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# **COMMENTARY**

# Pre-service Primary School Teachers' View of Nature of Science Helps Decisionmaking on Socio-scientific Issues

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Abstract: Since the 20th century, science and technology have developed rapidly, and the industrialization and modernization of countries around the world have been in full swing. In this context, the education of Socio-scientific issues (SSI) in classroom teaching in primary and secondary schools becomes particularly important. SSIs can serve as an important carrier for scientific, ethical, and moral education, an important path to develop the core competencies of individuals in the 21st century. As future teachers, pre-service primary school teachers receive good science education in the university, develop fundamental scientific literacy, and obtain a basic understanding of nature of science (NOS). Their mastery of NOS has a significant impact on their decision-making skills on SSIs. In science education for pre-service primary school teachers, more attention should be paid to improving their comprehension of NOS and critical thinking ability.

**Keywords**: Pre-Service Primary School Teachers, Nature of Science (NOS), Socioscientific Issue (SSI), Decision-making Skills

SCIENCE and technology are a double-edged sword. They have played a key role in the history of human development, civilizing and modernizing human society. However, the progress of science and technology has also brought numerous environmental, ethical, and moral issues. Since the 1990s, faced with problems induced by industrialization and modernization, many countries have begun to include socio-scientific issues (SSI) in primary and secondary school science education. SSIs are controversial social issues which relate to science (Zeidler & Keefer, 2003), including genetic engineering, global warming, medical experiments on animals, etc. They are used in

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science education to promote students' scientific literacy and ability to apply scientific and moral reasoning to the real-world issues. A number of studies have demonstrated that SSI education can effectively improve students' understanding of science, empathy and moral reasoning. Compared with conventional STS (Science, Technology and Society) courses, the introduction of SSIs into science education can better encourage students to reflect on the relationships between science and technology, mankind, and social development in real-world situations, and enables students to have a more comprehensive understanding of scientific knowledge and a deeper comprehension of nature of science (NOS). In general, teaching based on SSIs in primary and secondary schools helps primary and secondary school students apply and reflect on scientific knowledge in authentic science scenarios and assists in cultivating citizens with scientific literacy by providing a contextual environment for the learning of scientific knowledge. In addition, SSI education encourages students to reflect, reason, and demonstrate to develop a social conscience (morality) and critical thinking based on scientific knowledge and social issues. As a result, it fosters "functional scientific literacy" in primary and secondary school students (Zeidler et al., 2005) through analysis, reasoning, interpretation, and even self-regulation, which is also the core competence that every world citizen should have in the 21st century (Lee et al., 2012).

SSI education demands students' active participation in SSI decision-making to achieve educational goals. Therefore, decision making is a key capability SSI education intends to foster. Previous studies have shown that students' scientific knowledge, NOS concepts, individual emotions, morality and values can affect their socio-scientific decision-making (Jho et al., 2014). Teachers also need good decision-making skills to carry out SSI instruction, and such decision-making skills depends on whether they have a profound understanding of scientific knowledge and nature of science. How to transform this understanding into reasoning and decision-making skills on SSIs, and how to implement classroom teaching based on pertinent SSIs have become the challenges in pre-service teacher education and in-service teacher training.

"Pre-Service Primary School Teachers' Application of the Features of the Nature of Science to Socio-scientific Issues" conducted in-depth research into this topic (Saka, 2023). This article states that NOS education includes scientific epistemological beliefs and beliefs of individuals about NOS knowledge as well as some assumptions, apart from the distinctive features of scientific knowledge (Khishfe & Lederman, 2007) and argues that it is worth studying how pre-service primary school teachers apply their NOS knowledge to controversial SSIs. An exploratory qualitative research method was used to collect data from 77 pre-service primary school teachers in the third grade of college based on the learning environment of the "Science and Technology Teaching" course. Research findings showed that pre-service primary school teachers could make good use of the characteristics of NOS, the tentativeness of scientific knowledge, and the fact that science is based

on observation and experiment in socio-scientific decision-making. The use of subjectivity, creativity, and observational features of scientific knowledge by pre-service primary school teachers could improve their decision-making skills in addressing SSIs. This study provides empirical evidence for the application of NOS knowledge to decision-making on SSIs by pre-service teachers. In science training for pre-service teachers, universities should pay more attention to NOS education and reflective science education to improve their scientific literacy and critical thinking skills including socio-scientific decision-making.

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Conflict of Interests: None.

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## **COMMENTARY**

# The Education of Nature of Science in the Internet Era

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"There is no education without nature."

-Charlotte Mason

ODERN science and technology can not only promote social develpment for the benefit of mankind but may also cause catastrophic consequences if improperly employed. They are the two sides of the same coin. Science education plays an increasingly important role in the rapidly developing human society. With the rise of new educational strategies in the "internet plus education" era, the education of nature of science (NOS) exhibits its significant value in contemporary primary science curricula (Zhu & Yu, 2008). Science is not about conclusive truth. The history of science has witnessed numerous controversial issues which often sparked intense debate. The introduction of socio-scientific issues (SSI) to science education allows students to experience the process of scientific development. NOS education concerning scientific questioning, experimentation, and investigation and the establishment of scientific laws and theories as well as their application is of great significance to the development of teaching philosophy and methods in pre-service primary school teachers (Liu, 2003). It also poses new requirements and challenges in the reform of basic education in the internet era.

Pre-Service Primary School Teachers' Application of the Features of the Nature of Science to Socio-scientific Issues in this issue of the journal (Saka, 2023) attempts to examine the ability of pre-service primary school teachers to transfer their knowledge of NOS to socio-scientific decision-

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making using a socio-scientific scenario "Babies with Three Parents". Science education in the internet era includes controversial socio-scientific issues such as genetic engineering, vaccine research (Ekborg et al., 2013), etc., which can deepen students' understanding of the characteristics of scientific knowledge and guide them to think like scientists. SSI education also help stimulate inquiry interest and initiative of students, cultivate scientifically literate citizens who are able to apply evidence-based scientific knowledge to real-world socio-scientific scenarios, and promote critical thinking skills, such as analysis, inference, explanation, evaluation, and interpretation.

Relevant research findings demonstrate that for many people, science education does not necessarily lead to understanding how scientific knowledge is constructed and applied. The education of NOS is one of the pathways to the solution of this issue (Inêz et al., 2021). It enhances students' comprehension of science concepts and enables them to make informed decisions about personal and societal issues. Traditional science education emphasizes the mastery of content knowledge. Even though a series of reforms have been implemented in science education, they have not been successful enough in inspiring autonomous inquiry of students and integrating NOS - in other words, the characteristics of scientific knowledge - in regular teaching. The teacher who can only deliver conceptual knowledge but lacks scientific literacy including practical, explorative skills is not fit for science instruction in the new era. To improve scientific literacy and critical thinking skills of pre-service primary teachers, it is necessary to incorporate NOS education in their curriculum.

SSIs can draw students' attention to the relevance of social life in science education and develop their scientific creative thinking (Develaki, 2012). Facing the ever-increasingly complicated SSIs, pre-service science teachers should be well trained to integrate the characteristics of scientific knowledge into lesson planning. Colleges and universities of teachers should make use of SSIs in their science training to inform future educators of the potential issues that the development of science and technology may cause and the relationships between science and technology and social life. In the internet era, "interaction between science, environment, and health" can be used as a teaching concept to help students comprehend the true meaning of science, to heighten their commitment to scientific endeavors, and to develop their ability to address complex issues in real-world situations using transdisciplinary knowledge (Yan & Zhai, 2021). Improved scientific literacy, including the understanding of NOS can effectively enhance critical thinking skills and socio-scientific decision-making of the public.

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# Pre-Service Primary School Teachers' Application of the Features of the Nature of Science to Socioscientific

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Abstract: The purpose of this study is to determine which features of the nature of science pre-service primary school teachers refer to while making a decision on a socioscientific issue at the end of the explicit reflective nature of science education. For this purpose, an exploratory qualitative research design was used in the study. The research group comprised 77 pre-service primary school teachers in their third year of studies at a public university. The study was carried out within the scope of the "Science and Technology Teaching" course. As a data collection tool, the socioscientific scenario "Babies with Three Parents" was used. Content analysis and descriptive analysis were used to analyze the data. According to the findings of the study, pre-service primary school teachers have a good level of ability to use the features of the nature of science, the changeable nature of scientific knowledge, and the fact that it is based on observation and experimentation when deciding on a socioscientific issue. Furthermore, pre-service class teachers primarily used the subjectivity and creativity features of scientific knowledge as well as the features of observation.

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**Keywords:** Nature of Science (NOS), Socioscientific Issues (SSIs), Pre-service Primary School Teachers

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# Introduction

RIMARY school pupils constantly ask questions, which is understandable considering their age. These abilities are considered to have a significant effect on the development of scientific inquiry abilities (Gormley & France, 2019). Primary school teachers, who have a significant impact on the development of this skill, should carry out the learningteaching process in science, as well as many other areas of the curriculum, by knowing where, how, and when to lead the process. Teachers' content knowledge, pedagogical competence, beliefs and attitudes toward science, as well as students' knowledge and beliefs about science, all influence this process (Fitzgerald, 2012). Similarly, teachers' knowledge and perceptions regarding the nature and features of science, one of the fundamental subjects of science, have a significant influence on the students' learning processes. Teachers who view science as a compilation of absolute truths find it challenging to incorporate the qualities of scientific knowledge and the nature of science into their inquiry-based learning methodologies. As a result, science could be neglected in these classrooms or learning activities that do not include scientific inquiry might also be presented (Appleton, 2002). These conditions disrupt and disconnect student learning not only from other curricular areas, but also from the context of life experience. The application of socioscientific issues is a highly effective method for observing the implementation of the features of the nature of science. In this context, it is important to determine the skills of teachers, who are an important element in teaching, to use the features of the nature of science. In addition to being controversial, it is important to figure out how this information can be used in the decision-making process of a socioscientific issue that can have a big impact on our lives in terms of how we learn and teach.

