relationship between self-learning readiness in the laboratory and global scientific literacy in the model?

5. To what extent do the variables of perception of science process skills and inquiry skills mediate the relationship between the attitude towards the laboratory and global scientific literacy in the model?

6. To what extent do the variables of perception of science process skills and inquiry skills mediate the relationship between laboratory course(s) success and global scientific literacy in the model?

Method

Model of the Research

Correlational research method was used in the study since the structural model developed in line with the purpose of the research requires advanced analysis techniques. In multivariate correlational studies, structural equation modeling was used because it is a method used to explain the theoretical framework by revealing the existence of correlations (Şimşek, 2007, p.43). The difference of SEM from other analyses is that it is a statistical approach that is used to test models in which correlational and causal relationships between observed (explicit, measured) and unobserved (latent, unmeasured) variables are present in their entirety (Yılmaz, 2004). Correlational studies are used to determine the relationship between at least two variables. In studies carried out using this methodology, the variables are not subjected to any external manipulation; rather the degree to which the known variable is related to other variables and the type of this relationship are determined. Hence, conclusions and remarks concerning cause and effect are drawn (Fraenkel et al., 2012).

Study Group

In the study, one of the non-random sampling methods, the convenience sampling method, was used. According to the convenience sampling method, the researcher chooses the sample that is easy to contact and obtain their participation (Fraenkel et al., 2012). From this point of view, the universe of the study consists of pre-service teachers studying in science education departments (chemistry, physics, biology and elementary science education) at the Faculty of Education. The sample consists of 294 volunteer pre-service teachers at all grade levels who are continuing their education in the science departments of the Faculty of Education of a state university in Turkey. The frequency (f) and percentage (%) values of the demographic characteristics of the sample group are given in Table 1.

Table 1

Demographic Characteristics of Pre-Service Science Teachers

Demographic Characteristics		*f*	%	*Laboratory Grades*
Gender	Girl	240	81.6	
	Boy	54	18.4	
Department	Chemistry Education	70	23.8	70.1
	Physics Education	35	11.9	65.0
	Biology Education	45	15.3	86.0
	Elementary Science Education	144	49.0	72.7
Grade Level	1	54	18.4	
	2	59	20.0	
	3	84	28.6	
	4	97	33.0	
Age	18	11	3.7	
	19	29	9.9	
	20	64	21.8	
	21	84	28.6	
	22	69	23.5	
	23	20	6.8	
	24	10	3.4	
	25 and above	7	2.3	
Total		294	100	

Data Collection Tools

Personal Information Questionnaire

Within the scope of the research, a questionnaire was created in order to obtain the demographic information of the pre-service teachers. Pre-service teachers were asked about their department, grade level, gender, age and laboratory grades in this survey. The data on the success in the laboratory course(s), which is one of the independent variables of the study, were presented on the basis of the grades that the pre-service science teachers took from the laboratory courses in the 2018 curriculum. To avoid interfering with each pre-service teacher's responses to the scales and to ensure that the analysis was carried out accurately and reliably, the pre-service teachers were asked to write their school numbers on the questionnaire.

Global Scientific Literacy Scale

The scale of Global Scientific Literacy (GSL), developed by Mun et al. (2015) considering 21st century skills and competencies, is based on raising global individuals who have social consciousness, character and values, and who have a good command of socio-scientific issues. The scale, adapted into Turkish by Çelik (2016), consists of 48 items. The validity and reliability studies are categorized under 4 factors of the scale of GSL, which was carried out on a sample of 645 pre-service teachers. The factors belonging to the scale, factor loading values and reliability coefficients are given in Table 2.

Table 2

Validity and Reliability of the Scale of GSL

Factors	Cronbach Alpha (α) Reliability Coefficient	Factor Loading Values	Number of Items
Habits of Mind	.81	.48–.67	13
Character and Values	.76	.46–.76	9
Science as a Human Endeavor	.79	.41–.65	13
Metacognition and Self-Direction	.85	.42–.71	13
Total	.91	.41–.76	48

The results of the Confirmatory Factor Analysis (CFA) of the construct validity of the scale are as follows: $\chi 2$ /df = 2.03, NFI = .94, NNFI = .97, CFI = .97, GFI = .88, AGFI = .86 and RMSEA = .04 The CFA results show that the model is compatible (Çelik, 2016). Within the scope of the research, the reliability of the scale was recalculated over 294 participants and the reliability coefficient of the whole scale was found to be .86. The 5-point Likert-type scale has a rating of "Strongly agree (5), Agree (4), Undecided (3), Disagree (2) and Strongly Disagree (1)". There is no negative item in the scale. The highest score obtained from the scale is 240, and the lowest score is 48.

Inquiry Skills Scale

The scale of Inquiry Skills (IS) was developed by Aldan Karademir and Saracaloğlu (2013) to assess the inquiry skills of pre-service teachers which is one of the thinking skills that pre-service teachers have in their academic lives. The scale of IS has a 3-factor structure and consists of 14 items in total. The factor loading values of the scale are above .40. The “acquiring knowledge” factor consists of 6 items, the “controlling knowledge” factor consists of 5 items and the “self-reliance” factor consists of 3 items. The results of the CFA of the scale are as follows: $\chi 2$ /df = 4.55, NNFI = .91, CFI = .93, GFI = .95, AGFI = .93 and RMSEA = .06. The CFA results show that the model is compatible (Aldan Karademir & Saracaloğlu, 2013). The Cronbach Alpha (α) reliability coefficients of the factors are .76, .66 and .82, respectively. The reliability coefficient of the overall scale is .82. Furthermore, the researchers recalculated the scale's reliability over 294 participants, and the overall scale's reliability coefficient was found to be. 65. There are no negative items in the scale, which is rated as "Never (1), Rarely (2), Sometimes (3), Often (4), and Always (5)" on a 5-point Likert scale. The lowest score for the scale is 14, and the highest is 70.

Perception of Science Process Skills Scale

The scale of Perception of Science Process Skills (PSPS) developed by Ünal (2018) consists of 2 factors: basic and experimental. The scale, which is based on the development of these skills through the use of observation, examination and research in experimental activities, associating experiments with the subject and structuring concepts in the mind, is in 5-point Likert type format and is "Never (1), Rarely (2), Sometimes (3), Often (4) and Always (5)". The scale consists of 18 items and factor loading values range from .52 to .79. The scale's factor titled "perception of basic process skills" contains 7 positive and 3 negative items, whilst the factor titled "perception of experimental process skills" contains 4 positive and 4 negative items. $\chi2$ /df goodness of fit value calculated in the CFA conducted to test the accuracy of the model related to the PSPS is 4.12. The Cronbach Alpha (α) reliability coefficients of the factors are .74 and .72, respectively. The reliability coefficient of the overall scale is .76. In addition, the reliability of the overall scale was recalculated over 294 participants and it was found to be .83. While the lowest score that can be obtained from the scale is 18, the highest score is 90. The data obtained from the scale reveal the mediatory role of the perception of science process skills on global scientific literacy.

