sustainability

Article

Factors Related to Cognitive Reasoning of Pre-Service Teachers' Science Process Skills: Role of Experiments at Home on Meaningful Learning

Esme Hacıeminoğlu [1,*], Nadire Gülçin Yıldız [2] and Renan Şeker [3]

1 Elementary Science Education Department, Faculty of Education, Akdeniz University, 07070 Antalya, Turkey
2 Department of Guidance and Counseling, Faculty of Education, Istanbul Medipol University, 34815 Istanbul, Turkey; ngyildiz@medipol.edu.tr
3 Science Education Department, Ahmet Keleşoğlu Faculty of Education, Necmettin Erbakan University, 42090 Konya, Turkey; rseker@erbakan.edu.tr
* Correspondence: ehacieminoglu@gmail.com

Abstract: This study aims to ascertain the level of science process skills (SPSs) among pre-service science teachers and to describe how these skills are reflected in their learning approach during the knowledge acquisition process. Additionally, we intend to explore those factors (i.e., those related to cognitive reasoning) that are utilized by pre-service teachers during science experiments conducted at home, in terms of the attainment of SPSs. The course documents of 36 pre-service science teachers were used to help further our understanding of the nature of learning about science through active participation in the inquiry process. Data collection procedures were conducted during a Laboratory Application Course; the participating students were required to undergo the Science Process Skills Test, completed to ascertain their pre-existing skills, as well as a project report investigating the factors affecting plant growth to ascertain levels of SPSs. These data were analyzed using a document analysis method. Data from a Science Process Skills Test were analyzed using the SPSS 20.0 program, along with the descriptive statistics. The findings indicate that the skills that achieved the highest averages included the formulation of preparation predations, as well as experimentation, while the lowest point averages went to the subcategories of proof through experience and communication. Upon an examination of the project reports, several pre-service teachers soon realized they had made certain errors during the design phase of the experiment, and returned to the initial stage. Still others made errors in the descriptions of variables, findings, and inferences, with the smallest minority committing errors in terms of observation. Students who possessed a meaningful learning approach were deemed as having internalized and recalled concepts in a meaningful way.

Keywords: cognitive reasoning; educational psychology; learning approach; meaningful learning approach; mental models; pre-service science teachers; science process skills; 21st-century skills

Citation: Hacıeminoğlu, E.; Yıldız, N.G.; Şeker, R. Factors Related to Cognitive Reasoning of Pre-Service Teachers' Science Process Skills: Role of Experiments at Home on Meaningful Learning. *Sustainability* **2022**, *14*, 7703. https://doi.org/10.3390/su14137703

Academic Editor: Andreas Ch. Hadjichambis

Received: 23 April 2022
Accepted: 13 June 2022
Published: 24 June 2022

1. Introduction

The modern age is one that is marked by rapid advancements in the fields of science and technology. These advances, however, necessitate vital importance being given to the development of skills related to accessing, producing, and interpreting research, as well as the employment of knowledge (see Enger and Yager, 1998; Heppner, Wampold, and Kivlighan, 2008; Livermore, 1964) [1–3]. Contemporary educational approaches are crucial in allowing individuals to acquire the needed skills for use over the course of their lives, by placing an emphasis on the production of knowledge in lieu of the rote-learning style favored by more traditional teaching practices. The central goal of such an education system should be directed toward establishing a society founded on individuals who can question and interpret knowledge, think scientifically, and create the means to solve problems, as well as possess the skills to access and use such knowledge (Temiz, 2001) [4].

Undeniably, the effect of science and technology in every aspect of our lives is ever-present. In an era characterized by the massive expansion of activities in research and technology, there is a huge demand for education systems that prioritize these fields—whether for the future of nations or for society in general. Considering such a demand, countries across the world—and developed nations, in particular—are deeply embroiled in efforts to increase the quality of their curriculums in terms of the fields of science and technology (Aydoğdu and Kesercioğlu, 2005) [5]. Over the course of the instruction process, the teacher should act as a guide, allowing students to take on a more active role. The goal is to encourage students to get involved in the learning process and arrive at a personal understanding of scientific facts through their own investigation. Aside from attaining knowledge, those who undertake scientific studies learn to approach the problems faced in daily life with a scientific approach and—with time—develop an ability to acquire information by implementing the required steps while furthering their understanding of the nature of science through active participation in its processes (Bağcı-Kılıç, 2003) [6].

Science and technology have an effect on learning in multidimensional ways that is both positive and negative. Therefore, students must be encouraged to aspire to more effective ways to engage in the learning process, through the use of scientific research methods, as an approach when responding to both their academic and daily problems (Bağcı-Kılıç, 2003) [6]. Research highlights the role of learning contexts in which workplace competencies could be best gained in a more hands-on setting (Alam and Parvin, 2021) [7]. DiBenedetto and Myers (2016) [8] suggest that career technical education courses offer "contextual real-world learning experiences that have engaged students and exposed them to opportunities to transfer and apply those skills in occupational settings" (p. 31), accentuating the role of school stakeholders. Similarly, SPSs help students to develop core academic skills, which, in turn, enhance their employability. As noted by Mobley, Sharp, Hammond, Withington, and Stipanovic (2017) [9], real-life experience and hands-on projects, rolled out alongside technical courses, nurture student's career development and planning. Bridging the gap between theory and practice is key in preparing students for their future careers, taking into account the impact of technology and virtual learning environments on education (Woolfolk, Winne, and Perry, 2006) [10].

A meta-analysis of 115 studies conducted by Yıldırım, Çalık, and Özmen (2016) [11]. between 2000 and 2015 focused on gauging the concept's determining variables among both teachers and students. The goal of a mere 15 studies, meanwhile, focused on determining students' and teachers' views on SPSs in general. While 93 studies launched over the same time period represent experimental studies, 45 take the form of surveys. A large proportion of the studies over this time period have been founded on survey data. Furthermore, 156 of the studies made use of multiple-choice questionnaires, while 38 involved open-ended questionnaires and six Likert-type surveys. Meanwhile, a small number comprised document analyses and worksheets (n = 2). The number of studies measuring SPSs through document analyses and worksheets remains low.

Project-based learning (PBL) is an innovative way to teach a variety of strategies that are critical for success in the 21st century. Students take charge of their own learning using the inquiry process while working in partnership to complete projects that reflect their learning experience (Bell, 2010) [12]. Pre-service teachers must employ instructions to enhance students' 21st-century skills to prepare K-12 students for the globalizing science, technology, engineering, and mathematics (STEM) workplace (Owens and Hite, 2022) [13].

Currently, there are efforts to integrate standards into education that are related to curricular content and higher-order thinking skills. Proposing to modify the curricular, assessment, and accountability frameworks globally, documents such as the Partnership for the 21st Century (P21; 2014a) [14], for instance, assert that we should "bring together the business community, education leaders, and policymakers to position 21st-century readiness at the center of US K–12 education" (P21, 2014b) [15]. In particular, as P21 discussed, "US schools must align classroom environments with real-world environments"

(P21, 2014c) [16], proposing a framework that illustrates student outcomes and learning support systems (P21, 2014d) [17].

It is important to note that cognitive reasoning ability and creative thinking skills are underlined in the P21 framework. An example in science education follows: "As part of a class gardening project, students produce an ongoing podcast or use a wiki to illustrate their processes for determining the ideal conditions for growth, nutrition, and maintenance through the class's design activities" 21st Century Skills Map-Science 2009, p. 3) [18]. Another example can be found in the science map: "Students choose a scientific theory and research the history of its development, then use concept mapping or timelining software to diagram previous discoveries, ideas, and technologies upon which the theory was predicated and the different disciplines from which previous knowledge was drawn. Students report on how this theory represented a creative way of approaching this scientific question" (21st Century Skills Map-Science, 2009, p. 3) [18].

The 21st Century Skills Map goes beyond the basics of reading, writing, interpretation, and synthesis. Consistent with the work presented here, Ananiadou and Claro's (2009) [19] approach underlines the role of cognitive, intrapersonal, interpersonal, and technical skills, which role is later woven into the Organization for Economic Cooperation and Development (OECD) approach. Cognitive skills include, among others, originality in problem-solving, critical thinking, and systems-thinking skills (Geisinger, 2016) [20]. Moreover, in an editorial introduction of *The Science Teacher*, devoted to 21st-century skills, Metz (2011) [21] presented the following list of skills: core subject-matter knowledge, especially in science; flexibility, adaptability, and innovation; critical thinking, creativity, and non-routine problem-solving; complex communication, collaboration, social and cross-cultural skills; self-direction, productivity, and accountability, highlighting the role of experiments at home on meaningful learning, considering the factors related to cognitive reasoning in terms of pre-service teachers' SPSs. The Organization for Economic Cooperation and Development (OECD) offers a vision for educational standards and the skills needed to achieve them. The OECD Learning Framework 2030 outlined creating new value (i.e., values related to an individual's adaptability, creativity, curiosity, and open-mindedness), reconciling tensions and dilemmas (i.e., thinking and acting in integrated, interconnected, and interrelational ways), and taking responsibility (the sense of responsibility, self-regulation, self-control, self-efficacy, and problem-solving) as three transformative competencies (OECD, 2018) [22]. Future learners equipped with these competencies will exercise agency in developing individual as well as societal well-being.

P21 identified the 21st Century Skills Map as a response to the challenges faced today in answering the problems faced. While offering ideas on what is needed for students to become effective problem-solvers in the new world, the rationale in the current study is to acknowledge that the content-based knowledge transmission of conventional education systems is no longer a sufficient way to teach. P21 identified three core subjects and seven skills as twenty-first-century skills (Thrilling and Fadel, 2009) [23]. The core subjects are reading, writing, and math, with 21st-century emphasis. The seven skills include critical thinking and problem-solving, creativity and innovation, collaboration and teamwork, and self-reliance with career and learning. The importance of these new sets of skills and abilities has been discussed as a way to face the problems of a rapidly changing, technology-driven digital world (Özdoğru, 2022) [24]. According to the US Bureau of Labor Statistics on Employment in STEM occupations (i.e., science, technology, engineering, and math), it is projected that STEM occupations would earn twice as much compared to other disciplines by the year 2030.

Bridging theory and research is a foundational objective in science education that facilitates the integration of science and technology, resulting in many benefits (such as an academic–industry partnership). Without the ability to bridge theory and research, individuals may be unable to utilize a strategy that they know to be useful because they do not know how to complete the practical steps involved (McCormick and Pressley, 1997; Harris et al., 2012) [25,26]. The real-life setting requires knowledge integration and the application of skills in a proficient manner, rather than just the accumulation of information.

While employers assert that new employees lack communication skills, problem-solving capacities, motivation, and "soft skills" such as the ability to persuade or think critically (MacDermott and Ortiz, 2017) [27], this lack is often addressed with training on the job (Chand and Tipnis, 2016) [28]. There is a gap in the existing literature on how to go about integrating such skills during formal science education. Therefore, the main objective of this study is to examine the level of SPSs among pre-service science teachers and to describe how these skills are reflected in their learning approach through document analysis.

2. Theoretical Background

Researchers in the field of educational and cognitive psychology postulate that when people process their surroundings, they create a mental model that refers to internal representations of physical encounters (Hestenes, 2006; Holland, Holyoak, Nisbett, and Thagard, 1986) [29,30]. A number of items are reflected in a mental model. Learning processes engage one in a deep-seated synthesis of epistemology from an interdisciplinary perspective, which demands an integrated problem-solving approach and induction in these established mental models (Holland et al., 1986; OECD, 2016) [30,31]. Johnson-Laird (1983) [32] insists that a mental model is not necessarily the same as a schema. A schema refers to a piece of information saved in the long-term memory, indicating how ideas and concepts relate to one another. However, mental models refer to relationships that are constructed as input (i.e., they are encountered and processed). Mental models can incorporate schema with the new input and by integrating previous input (Pressley and McCormick, 1997) [33].

Procedural and declarative knowledge are distinctive elements in efficient information processing (Byrnes, 1992) [34], which may be helpful in explaining the difficulties experienced by some pre-service teachers during the attainment of SPSs. When their project reports were examined, several pre-service teachers realized that they had made certain errors at the design phase of the experiment and returned to the initial stage, while others made errors in the descriptions of variables, findings, and inferences, with the smallest minority committing errors in terms of observation. When constructing mental models, all forms of knowledge are required to interact. Models of thinking are constructed around productions and involve procedural and declarative knowledge (Pressley and McCormick, 1997) [33]. As Brown, Collins, and Duguid (1989) [35] state, knowledge is not separate from action, as conceptual knowledge cannot be separated from the situations in which it is learned and applied, i.e., "situated knowledge" (Pressley and McCormick, 1997) [33]. Collins, Brown, and Newman (1989) [36] coined the term "cognitive apprenticeship" to describe such shortcomings in pedagogical practices when instructing students, which does provide grounds for the acquisition of knowledge (i.e., accessible to be used for something). As Joel Michael stated during his 2001 Claude Bernard Distinguished Lecture: In Pursuit of Meaningful Learning: "It results in knowledge that is stored in a way that allows it to be accessed from many different starting points. That is, it is knowledge that is well integrated with everything else that you know. Meaningful learning is accompanied by the building of multiple representations [mental models], models that are connected to models for many other phenomena" (Michael, 2001, p. 147) [37].