For more than thirty years, the primary goal of scientific education has been to develop science literacy skills, and it has been highlighted that with the reforms implemented, science education should be carried out in a meaningful and practical way (Karisan & Zeidler, 2017). The main objective of science literacy is to enable individuals to acquire decision-making abilities through the application of scientific information and scientific thinking in everyday life (Roberts, 2007). In this context, socioscientific issues include real-life topics that will enable students to gain these skills practically. As is well known, socioscientific issues are inevitably included in many areas of our lives, such as health and technology. Incorporating socioscientific issues into the educational process has been widely used over the last three decades to facilitate the acquisition and use of 21st century skills such as critical thinking, analytical thinking, and decision-making. In addition to being controversial, socioscientific issues are subjects that involve different social domains, such as political, economic, and ethical, and specifically in-

volve ethical and moral evaluation and decision-making process (Evagorou, Jimenez-Aleixandre, & Osborne, 2012). Many contentious subjects, such as GMOs, nuclear power plants, vaccine research, and cloning, fall under the category of socioscientific issues. We have been confronted with these difficulties, which involve moral and ethical issues, particularly in recent years (Espeja and Lagar ón, 2015). It is crucial for students to encounter real-world challenges in developing their decision-making skills by using the scientific knowledge they have learned (Osborne, 2008, Gomley et al., 2019). One of the primary purposes of education is to enable students to apply their conceptual knowledge in different contexts (Khishfe, 2013, De Corte, 2003). The use of socioscientific issues in the lessons also enables students to develop scientific literacy and positive attitudes towards science (Gomley et al., 2019; Hodson, 2013; Zeidler, 2014). In socioscientific issues, teachers should be able to effectively use science and nature of science concepts to enable students to engage in effective decision-making processes, as well as to structure and analyze presented arguments (Pezaro et al., 2014). It is well known that incorporating socioscientific issues into science education helps students have a better knowledge of science topics, improve their argumentation abilities, and comprehend the nature of science (Levinson, 2006; Zeidler & Sadler, 2008; Zohar & Nemet, 2002; Khishfe & Lederman, 2006).

In general, NOS includes scientific epistemological beliefs and beliefs of individuals about NOS knowledge, as well as some assumptions besides the distinctive features of scientific knowledge (Lederman, 2007; Hofer & Pintrich, 1997). In this regard, it is essential to observe pre-service primary school teachers' capacity to apply the nature of science to a socioscientific issue that is both debatable and scientific.

Recently, there have been numerous research studies in the field of socioscientific issues, which is an effective area that contributes to the growth of science literate individuals and should be appropriately included in science education programs (Hofstein et al., 2011; Sadler, 2003; Top qu, 2008; Walker & Zeidler, 2007; Zeidler & Keefer, 2003; Zeidler et al., 2005). According to studies, socioscientific issues can help students contribute to decision- making on local and global issues, understand the features of the nature of science, and gain experience in discussing controversial issues (Lee et al., 2013). Moreover, solving problems related to a socioscientific issue will encourage students to use scientific knowledge, and socioscientific issues in science education can be a tool to increase the priority of civic goals (Lee et al., 2012).

Studies on the relationship between SSI and NOS primarily focus on how the nature of science is used in the decision-making process of socioscientific issues (Bell & Lederman, 2003; Khishfe, 2012; Sadler, 2009). Over time, research on teaching the nature of science in an SSI setting has begun to be conducted from a variety of approaches. The majority of studies on the

development of understanding of the nature of science using SSI applications have found that understanding of the nature of science has improved (Walker & Zeidler, 2007; Zeidler et al., 2011). However, it has been observed that SSIs are insufficient in conveying the features of science into the discussion and decision-making processes (Han Tosunoğlu & İrez, 2019).

In order to realize the reasoning and decision-making process, which is the most important goal of socioscientific issues, individuals must master the principles of scientific knowledge and scientific thinking. The significance of understanding the nature and features of science emerges, particularly in determining whether the information presented is scientific or not. Another cognitive condition, students' views on the nature of science (NOS), or scientific epistemological beliefs, was highlighted in a literature review on socioscientific decision-making (Sadler et al., 2004; Schommer-aikins & Hutter, 2002).

All science education programs that accept scientific literacy as a basic component emphasize providing students with information on the nature of science, such as the changeability of scientific knowledge that forms the basis of scientific studies and the fact that scientific knowledge is based on observation and experimentation (NGSS, 2013; NRC 1996; ACARA 2014). In our country, the concept of science literacy, which was first introduced in the 2005 science curriculum, is now one of the general targets in the curriculum since 2013. Furthermore, the 2018 curriculum included "Developing reasoning ability, scientific thinking habits, and decision-making skills through the use of socioscientific issues" (MEB, 2019). At this point, science literate individuals must gain awareness of current events affecting their society and have scientific thinking abilities when expressing their opinions on potential solutions to society's problems (Calık & Coll, 2011). Looking at the main objectives of the 2018 science curriculum, it is seen that emphasis is put on individuals having the necessary skills to come up with solutions to possible problems that they may encounter in their daily lives (MEB, 2018). The program aims to teach students about NOS and to help them develop decision-making skills related to SSI throughout the entire science teaching program, starting from primary school. However, one of the most important issues that should not be ignored here is that teachers and pre-service primary school teachers have these knowledge and skills. When we look at the studies conducted in our country, it is seen that there are no studies involving primary school teachers, whereas studies involving pre-service primary school teachers try to determine their level of knowledge and opinions about both the nature of science (Akgün, 2015; Ateş & Öner, 2020; Taşdere et al., 2014) and socioscientific issues (Küçükaydın, 2019; Öztürk et al., 2018).

This research is significant in this context since it attempts to determine the ability of pre-service primary school teachers to transfer the features of the nature of science to socioscientific issues, as well as their ques-

tioning skills. In this regard, the problem statement of the research is as follows: "How do pre-service primary school teachers who receive explicit reflective nature of science education make use of the features of the nature of science while making a socioscientific decision?"

# **Method**

In this study, an exploratory qualitative research design was used to address the research problem. The purpose of this study was to determine whether NOS education, as well as acquired knowledge and skills, was applied to a SSI with a randomly selected group of pre-service primary school teachers. While exploratory qualitative research allows researchers to get more detailed information about the study group (Kathlke, 2014), it also better explains people's feelings, thoughts, approaches, or beliefs (Percy et al., 2015).

# **Participants**

The study was conducted with pre-service primary school teachers in their third year of study at a state university. The study group consisted of students enrolled in the two-semester "Science and Technology Teaching" course. The research group consisted of 77 participants in total, with 63 female and 14 male pre-service primary school teachers. Participants are between the ages of 20 and 22. Prior to this academic year, the participants completed science subject knowledge enhancement courses (basic physics, basic chemistry, and basic biology), science teaching laboratory applications, pedagogy courses (education psychology, education philosophy), methodology, and assessment and evaluation courses.

# Data Collection Tool

In order to determine how pre-service primary school teachers use their skills on the nature of science in socioscientific issues, debate scenario titled "Babies with three parents" was presented within the scope of the research. The scenario includes a study on mothers with defective mitochondria to have healthy children by receiving healthy mitochondria from another mother. Although very few studies have included healthy babies, there is no conclusive result; instead, they provide the views of scientists on the possibility of having unhealthy babies due to the transmission of mitochondria from the mother. Along with the scenario, several questions are asked to preservice teachers in order to elicit their thoughts on the issue. The following are some examples of questions about the scenario.

- Do you agree with this recommended approach to preventative medicine?
- Explain the reason for your decision.

- What finding or findings might change your decision?
- Do you think there is disagreement among scientists?

The preceding questions are based on Khishfe's (2012a) and Zeidler, et al.' (2002) approach that the nature of science is related to socioscientific issues, as well as the changeable nature of science, the experimental nature of science, the creativity and imagination of scientific knowledge, and the subjectivity of scientific knowledge. As a result, the purpose of this study was to ascertain pre-service primary school teachers' application of the features of the nature of science described in the given scenario.

# Data Collection

The research lasted two semesters and 12 weeks and was conducted within the framework of "Science and Technology Teaching" (**Table 1**). At the beginning of the implementation process, the history and importance of science teaching programs were emphasized. Then, the teaching methods and techniques used in science education were taught practically. After introducing the constructivist approach that underpins the science curriculum, the 5E instructional model was introduced and practiced with pre-service teachers. The features of the nature of science were figured out in the process through the activities of the explicit-reflective nature of science. In this context, the activities prepared by Yalaki (2016) were used. Additionally, the researcher prepared and implemented the teaching process using the 5E instructional model to ensure that pre-service primary school teachers could better understand the 5E instructional model. After instructing pre-service teachers on the nature of science, they were asked to prepare lesson plans according to the 5E instructional model. While preparing the 5E lesson plan, it was stated that the pre-service teachers should plan with the features of the nature of science in mind.

# Data Analysis

In the analysis of the answers given by the pre-service primary school teachers about the scenarios presented, criteria were created within the framework of descriptive analysis. The nature of science, the changeable nature of scientific knowledge, the reliance of scientific knowledge on observation and experiment, the subjectivity of scientific knowledge and creativity, and the use of observation and inference differences in the given scenario were all evaluated using the criteria developed. As shown in **Table 2**, the perceptions fell into three categories: sufficient (knowledgeable), inconsistent, and weak. If a participant did not mention the nature of science while expressing their opinion, they were evaluated as weak; if they expressed the features of the nature of science, but they did not provide a sufficient explanation, they were

Table 1	. Teaching Process.
Weak	Teaching Process
Weak 1	Purpose and importance of science teaching
Weak 2	History of science curriculums
Weak 3	Information about the constructivist approach
Weak 4-5	What is the 5E instructional model? Which steps are important and why?
Weak 6-7-8-9- 10	<ul> <li>Nature of science teaching based on explicit reflective approach integrated into unit outcomes Heat and temperature: Observation and inference are different things.</li> <li>How does light travel? Observation and experimentation are the foundations of scientific knowledge.</li> <li>Let's classify living things: Scientific knowledge depends on imagination and creativity.</li> <li>Environmental pollution (Which of us is more expert?): Scientific knowledge is affected by social and cultural structures.</li> <li>Is the orientation geocentric or heliocentric? Scientific knowledge is changeable.</li> <li>Footprints: Scientific knowledge is subjective.</li> <li>The structure of scientific theories and laws and their interrelationships.</li> </ul>
Weak 11- 12	5E lesson plan writing (pre-service class teachers)

Table 2. Creative and Imaginative Nature of Scientific Knowledge.			
Theme	Explanation		
Sufficient (Knowledgeable)	Stating that imagination and creativity can be used at every stage of scientific studies together with justifications		
Inconsistent	Stating that imagination and creativity can only be used at certain stages of scientific studies		
Weak	Expressing that while imagination and creativity are used in the design and planning stages of scientific studies, they are not used in data collection, analysis, and interpretation		

Table 3. Pre-service Primary Teachers' Decisions and Justifications on the SSI.					
Opinions	f		Justifications	f	%
I am in favor 15	15	40.4	The probability of having a healthy baby	10	66.6
	15	19.4	The results obtained are sufficient	5	33.3
			Uncertainty/There are no definitive results	19	73.0
		33.7	It causes negative consequences	5	19.2
I am against	26		There is no legislation	1	3.8
			Insufficient explanations	1	3.8
			It is not ethical	1	3.8
			Uncertainty/Insufficient evidence/Inconclusive results	25	69.4
		46.7	It is risky/ There is no guarantee	8	22.2
I'm undecided	36		The studies are very new.	1	2.7
			It is not ethical	1	2.7
			Evaluation from different perspectives	1	2.7

evaluated as inconsistent; if they made reference to the nature of science while providing a sufficient and correct explanation, they were evaluated as sufficient (knowledgeable).