Laboratory Attitude Scale

The scale of Attitude towards Laboratory (AL) was developed by Akpınar and Yıldız (2006), which measures pre-service teachers' attitudes towards the laboratory within the scope of various factors. The LAS is a 5-point Likert-type data tool with a rating of "Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), and Strongly Disagree (1)". The validity and reliability of the scale of AL were examined using data from a sample of pre-service science teachers who took laboratory courses. The scale consists of 14 items and 4 factors. The Cronbach Alpha (α) reliability value of the four-item "enjoyment" factor is .75, the three-item "communication" factor is .70, the three-item "necessity" factor is .71, and the four-item "significance" factor is .66. The α reliability coefficient of the overall scale is .86. The reliability coefficient, which was recalculated over 294 participants within the scope of the research, is .75. The scale of AL has positive 9 items and 5 negative items. The minimum score that can be obtained from the scale is 14, and maximum score is 70.

Self-Directed Learning Readiness in Laboratory Scale

Cognitive, affective, and psychomotor characteristics are needed for an individual to be able to independently learn a particular subject and, as a result, to achieve a new behavioral change. The scale of Self-Directed Learning Readiness in Laboratory (SLRL) was developed by Alkan (2012), which is based on the idea that a person with these characteristics chooses what, how, where, and when to learn by taking control of the learning process. The scale consists of 5 factors and 32 items. The 5-point Likert-type scale has a rating of "Strongly Agree (5), Agree (4), Undecided (3), Disagree (2) and Strongly Disagree (1)". The scale of SLRL includes the factors of “desire for self-directed learning in laboratory” (11 positive items), “anxiety for self-directed learning in laboratory” (7 negative items), “self-management in laboratory” (5 positive items), “self-confidence in laboratory” (6 positive items) and “preliminary study for self-directed learning in laboratory” (3 positive items). The Cronbach Alpha (α) reliability coefficient for the overall scale is .93, and the Cr α values for the scale factors are .92, .84, .85, .76 and .75, respectively. Since the items in the “self-learning in laboratory” factor contain similar expressions with the items in the “enjoyment” factor in the attitude towards the laboratory scale, the “self-learning in laboratory” factor is not included in the research. The reliability coefficient of the scale was recalculated by subtracting this factor and it was found to be .71. Therefore, the highest score that can be obtained from the scale is 105 and the lowest score is 21.

Procedure and Ethical Approval

At the data collecting stage, valid and reliable scales appropriate for the purpose of the study were first sought. Before beginning the application phase of the scales, necessary permissions were obtained from the researchers who developed the scales. This process is followed by obtaining ethical committee permissions from the relevant institution, obtaining the necessary permissions from the university where the application will be made, and applying the scales. Ethical approval for this study was obtained from the Ethics Committee of the University dated 31.03.2021 and numbered E.85316909-640.99-36670. In addition, the research was carried out on volunteer pre-service teachers. For this, pre-service teachers were informed about the purpose of the study before proceeding to the scale application stage and the option of consent for voluntary participation was presented.

The application was carried out in the 2020-2021 Spring semester. Due to the pandemic process during this period, the application was made through the Google Forms survey management program, which is an online form creation tool. In order to test the model, it was ensured that each pre-service teacher filled out every scale completely. To avoid scale filling bias, the scales were administered throughout a five-week period, one scale per week, and the scales were not applied during the exam weeks to boost the research's reliability.

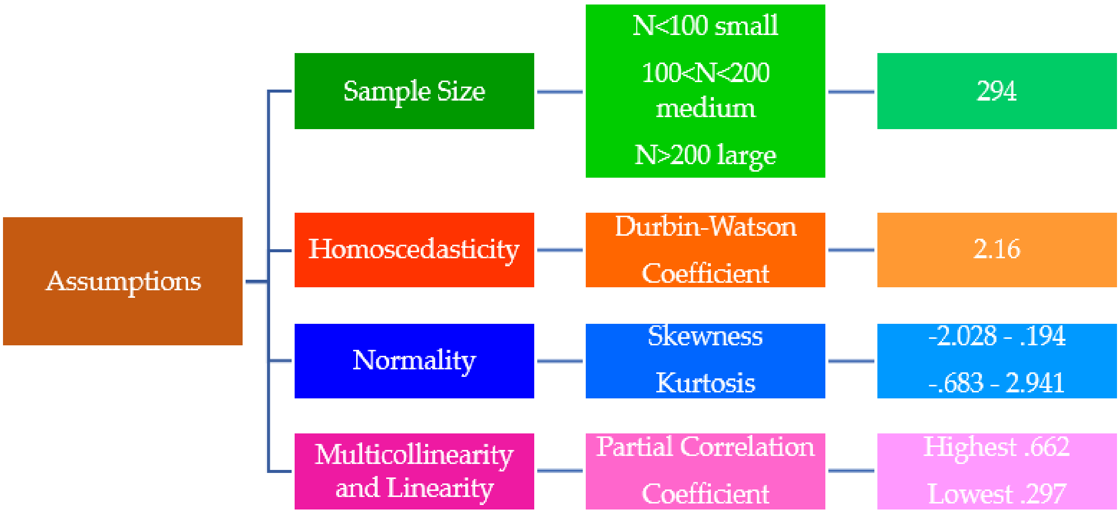
Analysis of Data

The variables in the proposed structural model are tested through a single model within the context of the indirect and direct relationships between the observed and latent structures. SEM attempts to explain the latent structures that cannot be measured directly and established in a theoretical framework using various indicators SEM also demonstrates how well the model fits the theoretical framework by revealing the existence of random correlations in the latent structure (Şimşek, 2007, p.51). SEM is a method that is frequently used in different disciplines and reveals how accurate models constructed using a deductive approach are. In this respect, SEM analyzes consist of confirmatory techniques (Şimşek, 2007, p.43). The well-known name for the statistical method that includes factor analysis and multiple regression is structural equation modeling (Kline, 2015). As a result, before beginning the analysis in multivariate statistics, it is crucial to decide which assumptions are required (Sümer, 2000). In this context, the assumptions of missing values, outliers, sample size, normality, multicollinearity, linearity and homoscedasticity were examined. First of all, the missing values in the data set were analyzed and it was seen that the scale items were filled in completely. According to Mertler and Reinhart (2017), extremely high or low values excluding the mean values in the data set are considered as outliers. The accuracy of the results drawn from the data set is significantly impacted by beginning the analysis without eliminating these values. For this reason, standardized z-scores were calculated to identify univariate outliers. In the literature, z scores that are not between -3 and +3 are considered outliers (Mertler & Reinhart, 2017, p.30-31). Mahalanobis distance values were examined to determine multivariate outliers. For this, chi-square values were calculated and values below .001 were determined as outliers (Tabachnick & Fidell, 2007). A total of 26 data were excluded from the data set as outliers after the z scores and Mahalanobis distance values were analyzed. Examination of the assumptions and analysis was carried out on 294 participants.