2.1. Science Process Skills and Meaningful Learning

Numerous international studies have been conducted regarding the use of SPSs. The topic has become a principal point of focus among education programs since its development in the 1950s. SPSs embody a type of mental model for transferring thought processes on various issues and can be used in the instruction of specific subjects (e.g., math, science, or humanities) when processing problems (Tobin and Capie, 1980) [38]. Researchers have defined SPSs in a variety of ways over the years; however, a number of common characteristics can be identified. Humankind has always attempted to reach a greater understanding of nature; it is for this very reason that it continues to question its surroundings (Arı, Peşman, Baykara, and Sunar, 2016) [39]. SPSs encourage the more active participation of students, rendering their learning more permanent, as practical learning experiences are more effective than other methodologies.

Livermore (1964) [3], Padilla, Okey, and Garrard (1984) [40], as well as Tobin and Capie (1980) [38], in their work "In Science—A Process Approach", separate their studies into two parts, namely, (1) science process skills and (2) basic and integrated science process skills. The classification of basic and integrated SPSs are presented here and Basic Process Skills include (a) Observing; (b) Classifying; (c) Measuring; (d) Communicating; (e) Inferring; (f) Predicting; (g) Recognizing Space/Time Relations; and (h) Recognizing Number Relations. Integrated Process Skills include (a) Formulating Hypotheses; (b) Making Operational Definitions; (c) Controlling and Manipulating Variables; (d) Experimenting; (e) Interpreting Data; and (f) Formulating Models (Livermore, 1964) [3].

Rather than the furthering of information and knowledge, the aim of promoting SPSs is to teach individuals how to acquire reliable information and solve everyday problems. Those who acquire SPSs leave little to chance and can confront issues in life with greater ease and a broader perspective (Güden and Timur, 2016) [41]. They represent a basic skill needed in the teaching of science, where problem-solving and research are required, encouraging students to consider and research appropriately. In this sense, SPSs represent an important tool in promoting a deeper understanding of the facts of science and constitute a significant goal in its teaching (Barut, 2020) [42].

What is primarily required for imbuing students with the ability to approach daily issues from a scientific perspective and with a command of SPSs is for the educators themselves to have sufficient information on the chosen subjects (Bakaç, 2020) [43]. Implementing the "Bologna Process" in order to develop educational standards and qualifications has reformed educational practices. As a result, pre-service teacher training changed after the formation of the European Community by the Treaty of Rome in 1957 (Lunt, 2005) [44]. Hence, teaching approaches moved toward a more student-centered methodology, away from conventional teaching (Hernández-Barco, Sánchez-Martín, Corbacho-Cuello, and Cañada-Cañada, 2021) [45]. In inquiry-based learning, students are actively engaged in the learning process. Creating dynamic learning communities empowers students intellectually, and it is socially and personally responsive. Therefore, it facilitates the development of creativity, innovation, critical thinking, and SPSs, which are held to be essential 21st-century skills (Brumann, Ohl and Schulz, 2022; MoNE, 2018, 2022; Hlebowitsh, 2001) [46–49].

When students are presented with SPSs-related tasks, they tend to seek prior knowledge, causing them to pay extremely selective attention and distort the information presented to them during instruction. This may explain some of the challenges they encountered during their task completion (McCormick and Pressley, 1997) [25]. Often, previously held beliefs are so strong that students have trouble believing contradictory observations, while other biases reduce their comprehension of scientific content by focusing on "big words", scientific facts, and other details to reduce the process of investigation to simple rote-learning, which diminishes the meaningful learning approach (Bou Jaoude, 1992; Cavallo, Rozman, Blickenstaff, and Walker, 2003) [50,51]. Therefore, since pre-service teachers' previously held beliefs are so strong, they can still make mistakes in terms of determining the dependent, independent, and control variables, as well as when forming hypotheses.

Science programs ought to have a structure that encourages and guides future teachers to feel responsible for educating themselves, participating actively in the learning process, and transforming their findings into results. A good approach to learning inculcated in trainees represents an important factor that contributes to achieving the stated goals of science education (MoNE, 2018; Ahmed and Ahmad, 2017) [47,52]. According to Asubel (1963) [53], a learning approach is described as (1) meaningful and (2) via rote-learning. Meaningful learning is founded on linking thoughts, concepts, and scientific content—the idea being that when a student integrates a new idea or concept with the related concepts, a more meaningful understanding is forged. The recognition of the relevance of previously learned knowledge and its interconnection with new information over the course of the learning process is the founding component of this integration. If students are not capable of integrating new ideas and concepts into related ones, or if they are unable to make a link with the relevant subject/fields of understanding, they will attempt to learn by memorization. Over the course of this rote-learning, a student will fail to link the new information gained to their previous knowledge and will be unable to forge any connections. This being the case, the student will fail to formulate a conceptual link and is likely to develop a tendency to rote-memorize scientific information. In essence, rote-learning prevents the meaningful understanding of concepts, as noted extensively in the literature (Bou Jaoude, 1992; Cavallo, Rozman, Blickenstaff, and Walker, 2003; Cavallo, 1996; Cavallo, Rozman, and Potter, 2004; Cavallo, Rozman, Larabee, and Ishi-kawa, 2001; Hacieminoglu, 2021) [50,51,54–57].

2.2. Teaching for Conceptual Transformation

Due to students' misconceptions, errant prior knowledge can be lasting, which affects their SPSs. Mental models are created using new knowledge and existing understanding from previous learning; therefore, they are shaped by years of experience, showing consistencies with knowledge that is acquired later (Duit 1991) [58]. Errant information refers to knowledge that is not verified but absorbed in childhood. A learner's prior knowledge may direct them to process new knowledge in prejudiced ways, which presents problems further down the line. This is a common mistake made by students in the application of SPSs. Piaget's cognitive development theory may offer some insight for a better understanding of this aspect of students' reasoning. Piaget stated that new information is absorbed by earlier knowledge, instead of prior knowledge being accommodated to fit new information (e.g., the conceptual explanation of students regarding photosynthesis in plants) (Brotherton and Preece, 1995; Santrock, 2011) [59,60]. A specific amount of new knowledge is seized upon and incorporated into students' prior knowledge, which may be logically erroneous and at odds with the scientific concept being investigated (Brotherton and Preece, 1995, Harris et al., 2012, Pressley and McCormick, 1997) [26,33,59], challenging students conceptually in their meaning-making process.

Often, students apply alternative frameworks when learning and assessing SPSs (Rezba, Sprague, Fiel, Funk, Okey, and Jaus, 1995) [61]. These alternative frameworks are not only persistent but also distort the students' understanding of plausible scientific procedures. Students are inclined to process content superficially, without making an attempt to understand it fully. While it is crucial to be positive, often students are not properly directed in their attempts to understand the meaning and significance of curricular science content (McCormick and Pressley, 1997; Harris et al., 2012) [25,26]. They actively seek to accommodate new information, which is absorbed by earlier knowledge. The meaningful learning approach gives purpose to skill attainment. If this is not present, SPSs attainment may be hindered (Cavallo, 1996) [54].

John Dewey, a renowned American philosopher, had a strong influence on the educational approach when training teachers. Dewey described the school as a place where children learn values, skills, attitudes, and knowledge. In school, students learn the general skills and competencies to lead a good life. Unlike essentialists, experimentalists spurn the notion of "mind-training" in place of discussions and debates underlining "life-experience", especially in the Deweyan form of experimentalism. This progressive tradition of teaching philosophy has a conceptual emphasis on the idea that the subject matter to be taught must be problem-focused. With this ideal, experimentalists accentuate the importance of inquiry-based learning, where the school is at the core of this "reconstruction and reorganization" of the experience. Subsequently, students avoid making similar mistakes, which then contributes to their ability to make well-rounded decisions (Hlebowitsh, 2001) [49] According to Dewey, teaching students a method of intellectual inquiry equips them with the necessary skills to handle their personal and social lives efficiently. Consistent with this notion regarding the foundation of all education, Dewey suggested the importance of the "reconstruction and reorganization of the experience which adds to the meaning of experience" (Dewey, 1916, p. 89) [62]. The level of SPSs among pre-service science teachers can be gauged by their learning approach (during the knowledge acquisition process), providing meaning to what students discover when they investigate. Learning from an experience is an important principle, in order to avoid repeating mistakes, so that learners become capable of making better and more informed decisions.

The aim of this study was to ascertain the level of SPSs among pre-service science teachers and describe how these skills were reflected in their learning approach during the acquisition process. Presenting leadership in a number of fields of relevance in the 21st century, ranging from technology to economics, health, and education, requires the integration of knowledge. This can be simplified using basic and integrative SPSs (i.e., involving observation, communication, classification, measurement, inference, and prediction). The development of scientific thinking skills can be facilitated through the use of SPSs, which should not be viewed as independent from the learning approach of students in their acquisition process. Therefore, in order to promote scholarship through research and practice to improve science instruction, the skills that need to be taught must be practiced.

The main objective of this study was to explore the factors, such as those related to cognitive reasoning, that are utilized by pre-service teachers during science experiments conducted at home, in light of their role in the attainment of SPSs. To this end, it is hoped that the present study can further our understanding of the nature of learning in science through active participation in the inquiry process.

2.3. Research Questions

Based on the purpose of this study, the following research aims are used:

1. To ascertain the level of pre-service science teachers' science process skills;
2. To understand pre-service science teachers' reflections regarding their learning approach.

3. Materials and Methods

As part of this research, document analysis was applied (i.e., one of the qualitative research designs). A systematic methodology was followed in evaluating all documents, including document analysis, as well as a further look at print and electronic material. As with the methods used to assess the qualitative research, the present data needed to be studied and interpreted in terms of drawing conclusions via document analyses to form an understanding of the relevant research (Corbin and Strauss, 2008; Kıral, 2020) [63,64]. As required by the premises of the science laboratory application course taken by students following their study period, a *Science Process Skills Test* and a *Factors Affecting Plant Growth Project Report* were completed. To assess the pre-service science teachers' levels of SPSs, teachers were asked to write reflection papers regarding their learning approach, which are described in the following findings.

3.1. Document Analysis Sample

The course documents of 36 pre-service science teachers were used in this study. Documents included the following materials: *The Science Process Skills Test* and the *Report on Factors Affecting Plant Growth,* along with reflection papers regarding their learning approach (these were used to assess the pre-service science teachers' levels of SPSs and to clarify how their SPSs were reflected in their learning approach). These documents were required as part of the *Laboratory Application Course* taken by students, following their study period. Ethical approval was obtained for the documentation of the students' portfolios to be accessed, as required by the framework of the course. Pre-service teachers who were at the end of their required *Laboratory Application Course* completed these documents.

3.2. The Science Process Skills Test

In order to determine the level of SPSs among pre-service teachers, the Science Process Skills Test, first developed by Enger and Yager (1998) [1] and subsequently translated by Koray, Köksal, Özdemir, and Presley (2007) [65], was used. The test is made up of 31 multiple-choice questions, for which only one answer may be selected each time. The reliability coefficient of the test came to 0.81. The skills measurements that are included involve the ability to observe (two questions), recognize space/time relations (three questions), classify (three questions), use numbers (three questions), measure (three questions), communicate (three questions), make predictions (three questions), check variables (three questions), interpret data (two questions), form hypotheses (three questions), prove theses via practical measurement (one question), and experiment (two questions).

Points Awarded for Science Process Skills

A calculation was made of the answers given by the third-year pre-service science teachers, aiming to garner an indication of their internalization of SPSs, with one point given for each correct answer and zero points given for each incorrect response. The average points gained following the completion of this 31-question test, which offered a maximum of 31 points, showed a score of 18.6, with 64.7% of pre-service science teachers showing success. While the lowest number of points achieved came to 15 out of 31, a record of 21 was the highest number of points awarded (Ss = 1.69). Findings imply that the pre-service science teachers showed an average level of success.

3.3. Data Collection Procedures

Data collection procedures were conducted during the *Laboratory Application Course*, requiring respondents to take the survey as part of their program training. Activities were planned to garner the most effective means of gaining the best understanding of how pre-service teachers could develop SPSs. Importance was given to planning the most suitable activities for discovering which SPSs the pre-service teachers possessed, and which were found to be lacking. For this purpose, pre-service teachers were asked to take the *Science Process Skills Test* devised by Enger and Yager (1998) [1] to assess their skill levels, to be included in their online portfolio. Students who possessed a meaningful learning approach were deemed to be those who had absorbed and recalled concepts in a meaningful way, using this to approach problems related to the particular field and, most likely, solving such problems, while being able to transfer this knowledge to other formats. Although students who had memorized the same concepts might be able to answer the relevant questions on their definition and terms, they were deemed not to have used their knowledge to a sufficient degree to be able to answer open-ended questions on the relevant concept.