Additionally, the content analysis method was used to examine if respondents approved of the treatment procedure in the particular scenario. The content analysis method was used to determine the codes based on the categories generated in this way. Analyses were also carried out by another field expert besides the researcher. The researchers conducted the analyses independently at first, and then collaborated to complete the analysis until consistency between the analyses was achieved. While organizing the data analysis findings, sample quotations from participants are provided.

# **Findings**

This section contains analysis findings on how pre-service teachers apply certain features of the nature of science to their decision-making processes when confronted with specified socioscientific issues. **Table 3** shows the pre-service teachers' responses to the question of whether they support the treatment and the rationales they employed in their thinking processes.

As shown in Table 3, the majority of pre-service teachers expressed that they were undecided (46.7%) about this treatment method. The reason for this hesitancy is seen to be the inadequacy of the study results (69.4%), the inadequacy of data, and the uncertainty around the likelihood of being ill. Along with the procedure being risky (22.2%), the fact that the investigations were still in their infancy was cited as another justification. Below are sample sentences reflecting the views of pre-service teachers.

"I am undecided because there is no certainty. It is unproven information, it has good sides and bad sides. And that makes me indecisive."

"I'm indecisive because it's scary to choose between having or not having children because of defective mitochondria, and the fact that defective mitochondria continue to be handed down to girls even if they recover. .... I can't decide as there is no clear data. It can also inherit other traits, such as intelligence, physical characteristics of the parent with healthy mitochondria. This is also a risk."

It was also noted that pre-service teachers who were against the treatment most frequently cited a lack of conclusive results (73%). Additionally, several pre-service teachers expressed concerns about the potential negative outcomes (19.2%) and the absence of legal regulations (3.8%). Below are sample sentences reflecting the views of pre-service teachers.

"I disagree because this modification does not provide definitive data on disease prevention. It can lead to a result that is not ensured."

"Because I think mitochondria damage will occur again in future generations. Also, two different DNAs seem to affect the whole cell structure. It may result in worse outcomes."

It was determined that the pre-service primary school teachers who were in favour of the treatment and expressed a positive opinion were in the minority (19.4%). It is evident that pre-service teachers who agreed emphasize the likelihood of having healthy babies (66.6%). Additionally, it was revealed that some pre-service teachers stated that the study's findings were sufficient (33.3%). Below are sample sentences reflecting the views of pre-service teachers.

"Yes, I agree; it can be a dangerous situation. However, the alternative is also dangerous and can result in disorders. As a result, I propose to give the opportunity to attempt to those who desire."

"Because the birth of a child with a disorder would have a negative impact on both the child and the family. The absence of a disease, so far, was also important when I made my decision" "If a woman is likely to have a healthy child, even if there is a low

probability, she should give it a try."

It was observed that only two of the participants evaluated the treatment by addressing the ethical dimension of socioscientific issues as inappropriate.

When the use of the experimental nature of scientific knowledge in socioscientific decision-making processes was examined, it was observed that most pre-service teachers were at the most knowledgeable level (**Table 4**). Therefore, it is seen that most of the pre-service teachers consider experiments and observations in their decision-making processes.

As shown in **Table 4**, the group with inconsistent structure (35 percent) was ranked second, as pre-service teachers considered experiment and observation in their decision-making processes but were inadequate in explaining in depth. It is seen that the weak group, which does not take into account the experiment and observation in the decision-making processes, constitute the smallest (27.2%) group.

**Table 5** shows the frequencies at various levels and examples of the responses participants provided about the use of socioscientific issues in the decision-making process regarding the changeable nature of scientific knowledge.

# Table 4. Pre-service Primary Teachers' Use of Experimental Nature of Scientific Knowledge in Reasoning Processes on Socioscientific Issues.

Theme	f	%	Example sentences
Knowledgeable	29	37.6	<ul> <li>If the researches are completed and reach a definite conclusion, scientifically proven and data are presented, my decision may change.</li> <li>If this hypothesis is proven and generalized through experiments and observations, my decision may change.</li> <li>As a result of the experiments and observations, if the genetic modification of the embryos does not cause any incompatibility problems, if it is proven that they will have characteristics like other children, or if a certain rate is obtained against the damage, I could be in favor of it.</li> </ul>
Inconsistent	27	35	<ul> <li>My opinion may change if it is determined that a child born with the mitochondria of the two women will be one-hundred percent healthy; however, this claim must be supported with solid evidence. If there is a certainty that the children born with the mitochondria of two women will carry the mitochondrial disease to the next generation and the findings are robust, my decision may change.</li> <li>The fact that (the baby) is genetically related to only one of the two women can change my opinion or the assurance that the baby will be healthy can change it. The fact that faulty mitochondria can be found in the ovaries of all girls and may be transmitted to the next generation may change if new findings become available.</li> </ul>
Weak	21	27.2	<ul> <li>An increase in miscarriage raters and an increase in mitochondrial disorders in subsequent generations change my decision.</li> <li>There is no assurance that children with two different genes, except for the father's, will be healthy, and all girls pass on the genes from generation to generation.</li> </ul>

# Table 5. Pre-service Primary Teachers' Use of the Changeability of Scientific Knowledge in Reasoning Processes on Socioscientific Issues.

Theme	f	%	Example sentences
Knowledgeable	27	35.5	<ul> <li>It can change. If much more research has been done) on this subject and more precise data is reported, my decision may change.</li> <li>Research can be scientifically proven.</li> <li>My decision can change if the results of experiments in long-term studies are mostly positive, that is, if mitochondrial incompatibility does not occur.</li> </ul>
Inconsistent	36	47.3	<ul> <li>If it is proven that the defective mitochondria of the mother are not transferred to the ovaries of her children when the defective mitochondria are replaced, and if a method can be developed to ensure that the babies do not receive genes from two different women, but only the mother's, my decision may change.</li> <li>My decision may change if the results show that one has been considerably healed, that it has not been handed down to subsequent generations, or that the negative qualities of the person whose healthy mitochondria will be used, will not be passed down to the newborn individual.</li> </ul>
Weak	13	17.1	<ul> <li>I believe there are no findings or findings that can change my mind about this since, while it is a disorder that has not occurred previously, it is not certain that such a circumstance will not develop in the future.</li> </ul>

Table 6. Pre-service Primary Teachers' Use of the Subjectivity of Scientific Knowledge in Reasoning Processes on Socioscientific Issues.

Theme	f	%	Example sentences
Knowledgeable	25	32.4	<ul> <li>The reason for their difference of opinion is that they look at it from different angles, each defending what is right in his own view.</li> <li>But the center of his ideas is the same experiment and results.</li> <li>The researchers make decisions and produce ideas based on their own knowledge, influenced by their social and cultural context, and based on their level of expertise on this subject. They generate ideas by adjusting them to their own subjective judgments based on the results of their experiments and studies. There may also be disagreement because scientific knowledge is subjective.</li> </ul>
Inconsistent	18	23.3	<ul> <li>Since the two opposing viewpoints are so strong, they cannot be refuted. Disagreements emerge when scientists advocate for what is more correct from their own point of view.</li> <li>One group aims to eliminate chronic disorders from the start, whereas the other group examines the negative consequences. Both groups approach the problem from different angles.</li> <li>Because both sides approach the same method from different perspectives.</li> </ul>
Weak	34	44.1	Because there are still risks. There may not have been any problems in the two test subjects. However, other experiments may find problems. In addition, the mitochondrial gene has an increasing importance day by day. Is it ethical (for an individual) to carry the genes of two different women? I think scientists are divided because of these reasons.  Because it is not stated that they would never develop disorders. There is a chance, and a human with someone else's genes and the increasing effects of these genes may have split them in two.  Because they are still unsure, it is also explained in the paragraph.

When the answers of the pre-service primary school teachers were examined, it was discovered that the majority of them (47.3%) fell into the inconsistent category, meaning that they considered the changeability of scientific knowledge in the decision-making processes of the socioscientific issue, but their explanations were insufficient. It can be seen that pre-service teachers who could provide appropriate explanations regarding the changeable nature of scientific knowledge rank second (35.5%). The number of pre-service teachers who were unable to employ the changeable nature of scientific knowledge in the decision-making process of the socioscientific issue was the smallest in the group (17.1%).

When the responses provided by pre-service teachers to issues about the varying views of scientists while making decisions on socioscientific issues are analyzed, it is discovered that they mostly have a poor level of knowledge (44.1%) and are unable to explain the subjective nature of scientific knowledge (**Table 6**).

According to the analysis, some pre-service teachers (55.7%) who used the subjectivity of scientific knowledge in the decision-making process of SSIs were in the knowledgeable group (32.4%), and they explained the

difference between observation and inference (the subjectivity of scientific knowledge), and imagination and creativity.

# **Discussion, Conclusions, and Suggestions**

According to the research findings, the majority of pre-service primary school teachers claimed that they were indecisive or against making decisions in the given socioscientific issue. The most significant finding is that pre-service teachers emphasize the inadequacy of the information or studies presented in decision-making processes. Therefore, it can be stated that preservice teachers have the skills to apply scientific knowledge to everyday issues.

It is seen that pre-service teachers have generally a good level of knowledge when it comes to utilizing the nature of science as being based on observation and experimentation, which are the most basic features of the nature of science, in the decision-making processes of the socioscientific issue. Considering the results in Table 2 and Table 3, it can be said that the majority of pre-service teachers use the experimental nature of scientific knowledge in their decision-making processes regarding socioscientific issues. Similarly, Zeidler et al. (2002) noted that owing to the nature of science education, provided to pre-service high school and science teachers through explicit-reflective argumentation education, pre-service teachers were able to reflect the experimental nature of scientific knowledge in their evaluation procedures for socioscientific issues. In addition, although some studies have shown that pre-service class teachers develop views on the nature of science, there are also research results in which they make judgments about socioscientific issues that are not supported by evidence, rely on irrational thinking, or are founded on assumptions (Alker & Zeidler, 2007). Another research involving pre-service primary school teachers discovered that some preservice teachers make unscientific claims about socioscientific issues. Additionally, pre-service class teachers who made scientific claims provided insufficient proof and reasoning (Pezaro et al., 2014). Such results support the notion that pre-service primary school teachers may influence their future pupils to assert their claims that are not supported by scientific evidence.

Again, according to the findings, the majority of pre-service teachers reflect the changeable nature of scientific knowledge to decision-making processes in the socioscientific scenario, which is consistent with the findings of other studies (Matkins & Bell, 2007; Sadler et al., 2004) in which the changeable nature of scientific knowledge is used in decision-making processes on socioscientific issues.