One of the assumptions examined for the SEM analysis is to test the adequacy of the sample size for data analysis. A sample size of less than 100 is regarded as small, while values between 100-200 are considered medium, and values of 200 and above are considered large sample sizes (Khine, 2013). Siddiqui (2013) reports that a sample size of 200–400 is needed for 10-15 estimators (variables) for SEM in his review study, which cites numerous papers. In our study, 294 data were found to be sufficient for analysis, indicating that the sample size assumption was met. Homoscedasticity, which is a constant (or homogeneous) variance in a set of random variables is another necessary assumption for the SEM analysis. In order to meet this assumption, there should be no autocorrelation between the variables. For this reason, the Durbin-Watson coefficient is checked. The fact that this value is in the range of 1.5-2.5 indicates that the assumption is met (Kalaycı, 2009). The Durbin-Watson coefficient of the data set was found to be 2.16. This result shows that there is no autocorrelation in the data set. Another pre-analysis assumption is that the data set has a normal distribution (Tabachnick & Fidell, 2007). The study determined whether or not our data had a normal distribution by assessing the kurtosis and skewness coefficients, as well as the statistical, histogram, and P-P graphs from a graphical standpoint. When the literature is examined, it is stated that skewness and kurtosis values should be within ±3 limits in order to meet the normality assumption (Kalaycı, 2009; Kline, 2015, p.50). It was determined that the skewness coefficient of the data set was between -2.028 and .194, and the kurtosis coefficient was between -.683 and 2.941. These values indicated that the normality assumption was met. The partial correlation coefficient between the variables was examined for the multicollinearity and linearity assumptions. To meet these assumptions, it is preferable that the correlation between the observed variables be low. While Kline (2015) considers .85 and above to be a multicollinearity problem, this value is expressed as .90 or higher by Tabachnick and Fidell (2007). Examining the partial correlation coefficient, it was found that the highest correlation value was between PSPS and SLRL variables (.662) and the lowest correlation value was between AL and LCS variables (.297). These values indicated that the multicollinearity and linearity assumptions were met. Figure 2 summarizes the study's assumptions for the analysis and its findings. SPSS 22.0 statistical program was used in the analysis of all these assumptions.

Figure 2

Assumptions and Results of the SEM Analysis



The proposed structural equation model was analyzed using the LISREL 8.51 statistical program. Because no one criterion is acceptable within the scope of the SEM analysis, many fit indices are examined. In order to evaluate the model fit; Chi-square/Degree of Freedom ($\chi 2$ /df), Root Mean Square Error of Approximation (RMSEA), Normed Fit Index (NFI), Standardized Root Mean Square Residual (SRMR), Non-normed Fit Index (NNFI), Goodness of Fit Index (GFI), Incremental Fit Index (IFI), Comparative Fit Index (CFI), and Relative Fit Index (RFI) were examined (Şimşek, 2007, p. 57).

Results

Findings of the Relationships Between the Variables

The correlation values between the variables in the suggested model were examined prior to the measurement model.

When Table 3 is examined, the correlations between the variables range between .02 and .73. "The perception of experimental process skills" factor of the PSPS scale and "the necessity" factor of the LT scale has the lowest relationship between observed variables (r= .02, p<.05). The highest correlation was between the "habits of mind" and "metacognition and self-direction" factors belonging to the scale of GSL (r= .73, p<.01). The observed variables' correlations were found to be moderately positive and significant in general. However, it can be said that the relationship between the factor of "necessity" and "preliminary study for self-directed learning in laboratory" is negative, low and insignificant (r= -.12, p<.05).

Table 3

Mean, Standard Deviation and Correlation Values of the Variables

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.1.BASIC	39.95	4.33	1																
1.2.EXPERIMENTAL	29.57	3.93	.714**	1															
2.1.ANXIETY	27.85	4.66	.549**	.457**	1														
2.2.SELF-MANAGEMENT	20.37	2.17	.527**	.444**	.536**	1													
2.3.SELF-CONFIDENCE	21.04	3.36	.496**	.510**	.592**	.553**	1												
2.4.PRELIMINARY	12.63	1.80	.338**	.368**	.250**	.254**	.247**	1											
3.1.ENJOYMENT	17.49	2.22	.398**	.266**	.486**	.452**	.438**	.109	1										
3.2.COMMUNICATION	12.76	1.97	.341**	.223**	.436**	.382**	.370**	.155**	.621**	1									
3.3.NECESSITY	14.66	0.73	.055	.020	.139*	.088	.134*	-.117*	.180**	.215**	1								
3.4.SIGNIFICANCE	18.03	1.95	.322**	.171**	.330**	.407**	.345**	.043	.633**	.541**	.198**	1							
4.1.HABITS OF MIND	54.98	5.31	.483**	.385**	.389**	.500**	.341**	.140*	.368**	.295**	.094	.353**	1						
4.2.CHARACTER-VALUES	38.74	4.28	.367**	.288**	.258**	.349**	.191**	.175**	.261**	.298**	.171**	.324**	.610**	1					
4.3.SCIENCE	56.16	2.10	.400**	.251**	.237**	.382**	.171**	.183**	.218**	.281**	.088	.289**	.534**	.571**	1				
4.4.METACOGNITION	55.35	6.11	.425**	.346**	.320**	.481**	.264**	.149*	.386**	.306**	.145*	.361**	.730**	.639**	.628**	1			
5.1.ACQUIRING	25.86	2.27	.365**	.254**	.230**	.302**	.184**	.180**	.224**	.174**	.129*	.261**	.561**	.391**	.380**	.509**	1		
5.2.CONTROLLING	18.61	2.84	.360**	.387**	.260**	.267**	.296**	.205**	.299**	.266**	.091	.263**	.467**	.345**	.316**	.489**	.528**	1	
5.3.SELF-RELIANCE	10.82	2.62	.287**	.219**	.302**	.202**	.295**	.081	.245**	.198**	.096	.174**	.249**	.164**	.153**	.158**	.226**	.322**	1