With this in mind, students must be made aware that rote learning is liable to cause deficiencies in knowledge. Pre-service teachers were first encouraged to forego the traditional rote-learning approach, with the importance of meaningful learning being emphasized. Throughout the course, they were informed that no questions would be asked in the final examinations that would require rote learning and that a rather more meaningful learning acumen would be required in order to pass the test. As part of the main activity of the laboratory application course, the students were then given the project of investigating *Factors Affecting Plant Growth,* to determine their basic and integrated science process skills. At least three weeks of work, including 21 measurement samples, were required as part of the study. Absolutely no special interventions were staged to assist the students in the study, and the science laboratory application course was carried out as it would be in any other typical assignment. At the end of the study period, the students were asked, as part of the premise of the program, to hand in an electronic project report on the activity, along with reflection papers regarding their learning approach in this process.

3.4. Factors Affecting Plant Growth Project Reports

Pre-service teachers were asked to participate in an activity aimed at gauging the reports on *Factors Affecting Plant Growth*, with 21 days' worth of data and observations being compiled. The activities required the monitoring, use, and reporting of all SPSs. The activities required skills in developing hypotheses, observing procedures, controlling variables, collecting data, plotting graphs, and drawing conclusions.

3.5. Data Analysis

Data from the *Science Process Skills Test* were analyzed using the SPSS 20.0 program, along with the descriptive statistics (i.e., correct answers corresponded to a single-digit number, while incorrect answers were equal to zero). The lowest possible score for the test corresponded to zero, while the highest possible score was 31. The reports on *Factors Affecting Plant Growth* were screened for validity in terms of integrated SPSs. Each report was checked to ensure that the correct science process steps were taken.

Aside from descriptive analysis, the data were analyzed using the document analysis method (Yıldırım and Şimşek, 2011) [66]. The contents of the report were in line with the principles of the Turkish Science and Technology Research Institution (TÜBİTAK), the ninth article of the Research and Publication Ethical Commission, the Inter-University Commission (ÜAK), the fourth article of the Directive on Scientific and Publication Ethics and Institution for Higher Education (YÖK), and the eighth article of the Directive on Scientific and Publication Ethics. As stated, in line with these legal precepts, "the use, interpretation, reporting, and publication of these legally valid documents cannot be accompanied with the use of unsubstantiated data, presented fictitiously, be fabricated, have such information reported and published, used as a tool of research, have its records manipulated, be manipulated to be assumed as the results of another study, be presented as none other than the writings, structure, thoughts, methods, data, or documents of another and cannot be used without permission" (Kıral, 2020, p. 15) [64]. As stated here, this study is in line with the abovementioned legal ethical rules and regulations.

4. Results

The primary results are grouped under the following two sub-headings: (a) the *Science Process Skills Test*, and (b) the *Factors Affecting Plant Growth* project reports.

First, the analyses indicated that the pre-service teachers demonstrated high-level skills in terms of observation, recognition of space/time relations, and the use of numbers. In addition, they exhibited skills in taking measurements, testing predictions, controlling variables, formulating hypotheses, and setting up the experiment. Conversely, they showed lower-level skills in terms of classification, communication, interpreting data, and proving theses through practice. The results of the *Science Process Skills Test* indicated that pre-service teachers have attained a satisfactory level of cognitive reasoning skills, which refers to "the ability to analyze and perceive any given information from different perspectives by breaking it down into manageable components and structuring the information in a logical order" (Mettl, 2022) [67]. Second, when analyzing their *Factors Affecting Plant Growth* project reports, it transpired that several pre-service teachers stated that they had realized they had made certain errors during the design phase of their experiment and had returned to that initial stage, while others made errors in the description of variables, findings, and inferences, with the smallest minority committing errors in terms of observation. The value and the importance of curiosity in the scientific research inquiry process are undeniable, most notably at this stage, specifically in terms of designing experiments at home to enable a meaningful learning experience. As observed from the results, experiential learning contributed to pre-service teachers' SPSs, mainly in their ability to demonstrate cognitive reasoning (Holstermann, Grube, and Bögeholz, 2010) [68]. The COVID-19 pandemic forced students to engage in learning activities in creative ways. Sheehy (2018) [69] makes a compelling case for having an attitude of "curiosity-driven research", asserting that the technology we employ in the present time is directly tied to curiosity-driven experimentation. Interestingly, curiosity is a significant strength that is most commonly linked to satisfaction with life, well-being, and positive relationships; (Buschor, Proyer, and Ruch, 2013; Park et al., 2013) [70,71].

4.1. Science Process Skills Test

The SPSs used by scientists to attain knowledge regarding any given issue present the means to approach problems and provide a greater guarantee that the right answers will be reached, in terms of reliable findings and the interpretation of conclusions (Arı, Peşman, Baykara, and Sunar, 2016) [38]. According to Harlen (1999) [72], SPSs are necessary for literacy in science and for the elevation of living standards in every aspect of daily life. Those who possess SPSs take an active role in their learning environment, develop increased feelings of responsibility, show more confidence in class, refrain from rote memorization, and approach information with a higher degree of intuition. In addition, they are better equipped to link each item of new information with aspects of daily life. Furthermore, SPSs facilitate greater ease in learning, ensure greater participation in the classroom environment, enable more meaningful learning, have a positive effect on the development of problem-solving skills, and provide the essential basis for students to attain greater skills in general (Çepni, Ayas, Johnson, and Turgut, 1996 [73]; Hacieminoglu, 2019 [74]; Johnson-Laird, 2001 [75]; Tan and Temiz, 2003 [76]; Temiz, Taşar, and Tan, 2006) [77].

In this section, the success rates of the pre-service teachers in terms of SPSs are presented in the form of descriptive statistics, including testimonies from the participants themselves, as given in the individual project reports and reflection papers. Table 1 shows the average number of points awarded to pre-service teachers following the *Science Process Skills Tests*.

Table 1. The number of points awarded to the pre-service science teachers and the skills measured in the *Science Process Skills Test*.

Questions	Skill Measured	Success Rate (%)
1 and 2	Observation	77.75
3, 4 and 5	Space/Time Connection	75
6, 7 and 8	Classification	34.26
9, 10 and 11	Recognizing Number Relations	66.6
12, 13 and 14	Measuring	69.5
15, 16 and 17	Communicating	28.7
18, 19 and 20	Predicting	90.7 **
21, 22 and 23	Controlling and Manipulating Variables	52.8
24 and 25	Interpreting Data	41.7
26, 27 and 28	Formulating Hypotheses	79.6
29	Proving through Practice	13.9 *
30 and 31	Experimentation	86.1

The first column shows the list of questions representing certain SPSs, the second column represents the specific skills measured by these questions, and the third column lists the percentage of pre-service teachers. ** we marked as the highest value. * we marked as the lowest value.

Table 1 shows the questions representing certain SPSs and the percentage of pre-service teachers who successfully identified them. The analyses indicated that pre-service teachers demonstrated high-level skills in observation, recognition of space/time relations, and the use of numbers. In addition, they exhibited skills in taking measurements, testing predictions, controlling variables, formulating hypotheses, and setting up the experiment. However, they showed lower-level skills in classification, communication, interpreting data, and proving theses through practice. While the pre-service teachers felt most encouraged when testing predictions, they demonstrated limited skills in proving their theses via practical demonstrations.

The descriptive statistics drawn from the responses to the *Science Process Skills Test* indicate that those pre-service teachers who correctly answered question 1, assessing skills in observation, came to 58.3% (21), while 35 correctly answered question 2, marking a high of 97.2%. Meanwhile, an average success rate of 77.75% was recorded in terms of observation skills overall. Hence, these descriptive statistics are further interpreted below.

The number of students who correctly answered question 3, which measured skills in recognizing space/time relations, came to a total of 36 (100%), while 20 students correctly answered question 4 (55.6%). Among the students, 25 correctly answered questions 5 and 6, showing a total of 69.4%. In terms of recognizing space/time relationships overall, the students showed an average success rate of 75%.

Among the participants, 32 correctly answered question 6, which assessed skills in classification, giving a total of 88.9%, while eight students correctly answered question 7, giving an extremely low percentage of 5.6%. Meanwhile, 32 students correctly answered question 8, giving a total of 88.9%. Overall, the average success rate of the students in this field came to 88.9%.

Furthermore, 36 students correctly answered question 9, which measured the use of figures, marking a total of 100%. Meanwhile, 100% of students, or all 36 participants, correctly answered question 10, yet no students correctly answered question 11, marking the lowest possible success rate in the entire test. Skills in terms of recognizing space/time relations corresponded to 66.6% of students.

Moreover, 27 students correctly answered question 12, which assessed skills in measurement (i.e., 75%), 19 students correctly answered question 13 (i.e., 52.8%), and 4 students correctly answered question 14 (i.e., 11.1%). Furthermore, question 14, which also assessed skills in measurement, showed the lowest rate of success. The total average rate of skills in terms of measurement came to 69.5%.

In all, only two students correctly answered question 15, which measures the ability to communicate, making a total of 5.6%; likewise, two students correctly answered question 16, forming a total of 5.6%, while 27 students correctly answered question 17, forming a total of 75% of the sample. Meanwhile, only two students, or 5.6% of the sample group, correctly answered questions 15 and 16, which investigated communication, bringing the average success rate for this skill to 28.7%.

In total, 30 pre-service teachers (88.3% of the sample) correctly answered question 18, which measured skills in forming predictions, while 32 students, or 88.9%, correctly answered question 19. Furthermore, 36—100% of the sample—correctly answered question 20. The total amount of success in terms of forming predictions came to 90.7%.

Of the students, 24 correctly answered question 21, which examined skills in checking for variables (i.e., corresponding to 66.7% of the sample). Meanwhile, 33 students (91.7%) correctly answered question 22, and none of the students—0% of respondents—correctly answered question 23, marking the lowest possible points given for a question on the test. In total, success in controlling variables came to an overall total of 52.8%.

While 29 students (80.6%) correctly answered question 24, which measured skills in interpreting data, one student (2.8%) correctly answered question 25, which demonstrated an extremely low success rate. In total, the group showed a success rate of 41.7%, in terms of skills in interpreting data.

Thirty-five students correctly answered question 26, concerning the ability to formulate hypotheses, marking a total of 97.2%. Twenty students (55.6%) correctly answered question 27, while 31 students (86.1%) correctly answered question 28, bringing the overall total in this skill set to a 79.6% success rate.

Five of the students correctly answered question 29, which regarded skills in finding proof through practical application, corresponding to 13.9%. This figure shows a rather low reading for the skills in this category.

Furthermore, 36 students—or 72.2% of respondents—correctly answered question 30, which involves skills in experimentation, while 144 students–or 100%—correctly answered question 31. In summary, a total of 86.1% of students showed success in this skill set.

Upon examining the findings, one can see that the highest-scoring skillsets included making predictions and experimentation, while the lowest-scoring skillsets included practical inquiry and forging connections. About these skillsets, one can see that the lowest sets of results appeared for question 11, regarding the use of numbers. None of the students in the control group were able to provide a correct answer to question 23.

In terms of some of the lowest-scoring skillsets, while only four out of the 36 students surveyed correctly answered question 25 regarding skills in interpreting data, only two students correctly answered question seven on classification, as well as questions 15 and 16 on communication. Meanwhile, only four students correctly identified the answer to question 14 regarding measurement skills, and five answered question 29 correctly on finding proof through practical application.

4.2. Factors Affecting Plant Growth Project Reports

The greater the number of senses evoked in students by an educator, the more lasting that experience of learning will be. Learning that is acquired through experience is information that effectively enlivens all the senses. In this way, the learning process is rendered more permanent, simple, and effective. Thus, the development of SPSs ought to be considered as one of the most important goals of effective science instruction (Aydoğdu, 2006; 2014) [78,79]. The statements below offer examples regarding the erroneous experiment.

When the reports on factors contributing to plant growth were analyzed, it appeared that 10 of the students, soon after the design phase of the activity, realized that they had made a mistake and concluded that they would have to restart the task. The following passages are presented as examples from the erroneous experiment:

> *Participant 5:* The student hypothesized that sunlight would boost the growth of the plant, placing it in sunlight and watering it regularly for 10 days. They then aimed to leave it in the dark for 10 days, while continuing to water it.

> *Participant 28:* The student sought to investigate how much water and sunlight would be needed in order to boost the plant's growth. They bought two plants identical in type to investigate the effect of watering in one and sunlight in the other. However, the student did not buy another plant to form a control group.

When the reports on factors contributing to plant growth were analyzed, 8 students wrote down their hypotheses incorrectly. Examples of correct and incorrect hypotheses are given below.

> *Participant 3:* "What will be revealed by placing one of the plants in fertilizer containing minerals and another in fertilizer containing none." (Incorrect hypothesis).

> *Participant 9:* "The seeds placed in sunlight will germinate." (Correct hypothesis)

> *Participant 13:* "The plant placed in the sun and given regular water will grow faster." (Correct hypothesis)

Upon examining the teachers' reports, it is clear that while 24 students successfully proved their ability to identify variables, 10 expressed that they continued to face problems in this area.

Below are a number of statements from the students, who expressed both comfort and difficulties with the identification of variables. In these statements, students expressed an issue with the use of independent variables.