According to the findings of this study on the ability to utilize the subjective structure of scientific knowledge in the socioscientific issue, preservice primary school teachers refer to the subjectivity of scientific knowl-

edge at the lowest level in the decision-making process of SSIs. Considering the relationship between understanding the nature of scientific knowledge and reasoning on socioscientific issues, individuals must accept that scientists' suggestions can be significantly influenced by the fact that science contains correct or incorrect information, especially due to differences in imagination and creativity. Additionally, while scientists defend their arguments, they should embrace the debates that result from divergent views as natural and justify this with the subjectivity of scientific knowledge (observationinference difference) as well as imagination and creativity. Studies have shown that the reasoning quality of the students increased in the analyzes based on experiment and observation (Wu and Tsai, 2011), and students who accept the changeable nature of scientific knowledge develop skills such as understanding complex contexts, approaching issues from different perspectives, and questioning authority (Liu et al., 2011). These results reveal that the features of the nature of science are important in the development of students' skills such as decision-making, questioning, and evaluation, and that these skills should be acquired by both students and teachers and pre-service teachers, who are essential elements of education.

Additionally, when individuals perceive, evaluate, and make decisions on contradictory situations in a socioscientific context, their beliefs, interests, and social circumstances are influenced by a variety of factors relating to the nature of science (Sadler et al., 2002). In this context, it can be interpreted as a significant finding that the majority of pre-service primary school teachers made decisions in socioscientific issue evaluations by considering the changeable nature of scientific knowledge, which is based on experiment and observation, creativity and imagination, observation and inference. Furthermore, studies have shown that long-term learning contexts in which the planning of teaching the nature of science in a clear and reflective manner, as well as learning environments with rich content in which the nature of science is reflected in a variety of different contexts, could effectively develop pedagogical content knowledge regarding the nature of science (Akerson et al., 2017; Wahbeh & Abd-El-Khalick, 2014).

This study indicates that pre-service primary school teachers who receive explicit reflective nature of science education can effectively apply the features of science, particularly the changeable and experimental nature of scientific knowledge, to the evaluation and decision-making processes for a socioscientific issue. Additionally, approximately half of the sample group incorporated the creative and imaginative features of scientific knowledge, as well as the subjectivity of scientific knowledge, into their decision-making processes. When these findings are compared to the literature, it becomes clear that in order to make a greater contribution to science education, additional research on the effect of explicit reflective NOS practices on primary school students at different grade levels and on the level of transferring

this to socioscientific issues should be conducted in the future. Additionally, the study can be conducted with primary school teachers, to assess their current situation and to conduct evaluations on socioscientific issues, as well as other studies on applications for the advancement of the NOS. Furthermore, more detailed studies can be designed on how primary school pupils, the main target group, can be affected by the work to be done with primary school teachers. Thus, it is possible to ensure that the effect of the teacher factor on the decision-making processes of primary school pupils on SSIs, as well as the NOS education addressed in the programs, can be monitored.

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# Development of Digital Education in the Age of Digital Transformation: Citing China's Practice in Smart Education as a Case Study

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Abstract: Digital education has been catalyzing educational transition, transforming the educational views and instructional techniques while also providing opportunities for high-quality educational development. This is a subject that all nations throughout the world are concerned about. The worldwide practice of integrating digital technologies in teaching has yielded positive results. The Global Digital Education Conference, which was held in Beijing, China, in 2023, called for global collaboration on digital education development. This paper sought to illustrate the significance of digital education for educational reform and to investigate ways for digital education development in this context, using China's smart education practice as evidence.

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IGITAL technologies are significantly altering not just education and teaching methods but also lifestyles (Lu & Zhou, 2020). "Digital learning and transformation" was made one of the five thematic action tracks for the UN's Transforming Education Summit in 2022, with the emphasis that "digital transformation requires harnessing technology as part of larger systemic efforts to transform education, making it more inclusive, equitable, effective, relevant, and sustainable." (United Nations, 2022). The World Digital Education Conference (WDEC) was co-hosted by the Chinese National Commission for UNESCO and the Chinese Ministry of Education on February 13-14, 2023. The conference's focus was on "digital education transformation, development and application of digital learning resources, improvement of teachers' and students' digital literacy, digital governance of education, and evaluation of digital education development in basic education, vocational education, higher education, and other fields." The conference's theme was "Digital Transformation and the Future of Education." (Huai, 2023). At this conference, China reaffirmed its commitment to developing high-quality digital education, advancing educational reforms, creating a society that values learning, and fostering international collaboration in the field of digital education.

### The Significance of Digital Education for Educational Transformation

Education is an intricate human activity that includes a variety of components such as teachers, students, instructional content, teaching methods, and media. With an educational system's generally defined instructional content, teaching methods and media have become a major driving factor for educational improvements. Digital technology is driving the transformation of educational paradigms.

### Digital Education Marks a New Stage in the History of Education

History has witnessed two revolutions in human education. Schools are the first mechanism that facilitates the purposeful, organized transmission of human culture. The second educational revolution was distinguished by the emergence of a contemporary education system dominated by class-based instruction. Class-based instruction makes mandatory education and talent training on a broad scale practicable, hence satisfying the needs of industrialization (Zhao & Bao, 2014). Currently, many individuals anticipate a new revolutionary shift and are prepared to dub it "the third educational revolu-

Table 1. Five Stages of the Evolution of Cognitive Intelligence.			
Stages of Cognition Development	Description		
Perception	The ability of the computer system to recognize and comprehend the audio and visual inputs and to abstract features and models from them.		
Representation & Reasoning	The ability of the computer system to process language, knowledge, and concepts and perform reasoning and problem-solving.		
Autonomous Learning	The ability of the computer system to learn from experience and constantly improve models and algorithms to enhance its cognitive capability.		
Creative Thinking	The ability of the computer system to think and invent creatively like mankind to innovate concepts, models, and algorithms.		
Nature Interaction & Socialization	The ability of the computer system to interact with human beings at the nature and intelligence level and to perform basic socialization functioning.		

tion." Educational reform has been stimulated by technological progress. Digital technology will inevitably induce educational change (Yuan, 2023).

Today's world is experiencing a new wave of industrial transformation and a scientific and technological revolution. Digital transformation is transforming society, the labor market, and the future of work as it is propelled by technological advancement and innovation. A crucial factor in this process is education. The digital transformation of education is being accelerated by the proliferation of connectivity, the usage of digital tools and apps, and the rising demand for digital skills (Huai, 2023).

The latest release of ChatGPT represents a major development milestone in artificial intelligence (AI). According to **Table 1**, the creators of ChatGPT believe that the evolution of cognitive intelligence may be broken down into five stages: perception; representation and reasoning; autonomous learning; creative thought; nature interaction and socialization (Yang & Xiao, 2023).

Currently in its third stage, ChatGPT is only partially accomplishing autonomous learning, which has a significant effect on the growth of every sector. A few Chinese businesses are also investing heavily in AI research. Tech giants like Baidu and iFLYTEK have made significant advancements in this area. Through its AI application, iFLYTEK helps Chinese schools execute "teaching to students' aptitudes" in the education sector. More than 130 million teachers and students have utilized iFLYTEK's AI technology to increase the effectiveness of their teaching and learning in more than 50,000 schools to date (Yang & Xiao, 2023). In order to support educational reform and school teaching, a number of small and medium-sized high-tech enterprises have invested in the research and development of AI technology. For instance, Shanghai Moofen Technology Co., Ltd. has used AI to give precise

data analytics to schools in Sichuan, Guizhou, Chongqing, Jiangsu, and other provinces (Li, 2021; Huang, 2022).

# Digital Education has Unique Advantages in Individualized Learning

In the past centuries, modern education has provided the industrialized society with an abundance of the talents it requires. Nonetheless, it has disadvantages, such as the passive learning of students and the lack of innovation in the class-based instructional style. Class-based training necessitates uniform teaching content, predetermined teaching progression, and standardized answers and solutions, so severely limiting the customized and free growth of people (Yuan, 2023).

Educators have tried a number of experiments in an effort to change the class-based instruction paradigm, including credit banks, elective course-based curricula, non-fixed class sizes, and flexible educational systems, all of which were designed to counteract the homogeneity of the class-based instruction paradigm. Their initiatives have not had much of an impact thus far. They now have the chance to address this problem because of the development of digital technologies like big data, AI, and internet technology. Teachers can gather data on students' everyday learning, monitor their learning progress using data analytics, and then provide them with individualized instructions and learning plans with the use of digital education technologies. As a result, teachers may deliver instruction with accuracy, meet the unique learning demands of each student, and so dramatically improve student learning effectiveness.

# Digital Education is a Steppingstone to Universally Fair and Higher-Quality Education

The COVID-19 pandemic has posed significant obstacles to worldwide schooling. Since the year 2020, roughly 147 million students have been robbed of more than 50% of their in-person education, and more than 90% of youngsters worldwide have been struggling with learning. Approximately 244 million children and adolescents were out of school in 2021. The pandemic has created an unparalleled sense of urgency for large-scale online instruction, hence driving the digital transformation of education (Huai, 2023).

China has developed the largest and fastest-growing education system in the world and has made outstanding advancements in educational growth. By 2021, there were 529,500 schools around the nation, serving 291 million students, and 18.4437 million full-time instructors (Ministry of Edu-

cation of China, 2022). Notwithstanding these successes, it is important to keep in mind that imbalanced development is a key aspect of Chinese education, and a higher standard of quality is expected of the entire educational system (Xue & Li, 2022). The development of a top-notch, fair, and high-quality educational system is a crucial undertaking for the country that calls for the support of digital technology. Information, big data, and AI technologies can help create a successful educational system that is advantageous to everyone.

#### Leveraging Digital Technology to Drive Education Transformation has become a Global Consensus

The importance of digital transformation in education is widely acknowledged on a global scale. Many nations, particularly those that are developed, have placed a high value on digital technology in educational reform and have taken proactive steps to enhance digital education.

In 2017, the European Union published the Digital Competence Framework for Educators (DigCompEdu), which covers 22 digital competences such as digital resource selection, development and modification, management, security, and sharing (Redecker, 2017). Two strategic goals for school digitization were outlined in the Digital Education Action Plan 2021–2027, which the European Union unveiled in September 2020: (i) promoting the creation of an environment for high-performing digital education, and (ii) improving digital competencies for the digital transition (European Commission, 2020). The OECD published a report titled "Innovating Teachers' Professional Learning through Digital Technologies" that same year that outlines the requirements for improving teacher learning through new technologies. These requirements include ensuring that teachers have access to high-quality ICT, enhancing teachers' digital competence, and encouraging teachers to participate in technology-based learning activities such as MOOCs, online courses, and online learning communities (Minea-Pic, 2020).