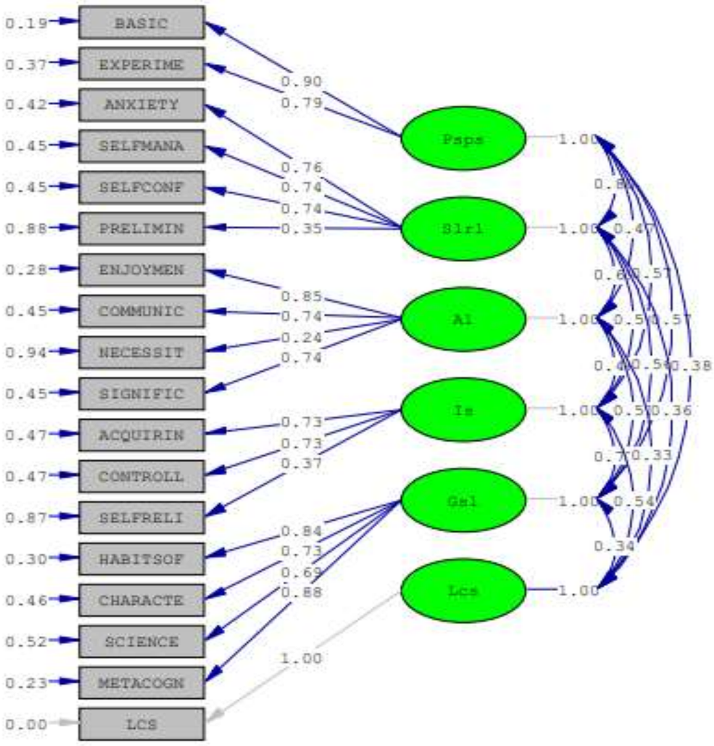
Note. *N*= 294. **p*<.05, ***p*<.01; 1. *Perception of basic process skills, 2. Self-directed learning readiness in laboratory, 3. Laboratory attitude, 4. Global scientific literacy, 5. Inquiry skills*

Findings Related to Testing the Measurement Model

A two-step approach is often used in the SEM analysis to test the research model. Accordingly, first of all, it is checked whether the observed variables are reliable indicators of latent variables with the measurement model (Byrne, 2010; Şimşek, 2007, p.107). Defining the measurement model correctly and in accordance with its purpose is extremely important for the structural model. Because it is impossible to discuss the correlations between the structures without first examining how accurately the model's observable variables represent the latent variables. Standardized values of the measurement model are shown in Figure 3, and t values are shown in Figure 4.

Figure 3

Standardized Values of the Measurement Model



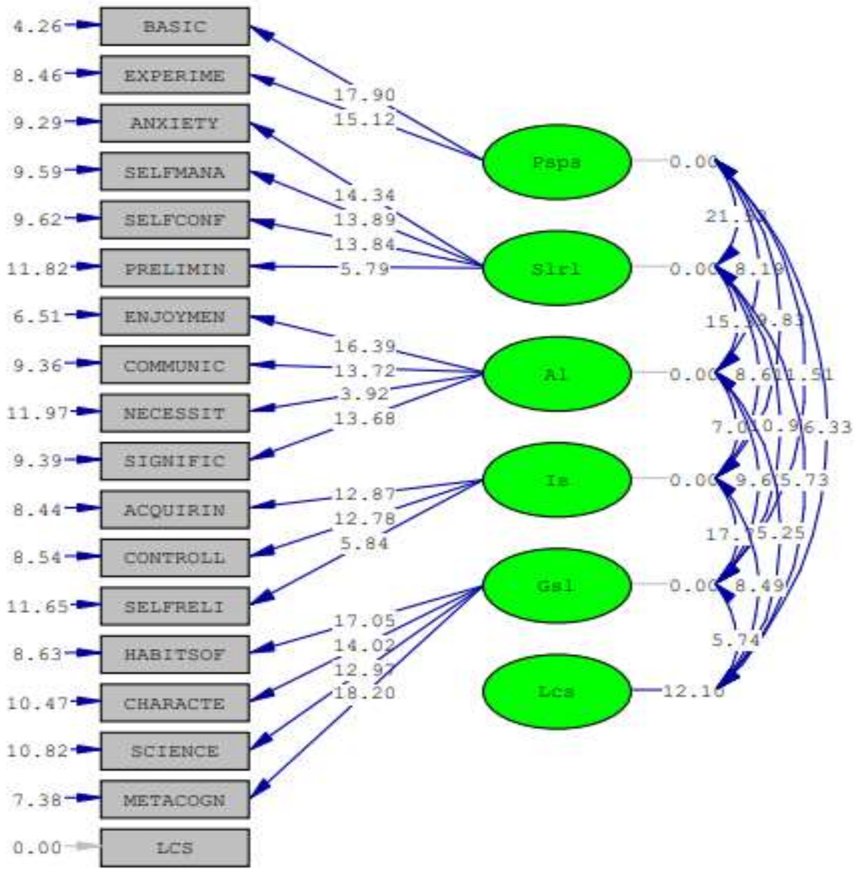
Chi-Square= 246.85, df= 121, p-value= 0.00000, RMSEA= 0.060

When the values in Figure 3 are analyzed, the factor loadings are found to be generally above .70. These values are an important indicator for the acceptance of the measurement model, but they are insufficient on their own. For this reason, all t-values of the measurement model should be statistically significant and the goodness of fit indices should be within the desired limits. Figure 4 also shows the t values for the factor loadings, and it is assumed that all of the t values are statistically significant.

If the significance level is .05, the critical t value is 1.96 (Şimşek, 2007, p.17). As a result, all observed variables in the model were found to be reliable indicators of latent structures.

Figure 4

t Values of the Measurement Model



Chi-Square= 246.85, df= 121, p-value= 0.00000, RMSEA= 0.060

Goodness-of-Fit Indices for Measurement Model

Goodness-of-fit indices obtained through the observed variables of the study are given in Table 4.

Table 4

Goodness-of-Fit Indices of the Measurement Model

Goodness-of-fit Indices	Good Value	Acceptable Value	Measurement Value	Interpretation
χ^2			246.85	
df			121	
χ^2 / df	2	5	2	Good
RMSEA	0<RMSEA<.05	.05<RMSEA<.10	.06	Acceptable
SRMR	0<SRMR<.05	.05<SRMR<.08	.05	Good
NFI	.95<NFI<1	.90<NFI<.95	.96	Good
NNFI	.95<NNFI<1	.90<NNFI<.95	.97	Good
GFI	.95<GFI<1	.90<GFI<.95	.91	Acceptable
CFI	.95<CFI<1	.90<CFI<.95	.98	Good
IFI	.95<IFI<1	.90<IFI<.95	.98	Good
RFI	.95<RFI<1	.90<RFI<.95	.94	Acceptable

When the goodness-of-fit indices of the measurement model were examined (see Table 4), it was found that $\chi2$ /df = 2, SRMR = .05, NFI = .96, NNFI = .97, CFI = .98 and IFI = .98 were at the level of good fit indices. The indices of RMSEA = .06, GFI = .91 and RFI = .94 appeared to be acceptable values. All these values showed that the measurement model as a whole was supported by the sample data. With these findings, the measurement model was confirmed.

Correlations Between Latent Variables

The findings in Table 5 indicate that the relationships between latent variables are generally at medium and high levels. It was observed that the highest correlations were between “global scientific literacy” and “inquiry skills” (r= .77), and “perception of science process skills” and “self-directed learning readiness in laboratory” (r= .78). The lowest correlation with latent variables was seen in the “laboratory course success” variable (r= .33).