- **Correct Independent Variable**
- Participant 2: Dependent Variable: Plant length
- Independent Variable: Soil type
- Participant 12: Independent Variable: Water amount
- Dependent Variable: Growth amount

- **Erroneous Independent Variable**
- Participant 7: Independent Variable: Sunlight and water
- Dependent Variable: Growth
- Participant 14: Dependent Variable: Growth amount
- Independent Variable: Presence or absence of light

Out of the sample group, 17 students proved to possess knowledge of how to write conclusions and how to infer, while 8 were limited in their knowledge of how to write conclusions alone and 3 showed only skills in making inferences. Meanwhile, eight students demonstrated skills in distinguishing between conclusions and inferences.

There are a number of reasons why students engage in faulty thinking, apart from recalling basic facts related to the material presented. It should be remembered that student misconceptions cannot always be overborne (Harris et al., 2012; Pressley and McCormick, 1997;) [26,33], even when new skills such as SPSs are acquired. Referring to Whitehurst's concept of "inert knowledge" (i.e., knowledge that seems available but that is not used for problem-solving) may help interpret such situations (Renkl, Mandl, and Gruber, 1996) [80].

The following statements reveal the strengths of one student could be seen in terms of formulating conclusions and making inferences.

> *Participant 1:* Conclusion: " . . . When I gave one of the plants a lesser amount of water than needed, it grew at a slower pace than the other plant."
>
> Deduction: "The plant should not be watered any more or less than needed, otherwise it may either grow slowly or wilt."

Below, one can find statements by students who failed to distinguish between how to write inferences and conclusions, appearing to confuse the two:

> *Participant 6:* Conclusion and Inference: "I considered that a plant placed in sunlight would grow faster and healthier. However, the plant that was placed in darkness appeared to grow faster than that placed in the light. However, it grew in a less healthy way, eventually dying. Meanwhile, the plant that was placed in the sunlight grew healthier, albeit slower, and continues to grow."

Many students showed ability in terms of observation and were able to compile their data to plot a graph. An example of one such graph can be found below. Meanwhile, six of the students stated that they conducted observations without additional measurements. Below can be seen some of the observations made by the participants:

> *Participant 19:* " . . . The leaves have expanded to 5 cm. By June 18, the plant which received more water had grown in leaf size to an expanse of 5.8 cm, while those of that less watered had grown to 7 cm."
>
> *Participant 10:* "The plant placed in sunlight has grown to the height of 53 cm. Meanwhile, that which has remained out of the sun has grown to 47.7 cm."
>
> *Participant 22:* "The first plant has grown to 12.5 cm, the second 20 cm, and the third 23 cm"
>
> *Participant 4:* The length of the plant has grown in line with the amount of water given.

A small number of the students wrote down their findings where they should have written their observations. Data presented by 27 students were compiled in tables and graphs. However, nine of the students did not include either layout.

Sample photos of the plants included in an experiment growth figures, chart and graphic (Figure 1) from the pre-service science teachers' portfolios are shown below.

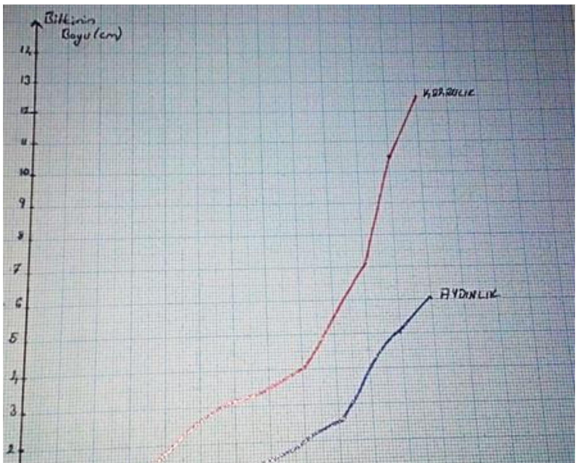
When the plant growth factor reports and science process skills tests were examined together, it is clear that although the students' experiment design, conclusion-forming and inferring skills proved insufficient, their ability to formulate hypotheses, determine variables, measure, observe, plot graphs, and save data proved to be at an adequate level. Meanwhile, in terms of determining the dependent, independent, and control variables, as well as forming hypotheses, a number of students proved to be capable of errors.

Thirty-six pre-service science teachers were asked to reflect on their learning approach throughout the activity in the form of a report. The results showed that the students had made use of a meaningful learning approach as a preference in the *Laboratory Application Course*, in learning the relevant concepts, participating in activities, and attaining scientific process skills. Furthermore, the results showed great satisfaction with the approach.

28. Day in Sunlight

DAY	SUNLIGHT	SHADE
4	0.5 cm	0.7 cm
8	1.5 cm	2.5 cm
12	4.5 cm	8 cm
16	8.5 cm	20 cm
20	11.8 cm	30 cm
24	15.6 cm	42 cm
28	19.2 cm	57 cm
32	24 cm	70 cm

28. Day in Shadow



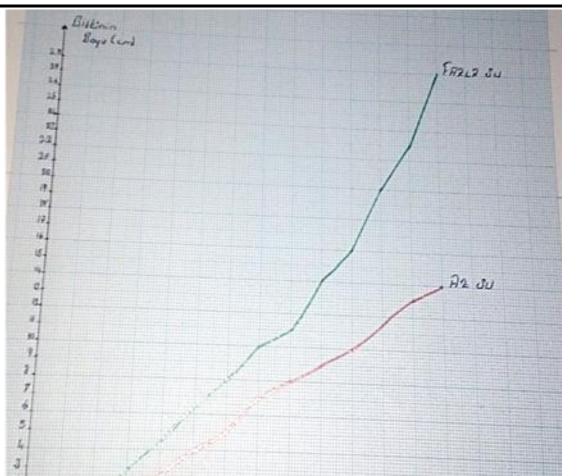


Figure 1. Examples from *Factors Affecting Plant Growth* project reports.

The following excerpts are taken from the students' reports, to support the stated findings:

Participant 15: Generally, I prefer more meaningful learning. This changes sometimes depending on the course, level of difficulty, whether the course is practical in nature, the expectations of myself or my teacher, whether I believe the information will benefit me in the future or other such factors. For this specific class, I opted to take a meaningful learning approach, as the topics dealt with, as well as SPSs in general, are those that I will constantly come across in my field. The skills I have learned in this class will allow me to offer students a more effective, productive, and lasting learning environment. I chose to take on a meaningful learning approach to better develop my students and to help them absorb SPSs and research skills.

Participant 21: Thanks to this class, I realized that nothing I had rote-memorized was . . . a waste of time. When I observed these experiments, I was able to make connections in my mind. I have since given up rote-memorizing. I now better understand the concept of meaningful learning. Aside from the information, the class was practical, offering the chance to observe and conduct experiments. As the use of SPSs allowed me to better understand the concepts taught, I selected the option for a meaningful learning approach. Indeed, I still made a number of mistakes. For instance, in the experiment aimed at finding the factors behind plant growth, I was mistaken in terms of manipulating and controlling variables. Although I've conducted the same experiment many times, I learned something in the end. For me, I found the easiest, most meaningful, and lasting means of learning and I thank you for offering me that gift and for all your hard work.

Participant 16: I choose to take a rote-learning approach to theory-based classes and a meaningful learning approach to more practical classes. For this particular class, I chose the latter, as the topic related to the internalization of knowledge and the skills students need in order to develop their thinking skills. This is not the kind of learning that can be memorized. As this was a very important class for teaching our students, with many practical applications, I opted to approach it with the meaningful learning style.

Participant 1: I've had classes where I've been forced to take the rote-memory approach, especially the day before an exam, and just want to save the day. It's always such a strain and by the next day, everything I learned just vanishes into thin air. As you explained yourself, this isn't the kind of class where such an approach can be taken. A number of topics are involved and the SPSs that we need to develop are those that can benefit us in our everyday lives–so why opt for rote learning? The course was not just theoretical, but practical too, making it a lot more fun. I had a great time.

Participant 6: Both for the experiments and preparing the study portfolio, I used a meaningful learning approach, I can still remember all the information taught and I think the class will have a positive effect on my work. I believe I have internalized the lessons learned and am now more aware of the meaningful learning approach. Thank you for all your help throughout this process.

On the other hand, despite the pre-service teachers' all having expressed support for a meaningful learning approach and having praised it as a preferable means of teaching SPSs in laboratory-based classes, many of the respondents felt forced to continue the practice of rote-learning in some form, however undesirable.

Participant 22: I generally prefer the meaningful learning approach. This varies depending on how much the teacher asks questions. If they elicit the information by asking questions, I opt for the meaningful approach. In classes where we are asked about our method, analysis, synthesis, and evaluations, again, I try to learn in a meaningful way.

Participant 17: I definitely think that the meaningful learning approach is more effective, and I try to utilize as best I can, however, because most of our education is based on rote learning and a lot of our exams require one to memorize the answers, I may have to continue with the older method. I can confidentially say I used this method in the class in question, as the practical aspect of the class ensured I went through each step knowingly–thus, making the lesson more memorable.

Participant 10: I generally have to maintain a preference for the rote-learning approach. But my learning approach changes depending on the class, such as

> whether the teacher simply talks the whole time, classrooms, etc. For this class, we were encouraged to take on board a meaningful learning approach to develop our SPSs and it was of great benefit. Topics included how to transfer knowledge with examples and practical lessons and how this could improve student participation.

To nurture scientific literacy, science teachers need to acquire SPSs as an essential 21st-century skill. These are skills that develop over time, with the deliberate intention to follow up curricular practice using procedural knowledge (Harris et al., 2012; Pressley and McCormick, 1997;) [26,33]. Dewey (1916) [62] stated that school experience must be inquiry-based, while integrating action to "situate knowledge" (Brown, Collins, and Duguid (1989) [34]. Therefore, pre-service teachers could still make mistakes in their ability to change and control variables and form hypotheses because of their misconceptions, their grading concerns regarding the course, missing steps, making mistakes during the inquiry process, or the possession of errant prior knowledge, to name a few. In this process, where a rapid inquiry method was applied, students were encouraged to practice all their SPSs. In this way, they moved away from rote-learning approach habits and prioritized the meaningful learning approach. Thus, they stated that they were satisfied with the experience of their learning environment.

5. Discussion

The findings of this study, which aimed to determine the SPSs of a number of pre-service science teachers, found an average score of 18.6/31 (64.7%) in light of the results of the *Science Process Skills Test*. The skills level of the pre-service teachers was, thus, deemed average, with room for improvement. It appears that in the absence of such skills being included in the latest science programs, pre-service science teachers entering the field cannot be expected to attain a sufficient level of SPSs (MoNE, 2018) [47]. For students to gain these skills to the required degree, both instructors and pre-service science teachers must be engaged in relevant studies aimed at developing their own abilities. It is only through such endeavors that future generations will be able to demonstrate SPSs to a sufficient degree.

When both the activity reports and *Science Process Skills Tests* were analyzed, the students were found to exhibit sufficient knowledge of experiment design, conclusion writing, and inferring; yet, in terms of formulating hypotheses, identifying, and controlling variables, measuring, observing, drawing up tables and saving data, there is room for growth. Similarly, in terms of determining the dependent, independent, and control variables, as well as forming hypotheses, several students proved themselves capable of errors. Results from the multiple-choice test showed that although the pre-service science teachers could select the right answer in terms of identifying the correct format of a hypothesis, they proved highly capable of making significant errors in formulating their own hypotheses during the experiments. The study sample showed that students were unable to answer analyses and syntheses questions related to the controlling study variables.

Furthermore, in one study designed to examine the effect of acid rain on fish populations, two tanks were filled with equal amounts of water, but one received an additional dose of 50 drops of acid in the form of vinegar, the other remaining untainted. Ten fish of identical species were added to each jar, with the same amount of food and oxygen added to each. A period of one week was dedicated to monitoring the behavior of the fish. The observations led to several findings. Despite no further variables being added in the experiment, in terms of the analyses and synthesis reports examining skills in the manipulation and control of variables, not a single pre-service teacher was able to answer the relevant questions correctly. However, as mirrored in the findings by Tan and Temiz (2003) [76], the students tended to note more than one variable.

Similar findings were discovered by Ateş (2005) [81], who found the biggest common inadequacy among pre-service teachers included "controlling and manipulating variables" alongside "data analyses and graph plotting". Furthermore, Gultepe (2016) [82] found that physics, chemistry, and biology teachers displayed far more success in observing, predicting, experimenting, and inferring, compared to other skills. Thus, educators must aspire to instill in students the necessary skills starting from primary school. Mental model theory refers to interactions between partly completed internal representations and a corresponding environment to fill the gaps (as can be seen in the comments of participants 2, 12, 7, and 14). This implies that one's ideas are being created across productions. The production types of these mental models consist of both procedural and declarative knowledge, thus, constantly interacting as part of thinking and learning (Pressley and McCormick, 1997) [33].

Likewise, in terms of recognizing number relationships, for instance, it was noted in one experiment that the previous day's temperature was at −6 °C, rising to 2 °C on the next. However, when asked to point out the difference that this represented, not a single pre-service teacher was able to offer the correct answer. Thus, it must be theorized that an improvement is needed in the conceptualization of the relationship between mathematics and science. Indeed, programs must include activities aimed at improving teachers' knowledge of the links between such numerical phenomena as positive and negative numbers, thermometer reading, four-mode operations, natural sine waves, powered numbers, and fractions (Hacieminoglu, 2019; Livermore, 1964) [3,69].