Following the UN Transforming Education Summit, the majority of participating nations included digital education as a fundamental component in their national commitment statements (Liu & Gu, 2023). According to China's statement, it will continue to implement the National Strategic Action for Education Digitalization, increase the supply of digital educational resources, create a large and open learning environment, accelerate resource sharing among learning platforms of various types and levels, advance the integration of new technology into education and learning, and accelerate the digital transformation of education (Ministry of Education of China, 2023b).

### China's Strategic Action for Digital Transformation in Education

The digital transformation of education is a comprehensive campaign that includes the modification of educational concepts, the deployment of network infrastructure, the construction of education platforms, the selection of educational resources, the use of digital tools, the evaluation of digital applications, and the training of teachers. In-depth integration of digital technology in education and instruction can only be achieved through complete, methodical, and scientific digitalization (Cheng, 2020).

#### Policy Support for Digital Transformation in Education

To promote digital transformation in education, it is required to educate key stakeholders on the importance and value of digitalization in education transformation, the possible applications of digital technology in education, and national plans for supporting digital education (Zhou et al., 2020). To advance the national strategic action of digital education and maximize the norms and standards of educational technology, the Chinese government has published a number of policies to guide the development of digital education.

To ensure the successful implementation of the national strategy of digital transformation and progressively realize the digitalization of education, government papers such as the 13th Five-Year Plan for Educational Informatization, the Education Informatization 2.0 Action Plan, and the Modernization of China Education 2035 advocate integrating AI, big data, and other information technologies in education and teaching in depth, developing lifelong digital education, and accelerating the construction of high-quality personalized learning systems that everyone can access anywhere at any time.

Meanwhile, the Chinese government has issued a series of guidance documents for the implementation of digital education, such as *Basic Requirements for the Functions of the Smart Education Platform, Technical Requirements for Digital Education Resources on the Smart Education Platform, Basic Classification Codes for Digital Education Resources, Basic Data of Education, Basic Data of Personnel in the Education Sector, Basic Data of Primary and Secondary Schools, and Digital Literacy of Teachers.* 

Policy support and publicity in various forms have increased all stakeholders' engagement in digital education development in terms of teaching, learning, school governance, and educational innovation, as well as ensuring the successful execution of the "School is Out, But Class is On" program during the COVID-19 pandemic prevention and control and facilitating the "Double Reduction" work. As a result, educational equity and

quality have improved, and new paths for advancing digital education have opened up.

### Setting Objectives for the Development of Digital Education

Digital education is a relatively new practice in educational history. When confronted with this new trend, it is vital to define directional goals. What should be the practical and achievable aims of digital education development is an issue shared by all governments throughout the world. To respond to this question, Huai (2023), China's minister of education, proposed the following goals at the WDEC:

### Strengthening the National Center to Pool and Share Quality Resources

The National Digital Resources Construction Committee will be established to coordinate the development of high-quality resources and the delivery of public services, to evaluate digital resource management and application, to improve the quality of campus education and digital education empowerment, to coordinate policy and academic research and practical innovation, and to develop standards and specifications to ensure safe and efficient operation. The National Center will be divided into several sections, including a resource development and utilization center, a public service center, an application development center, a comprehensive research center, and a safety operation and maintenance center. At the same time, the center will serve as a model for the development of regional service centers for educational resources. The government will actualize resource sharing and mutual recognition, as well as build a national public service system on digital education with multi-level and multi-party collaboration, by improving the national center's hub capacity and connecting regional centers.

# Strengthening Data Empowerment and Improving Educational Effectiveness

Enormous amounts of data will be employed to create learner profiles and generate educational schema that are better suited to the abilities of learners. Schools will support decentralized and diverse teaching and learning, conduct pedagogical research in digital education, increase teachers' digital literacy, as well as create and implement diverse education models and evaluation methodologies to enhance teaching quality. Administrators will develop education governance that is efficient and targeted. Through the application

of AI and big data technologies, corporate collaboration, process optimization, structural remodeling, and targeted management may be achieved to enhance the efficiency of education management and create a solid foundation for well-informed education decisions.

#### Improving Digital Literacy for Lifelong Learning for All

The extensive and in-depth application of Smart Education of China makes the "Learning for All" initiative feasible, which will not only provide curriculum resources for students but also a learning service environment for the elderly and other members of society, thereby constructing a learning support platform for learners around the world to ensure that everyone has equal learning opportunities.

### Strengthening International Cooperation for the Prosperous Development of Civilizations

The advancement of digital education enables teenagers from different countries, with different skin colors and languages, to learn and grow together in a common digital space and enables people from different countries to engage in closer people-to-people and cultural exchanges, so as to deepen exchanges, tolerance, and trust, eliminate barriers and misunderstandings, and promote mutual understanding and the advancement of humanity.

# Persistent Investment in the Construction of Digital Facilities in the Educational Community

The construction of ubiquitous digital infrastructure is the precondition for digital transformation in education. Continuously upgrading digital infrastructure is essential to the effective operation of digital education (Cheng, 2020). China has long been committed to the creation of infrastructure for digital education, focusing on:

#### Deploying Digital Network Infrastructure

Connectivity facilities serve as the cornerstone for digital education deployment. China launched the "Three Links and Two Platforms" program in early September 2012, with all higher education institutions and basic and secondary schools participating by 2013. The "Three Links," which refer to "the school links to a broadband-based network, the class links to good teaching resources, and the individual links to an online learning space," have ensured China's digital transformation in education. China's educational informatization has advanced dramatically as a result of the project,

Table 2. State-level Digital Education Cloud Platforms in China.				
Names of Platforms	Developers			
Smart Education Gateways	Department of Science, Technology and Informatization, Ministry of Education			
Smart Primary and Secondary Education of China	Department of Basic Education, Ministry of Education			
Smart Vocational Education of China	Department of Vocational and Adult Education, Ministry of Education			
Smart Higher Education of China	Department of Higher Education, Ministry of Education			
Pilot Demonstration of Smart Education	Ministry of Education			
Source: Official Website of the Ministry of Education of China				

with 100% internet connectivity on campus and 99.5% of primary and secondary schools equipped with multimedia classrooms (Ministry of Education of China, 2023a).

#### Developing Digital Education Cloud Platforms

The state-level cloud platforms that have been developed during the previous decade or so are presented in **Table 2**.

To satisfy the demands of local schools for digital education, provincial, city, and county-level cloud platforms have also been built. Furthermore, a few privileged schools have created their own smart cloud platforms for instruction. For instance, Shandong 271 Education Group created 271Bay to help the group's more than 8,000 teachers and more than 90,000 students in their digital teaching and learning (Sun, 2022).

The enhanced digital infrastructure facilitates the growth of digital education. During the lockdowns caused by the COVID-19 pandemic, the implementation of the "School is Out, But Class is On" program ran smoothly due to the deployment of rather complete digital facilities. More than 270 million Chinese students successfully completed learning assignments via online education (Lu & Zhou, 2020).

In China, digital technology and online education platforms are utilized not merely to support classroom instruction but also to aid in the moral and mental health education of students. For example, the Mental Health Cloud Platform in a city in Jiangsu has offered students psychological health care services such as evaluation, counseling, and therapy for mental health issues (Quan, 2020).

As well, by altering their teaching research methodologies, teachers have supported educational research through the use of increasingly common digital facilities in educational communities. Even instructors in border and

Table 3. State-level Digital Education Resource Banks.			
Names of Banks	Builders		
National Smart Education Resources	Ministry of Education		
College Graduate Employment Resources	Department of Vocational and Adult Education, Ministry of Education		
MOOC Resources	Department of Higher Education, Ministry of Education		
Curricular Teaching Module Resources Ministry of Education			
Source: Official Website of the Ministry of Education of China.			

minority areas have attempted to conduct educational research using the digital technology platform. For instance, teachers at a senior secondary school affiliated with Xingyi Normal University for Minorities successfully used the Intelligent Research and Training Platform to conduct instructional research (Gong, 2022).

### Promoting the Construction of Digital Education Resource Banks

The most essential aspect of digital education development is the development of digital resources. The widespread use of digital technology has created potential to better balance educational resources and close gaps between regions, urban and rural locations, and schools. China has established a preliminary digital education resource system that serves all types of schools at all levels. The present state-level digital education resource banks are shown in **Table 3**.

High-quality digital resources for basic education are available through the "Smart Primary and Secondary Education of China" platform. These resources span 10 sections, 53 columns, and 44,000 individual entries, and they cover topics like moral education, curriculum teaching, physical education, aesthetic education, labor education, after-school services, teacher preparation, family education, teaching reform experience, and teaching materials. Children who live far away in border and rural areas can "share the same class" with those who live in big cities. In order to continue student learning despite the suspension of in-person classes caused by the pandemic, the platform supported online learning for close to 200 million Chinese primary and secondary school students. Around 13 million teachers nationwide received specialized training over the winter and summer breaks to enhance their teaching and research skills (Huai, 2023).

To satisfy the demands of local schools for digital education, resource centers at the provincial, city, county, and school levels have also

been constructed. For instance, the Jiangsu Province city of Suzhou established the Suzhou Online Education Center, which amassed enormous volumes of instructional information. This center, which is funded by the Suzhou Municipal Bureau of Education and is supported by information and AI technologies, offers personalized online learning services that combine online and offline instruction with digital resources for in-class and extracurricular learning that have been prepared by the city's anchor teachers. This center is free for all students and covers all disciplines at the basic education levels as well as the entire learning process. Since its launch in 2018, the platform has provided 1.83 million questions based on all knowledge points at all levels, 126,000 entries of video resources, including micro-lectures on various subjects, and 14,500 subject-based lessons taught by city-level anchor teachers (including 180 lessons taught by foreign teachers) across all disciplines in the 12 grades of basic education (Suzhou Online Education Center, 2023b). Almost 1.5016 million instructors and students from ten districts and counties in the city have access to the platform as of February 2023. with a total of 275 million log-in person-times and more than 517 million views. Suzhou Online Education Center has adhered to the principle of "giving application and service precedence in digital education" proposed by Jinpeng Huai, China's minister of education (Suzhou Online Education Center, 2023a).

Sichuan, a western province of China, introduced the "Sichuan Cloud Education" project in 2018, which provides open access to live broadcasts of excellent classroom education. The platform uses top-notch educational materials from those schools in developed areas to their fullest advantage through ongoing development and iterative upgrading to deliver synchronous learning services for more than 200,000 students and over 20,000 teachers. A total of 44 "Sichuan Cloud Education" teaching alliances have been established as part of this project, benefiting over 1,600 underprivileged schools, including 523 minority schools (with more than 100,000 students) in relatively underdeveloped areas. These alliances cover all disciplines for primary and secondary schools as well as teaching content for kindergartens (Cui, 2022).

#### Digital Literacy Training for Teachers

Digital education is a new paradigm in education, necessitating new thought patterns and digital competencies among teachers. Professional and systematic training is required to assist teachers in modifying their educational philosophies, equipping them with digital abilities, and so increasing their work productivity.