Table 5

Correlations between Latent Variables in the Measurement Model

Latent Variables	GSL	IS	PSPS	SLRL	AL	LCS
Global Scientific Literacy (GSL)	-					
Inquiry Skills (IS)	.77	-				
Perception of Science Process Skills (PSPS)	.57	.58	-			
Self-Directed Learning Readiness in Laboratory (SLRL)	.56	.53	.78	-		
Attitude towards Laboratory (AL)	.54	.46	.48	.70	-	
Laboratory Course Success (LCS)	.33	.53	.39	.33	.33	-

Testing the Structural Model

The structural model was tested when it was verified that the observed variables in the model represented the latent variables according to the measurement model. The structural model examines the correlations between the latent variables defined in the research model. In this context, it was determined whether the model proposed in the research is adequately compatible with the data set. Goodness-of-fit indices for the structural model are given in Table 6.

When the results shown in Table 6 were examined, it was found that the proposed structural model generally fit the data at an acceptable level. However, when the suggestions produced by the LISREL program were examined, it has been determined that associating the errors between the “Basic” and “Experimental” observed variables of the latent variable of the PSPS causes a significant decrease in the chi-square value, and thus this situation will contribute to the model. The existence of a link between observed variables belonging to the same latent structure is, theoretically, an expected circumstance. The goodness-of-fit indices of the revised structural model are given in Table 7. As a result of the modification, an improvement was observed in the goodness-of-fit indices.

Table 6

Goodness-of-Fit Indices for the Structural Model

Goodness-of-Fit Indices	Good Value	Acceptable Value	Value	Interpretation
χ^2			298.19	
df			128	
χ^2/df	2	5	2.33	Acceptable
RMSEA	0<RMSEA<.05	.05<RMSEA<.10	.07	Acceptable
SRMR	0<SRMR <.05	.05<SRMR<.08	.07	Acceptable
NFI	.95<NFI<1	.90<NFI<.95	.88	Acceptable
NNFI	.95<NNFI<1	.90<NNFI<.95	.91	Acceptable
GFI	.95<GFI<1	.90<GFI<.95	.90	Acceptable
CFI	.95<CFI<1	.90<CFI<.95	.92	Acceptable
IFI	.95<IFI<1	.90<IFI<.95	.93	Acceptable
RFI	.95<RFI<1	.90<RFI<.95	.85	Inadequate Compliance

Table 7

Goodness-of-Fit Indices for the Revised Structural Model

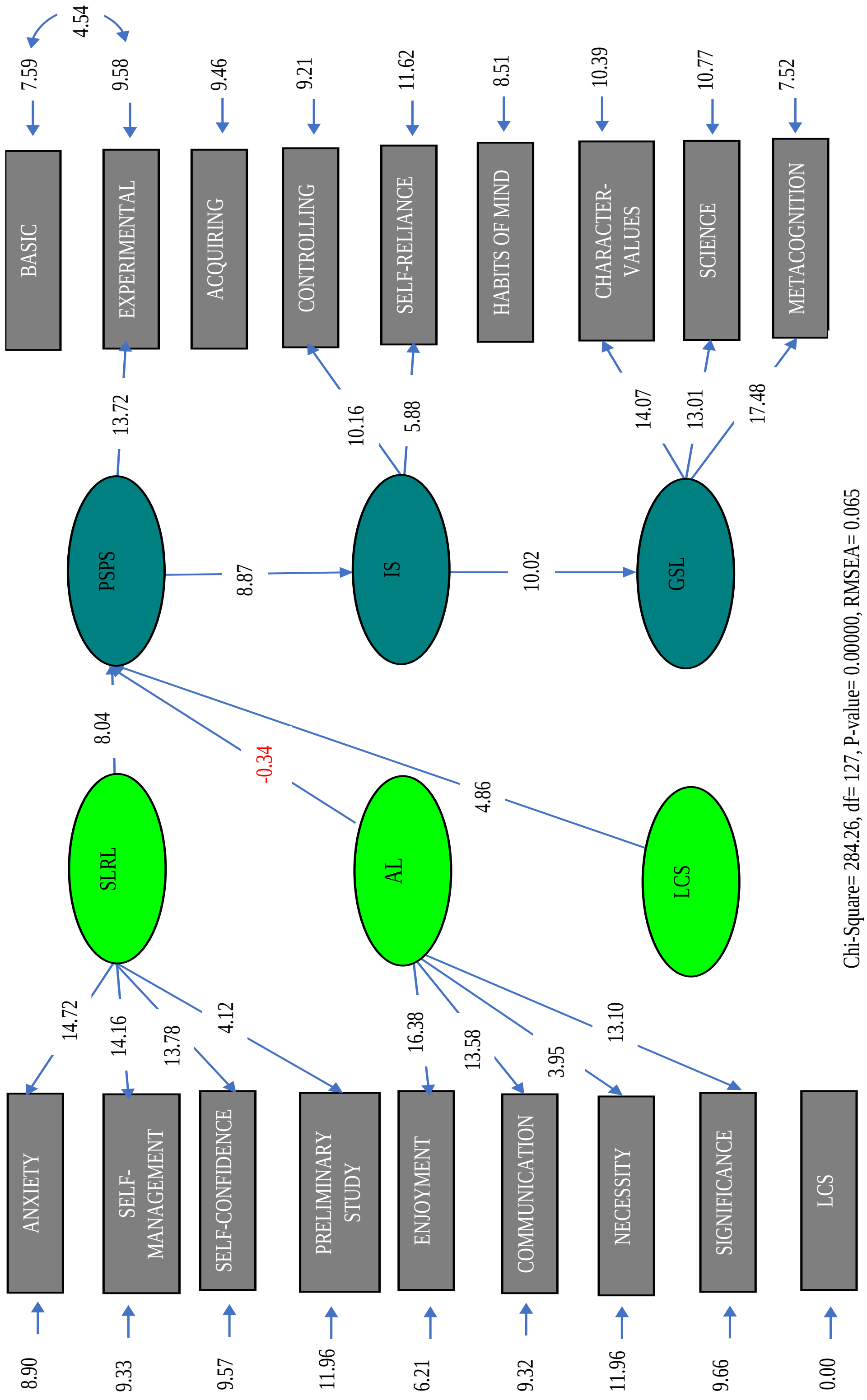
Goodness-of-Fit Indices	Good Value	Acceptable Value	Value	Interpretation
χ^2			284.26	
df			127	
χ^2/df	2	5	2.24	Acceptable
RMSEA	0<RMSEA<.05	.05<RMSEA<.10	.06	Acceptable
SRMR	0<SRMR<.05	.05<SRMR<.08	.06	Acceptable
NFI	.95<NFI<1	.90<NFI<.95	.95	Good
NNFI	.95<NNFI<1	.90<NNFI<.95	.97	Good
GFI	.95<GFI<1	.90<GFI<.95	.90	Acceptable
CFI	.95<CFI<1	.90<CFI<.95	.97	Good
IFI	.95<IFI<1	.90<IFI<.95	.97	Good
RFI	.95<RFI<1	.90<RFI<.95	.94	Acceptable

When the goodness-of-fit indices of the structural model (see Table 7) were examined, it was found that $\chi2$ /df = 2.24, RMSEA = .06, SRMR = .06, GFI =.90, and RFI = .94 were at an acceptable level. NFI = .95, NNFI =.97, CFI =.97 and IFI = .97 were in the good-fit range. As a result of all these findings, the structural model was verified.