Furthermore, Aktaş and Ceylan (2016) [83] aimed at identifying the SPSs of science teachers. The results of the *Science Process Skills Test* showed that pre-service teachers possessed the lowest average skills, in terms of controlling and manipulating variables (45%), with moderate skillsets recorded in the operational definitions (61%) and formulating hypotheses (66%), and the highest averages identified as research design (86%) and the interpretation of graphs and data (79%). The study found the lowest level of skillsets among pre-service teachers as those pertaining to the identification and control of variables. Furthermore, related to pre-service science teachers Karapınar and Şaşmaz Ören (2015) [84] identified a similar trend the results of this study; the lower scores among the subcategories of their own test also proved to pertain to those questions relating to the control of variables.

Inquiry-based learning refers to a model in which students are engaged in questioning, design, and research processes throughout the duration of a course. Therefore, they must have the opportunity to achieve fact-based knowledge by employing their skills in the most effective way (Ormancı and Balım, 2019) [85]. Seydioğlu and Barış (2021) [86] developed the sub-dimensions of SPSs by teaching each stage during course instruction. As a result, it was concluded that predicting, data use and interpretation, model formulation, and experiment skills increased in terms of SPSs. In a similar study, Şahintepe (2018) [87] stated that the inquiry-based learning method had a significant effect on metacognitive awareness and SPSs. The majority of pre-service teachers in this study reflected that guided inquiry-based laboratory practices improved their creative thinking skills. This finding is in line with other research into inquiry-based learning strategies (Çelik, Katrancı, and Çakır, 2017) [88] to improve creative thinking skills. Şen and Vekli (2016) [89] investigated the effect of the inquiry-based teaching approach on laboratory self-efficacy perceptions and the SPSs of science-teachers-in-training. The study harnessed a pre-test and post-test group design, concluding—as in our own study—that inquiry-based teaching had a positive effect on the laboratory self-efficacy and SPSs of teachers-in-training.

Meanwhile, Şensoy and Yıldırım (2017) [90], in their quasi-experimental study, aimed to determine the effect of inquiry-based learning on creative thinking and SPSs. For this purpose, the test was applied to third-grade science-teachers-in-training in their instructional technologies and material design course. While the lessons in the experimental group were carried out via inquiry-based activities, the lessons in the control group continued using a traditional teaching approach. The *Torrance Creative Thinking Test* and *Scientific Process Skills Test* were applied to the experimental and control groups. As a result of the tests, the authors concluded that inquiry-based learning did not affect students' creative thinking levels but did increase their scientific process skills. In his quasi-experimental study, Yetişir (2016) [91] aimed to determine the effect of guided inquiry-based learning on the academic achievement of pre-service teachers, and their views on this practice. With this in mind, he chose physics-teachers in-training to conduct inquiry-based learning activities, with lessons conducted for the control group using the standard lecture method. As a result, there was a significant increase in academic achievement among the experimental group. Furthermore, the evidence indicates that the students' backgrounds impacted the degree of education they achieved, which later influenced their career choice (Alam and Forhad, 2022) [92].

In a study conducted with the help of 45 classroom teachers in a science laboratory, Zeren Özer, Güngör, and Şimşekli (2011) [93] aimed to analyze the breadth of SPSs among pre-service teachers. The laboratory qualification observation checklist and SPSs analysis reports were used for data collection. The study showed that the highest levels of skills were represented among pre-service teachers when they were being monitored. The study further proved an enduring effect among pre-service teachers in experiments that required correct identification and classification, along with the control of variables. Despite testing for the formulation of conclusions, skills in experimentation, and the test of recognizing space/time relations, none of the teachers in the study mentioned such skills personally; thus, the findings in this regard are not included here. In another study by Lloyd, Braund, Crebbin, and Phipps (2000) [94], which focused on primary teachers' confidence in their understanding of process skills, the primary teachers professed awareness of the importance of this approach and trust in their own abilities; however, participants lacked the ability to correctly describe or put such skills into practice.

Additionally, the findings of a study performed by Pekmez (2001) [95], involving 24 science teachers, found the pre-service teachers' skills in scientific methodology and laboratory skills to be inadequate to the point that they could be deemed nonexistent. According to Işık and Nakiboğlu's (2011) [96] study with fourth- and fifth-grade teachers, they found that while 70% of teachers professed to have had a knowledge of the scientific method, none were aware of the best way to transmit such skills to their students within the context of classroom teaching. This was despite a qualitative study by Yıldırım, Atila, Özmen, and Sözbilir (2013) [97], with 16 pre-service science teachers, which reported a general awareness of the method among participants, while their knowledge was inadequate. Another study concluded that the pre-service teachers were unable to forge a link between science teaching programs and SPSs, as supported by the findings of further studies by Karslı, Yaman, and Ayas (2010) [98] and by Farsakoğlu, Şahin, Karslı, Akpınar, and Ültay (2008) [99]. Türkmen and Kandemir's (2011) [100] study on the SPSs, with eight classroom teachers, aimed to identify the degree to which pre-service teachers had absorbed an understanding of SPSs, along with the problems faced in terms of practical and potential solutions. As a result, the teachers proved to have little theoretical understanding of the method, suggesting that a visit to the school by a specially appointed science teacher could offer a possible solution.

The existing literature reveals numerous studies focusing on the SPSs of trainees and elementary school teachers. While Günsel and Azar (2006) [101] and Ünaldı (2012) [102] focused on SPSs in science teaching, Demirçalı (2016) [103] studied their effects via modeling, Gülay (2012) [104] focused on specially prepared activities, and Fansa (2012) [105] shone light on inquiry-based learning with elementary students, contributing greatly to the enhancement of SPSs through a number of experimental studies. Akben (2011) [106], Aksakal (2020) [107], Arı and Bayram (2011) [108], Baykara (2011) [109], Duru, Demir Önen and Benzer (2011) [110], Şenyiğit (2020) [111], Tatar (2006) [112], Usta Gezer (2014) [113] and Yaz (2018) [114] all used various types of inquiry-based laboratory activities to promote SPSs among pre-service teachers, to significant effect. Barut (2020) [42], Coştu (2021) [115], Kanlı and Yağbasan (2008) [116], Sağırekmekçi (2016) [117] and Tokur (2011) [118], meanwhile, have all contributed positively to the level and conceptual understandings of SPSs among pre-service teachers in the field of science, via the use of the predict-observe-explain (POE) technique. Furthermore, Öztürk (2019) [119] and Tekin (2019) [120] have focused on problem-based teaching approaches, while Önol (2013) [121] has developed problem-solving activities and Uysal (2018) [122] has adopted a design-based approach to STEM (Science, Technology, Mathematics, and Engineering) activities, to successfully develop the means to nurture SPSs among science students. Conversely, Yıldız (2010) [123] examined experiment applications in solving problem-based learning scenarios in science education. Akca (2020) [124] examined whether high school students' participation in robotic activities had an effect on the students' SPSs. The results showed that there was no significant change in SPSs, such as when describing variables, operational design, hypothesis setting and definition, the interpretation of graphs and data, and research design.

A study by Roth (2014) [125] is informative regarding the conflicts experienced by middle school students when reacting to texts that challenge their personal theories to accommodate scientific data. Many science educators are convinced that conceptual change strategy lies at the core of these interventions. Students can be taught to observe and solve the discrepancies between their own prior knowledge and new science content when they have a deep understanding of science (McCormick and Pressley, 1997; Harris et al., 2012) [25,26], e.g., the results of such processing in terms of plant growth. Pre-service teachers' hands-on experience of lab conditions and/or experimental settings create an emotional memory, which may be crucial for retention, comprehension, and learning SPSs. In a paper written on cognitive psychology by Craik and Lockhart (1972) [126], the authors argued that what is best remembered during a learning task is dependent on what the learner did, stressing the role of personally meaningful learning in SPSs (Cavallo, 1996) [52]. As stated by Participant 21, information obtained by using scientific-process skills, such as experimentation and observation, is easier to understand and make sense of. Thus, this process provides a meaningful learning approach, which is important for gaining SPSs.

In brief, successfully incorporating the SPSs with laboratory instructions, supplementary documentation, and fieldwork would cause the learning experiences to become stronger and more meaningful for students. When students are developing SPSs alongside curricular content, they are actively engaged with the science they are learning, demonstrating a deeper understanding of the subject. Finally, active engagement in science instructions would enhance attitudes toward learning science in meaningful ways, inspiring students to develop more interest in science, as stated by many participants. Considering the findings of this study, in order to develop SPSs, investigative thought, critical thinking, and problem-solving and decision-making skills in pre-service teachers, a generation of educators imbued with a lifelong desire to learn must be raised. These educators must aspire to achieve success at a high level of science literacy, in terms of observation, collecting data, conducting experiments, harnessing the appropriate approaches, and internalizing values, in line with the premise of SPSs. Factors involving (a) teachers (e.g., motivation and engagement), (b) learners (e.g., misconceptions), and (c) instructional variables (e.g., grading and instructional styles) are vital.

Some of the theoretical and practical implications of this research are summarized below. The primary goal of education being to prepare students for their future careers, improving students' skills for the job market must simultaneously increase their socioeconomic standards (Alam, 2021) [127], which is consistent with the standards of science education and STEM-focused career development (Schmidt, Hardinge, and Rokutani, 2012) [128]. Therefore, preparing students by giving them high levels of skills as they transition from high school to postsecondary education and/or the world of work (ASCA, 2014) is crucial for a wide range of contemporary job requirements. School stakeholders must strive to team up and collaborate (science education teachers, school counselors, school administrators, gifted student education centers) to realize the student competencies outlined in their professional job description. Ferguson and Lamback (2014) [129] posit that career-focused education has long been the main thrust of educational reform, in order to strengthen students' preparation for future careers and to guide planning, to fulfill the expectations of future generations entering the workforce. Similarly, career technical education (CTE) programs in the US enroll over 12 million high school and college students at any one time and have long been defended as a means of imbuing young people with hands-on experience. Both academic and technical skills are held up as pillars of workplace competence, which must be free from bias, regardless of students' socioeconomic status or educational backgrounds (e.g., often, engineering programs are viewed as representing white-collar jobs) (Alam, 2021) [127].

In skills development, SPSs are vital. As stated previously, mental models can incorporate schemas with the new input and by integrating previous input (Harris et al., 2012; Pressley and McCormick, 1997; [26,33]. Learners may possess misconceptions about themselves, such as those related to their intellectual ability and academic qualifications, in addition to the level of self-esteem they have, which may hinder their meaning-learning ability. Since these misconceptions may be developed due to their own emotions, such as feelings of inadequacy, these may be triggered in the face of adversity, including that provided by challenging instructional environments. Like mental models, the emotional schema model is a social cognitive model that focuses on beliefs about one's emotions. Hence, these emotions may override the interpretation, conceptualization, and assessment of emotions. Since they are closely linked to personal beliefs and appraisals, understanding these misconceptions may help to explain one's cognitive difficulties (Leahy, 2019; 2002) [130,131]. This may shed light on understanding the learner-related factors affecting SPSs. Examining the project reports in this study, several pre-service teachers realized that they had made certain errors during the design phase of the experiment and returned to the initial stage, while others made errors in the description of variables, findings, and inferences, with the minority committing errors in terms of observation.

The authors acknowledge that using document analysis has limitations, due to not having the ability to achieve one-one-one contact with the participants. It needs to be remembered that the results are generalizable only to this document sample. In addition, pre-service teachers may have other variables that affect their reports (i.e., their concerns related to grading, or a self-reporting bias).

6. Conclusions

The findings of this study prove that the development of SPSs requires a range of diverse instructional techniques and teaching methods. Experimental studies using a larger sample size must explore the lasting effects of these results. Considering the findings here, it can be stated that this new generation of educators must be raised with a lifelong desire to develop their research skills, investigative thought, critical thinking, problem-solving, and decision-making skills. These educators are supposed to have a higher focus on literacy in science (i.e., ways to acquire knowledge, harness the relevant approaches, and adhere to pertinent values) in line with the premise of SPSs. Pre-service teachers ought to dedicate more time in their classroom teaching to the use and development of SPSs. Nomxolisi, Shakespear, and Mabel-Wendy (2021) [132] have proffered the observation that pre-service teachers are given far more theoretical material, rather than practical classes. By the same token, aside from typical partial lessons, such as those taking place in physics, biology, and chemistry laboratories, there ought to be further integration of SPSs into the teaching of other studies for pre-service teachers to develop their knowledge of the methodology. More attempts should be made to integrate SPSs and research skills into teacher training. Furthermore, the importance of linking the knowledge, skills, values, and benefits of this approach in all aspects of life must be emphasized. Pre-service teachers must be trained to realize the importance of internalizing this methodology in their lives (i.e., not merely in relation to their field). As Boateng and Mushayikwa (2022) [133] conclude, just as teachers ought to develop an understanding of students' learning styles, so should they consider individual differences.