Chinese educational authorities give teachers' training in digital literacy a high priority. To direct teacher training in the context of digital educa-

tion, the Ministry of Education published Views on Comprehensively Deepening the Reform of Teacher Professional Development in the New Age in 2021. Based on the current digital proficiency of local teachers, all provinces, cities, counties, and schools offer various forms of teacher digital training (Ministry of Education of China, 2021).

#### **Achievements of China's Digital Education**

By altering instructional concepts, reforming pedagogies, and school administration, enhancing student learning strategies and outcomes, and boosting communication between the home, school, and community, digital education can drive educational transformation and encourage the high-quality development of education. Data that is relevant shows that China has achieved significant advancements in digital education.

The "Smart Primary and Secondary Education of China" platform has given particular emphasis to the demand-driven expansion of its capabilities and applications while continuing to assemble and upgrade resources. This platform has improved user interaction, added features like live broadcasting, resource evaluation, and application data analytics, and developed its mobile App and user registration function with the help of Regulatory Measures for the Operation of Smart Primary and Secondary Education *Platform (Interim).* The nine application scenarios it can now handle include autonomous learning, lesson planning, double-teacher classrooms, homework push, Q&A, after-school services, teacher training, home-school communication, and school district administration. It keeps gaining in intelligence. Additionally, it has conducted two rounds of platform application pilot projects, regularly summarized its findings, and showcased successful platform usage examples. The site has seen a tremendous increase in usage; as of January 31, 2023, there were 72.51 million registered users. It has developed into a sizable platform for educational services and a storehouse of educational resources. Primary and secondary school teachers in China apply digital technologies to a range of topics, including educational research, teaching, and assignments, as well as to a variety of scenarios, including synchronous classrooms, specialized classrooms for underprivileged schools, smart classrooms, smart homework, and online educational research, depending on their particular needs. As a result, there has been a large increase in the analysis and feedback of teaching and learning data, which has successfully improved teachers' instructional skills and boosted the efficiency of classroom instruction (Ministry of Education of China, 2023c).

China's strategic initiative for smart vocational education has also advanced significantly. The management of digital resources was first standardized by the "Smart Vocational Education of China" platform, which also established requirements for resource inclusion. More than 510,000 video

resources and more than 150,000 graphic and textual materials are now listed in it. Students gain access to 6,757 top-notch open online courses and 1,173 teaching resource banks at the state and provincial levels through this platform. Also, online training on the usage of this platform was arranged for teachers from all vocational schools and colleges with the help of the National Vocational Education Informatization Steering Committee. The regular "Summer-Vacation Teacher Training" program was jointly established on the platform by the Department of Vocational Education and Adult Education and the Department of Teachers of the Ministry of Education. To date, it has been utilized by 7,200 schools and 692,000 teachers (Ministry of Education of China, 2023e).

The platform of "Smart Higher Education of China" was constructed to high standards in the higher education community, including 27,000 toptier MOOCs and virtual simulation experiments, as well as more than 65,000 instructional materials, videos, and other learning resources. Almost all western Chinese colleges and universities have benefited from the MOOKs for Western China Initiative. In 2022 alone, it provided 45,000 MOOKs and on-demand courses to western universities and colleges, engaged 250 million person-times of students, and trained 355,000 person-times of teachers. Furthermore, the comprehensive integration of the next generation of digital technology with higher education has become the new norm. Chinese colleges and universities have successfully addressed the consequences of the COVID-19 pandemic using the internet and information technology. Rapidly emerging educational modalities and talent training paradigms include online and offline blended learning. Digital education-driven teaching reform has become a trend in China's higher education development (Ministry of Education of China, 2023d).

The national smart education platform system collects top-notch, diverse digital learning resources and offers students and the general public one-stop services constantly. This has aided in the equitable distribution of educational resources and the promotion of digitalization, while also addressing the individualized and selective learning needs of all students and strongly promoting lifelong learning (Huai, 2023).

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#### Impact of the Context of Socioscientific Issues on Discourse Patterns Used in Science Classes

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Abstract: This study is a qualitative study conducted to examine the effect of socioscientific issues (SSI) on discourse patterns used in the classroom. The research was conducted with four elementary science teachers working in a public school. The research was designed as case studies of these four teachers and data resources were video recordings of these teachers' routine and SSI based lessons. The data was analyzed through discourse analysis. The discourse patterns used by teachers were examined in terms of adjacent the utterance, triadic, and chain discourse patterns. The results indicated that the discourse patterns used by the teachers in their routine lessons changed dramatically in the context of SSI and the chain discourse pattern came to the fore in the courses processed in the context of the SSI.

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#### Introduction

HE concept of discourse is used in various fields, and underlying the word "discourse" is the idea that language is structured according to the patterns people's utterances follow when they take part in different domains of social life (Phillips & Jorgensen, 2002). In the context of education, classroom discourse, which is dialogic, represents the interaction of a variety of ideas, including students' ideas (Mortimer & Scott, 2003; Nystrand, 1997). It also refers to the language that teachers and students use to communicate with each other in the classroom. The pattern of discourse represents how language interacts in the classroom (Kaya et al., 2016).

Interaction in the classroom is fundamental to students' processes of meaning-making. As Vygotsky's sociocultural learning theory puts it, all learning originates in social situations, where ideas are rehearsed between people, mainly through talk (Mortimer & Scott, 2003). Through talk and interaction, people can make sense of what is being communicated, and the words used in social exchanges provide the tools needed for individual thinking. Hence, meaning-making is a dialogical process in which different ideas are brought together (Bakhtin, 1981). Besides being an essential component of learning (Gonzalez, 2008), enhanced classroom discourse helps to create a classroom community that is inclusive and supportive of all its members.

Simon (1997) indicated that by improving classroom discourse teachers can enrich the classical and authoritarian learning environments they widely use and transform them into interactive learning environments. Therefore, teachers are expected to differentiate the discourse patterns they use to improve dialogue in the classroom to make it easier for students to learn. Literature acknowledges that three distinct discourse patterns are used in classrooms. The contiguous rhetoric pattern is the discourse model consisting of the Initiation-Response stages (Schegloff, 1978). In this discourse pattern, evaluation and feedback are not present. The triadic discourse pattern usually involves explicit teacher evaluation of students' contributions (Scott et al., 2006) and is frequently conducted in an Initiation-Response-Evaluation (IRE) pattern (Mortimer & Scott, 2003). If the answers given by the students do not comply with the classical scientific knowledge, they are immediately given the correct answer or ignored by the teacher (Mortimer, 2005). A chain discourse pattern is a pattern of discourse consisting of Initiation-Response-Feedback (I-R-F-R-F) stages (Scott et al., 2006). In this pattern of discourse, instead of evaluating, the teacher gives feedback to prolong the dialogue by reflecting on the responses from the students (e.g., How? Why? Can you open this up a little bit more?). Thus, the students deepen their answers and can compare their old knowledge with their new knowledge (Scott & Ametller, 2007). Furthermore, an indispensable feature of the chain discourse pattern is that students are active participants in classroom discussions (Bosser & Lindahl, 2021; Nystrand, 1997). Chain discourse dialogues can remain open without teacher evaluation (I-R-F-R-F), while others end with a final assessment by the teacher (I-R-F-R-F-R-E). Rhetoric can create more complex and longer chain dialogues with students responding to each other's answers (Scott et al., 2006).

Arguably, the success of teaching depends on the teacher's ability to improve classroom interaction. Therefore, the discourse pattern used by the teacher in the classroom becomes important. However, studies on the discourses teachers use in their lessons indicate that teachers generally use authoritarian discourses (the adjacency pair or triadic discourse pattern) in classroom environments (Molinari & Mameli, 2010), which limit learning and interaction. On the other hand, researchers reported that in learning environments where discourse patterns are diversified towards more dialogic and communicative approaches, meaningful learning becomes possible (Buty & Mortimer, 2008; Myhill, 2006; Poimenidou & Christidou, 2010; Scott et al. 2006), students are encouraged to come up with new ideas (Scott et al. 2006), and students model the discourse language of teachers (Dawes, 2004).

Interactive learning environments are no doubt required for effective science education. The use of socioscientific issues (SSI) as a context in science lessons has significant potential in this sense. SSI are socially controversial issues related to science (Kolstø, 2001; Sadler & Zeidler, 2004). Ratcliffe and Grace (2003) define SSI as issues that are important to society, have a scientific basis, come up often in the media, involve politically and socially important issues regionally, nationally, or internationally, question ethical values, require an understanding of probability and risk, and do not have a single right answer. Examples include genetically modified organisms, global warming, cloning and nuclear power plants, which are closely related to society in our changing world and cause controversy that directly affects people's lives (Sadler, 2011).

Considering the objectives of the scientific literacy movement, SSI have emerged as an important context in science teaching and found their place in the curricula of many countries (Dawson, 2001). Today, institutions and organisations around the world advocate the inclusion of SSI as a teaching and learning context in science education (Ministry of National Education of Turkey [MONE] 2013; National Research Council, 1996; NGSS Lead States, 2013).

Research indicates that SSI-based teaching, in which SSI are used as contexts for teaching and learning, can promote the required knowledge and understanding for scientific literacy (Zeidler et al., 2009). SSI can be used as an effective context for learning science knowledge and skills in the classroom and serve as a basis for understanding science content (Klosterman & Sadler, 2010; Sadler et al. 2016; Wongsri & Nuangchalerm, 2010) and the

nature of scientific knowledge (Khishfe & Lederman, 2006). SSI-based instruction can also promote students' interests and motivation towards science (Dori et al., 2003) and their development of argumentation practices (Venville & Dawson, 2010) and moral reasoning (Lee et al., 2012).

SSI-based teaching differs from teaching science content in important ways. SSI is controversial because they are open-ended and unresolved. These topics also include uncertainties and relativities (Zeidler & Nichols, 2009). The characteristics of SSI provide the context for the emergence of multiple perspectives (Bosser & Lindahl, 2021). Teachers are not the primary source of knowledge and should be skilled in managing open-ended discussions in SSI teaching. Students in the classroom are expected to share and discuss their ideas. Thus, SSI-based teaching can offer opportunities for classroom discourse (Bosser & Lindhal, 2021).