Figure 5 shows the t values for the structural model and the standardized values are given in Figure 6. As a result, when the t values were evaluated, the correlation between AL and PSPS variables was not significant, although the t values among the other variables in the model were significant.

Figure 5

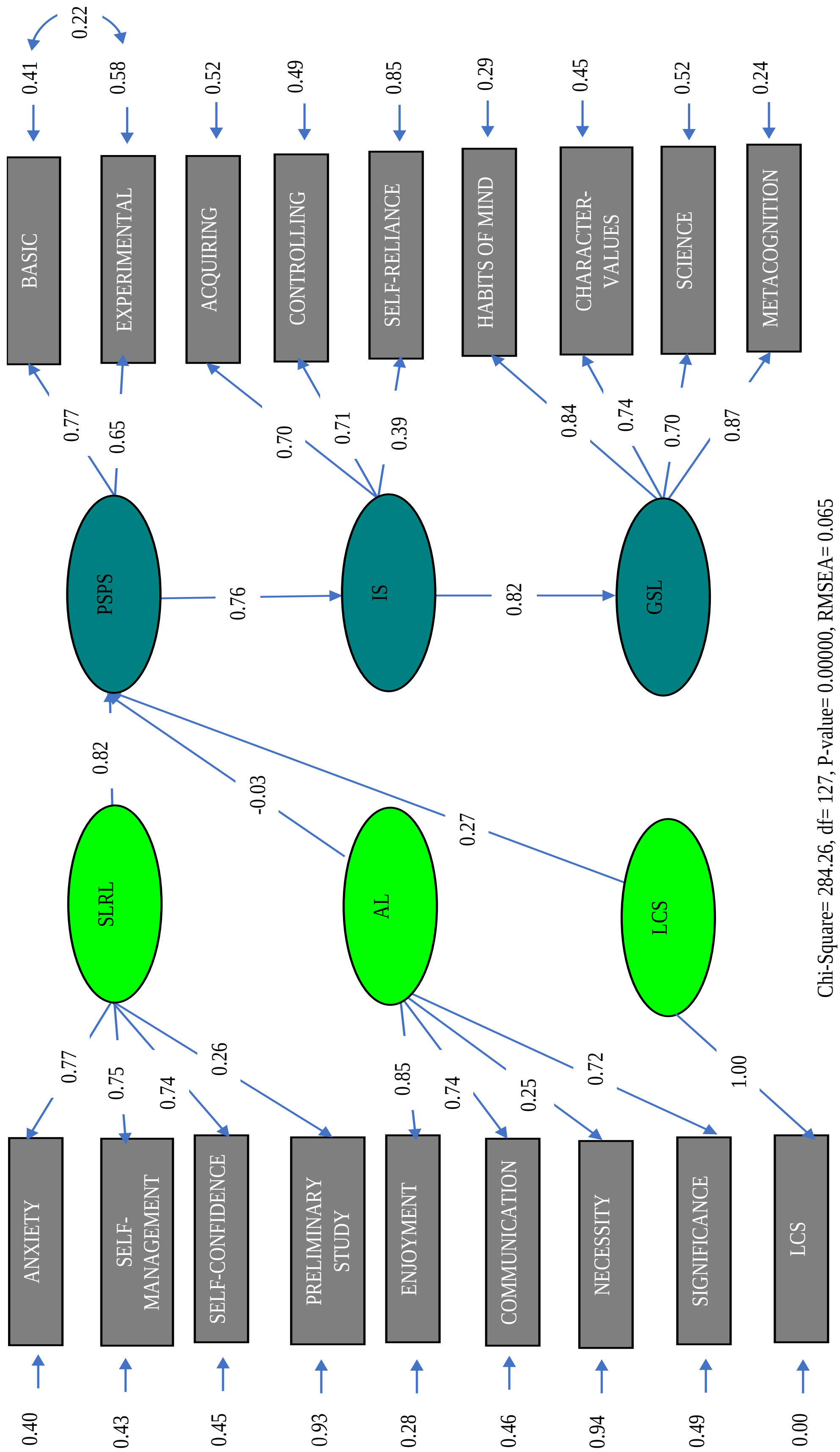
t-Values for the Structural Model



Note. *N*= 294. **p*<.05, ***p*<.01; *SLRL= Self-directed Learning Readiness in Laboratory, AL= Attitude towards Laboratory, PSPS= Perception of Science Process Skills, LCS= Laboratory Course Success, IS= Inquiry Skills, GSL= Global Scientific Literacy.*

Figure 6

Standardized Values for the Structural Model



Note. $N = 294$. *$p<.05$, **$p<.01$; *SLRL= Self-directed Learning Readiness in Laboratory, AL= Attitude towards Laboratory, PSPS= Perception of Science Process Skills, LCS= Laboratory Course Success, IS= Inquiry Skills, GSL= Global Scientific Literacy.*

When indirect effects were examined, the indirect effect of the SLRL variable on IS was determined to be .62 and statistically significant (SH= .09, t=6.80, p<.05), the indirect effect of the LCS variable on IS was determined to be .20 and statistically significant (SH=.01, t=4.54, p<.05) and the indirect effect of AL variable on IS was -.02 and this indirect effect was not statistically significant (SH=.07, t= -.34, p<.05). Similarly, the indirect effect of SLRL variable on GSL was .51 and this indirect effect was significant (SH= .07, t=6.87, p<.05), the indirect effect of LCS variable on GSL was .17 and this indirect effect was significant (SH =.00, t=4.56, p<.05) and the indirect effect of AL variable on GSL was -.02 and this indirect effect was not statistically significant (SH=.06, t= -.34, p<.05). Finally, it was concluded that the effect of PSPS variable on GSL was .62 and this indirect effect was statistically significant (SH= .08, t=9.04 p<.05). The results indicate that the variables of PSPS and IS mediate the relationship among SLRL, LCS and GSL. However, it was revealed that the variables of PSPS and IS did not play a mediating role in the relationship between the variables of AL and GSL. Table 8 summarizes the significance of the indirect effects among the latent variables in the structural model.