Teachers must embrace individual differences and be sensitive to students' learning goal orientations. Consistently, the participants of this study showed a noticeable level of preference for using the meaningful learning approach. Some have suggested that one of the factors that shape the approach taken by educators ought to depend on the means of evaluation, as proposed by Özdemir and İlhan-Beyaztaş (2018) [134]. For instance, if an examination (or project, presentation, or homework) is likely to involve critical thought and the use of previously learned information that is applied to a new scenario, then a reliance on the rote-learning technique will have a negative impact on the results, unlike that from a meaningful learning approach. On the other hand, if a similar test requires a selection from several descriptive answers, then a rote-memory teaching style may ensure success (Hacieminoglu, 2021) [54]. However, all teachers found the meaningful learning approach encouraging, in terms of student participation and the development of SPSs, through the formation of a conducive learning environment.

In particular, teachers should guide students in the right direction, in order to nurture their attitudes toward research. Likewise, Lotter and Miller (2017) [135] declared that teachers should better understand the importance of developing research skills and an attitude of inquiry in students; thus, they can help them to build skills in conceptualizing the content related to science. With this understanding, teachers and students should collaborate reaching in conclusions, applying this as an inquiry-based learning strategy. In the case of students, according to Kaya and Yılmaz (2016) [136], this strategy is expressed during the process in which research questions are formed and when solutions are discovered and discussed. In this procedure, it is crucial to use SPSs in hands-on practice rather than by rote memorization.

The purpose of the development of 21st-Century Skills (P21) and their implications for curriculum reform have been explored widely (Ananiadou and Claro, 2009; Silva, 2009) [19,137]. The essential qualities of a successful 21st-century education include recognizing the importance of a shared educational purpose, parent and community involvement, the quality of educators, attending to student needs, and self and career exploration. While critics question the content and evidence regarding beneficial practices, as related to the 21st-Century Skills (P21) (Guo and Woulfin, 2016; Greenlaw, 2015) [138,139], a growing body of literature supports their basic premises (Chu et al., 2021; Care, Griffin and McGaw, Griffin et al., 2012) [140,141]. In order to cultivate this 21st-century knowledge, these skills, capabilities in new generations, and educational practices must be geared toward employing the relevant strategies. Using the current literature to guide effective instructional approaches and the methods to support educational processes must be promoted.

Johnson-Laird stated (2001) [75] "To be rational is to be able to reason. . . . We construct mental models of each distinct possibility and derive a conclusion from them. The theory predicts systematic errors in our reasoning, and the evidence corroborates this prediction. Yet, our ability to use counterexamples to refute invalid inferences provides a foundation for rationality. On this account, reasoning is a simulation of the world fleshed out with our knowledge, not a formal rearrangement of the logical skeletons of sentences (p. 1).

There are many individuals who possess the natural skills needed to get the most out of the scientific process, but who can still benefit from an increasingly interdisciplinary perspective, to display greater leadership in a number of fields of pertinence in the 21st century, ranging from technology to economics, health, and education. Teachers play a strong leadership role in their teaching communities. The responsibility of educating the next generation of learners to prepare them for diverse occupations in the world of work is a crucial task, which falls under the umbrella of the faculties of education. With this in mind, teaching programs must train future educators so that they have the power to develop the next generation of scientists. To this end, the nurturing of SPSs in pre-service teachers is a key demand since "We are currently preparing students for jobs that don't yet exist . . . using technologies that haven't been invented . . . in order to solve problems we don't even know are problems yet."—Richard Riley, former Secretary of Education.

Author Contributions: Conceptualization, E.H., N.G.Y. and R.Ş.; Data curation, E.H. and N.G.Y.; Formal analysis, E.H. and N.G.Y.; Investigation, E.H., N.G.Y. and R.Ş.; Methodology, E.H. and N.G.Y.; Project administration, N.G.Y.; Resources, N.G.Y.; Visualization, R.Ş.; Writing—original draft, E.H. and N.G.Y.; Writing—review & editing, E.H., N.G.Y. and R.Ş. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were waived for this study. There is a detail explanation of the procedures administered, which outlined in the Section 3. In this document analysis study, the students were asked to hand in their portfolios as part of the program premise by the end of semester for their Laboratory Application Course. The course was carried out like any other typical undergraduate course with no intervention staged to assist the students. Once the researcher decided to analyze course documents applied to University Ethics Committee. They received a statement that the studies involving document analysis are exempt from IRB ethical approval. Documentation of the reason for exemption is provided to the journal.

Informed Consent Statement: The Informed Consent form was obtained from the students for the Turkish version of The Science Process Skills Test during their Laboratory Application Course. We have received permission to use this adapted version of the test. Also, Enger and Yager (1998) had published the test in *Assessing Student Understanding in Science: A Standards-Based K-12 Handbook*, in 2001 with the condition to cite as a reference.

Data Availability Statement: The article is based on pre-service teachers' documents.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Enger, S.G.; Yager, R.E. *The Iowa Assessment Handbook*; Science Education Center of The University of Iowa: Iowa, IA, USA, 1998.
2. Heppner, P.; Wampold, B.; Kivlighan, D. *Research Design in Counseling Psychology*, 3rd ed.; Brooks/Cole: Belmont, CA, USA, 2008.
3. Livermore, A.H. The process approach of the AAAS commission on science education. *J. Res. Sci. Teach.* **1964**, *2*, 271–282. [CrossRef]
4. Temiz, B.K. Lise 1. Sınıf Fizik Dersi Programının Öğrencilerin Bilimsel Süreç Becerilerini Geliştirmeye Uygunluğunun İncelenmesi. Master's Thesis, Gazi Üniversitesi, Ankara, Turkey, 2001.
5. Aydoğdu, M.; Kesercioğlu, T. *İlköğretimde Fen Ve Teknoloji Öğretimi*; Anı Yayıncılık: Ankara, Turkey, 2005.
6. Bağcı-Kılıç, G. Üçüncü uluslararası matematik ve fen araştırması (TIMMS): Fen öğretimi, bilimsel ve araştırma ve bilimin doğası. *İlköğretim Online* **2003**, *2*, 42–51.
7. Alam, G.M.; Parvin, M. Can online higher education be an active agent for change?—Comparison of academic success and job-readiness before and during COVID-19. *Technol. Forecast. Soc. Chang.* **2021**, *172*, 121008. [CrossRef]
8. Di Benedetto, C.A.; Myers, B.E. A conceptual model for the study of student readiness in the 21st century 1. *NACTA J.* **2016**, *60*, 28–35. Available online: http://search.proquest.com.ezproxy.gvsu.edu/docview/1791660471?accountid=39473 (accessed on 27 March 2022).
9. Mobley, C.; Sharp, J.; Hammond, C.; Withington, C.; Stipanovic, N. The Influence of Career-Focused Education on Student Career Planning and Development: A Comparison of CTE and Non-CTE Students. *Career Tech. Educ. Res.* **2017**, *42*, 57–75. [CrossRef]
10. Woolfolk, A.; Winne, P.H.; Perry, N.E. *Educational Psychology*; Pearson Allyn and Bacon: Toronto, ON, Canada, 2006.
11. Yıldırım, M.; Çalık, M.; Özmen, H. A meta-synthesis of Turkish studies in science process skills. *Int. J. Envi-Ronmental. Sci. Educ.* **2016**, *11*, 6518–6539.
12. Bell, S. Project-Based Learning for the 21st Century: Skills for the Future. *Clear. House A J. Educ. Strat. Issues Ideas* **2010**, *83*, 39–43. [CrossRef]
13. Owens, A.D.; Hite, R.L. Enhancing student communication competencies in STEM using virtual global collaboration project based learning. *Res. Sci. Technol. Educ.* **2022**, *40*, 76–102. [CrossRef]
14. Partnership for 21st Century Skills. 2014a. FAQ. Available online: http://www.p21.org/about-us/p21-faq (accessed on 26 March 2022).
15. Partnership for 21st Century Skills. 2014b. Our History. Available online: http://www.p21.org/about-us/our-history (accessed on 26 March 2022).
16. Partnership for 21st Century Skills. 2014c. Our Mission. Available online: http://www.p21.org/about-us/our-mission (accessed on 25 March 2022).
17. Partnership for 21st Century Skills. 2014d. Resources for Educators. Available online: http://www.p21.org/our-work/resources/for-educators (accessed on 25 March 2022).
18. 21st Century Skills Map, 2009. Science. Available online: http://marsed.mars.asu.edu/sites/default/files/pdfs_resources/21stCSkillsMapScience.pdf (accessed on 25 March 2022).
19. Ananiadou, K.; Claro, M. 21st Century Skills and Competences for New Millennium Learners in OECD Countries. *OECD Educ. Work. Pap.* **2009**, *41*, 33. [CrossRef]
20. Geisinger, K.F. 21st Century Skills: What Are They and How Do We Assess Them? *Appl. Meas. Educ.* **2016**, *29*, 245–249. [CrossRef]
21. Metz, S. Editor's Corner: 21st Century Skills. *Sci. Teach.* **2011**, *78*, 6.
22. OECD. The Future of Education and Skills Education 2030. 2018. Available online: https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf (accessed on 31 July 2020).
23. Thrilling, B.; Fadel, C. *21st Century Skills: Learning for Life in Our Times*; John Wiley and Sons: Hoboken, NJ, USA, 2009.

24. Özdoğru, A.A. Revisiting Effective Instructional Strategies for Twenty-First-Century Learners. In *Educational Theory in the 21st Century*; Alpaydın, Y., Demirli, C., Eds.; Palgrave Macmillan Singapore: Singapore, 2022; pp. 175–195. [CrossRef]
25. McCormick, C.B.; Pressley, M. *Educational Psychology: Learning, Instruction, Assessment*; Longman Publishing/Addison Wesley L.: Harlow, UK, 1997.
26. Harris, K.R.; Graham, S.E.; Urdan, T.E.; McCormick, C.B.; Sinatra, G.M.; Sweller, J.E. *APA Educational Psychology Handbook, Vol 1: Theories, Constructs, and Critical Issues*; American Psychological Association: Washington, DC, USA, 2012. [CrossRef]
27. MacDermott, C.; Ortiz, L. Beyond the business communication course: A historical perspective of the where, why, and how of soft skills development and job readiness for business graduates. *IUP J. Soft Ski.* **2017**, *11*, 9–24. Available online: http://search.proquest.com.ezproxy.gvsu.edu/docview/1916950578?accountid=39473 (accessed on 28 March 2022).
28. Chand, A.; Tipnis, J. The role of soft skills in the development of employee in an organization. *Int. J. Eng. Res. Gen. Sci.* **2016**, *4*, 437–452.
29. Hestenes, D. Notes for a Modeling Theory of Science, Cognition and Instruction. In Proceedings of the GIREP Conference: Modelling in Physics and Physcis Education, Amsterdam, The Netherlands, 20–25 August 2006.
30. Holland, J.H.; Holyoak, K.J.; Nisbett, R.E.; Thagard, P.R. *Induction: Processes of Inference, Learning, and Discovery. Computational Models of Cognition and Perception*, 1st ed.; MIT Press: Cambridge, MA, USA, 1986.
31. Organisation for Economic Co-operation & Development. PISA 2015 Results (Volume V): Collaborative Problem Solving. OECD Publishing. 2016. Available online: https://www.oecd.org/education/pisa-2015-results-volume-v-9789264285521-en.htm (accessed on 27 March 2022).
32. Johnson-Laird, P.N. Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. Harvard Univ Press: Cambridge, MA, USA, 1983.
33. Pressley, M.; McCormick, C.B. *Cognition, Teaching, and Assessment*; HarperCollins College: New York, NY, USA, 1997.
34. Byrnes, J.P. The conceptual basis of procedural learning. *Cogn. Dev.* **1992**, *7*, 235–257. [CrossRef]
35. Collins, A.; Brown, J.S.; Newman, S.E. Cognitive Apprenticeship: Teaching the Crafts of Reading, Writing, and Mathematics. In *Knowing, Learning, and Instruction*; Psychology Press: London, UK, 1989; pp. 453–494. [CrossRef]
36. Brown, J.S.; Collins, A.; Duguid, P. Situated Cognition and the Culture of Learning. *Educ. Res.* **1989**, *18*, 32–42. [CrossRef]
37. Michael, J. In pursuit of meaningful learning. *Adv. Physiol. Educ.* **2001**, *25*, 145–158. [CrossRef]
38. Tobin, K.G.; Capie, W. Teaching Process Skills in the Middle School. *Sch. Sci. Math.* **1980**, *80*, 590–600. [CrossRef]
39. Arı, Ü.; Pesman, H.; Baykara, O.; Sunar, Y. Fen bilimleri öğretmenlerinin bilimsel süreç becerilerinin gelişimi. *Uluslararası Türk Eğitim Bilimleri Derg.* **2016**, *7*, 44–52.
40. Padilla, M.J.; Okey, J.R.; Garrard, K. The effects of instruction on integrated science process skill achievement. *J. Res. Sci. Teach.* **1984**, *21*, 277–287. [CrossRef]
41. Güden, C.; Timur, B. Ortaokul Öğrencilerinin Bilimsel Süreç Becerilerinin İncelenmesi (Çanakkale örneği). *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi* **2016**, *16*, 163–182. [CrossRef]
42. Barut, D.B. Kavram Ağlarıyla Desteklenmiş TGA Etkinliklerinin Fen Bilgisi Öğretmen Adaylarının Laboratuvar Tutumlarına, Kaygılarına ve Bilimsel Süreç Becerilerine Etkisi. Master's Thesis, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara, Turkey, 2020.
43. Bakaç, E. Öğretmen Adaylarının Bilimsel Süreç Becerilerini Anlama Düzeyleri ve Öğretim Elemanlarının Onların Cevapları Hakkında Tahminleri. Master's Thesis, Atatürk Üniversitesi Eğitim Bilimleri Enstitüsü, Erzurum, Turkey, 2020.
44. Lunt, I. The Implications of the "Bologna Process" for the Development of a European Qualification in Psychology. *Eur. Psychol.* **2005**, *10*, 86–92. [CrossRef]
45. Hernández-Barco, M.; Sánchez-Martín, J.; Corbacho-Cuello, I.; Cañada-Cañada, F. Emotional Performance of a Low-Cost Eco-Friendly Project Based Learning Methodology for Science Education: An Approach in Prospective Teachers. *Sustainability* **2021**, *13*, 3385. [CrossRef]
46. Brumann, S.; Ohl, U.; Schulz, J. Inquiry-Based Learning on Climate Change in Upper Secondary Education: A Design-Based Approach. *Sustainability* **2022**, *14*, 3544. [CrossRef]
47. Ministry of National Education (MoNE). *Science Course Curriculum: Primary and Secondary School 3, 4, 5, 6, 7 and 8th Grades*; Ministry of National Education Board of Education and Discipline: Ankara, Turkey, 2018.
48. Ministry of National Education (MoNE) STEM PD Net. Available online: https://stem-pd-net.eu/en/mone/ (accessed on 27 March 2022).
49. Hlebowitsh, P.S. *Foundations of American Education*, 3rd ed.; Wadsworth, T., Ed.; Thomson Learning: Belmont, CA, USA, 2001.
50. Bou Jaoude, S.B. The relationship between high school students' learning strategies and the change in their misunderstandings during a high school chemistry course. *J. Res. Sci. Teach.* **1992**, *2*, 687–699. [CrossRef]
51. Cavallo, A.M.L.; Rozman, M.; Blickenstaff, J.; Walker, N. Learning, reasoning, motivation, and epistemological beliefs. *J. Coll. Sci. Teach.* **2003**, *33*, 18–23.
52. Ahmed, A.; Ahmad, N. Comparative Analysis of Rote Learning on High and Low Achievers in Graduate and Undergraduate Programs. *J. Educ. Educ. Dev.* **2017**, *4*, 111. [CrossRef]
53. Ausubel, D.P. *The Psychology of Meaningful Verbal Learning*; Grune & Stratton: New York, NY, USA, 1963.
54. Cavallo, A.M.L. Meaningful learning reasoning ability and student's understanding and problem of genetics topics. *J. Res. Sci. Teach.* **1996**, *38*, 625–656. [CrossRef]