Despite SSI's potential in developing classroom discourse, only a few studies focus specifically on how SSI contexts affect classroom discourse. Among these, Dawson and Venville (2010) explored teaching strategies that support students' discussion skills in decision-making through an SSI subject related to genetics. The results show that the teacher's facilitation of the process contributes to the resulting quality of argumentation and the students' consideration of different ideas. In another study, Puig and Jim énez-Aleixandre (2011) examined the teaching practices of a teacher in the context of an SSI involving Mendelian genetics. The researchers reported that the context and the efforts of the teacher had created a climate of confidence, which encouraged students to express and defend their opinions and ask one another to explain or support their claims. Chung et al. (2014) investigated the extent to which SSI instruction on gene modification technology contributed to enhancing students' communication skills in South Korea and concluded that SSI instruction could have a moderately large impact on students' ability to understand the key ideas of others and value others' perspectives and a marginally positive effect on developing active assertions. Bosser and Lindahl (2021) examined two science teachers' employment of a communicative approach during SSI-based teaching. The results indicated that teachers purposely use different communicative approaches to facilitate students' decision-making while promoting complexity in their reasoning.

These studies present valuable evidence about the potential of the context of SSI in classroom discourse. However, how SSI teaching affects and shapes the discourse in the classroom still needs to be explored and understood. To this end, the present study aims to examine the effect of SSI-based teaching on discourse patterns in the classroom.

#### **Materials and Method**

Table 1. Demographic Information of the Teachers Participated in the Study.				
Teacher	Age	Gender	Educational Background	Years of Experience
Kayra	30	Female	Bachelor's Degree	9
Sevil	30	Female	Bachelor's Degree	9
Seda	33	Female	Bachelor's Degree	10
Figen	35	Female	Bachelor's Degree	4

This study was conducted within the scope of a larger national project in Turkey, which was conducted to expand the use of SSI in science classes. In Turkey, the revised science curricula in 2013 and 2018 put a special emphasis on the use of SSI as a context in science education to promote scientific literacy nationwide. Therefore, supporting teachers' professional development concerning using SSI effectively in their classrooms has become an important issue. In this national project, the aim of which was to support science teachers in the teaching of SSI and to ensure their professional development, the main objectives were (i) to develop an SSI learning/teaching framework following the revised science curricula, (ii) to design sample teaching modules that science teachers can use during SSI teaching, (iii) to support the professional development of science teachers regarding SSI teaching, and (iv) to make learning environments based on student-centred inquiry more widely available in elementary schools.

As a part of this nationwide project, this study focused on how discourse patterns were affected in classrooms where SSI was used as a context. Discourse patterns that teachers routinely used in their classrooms were compared with those they used in the SSI context. Here, the term "routine" is used to refer to teachers' daily lessons, in which they applied their typical strategies and which were not interfered with by an external context or technique.

A qualitative research approach was used in this research, and as the study aimed to examine classroom discourse patterns in depth in the natural environment, the case study design was applied.

#### **Participants**

This research was conducted in an urban public elementary school in Istanbul. The school had approximately 600 students and the average class size was 30 students. Four science teachers teaching in the school voluntarily participated in the study. **Table 1** presents the demographic characteristics of the participants.

One of these teachers, Kayra, completed her undergraduate education at a state university and had nine years of teaching experience. Kayra was

Table 2. Topics Taught by Teachers in Routine Lessons.			
Teacher	Grade	Торіс	
Kayra	5th	Friction Force of Substances	
Sevil	6th	The Circulatory System	
Figen	7th	Pressure in Gases	
Seda	8th	Covalent Bonds	

Table 3. Socioscientific Issues Modules Used by Science Teachers.				
Grade	Unit Name	Unit Name (Project)		
5th	The Mystery of the Earth's Crust	Should Tourism be done in Fairy Chimneys, Cappadocia?		
6th	Matter and Heat	Should Buildings be Mantled?		
7th	Electrical Energy	Should Electricity be Generated from Nuclear Power Plants?		
8th	Living Things and Energy Relations	Should Tourism be done around Lake Seyfe?		

Table 4 of SSI.	Table 4. Topics Used by Teachers in the Courses They Process in the Context of SSI.					
Teacher	Grade	SSI Module	SSI1 Subject	SSI2 Subject	SSI3 Subject	
Kayra	5th	Should Tourism Be Done in Fairy Chim- neys, Cappadocia?	"Fairy Chimneys"	"Is our air polluted?"	"Should there be tourism in Fairy Chimneys or not?"	
Sevil	6th	Should buildings be mantled?	"What degree does the Ther- mometer Read?"	"Fuels" and "Electricity Generation from Re- newable Energy Sources"	"Should Buildings Be Mantled?"	
Figen	7th	Should electricity be generated from nuclear plants?	"Electricity in our Lives"	"News, News, News"	"Should nuclear plants be built or not?"	
Seda	8th	Should there be tourism around Lake Seyfe?	"Lake Seyfe" and "Food Chain"	"Therapeutic coding and Ms. Aylin", "How can we save Lake Seyfe?"	"Should or should not be farmed in Lake Seyfe?"	

teaching science to the 5th graders. The second teacher who participated in the study was Sevil. She completed her undergraduate education at a state university and had nine years of teaching experience. Sevil was teaching science to the 6th graders at the time of the study. The third teacher was Figen, who completed her undergraduate education at a state university and had four years of teaching experience. Figen was teaching science to the 7th graders. The last teacher who participated in the study was Seda. She also

graduated from a state university and had ten years of teaching experience. She was teaching science to the 8th graders.

#### Research Process and Collection of Data

In the first stage of the study, four teachers were asked to choose a class from the classes they taught. Following their choice, the routine forty-minute science lessons (lessons without using SSI) of each participating teacher were observed and video-recorded in classes of their choice. The aim was to identify the patterns of discourse that teachers used in a routine lesson. At this stage, teachers were not told the exact purpose of the classroom observations (to follow discourse patterns) so that they would not deviate from the course routines they normally followed. Instead, they were informed that the aim was to define how the lessons were managed in general. **Table 2** shows the subjects the teachers taught in their routine lesson observations.

After routine lesson observations, teacher's guides and student notebooks were delivered to the teachers. These guides and notebooks contained materials that would inform and guide them in using the SSI as a learning context in their classrooms. These materials were prepared within the scope of one of the objectives of the national project: "Designing sample teaching modules those science teachers can use during SSI teaching". To this end, four teaching modules were developed for the 5th, 6th and 7th and 8th grades. The grades in which these units are located and the names of the SSI modules prepared to correspond to these units within the scope of the project are presented in **Table 3**.

Each SSI module consisted of a student notebook, a teacher's guide and evaluation papers. Student notebooks contained spaces for students to answer questions, take notes and write discussion results. The teacher's guide included instructions on how to process the sections and activities in the student books. The evaluation papers contained open-ended and closed-ended questions that should be applied to students twice in each unit.

Later in the study, three lessons that each teacher taught using these SSI modules were observed and video-recorded. These observations examined the discourse patterns in the lessons in the context of the SSI. The topics of the lessons the teachers taught using SSI modules are given in **Table 4**.

#### Data Analysis

Video-recorded lessons of participating teachers were used as data sources during the analysis. These videos consisted of a total of four lessons for each teacher, including routine lessons and those in the context of the SSI. A descriptive analysis approach was used for data analysis. Descriptive analysis is the interpretation of the data according to previously determined themes (Strauss & Corbin, 1990).

The process of data analysis of discourse patterns in the research started primarily by transferring video recordings to the computer environment. Later, each video was transcribed verbatim. Two researchers independently read the transcribed texts repeatedly. In the next stage, the discourse patterns that emerged in each lesson were coded independently by the two researchers. The unit of analysis was determined as episodes characterised by teacher-student dialogues initiated by the teacher. When coding the discourse patterns, the researchers coded each discourse they discovered as adjacent utterance (Initiation-Response, Schegloff, 1978), triadic (Question-Response-Evaluation, Lemke, 1990) or chain (Initiation-Response-Feedback-Response-Feedback, Mortimer & Scott, 2003). After the independent coding, the two researchers came together to compare their coding and the interrater agreement between them was calculated and found to be 98%. The researchers worked together on codes that had not yet been agreed on until all the codes were compromised. Then, frequency tables were created by counting the number of times in which different discourse patterns were used in each lesson video. These frequency numbers were compared to the total number of discourse patterns, and percentage tables were created. Afterwards, the number of times each discourse pattern was used for each teacher's lessons was calculated, and the total used discourse pattern ratios and the discourse patterns used by the teachers in their lessons were compared. To establish the credibility of our interpretations, the episode examples are presented in the results section to allow readers to assess them. The percentages and frequencies in the analysis graphs presented in the following section cover interactions involving teacher-student dialogues, not the entire course.

#### **Results**

In this section, discourse patterns that emerged in both routine lessons and those in the SSI context for each teacher are presented under separate headings. Lessons in the context of SSI are encoded as SSI1, SSI2, and SSI3 in graphs and tables.

#### Kayra

Kayra conducted routine and SSI lessons in a 5th-grade class. **Figure 1** presents the analysis of discourse patterns observed in Kayra's routine and SSI lessons.

As seen in **Figure 1**, Kayra used a triadic discourse pattern in the entire routine lesson (38 times). However, she switched to a chain discourse pattern in SSI2 and SSI3. In other words, the triadic discourse pattern was replaced by the chain discourse pattern as Kayra's lessons moved to the context of the SSI.

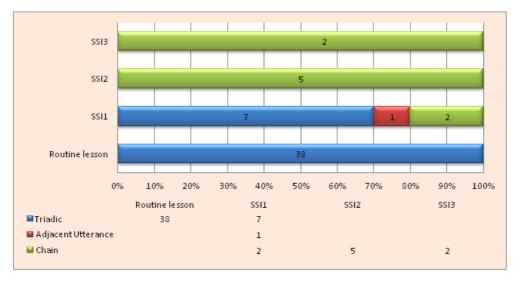


Figure 1. Discourse Patterns Observed in Kayra's Routine and SSI Courses.

Table 5. Triadic Discourse Pattern Sample Dialog Table of Kayra's Routine Lesson.				
Line	Speaker		Discourse Indicators	
1	Kayra	What about factors that reduce friction? Anyone who did not talk so far	Initiation	
2	Student	Planes have features reducing friction.	Response	
3	Kayra	Yes, planes have some features reducing friction. Let's write this example down. The sharp nose of a plane reduces air friction [Waits for students to write down]. Some of your friends gave examples earlier, there were other factors that affect the movements, let's remember them.	Evaluation/ Initiation	

The subject of Kayra's routine lesson was "friction force" and she started the lesson by repeating the previously learned concepts to measure whether the students understood the subject. In this process, she used the triadic discourse pattern. **Table 5** contains a sample dialogue of the triadic discourse pattern that Kayra used in her lesson.