Table 8

Indirect Effect between Variables

Variables	Indirect Effect
SLRL – IS	SIGNIFICANT
AL – IS	*INSIGNIFICANT*
LCS – IS	SIGNIFICANT
SLRL – GSL	SIGNIFICANT
AL – GSL	*INSIGNIFICANT*
LCS – GSL	SIGNIFICANT
PSPS –GSL	SIGNIFICANT

The amount of variance in the relationships among PSPS and SLRL, AL, and LCS can be discussed based on the regression equations given in Table 9. While SLRL and LCS variables predicted PSPS, it was seen that SLRL variable was the most important variable explaining PSPS. AL variable did not predict PSPS. Accordingly, these variables explained 84% of the PSPS (R^2 = .84). From this, it can be said that there is a close relationship between pre-service teachers' self-directed learning readiness in laboratory and their perception of science process skills. This regression equation, which confirms the relationship between LCS and PSPS, which is another variable, supports the view that pre-service teachers with high success in laboratory course success have a high perception of science process skills and perceive these skills correctly. When the relationship between the third variable, AL, and PSPS was examined, it was seen that the relationship between the attitude towards laboratory and the perception of science process skills is insignificant.

Table 9

Structural Equations among the Variables and the Amount of Variance Explained

Dependent Variables	Regression Equation of Independent Variable(s)	Amount of Variance Explained (R^2)
PSPS	.82*SLRL – .032*AL+ .035*LCS	.84
IS	.76*PSPS	.58
GSL	.82*IS	.67

In the second regression equation, the amount of variance explained by the mediator variable PSPS, which was the predictor of the IS variable, showed that the factors of PSPS were highly related to the factors of IS (R^2= .58). This shows that the inquiry skills of pre-service teachers are highly correlated with the perception of science process skills.

Finally, examining the third regression equation, the amount of variance explained by the mediator variable IS, which was the predictor of the GSL variable, showed that the factors of IS were highly related to the GSL factors (R^2= .67). In this context, it can be said that pre-service teachers' global scientific literacy is highly related to their inquiry skills.

Discussion, Conclusion and Recommendations

Within the scope of the research, we determined at what level the variables of self-directed learning readiness in laboratory, attitude towards laboratory, laboratory course success, perception of science process skills and inquiry skills predicted the global scientific literacy of the pre-service science teachers. In this context, we found that readiness for self-directed learning readiness in laboratory predicted global scientific literacy at a high level indirectly, and laboratory course success predicted global scientific literacy moderately and indirectly. However, it has been determined that the attitude towards laboratory does not explain global scientific literacy significantly. It was revealed that the perception of science process skills, which was another variable of the research, predicted global scientific literacy at a high level and indirectly, while inquiry skills predicted global scientific literacy at a high level and directly.

With the proposed structural model in line with these findings, it can be said that global scientific literacy is explained at a high level. Global scientific literacy, which is a concept that includes many skills, values and attitudes, has been discussed in a cross-sectional study involving pre-service science teachers. Thus, it has been tried to reveal how much global scientific literacy is related to the variables discussed and how much of it is explained. In this context, we found that the independent variables in the structural model, except for the attitude towards laboratory variable, explained the dependent variable of global scientific literacy at a significant and high rate, and the model was confirmed except for the attitude towards laboratory.

When the bilateral relations between the variables in the model were examined, we found that the pre-service science teachers' self-directed learning readiness in laboratory and their laboratory course success explained their perceptions of science process skills significantly; however, we determined that their attitudes towards laboratory did not significantly explain their perceptions of science process skills. In addition, we found that the most important variable predicting the pre-service science teachers' perceptions of science process skills was the self-directed learning readiness in laboratory (β= .82, p> .01). In this regard, it can be asserted that the pre-service teachers who have a certain level of readiness in the laboratory have higher perceptions of science process skill levels. The pre-service teachers' confidence and preparation for laboratory studies are other factors contributing to this readiness. Also, it can be argued that pre-service teachers with readiness can manage their anxiety about laboratory courses and be self-sufficient in the lab. Similarly, a significant and positive relationship was found between pre-service science teachers' laboratory course success and their perceptions of science process skills (β= .27 p> .01). Various studies have showed that laboratories enable individuals to develop their scientific process skills (Akkuzu Güven and Uyulgan, 2019; George-Williams et al., 2020; Irwanto et al., 2019). At the same time, it can be stated that the basic skills required for laboratory activities to achieve their objectives are science process skills. In their study, Sinan and Uşak (2011) determined that there was a positive relationship between the science process skills of biology pre-service teachers and their laboratory course grades. Similarly, Aktaş and Ceylan (2016) found that there was a moderate, positive and significant correlation between pre-service science teachers' science process skills and academic achievement. In this regard, it may be argued that the high success level of individuals in laboratory courses is an indicator that they appropriately perceive their science process skills.

Another result of the study was that there was a negative and insignificant relationship between the attitudes towards laboratory of pre-service teachers and their perceptions of science process skills (β= -.03 p >.01). Contrary to what was predicted in the theoretical framework, the reason why this relationship turned out to be negative and insignificant could be shown as the negative impact of distance education in the course of the pandemic on the functioning of laboratory courses. Because there were limitations in laboratory activities during the pandemic, face-to-face education could not be done and therefore pre-service teachers could not have concrete experiences. Therefore, it can be said that pre-service teachers could not develop a positive attitude towards laboratory. The attitudes of pre-service teachers towards the laboratory, who could not find the opportunity to practice in the laboratory environment are also affected. Furthermore, when this result was analyzed in terms of the factors of the attitude towards the laboratory, it demonstrated that the factors of "necessity" and "significance" could not be properly comprehended by the pre-service teachers. In this regard, the relationship between pre-service teachers' perceptions of science process skills and their attitudes towards the laboratory was affected. In parallel with the results of the research, Saputra et al. (2020) determined that pre-service physics teachers had negative attitudes towards the laboratory and pointed out that the reason for this was that the applications were not done efficiently. Demir (2007) carried out a study to identify the variables that directly and indirectly affected the science process skills of pre-service teachers; however, he found that positive attitude had a positive effect on the acquisition of science process skills. Similarly, Korucuoğlu (2008) claimed that the progressive improvement in the level of science process skills of pre-service physics teachers was related to an improvement in their attitudes toward the course, and thus attitude was a significant variable for science process skills.