55. Cavallo, A.M.; Potter, W.H.; Rozman, M. Gender Differences in Learning Constructs, Shifts in Learning Constructs, and Their Relationship to Course Achievement in a Structured Inquiry, Yearlong College Physics Course for Life Science Majors. *Sch. Sci. Math.* **2004**, *104*, 288–300. [CrossRef]
56. Cavallo, A.M.L.; Rozman, M.; Larabee, T.; Ishikawa, C. Shifts in Male and Female Students' Learning, Motivation, Beliefs, and Scientific Understanding in Inquiry-Based College Physics Course. In Proceedings of the Annual Conference of the National Association for Research in Science Teaching, St. Louis, MO, USA, 25–28 March 2001.
57. Hacıeminoğlu, E. Factors Predicting Middle School Pupils' Learning Orientations: A Multilevel Analysis. *Educ. Q. Rev.* **2021**, *4*, 40–423. [CrossRef]
58. Duit, R. Students' conceptual frameworks: Consequences for learning science. *Psychol. Learn. Sci.* **1991**, *75*, 649–672.
59. Brotherton, P.N.; Preece, P.F.W. Science Process Skills: Their nature and interrelationships. *Res. Sci. Technol. Educ.* **1995**, *13*, 5–11. [CrossRef]
60. Santrock, J.W. *Life-Span Development*; McGraw-Hill: New York, NY, USA, 2011.
61. Rezba, R.J.; Sprague, C.S.; Fiel, R.L.; Funk, H.J.; Okey, J.R.; Jaus, H.H. *Learning and Assessing Science Process Skills*, 3rd ed.; Kendall/Hunt Publishing Company: Dubuque, IA, USA, 1995.
62. Dewey, J. Democracy and education. *Free Press* **1916**, *9*, 1899–1924. [CrossRef]
63. Corbin, J.; Strauss, A. Basic of Qualitative Research. In *Techniques and Procedures for Developing Grounded Theory*, 3rd ed.; SAGE Publications: Thousand Oaks, CA, USA, 2008.
64. Kıral, B. Nitel bir veri analizi yöntemi olarak doküman analizi. *J. Soc. Sci. Inst.* **2020**, *15*, 1–20.
65. Koray, Ö.; Köksal, M.S.; Özdemir, M.; Presley, A.Ġ. Yaratıcı ve eleştirel düşünme temelli fen laboratuarı uygulamalarının akademik başarı ve bilimsel süreç becerileri üzerine etkisi. *İlköğretim Online* **2007**, *6*, 377–389.
66. Yıldırım, A.; Şimşek, H. *Sosyal Bilimlerde Nitel Araştırma Yöntemleri (8. Baskı)*; Seçkin Yayıncılık: Ankara, Turkey, 2011.
67. Mettl. Mettl Glossary. Available online: https://mettl.com/glossary/c/cognitive-reasoning/#:~{}:text=Cognitive%20reasoning%20is%20the%20ability,integral%20part%20of%20cognitive%20ability (accessed on 28 May 2022).
68. Holstermann, N.; Grube, D.; Bögeholz, S. Hands-on Activities and Their Influence on Students' Interest. *Res. Sci. Educ.* **2010**, *40*, 743–757. [CrossRef]
69. Sheehy, S. Suzie Sheehy: The Power and Potential of Curiosity-Driven Research. Available online: https://tedxsydney.com/talk/the-power-and-potential-of-curiosity-driven-research-suzie-sheehy/ (accessed on 15 June 2018).
70. Buschor, C.; Proyer, R.; Ruch, W. Self- and peer-rated character strengths: How do they relate to satisfaction with life and orientations to happiness? *J. Posit. Psychol.* **2013**, *8*, 116–127. [CrossRef]
71. Park, N.; Peterson, C.; Seligman, M.E.P. Strengths of Character and Well-Being. *J. Soc. Clin. Psychol.* **2004**, *23*, 603–619. [CrossRef]
72. Harlen, W. Purposes and Procedures for Assessing Science Process Skills. *Assess. Educ. Princ. Policy Pr.* **1999**, *6*, 129–144. [CrossRef]
73. Çepni, S.; Ayas, A.; Johnson, D.; Turgut, M.F. *Fizik Öğretimi: Milli Eğitimi Geliştirme Projesi Hizmet Öncesi Öğretmen Eğitimi*; Deneme Basımı: Ankara, Turkey, 1996.
74. Hacıeminoğlu, E. *Fen Öğretiminde Temel Beceriler. Akçay, B.E. Fen Öğrenme Ve Öğretme Yaklaşımları (138-150)*; Nobel Akademik Yayıncılık: Ankara, Turkey, 2019.
75. Johnson-Laird, P.N. Mental models and human reasoning. In *Language, Brain, and Cognitive Development: Essays in Honor of Jacques Mehler*; Dupoux, E., Ed.; The MIT Press: Cambridge, MA, USA; pp. 85–102.
76. Tan, M.; Temiz, B.K. Fen öğretiminde bilimsel süreç becerilerinin yeri ve önemi. *Pamukkale Üniversitesi. Eğitim Fakültesi Derg.* **2003**, *1*, 89–101.
77. Temiz, B.K.; Taşar, M.F.; Tan, M. Development and validation of a multiple format test of science process skills. *Int. Educ. J.* **2006**, *7*, 1007–1027.
78. Aydoğdu, B. Identification of Variables Effecting Science Process Skills in Primary Science and Technology Course. Master's Thesis, Dokuz Eylül University, İzmir, Turkey, 2006.
79. Aydoğdu, B. Bilimsel Süreç Becerileri. In *Fen Bilimleri Öğretimi İçinde (1. Baskı, s.87-113)*; Anagül, Ş.S., Duban, N., Eds.; Anı Yayıncılık: Ankara, Turkey, 2014.
80. Renkl, A.; Mandl, H.; Gruber, H. Inert knowledge: Analyses and remedies. *Educ. Psychol.* **1996**, *31*, 115–121. [CrossRef]
81. Ateş, S. Identification and control of the variables, inquiry method, demonstrative experimentation technique. *Gazi Univ. J. Gazi Fac. Educ. Fac.* **2005**, *25*, 21–39.
82. Gultepe, N. High School Science Teachers' Views on Science Process Skills. *Int. J. Environ. Sci. Educ.* **2016**, *11*, 779–800. [CrossRef]
83. Aktaş, İ.; Ceylan, E. Determination of pre-service science teachers' science process skills and investigating of relationship with general academic achievement. *Mustafa Kemal Univ. J. Grad. Sch. Soc. Sci.* **2016**, *13*, 123–136.
84. Karapınar, A.; Şaşmaz Ören, F. Fen bilgisi öğretmen adaylarının bilimsel süreç becerilerinin belirlenerek cinsiyet ve sınıf düzeyi bakımından incelenmesi. *Uluslararası Eğitim Bilimleri Derg.* **2015**, *2*, 368–385.
85. Ormancı, Ü.; Balım, A.G. Araştırma Sorgulamaya Dayalı Öğrenme Yaklaşımı. In *Fen Öğretiminde Yenilikçi Yak-Laşımlar (1. Basım), (s. 9-44)*; Balım, A.G., Ed.; Anı: Ankara, Turkey, 2019.
86. Seydioğlu, E.; Bariş, N. Bilimsel süreç becerileri uygulama örneği: Baloncuk araştirma laboratuvari. *Anadolu Öğretmen Dergisi* **2021**, *5*, 207–225. (In Turkish) [CrossRef]

87. Şahintepe, S. Sorgulamaya dayalı Öğrenme Yaklaşımının Öğrencilerin Üstbiliş Farkındalıklarına Ve Bilimsel Süreç Becerilerine Etki-Si. Master's Thesis, Afyon Kocatepe Üniversitesi, Afyonkarahisar, Turkey, 2018.
88. Çelik, H.; Katrancı, M.; Çakır, E. Fen öğretiminde açık uçlu araştırmacı sorgulayıcı laboratuvar yaklaşımının yaratıcı düşünme becerisine etkisi. *Turk. J. Prim. Educ.* **2017**, *2*, 1–10.
89. Sen, C.; Vekli, G. The Impact of Inquiry Based Instruction on Science Process Skills and Self-efficacy Perceptions of Pre-service Science Teachers at a University Level Biology Laboratory. *Universal J. Educ. Res.* **2016**, *4*, 603–612. [CrossRef]
90. Şensoy, O.; Yildirim, H.I. Araştırma sorgulama tabanlı öğrenme yaklaşımının yaratıcı düşünme ve bilimsel süreç becerilerine etkisi. *Cumhur. Int. J. Educ.* **2017**, *6*, 34–46. [CrossRef]
91. Yetişir, M.İ. Guided inquiry-based physics teaching: An analysis of prospective teachers' academic achievements and views about the method. *Ank. Univ. Egitim Bilim. Fak. Derg.* **2016**, *49*, 159–182. [CrossRef]
92. Alam, G.M.; Forhad, A.R. What makes a difference for further advancement of engineers: Socioeconomic background or education programs? *High. Educ.* **2022**, *83*, 1259–1278. [CrossRef] [PubMed]
93. Zeren Özer, D.; Güngör, S.N.; Şimşekli, Y. Sınıf Öğretmenliği Öğrencilerinin Biyoloji Deneylerini Uygulayabilme ve Bilimsel Süreç Becerilerini Analiz Edebilme Yeterlilikleri. *Uludağ Üniversitesi Eğitim Fakültesi Derg.* **2011**, *24*, 563–580.
94. Lloyd, J.K.; Braund, M.; Crebbin, C.; Phipps, R. Primary teachers' confidence about and understanding of process skills. *Teach. Dev.* **2000**, *4*, 353–370. [CrossRef]
95. Pekmez, E.Ş. *Fen Öğretmenlerinin Bilimsel Süreçler Hakkındaki Bilgilerinin Saptanması. Maltepe Üniversitesi Eğitim Fakültesi*; Yeni Binyılın Başında Türkiye'de Fen Bilimleri Eğitimi Sempozyumu: İstanbul, Turkey, 2001; pp. 543–549.
96. Işık, A.; Nakipoğlu, C. Determining primary school and science and technology course teachers' knowledge of science process skills (Sınıf öğretmenleri ile fen ve teknoloji dersi öğretmenlerinin bilimsel süreç becerileri ile ilgili durumlarının belirlenmesi). *Abant İzzet Baysal Univ. J. Educ. Fac.* **2011**, *11*, 145–160.
97. Yıldırım, M.; Atila, M.E.; Özmen, H.; Sözbilir, M. The preservice science teachers' views about the developing science process skills (Fen bilimleri öğretmen adaylarının bilimsel süreç becerilerinin geliştirilmesi hakkındaki görüşleri). *Mersin Univ. J. Fac. Educ.* **2013**, *9*, 27–40.
98. Karslı, F.; Yaman, F.; Ayas, A. Prospective Chemistry Teachers' Competency of Evaluation of Chemical Experiments in Term of Science Process Skills. In *World Conference on Educational Sciences*; Uzunboylu, H., Cavus, N., Eds.; Near East Üniversitesi: Nicosia, North Cyprus, 2010; pp. 778–781.
99. Farsakoğlu, Ö.F.; Şahin, Ç.; Karsli, F.; Akpinar, M.; Ültay, N. A study on awareness levels of prospective science teachers on science process skills in science education. *World Appl. Sci. J.* **2008**, *4*, 174–182.
100. Türkmen, H.; Kandemir, M. Öğretmenlerin Bilimsel Süreç Becerileri Öğrenme Algıları Üzerine Bir Durum Çalışması. *J. Eur. Educ.* **2011**, *1*, 15–24.
101. Günsel, Z.; Azar, A. İlköğretim Fen Ve Teknoloji Dersinde Bilimsel Süreç Becerileri Yaklaşımına Dayalı Öğretimin Yaratıcı Düşünme, Problem Çözme ve Derse Karşı Tutuma Etkisi. In Proceedings of the Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, Ankara, Turkey, 7–9 September 2006.
102. Ünaldı, Ö. Bilimsel Süreç Becerilerine Dayalı Fen Eğitiminin Öğrencilerin Fen Ve Teknoloji Dersine Ilişkin Tutumlarına Ve Bilimsel Sü-Reç Becerilerine Etkisi. Master's Thesis, Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara, Turkey, 2012.
103. Demirçalı, S. The Effects of Model Based Science Education on Students' Academic Achievement, Scientific Process Skills and Mental Model Development: The Sample of 7th Grade Unit of "The Solar System and Beyond: The Puzzle of Space". Ph.D. Thesis, Gazi University, Ankara, Turkey, 2016.
104. Gülay, A. Effect of Self-Regulated Learning on 5th Grade Students' Academic Achievement and Scientific Process Skills. Master's Thesis, Recep Tayyip Erdoğan University, Rize, Turkey, 2012.
105. Fansa, M. Araştırmaya Dayalı Öğrenme Yönteminin İlköğretim 5. Sınıf Öğrencilerinin Maddenin Değişimi ve Tanınması Ünitesindeki Akademik Başarı, Fen Dersine Karşı Tutum ve Bilimsel Süreç Becerilerine Etkisinin İncelenmesi. Master's Thesis, Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü, Hatay, Turkey, 2012.
106. Akben, N. Öğretmen Adayları Için Bilimsel Sorgulama Destekli Laboratuvar Dersi Geliştirilmesi. Ph.D. Thesis, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara, Turkey, 2011.
107. Aksakal, Ş. Sorgulayıcı öğrenme yönteminin öğretmen adaylarının bilimsel süreç becerilerine, başarılarına, akademik ve öğretmen özyeterliklerine etkisi. Ph.D. Thesis, Fırat Üniversitesi Eğitim Bilimleri Enstitüsü, Elazığ, Turkey, 2020.
108. Arı, E.; Bayram, H. Yapılandırmacı yaklaşıma dayalı kimya laboratuvar uygulamalarının öğrencilerin başarısına, bilimsel süreç becerilerine ve laboratuvar performanslarına etkisi. *West. Anatolia J. Educ. Sci.* **2012**, *3*, 1–18.
109. Baykara, H. Araştırmaya Dayalı Fen Laboratuvarının Etkililiğinin İncelenmesi. Master's Thesis, Pamukkale Üniversitesi Fen Bilimleri Enstitüsü, Denizli, Turkey, 2011.
110. Duru, M.K.; Demir, S.; Önen, F.; Benzer, E. Sorgulamaya dayalı laboratuvar uygulamalarının öğretmen adaylarının laboratuvar algısına tutumuna ve bilimsel süreç becerilerine etkisi. *Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi.* **2011**, *33*, 25–44.
111. Şenyiğit, Ç. Sorgulama temelli Öğrenmenin Sınıf Öğretmeni Adaylarının Bilimsel Süreç Becerilerine Ve Kavramsal Anlamalarına Etkisi. Ph.D. Thesis, Dokuz Eylül Üniversitesi Eğitim Bilimleri Enstitüsü, İzmir, Turkey, 2020.
112. Tatar, N. İlköğretim Fen Eğitiminde Araştırmaya Dayalı Öğrenme Yaklaşımının Bilimsel Süreç Becerilerine, Akademik Başarıya Ve Tutuma Etkisi. Ph.D. Thesis, Gazi Üniversitesi, Ankara, Turkey, 2006.

113. Usta Gezer, S. Yansıtıcı Sorgulamaya Dayalı Genel Biyoloji Laboratuvarı Etkinliklerinin Fen Bilgisi Öğretmen Adaylarının La-Boratuvar Kullanımı Özyeterlik Algıları, Eleştirel Düşünme Eğilimleri Ve Bilimsel Süreç Becerileri. Üzerine Etkisi. Ph.D. Thesis, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul, Turkey, 2014.
114. Yaz, Ş. Tasarlanan laboratuvar etkinliklerinin fen bilgisi öğretmen adaylarının bilimsel süreç becerileri algılarına ve tutumlarına etkisi. Master's Thesis, Kastamonu Üniversitesi Fen Bilimleri Enstitüsü, Kastamonu, Turkey, 2018.
115. Coştu, F. Tahmin Et-Açıkla-Gözle-Tartış-Açıkla Destekli Laboratuvar Etkinliklerinin Fen Bilgisi Öğretmen Adaylarının Başarılarına, Kavramsal Anlamalarına ve Bilimsel Süreç Becerilerine Etkisinin İncelenmesi. Ph.D. Thesis, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul, Turkey, 2021.
116. Kanlı, U.; Yağbasan, R. 7E modeli merkezli laboratuvar yaklaşımının öğrencilerin bilimsel süreç becerilerini geliştirmedeki yeter-liliği. *Gazi Üniversitesi. Gazi Eğitim Fakültesi Derg.* **2008**, *28*, 91–125.
117. Sağırekmekçi, H. "Tahmin-Gözlem-Açiklama" (Tga) Stratejisine Dayali Fen Ve Doğa Etkinliklerinin, Okul Öncesi Öğrencilerinin Bi-Limsel Süreç Becerilerine Ve Bilişsel Alan Yeteneklerine Etkisi. Master's Thesis, Mustafa Kemal Üniversitesi, Fen Bilim-leri Enstitüsü, Hatay, Turkey, 2016.
118. Tokur, F. TGA Stratejisinin Fen Bilgisi Öğretmen Adaylarının Bitkilerde Büyüme Gelişme Konusunu Anlamalarına Etkisi. Master's Thesis, Adıyaman Üniversitesi Fen Bilimleri Enstirüsü, Adıyaman, Turkey, 2011.
119. Öztürk, Z.D. Fen Bilimleri Dersinde Probleme Dayalı Öğrenme Yönteminin Öğrencilerin Akademik Başarılarına Ve Bilimsel Süreç Becerilerine Etkisi. Master's Thesis, Pamukkale Üniversitesi/Eğitim Bilimleri Enstitüsü, Denizli, Turkey, 2019.
120. Tekin, A.D. Probleme Dayali Öğrenme Yaklaşiminin 7. Sinif Öğrencilerinin Akademik Başarilari, Bilimsel Süreç Becerileri Ve Moti-Vasyonlari Üzerine Etkisi. Master's Thesis, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul, Turkey, 2019.
121. Önol, M. The Impact of Creative Problem Solving Activities on Scientific Process Skills and Success. Master's Thesis, Balıkesir University, Balıkesir, Turkey, 2013.
122. Uysal, E. Tasarım Temelli Fetemm (Fen, Teknoloji, Matematik Ve Mühendislik) Etkinliklerinin Fen Bilgisi Öğretmen Adaylarının Bilgi Düzeylerine Bilimsel Süreç Becerilerine Ve Tutumlarına Etkisi. Yayımlanmamış. Master's Thesis, Uşak Üniversitesi Fen Bilimleri En-stitüsü, Uşak, Turkey, 2018.
123. Yıldız, N. The Effect of Experiment Applications on the Success, Attitude and Scientific Process Abilities of the Students in the Solution of the Learning Scenarios Based on Problems in Science Education. Master's Thesis, Marmara University, İstanbul, Turkey, 2010.
124. Akca, Ö.F. Bilim Merkezlerinde Sorgulamaya Dayalı Robotik Etkinliklerin Öğrencilerin Kavramsal Başarıları, Mantıksal Düşünme ve Bilimsel Süreç Becerilerinin Gelişimine Etkisi. Master's Thesis, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara, Turkey, 2020.
125. Roth, K.J. Elementary Science Teaching. In *Handbook of Research on Science Education*; Routledge: Oxfordshire, UK, 2014; Volume 2, pp. 361–394.
126. Craik, F.I.M.; Lockhart, R.S. Levels of processing: A framework for memory research. *J. Verbal Learn. Verbal Behav.* **1972**, *11*, 671–684. [CrossRef]
127. Alam, G.M. Does online technology provide sustainable HE or aggravate diploma disease? Evidence from Bangladesh—A comparison of conditions before and during COVID-19. *Technol. Soc.* **2021**, *66*, 101677. [CrossRef] [PubMed]
128. Schmidt, C.D.; Hardinge, G.B.; Rokutani, L.J. Expanding the School Counselor Repertoire Through STEM-Focused Career Development. *Career Dev. Q.* **2012**, *60*, 25–35. [CrossRef]
129. Ferguson, R.; Lamback, S. Creating Pathways to Prosperity: A Blueprint for Action. 2014. Available online: https://www.hks.harvard.edu/publications/creating-pathways-prosperity-blueprint-action (accessed on 27 March 2022).
130. Leahy, R.L. Introduction: Emotional Schemas and Emotional Schema Therapy. *Int. J. Cogn. Ther.* **2019**, *12*, 1–4. [CrossRef]
131. Leahy, R.L. A model of emotional schemas. *Cogn. Behav. Pract.* **2002**, *9*, 177–190. [CrossRef]
132. Nomxolisi, M.; Chiphambo Shakespear, M.; Mabel-Wendy, M. Examining the support given to teachers to promote science learning and science literacy in selected South African schools. *PONTE Int. Sci. Res. J.* **2021**, *77*. [CrossRef]
133. Boateng, S.; Mushayikwa, E. Teaching electricity and magnetism to high school physical science learners: The effectiveness of learning style-based instructions. *Int. Sci. Res. J.* **2022**, *78*. [CrossRef]
134. Özdemir, B.; İlhan-Beyaztaş, D. Öğretmen Adaylarının Sınav Türüne Göre Kullandıkları Öğrenme Yaklaşımlarını Benimseme Nedenlerine İlişkin Görüşleri. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi.* **2018**, *46*, 363–385. [CrossRef]
135. Lotter, C.R.; Miller, C. Improving Inquiry Teaching through Reflection on Practice. *Res. Sci. Educ.* **2017**, *47*, 913–942. [CrossRef]
136. Kaya, G.; Yılmaz, S. Açık Sorgulamaya Dayalı Öğrenmenin Öğrencilerin Başarısına ve Bilimsel Süreç Becerilerinin Gelişimine Etkisi. *Hacet. Univ. J. Educ.* **2016**, *31*, 300–318. [CrossRef]
137. Silva, E. Measuring skills for 21st-century learning. *The Phi Delta Kappan.* **2009**, *90*, 630–634. [CrossRef]
138. Guo, J.; Woulfin, S. Twenty-First Century Creativity: An Investigation of How the Partnership for 21st Century Instructional Framework Reflects the Principles of Creativity. *Roeper Rev.* **2016**, *38*, 153–161. [CrossRef]
139. Greenlaw, J. Deconstructing the Metanarrative of the 21st Century Skills Movement. *Educ. Philos. Theory* **2015**, *47*, 894–903. [CrossRef]
140. Chu, S.K.W.; Reynolds, R.B.; Tavares, N.J.; Notari, M.; Lee, C.W.Y. *21st Century Skills Development Through Inquiry-Based Learning: From Theory to Practice*; Springer: Berlin/Heidelberg, Germany, 2017. [CrossRef]

141. Care, E.; Griffin, P.; McGaw, B. *Assessment and Teaching of 21st Century Skills*; Springer: Dordrecht, The Netherlands, 2012. [CrossRef]