Another result examining the perception of science process skills and inquiry skills of pre-service science teachers was that there was a positive and significant relationship between these two variables (β= .76, p> .01). This result showed that the perception of science process skills explained the inquiry skills significantly (R^2= .58). The primary goal of inquiry is to begin the process of acquiring knowledge, to seek knowledge from life, and to improve skills and attitudes through knowledge (Wilder & Shuttleworth, 2005). In this context, the factor of the inquiry skills scale, "acquiring knowledge", includes the themes of doing research and asking questions. Pre-service teachers employ more than one method of acquiring knowledge when questioning knowledge, notably observation (Aldan Karademir & Saracaloğlu, 2013). Settlage and Southerland (2007) claimed that inquiry was built on science process skills. The cause for this might be attributed to basic processes in science process skills. Observation, one of the basic process skills, is the process of acquiring knowledge through the use of sense organs or tools that augment the sensitivity of the sense organs (Bass et al., 2009). In this process, we create new knowledge on top of existing knowledge. This is necessary for the inquiry process to begin. In addition, the inquiry skill requires skills such as observing, classifying, measuring and predicting, which are among the basic process skills. There are studies in the literature that show the positive effects of pre-service teachers' science process skills through inquiry (Duru et al., 2011; Irwanto et al., 2019; Ünal, 2018). In their study, Valls-Bautista et al. (2021) expressed that inquiry-based laboratory activities improved pre-service teachers' science process skills. In her research in which she carried out scientific inquiry activities within the scope of the laboratory, Koyunlu Ünlü (2020) found that pre-service teachers who enhance their knowledge and inquiry skills also improve their science process skills. All of these studies indicate that there is a significant relationship between inquiry and science process skills, and considering the functionality of inquiry for education, inquiry-based experiences and science process skills can be internalized by properly applying them. Consequently, it can be claimed that scientific process skills and inquiry abilities interact and improve one another.

Another notable finding of the study was the existence of a positive and significant association between the inquiry skills of pre-service science teachers and global scientific literacy (β=.82, p> .01). This result showed that inquiry skills explain global scientific literacy significantly. Inquiry skills explain 67% of global scientific literacy. According to the "science as a human endeavor" within the factor of global scientific literacy, individuals should know the social effects of science and have the inquiry and science process skills (Choi et al., 2011). Thus, inquiring individuals can use their ideas and make comments while seeking solutions to existing problems. Furthermore, another factor part of scientific literacy is the habits of minds, which is an auxiliary element in problem solving related to the challenges that may be encountered. Individuals engage in a variety of intellectual activities, such as testing hypotheses, solving practical problems, and having Socratic discussions through questioning (Windschitl, 2003), but they also employ skills like defending scientific claims, providing evidence, communicating, and using systematic thinking during this process. This demonstrates how efficiently inquiry is applied to mental processes. Also, acting with awareness of one's own intellect and cognitive abilities is another crucial component of being scientifically literate. In this context, being able to direct and organize one's own learning; using cognitive processes such as self-planning, monitoring and evaluation is only possible if the individual goes through the inquiry process. Furthermore, Lederman (2009) asserts that experiencing the levels and methods of inquiry is critical for individuals to achieve their ultimate aim of being scientifically literate. In this regard, he claims that inquiry grows with scientific experiences and that it is critical to becoming scientifically literate. To summarize, inquiry skills are a crucial variable for individuals becoming effective scientifically literates.

When the mediation relations in the model were examined, we determined that the indirect effect of the self-directed learning readiness in laboratory on the global scientific literacy variable was .51 and this indirect effect was statistically significant (SH= .07, t=6.87, $p<.05$). Based on this result, the relationship between pre-service science teachers' self-directed learning readiness in laboratory and global scientific literacy is mediated by the variables of perception of science process skills and inquiry skills. This finding is interpreted as scientifically literate pre-service teachers with high perception of science process skills and strong inquiry skills have self-directed learning readiness in laboratory. Öztürk et al. (2017) found that the relationship between pre-service teachers' inquiry skills and self-learning skills was moderate, positive and significant. They have also claimed that inquiry skills and self-learning skills are explanatory and complementary to each other in learning. We determined that the indirect effect of success in laboratory course(s), which is the other independent variable of the study, on the global scientific literacy variable was .17 and this indirect effect was statistically significant (SH=.00, t=4.56, $p<.05$). This finding led to the conclusion that the variables of the perception of science process skills and inquiry skills had mediating roles in the relationship between pre-service science teachers' success in laboratory course(s) and global scientific literacy. This shows that scientifically literate pre-service teachers who have high perception of science process skills and strong inquiry skills also perform well in laboratory course(s). In their study, Tekin et al. (2016) determined that the higher the grade point average of pre-service science teachers, the higher their scientific literacy scores. In their study, Öztürk et al. (2017) determined that the inquiry skill levels of pre-service teachers were affected by the level of academic achievement, and they concluded that pre-service teachers with low academic success also had low levels of inquiry skill. In addition, Handayani et al. (2018) found a positive relationship between the scientific literacy levels of the pre-service biology teachers and their integrated science process skills. Finally, the indirect effect of the attitude towards laboratory variable on the global scientific literacy was examined and we found that this indirect effect was -.02 and not statistically significant (SH=.06, t= -.34, $p<.05$). This result reveals that the variables of perception of science process skills and inquiry skills do not have a mediating role in the relationship between pre-service science teachers' attitudes towards laboratory and global scientific literacy.

As a result, proposed structural model confirms the existence of a relationship among the variables of self-directed learning readiness in laboratory and laboratory course success and the perception of science process skills and shows that these variables predict global scientific literacy through the perception of science process skills and inquiry skills. Furthermore, a significant relationship was found between the perception of science process skills and inquiry skills in the structural model, and it was determined that the perception of science process skills predicted global scientific literacy through the inquiry skills. In conclusion, considering the goodness of fit indices, we found that the model was compatible with the data, and the entire model was confirmed except for the attitude towards the laboratory.

Implications

In the light of the results, the following suggestions are presented.

- The verification of the structural model set forth in this study was carried out by collecting the data instantaneously in a certain time period. In future studies, the structural model proposed by the researchers can be validated by examining pre-service science teachers' time-dependent changes and tendencies regarding these variables through longitudinal studies.
- Since this study took place during the pandemic, pre-service teachers attended their laboratory courses via distance education at the time. Considering the importance of laboratory applications that provide concrete experiences, the structural model established on the basis of laboratory experiences can be reanalyzed on individuals who have been doing all laboratory courses practically throughout their education.
- The participants of this study were selected from the population using convenience sampling method. Therefore, the results of the study cannot be generalized to all pre-service science teachers in the population. Accordingly, it is recommended that this study be conducted with a sample that has the power to represent the universe.
- In the study, the fact that the attitude did not explain the science process skills significantly reveals that this relationship should be reconsidered in different sample groups. As a result, the validity of the structural model may be examined in light of the studies carried out on pre-service teachers enrolled in the faculties of education at various universities, and the results can be compared.
- The structural model in the study was limited by considering the relevant variables. Considering the relationship between scientific literacy and various variables (nature of science, problem solving skills, critical thinking skills, etc.) in the literature, it can be analyzed by suggesting new alternative models.

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Statement of Responsibility

Derya Serbest; literature review, methodology, data collection, data analysis, processing and interpretation of data, writing-original draft, editing and visualization. Nalan Akkuzu Güven; literature review, design of research process, construction of the proposed structural model according to the theoretical framework, methodology, data collection, data analysis, processing and interpretation of data, writing-review & editing, translating, supervision and project administration.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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