As seen in the dialogue presented in **Table 5**, Kayra started the dialogue with a question (**Table 5**), "What about factors that reduce friction? ..." (Line 1). Here, the students gave examples that were debated in the previous lesson. When a student answered (Line 2), Kayra accepted the answer, stating "Yes, planes have some features reducing friction. Let's write this example down. The sharp nose of a plane reduces air friction" (Line 3). Such an evaluation finished the dialogue between the teacher and the student without

	Table 6. An Example of the Chain Discourse Pattern Observed in Kayra's SSI2 Lesson.				
Line	Speaker		Discourse Indicators		
1	Kayra	Let's get started on our ideas. Semih, what do you think can be done?	Initiation		
2	S2	Well, we can prove it by taking a picture.	Response		
3	Kayra	We can take pictures. Well, Semih said we can prove air pollution by taking a picture of it. Any other opinion?	Feedback		
4	S3	By experimenting.	Response		
5	Kayra	We make experiment. You are great, we measure them all, we experiment, we take pictures. Others?	Feedback		
6	S4	I would look at urbanization, so I can link air pollution with increase in urban population.	Response		
7	Kayra	Rumeysa says she would look at urbanization and the number of people in urbanized areas. She sees a connection with air pollution and urbanization rate. That is a good thought, too. Others?	Feedback		
8	S5	I would look if there are trees.	Response		
9	Kayra	Forestation! Furkan said he'd look at forests because trees help prevent air pollution. Isn't that right, Furkan?	Evaluation		

allowing the student to explain. Then Kayra moved to another question and started another triadic discourse pattern in the form of IRE.

Kayra also used the triadic discourse pattern in SSI lessons (SSI1 lesson, see **Table 5**), especially in dialogues where she evaluated student answers to questions about the pictures in the student notebooks. She used the adjacent utterance discourse pattern once (SSI2 lesson, see **Table 5**) to get approval for her explanation about a picture in the student notebook. The chain discourse pattern, on the other hand, was frequently observed in Kayra's SSI lessons. The SSI context promoted brainstorming, where different ideas were presented during the discussion of questions without a true or single answer. **Table 6** presents an example of a chain discourse pattern observed in Kayra's SSI2 lesson.

In Kayra's SSI2 lesson, the topic was air pollution, and the interaction presented in **Table 6** was a section of the lesson where students provided their ideas about whether vehicles used in tourism (such as tourist buses) cause air pollution in Cappadocia. As seen in the table, Kayra started a chain discourse pattern by letting a student share his ideas about the discussion. After getting an answer from the student, she repeated the answer and gave feedback. As seen, she did not evaluate the answer and end the discourse; instead, she continued with the question 'Others?' (Lines 3, 5 and 7) that allowed the students to brainstorm. In Line 9, she evaluated the student's answer (Line 8) by adding her opinion and ending the dialogue.

#### Sevil

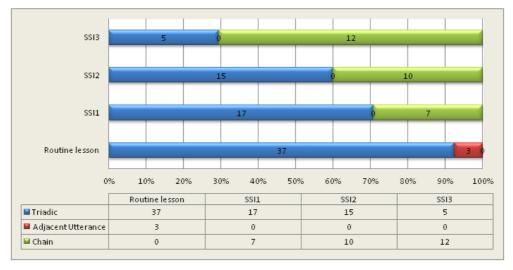


Figure 2. Discourse Patterns Observed in Sevil's Routine and SSI Lessons.

	Table 7. An Example of the Triple Discourse Pattern Observed in Sevil's Routine Lesson.				
Line	Speaker		Discourse Indicators		
1	Sevil	Remember our skeleton and musculoskeletal system. Which organs were protected by our skeletal system?	Question		
2	S1	Heart, lung.	Response		
3	Sevil	Lung, heart. Isn't it?	Evaluation/Question		
4	S2	Stomach	Response		
5	S3	Large intestine.	Response		
6	Sevil	No. Look, the rib cage is protecting our internal organs out front. It is the ribs part of our skeleton we call the rib cage. But the bones do not protect our organs in our abdomen; the muscles are protecting them.	Evaluation		

Sevil conducted her lessons in the contexts of routine and SSI in a 6th-grade class. Chart 2 presents an analysis of discourse patterns observed in Sevil's routine and SSI lessons.

In her routine lesson, Sevil used the triadic discourse pattern (37 times). She used this pattern in situations where she wanted students to associate new learning with existing learning. In these dialogues, the questions she posed to the students had a single answer and she expected to hear that answer. **Table 7** provides a sample dialogue recorded in Sevil's routine lesson.

As seen in **Table 7**, Sevil initiated the dialogue by reminding students of the skeleton and musculoskeletal system, which they had covered in

the previous lesson, and asked for the name of organs that were protected by the skeletal system (Line 1). Sevil assessed the students' answer, "Heart, lung" (Line 2) with the sentence "Lung, heart. Isn't that right?" (Line 3), and at the same time, she asked a new question and waited for the approval of the students. Students gave other examples of the organs protected by the skeletal system with examples such as "Stomach" (Line 4) and "Large intestine" (Line 5). Since these answers were not the ones that Sevil had expected, she finished the dialogue with an evaluation (Line 6).

As shown in **Figure 2**, the chain discourse pattern had become dominant in Sevil's SSI lessons. While she never used the chain discourse pattern in her routine lesson, she used it seven times in SSI1, ten times in SSI2 and 12 times in SSI3. Although she continued to use the triadic discourse pattern in SSI courses, she did not use the adjacent utterance discourse pattern. The analysis showed that Sevil continued to use the triple discourse pattern in SSI lessons, especially in cases where she had wanted students to remember previous learning. On the other hand, she used a chain discourse pattern, as exemplified in **Table 8**, to reveal students' pre- or misconceptions and to allow students to explain their ideas on the issue.

**Table 8** presents one of the dialogues between Sevil and a student in one of Sevil's SSI lessons. As seen, Sevil initiated the dialogue with a question about the thermal insulation of buildings and a student presented his ideas. Then, Sevil continued the dialogue by asking the student to explain the reason for his answer, providing feedback and asking for clarification. During the dialogue, Sevil provided feedback on the student's explanations (Lines 5 and 7) and finished the chain discourse pattern with an evaluation sentence indicating that she understood the student's answer.

#### Figen

Figen conducted both routine and SSI lessons in a 7th-grade class. **Figure 3** shows the discourse patterns observed in Figen's routine and SSI lessons.

As shown in **Figure 3**, while Figen used the chain discourse pattern only once in her routine lesson, it increased during lessons in the context of SSI (11 times in SSI1, nine times in SSI2 and 19 times in SSI3). While the triadic discourse pattern had the highest frequency of use in the routine lesson, its use decreased noticeably in the context of SSI. Figen usually used the triadic discourse pattern (88%) in her routine lesson to assess students' learning. **Table 9** contains a sample triadic discourse pattern observed in Figen's routine lesson.

Triadic discourse patterns contain initiation questions that have only one correct answer, which is known to the teacher, and have a testing quality. In the dialogue in **Table 9**, Figen asked, "...how do the solids move?" (Line 1), "... what do we need to measure the pressure of a solid?" (Line 3) and

	Table 8. An Example of the Chain Discourse Pattern Recorded in Sevil's SSI2 Lesson.				
Line	Speaker		Discourse Indicators		
1	Sevil	So, yes, is there any another idea now, should we coat our building with thermal insulation materials?	Initiation		
2	S1	I think we should not. Because all insulation materials have harmful effects for human health and, also negative effects for the environment. Some are flammable, some cause skin diseases. There are positive sides, of course, for example it lowers the gas bill, but I still don't prefer it.	Response		
3	Sevil	Well, how do you know they're so harmful?	Feedback		
4	S1	We talked about it earlier.	Response		
5	Sevil	We talked about it. What did we say?	Feedback		
6	S1	Well, we talked about the mantling stuff and all that harm they may cause.	Response		
7	Sevil	We talked about their potential harms, but were they certain?	Feedback		
8	S1	No, they were not.	Response		
9	Sevil	But since there are risks, you still don't prefer it. Well.	Evaluation		

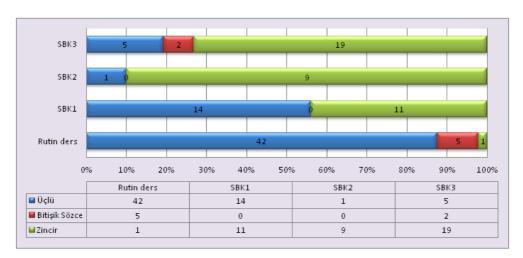


Figure 3. Discourse Patterns Observed in Figen's Routine and SSI Lessons.

waited for the known definitive answers from the students. In the dialogue, one student answered each question (Lines 2, 4 and 6). In addition, the teacher evaluated all the answers, and after receiving the expected answer, she continued the dialogue with a new question (Lines 3, 5 and 7).

In Figen's SSI lessons, she continued to use the triadic discourse pattern to remind her students of their previous learning. On the other hand, she used the chain discourse pattern in dialogues with no single correct answer, and answers varied from student to student. In these dialogues, she func-

### Table 9. An Example of the Triple Discourse Pattern Recorded in Figen's Routine Lesson.

Line	Speaker		Discourse Indicators
1	Figen	Ok, how do the solids move?	Initiation
2	S1	They vibrate.	Response
3	Figen	Um, they just vibrate. So, what do we need to measure the pressure of a solid?	Evaluation/Initiation
4	S1	The area of application.	Response
5	Figen	The surface area, the area of contact. OK, the other one?	Evaluation/Initiation
6	S2	Weight.	Response
7	Figen	Weight or force. Well, how about liquids?	Evaluation/Initiation

Table 10. An example of the chain discourse pattern observed in Fig	en's SSI2
losson	

Line	Speaker		Discourse Indicators
1	Figen	Kaan, what do you think? Could this journalist be misleading the issue?	Initiation
2	S1	No.	Response
3	Figen	Why do you think that?	Feedback
4	S1	These are things that could happen.	Response
5	Figen	You're saying these are things that can happen. What if it's not happening?	Feedback
6	S2	Then he wouldn't have chosen to publish this story.	Response
7	Figen	Well, what else?	Feedback
8	S3	We don't know if it's possible, but the journalist doesn't have any evidence, and if he had proof, we might have thought he didn't deflect it.	Response
9	Figen	Ok, any other opinion?	Feedback
10	S1	It may occur or not; but we would have understood if he deflected.	Response
11	Figen	You're saying if he deflects, it'll be understood by society.	Feedback
12	S2	Everyone has their own truth, maybe he is not deflecting it.	Response
13	Figen	You say, he may not be deflecting the issue	Feedback
14	S3	He may be deflecting.	Response
15	S4	He may be misleading the society. That's why scientists should do research on the issue.	Response
16	Figen	So, my question is, why would those making such news wanted to mislead society?	Feedback
17	S1	Of course, they may be right, but it's already proven that nuclear plants are potentially harmful.	Response
18	S2	I think he reflects his own thoughts, it may inevitably be right or wrong.	Response
19	Figen	Your friend says that the journalist has his own thoughts, he has his own feelings, so those thoughts and feelings may have an effect on what he claims. I like to hear your thoughts about this?	
20	S1	Everyone has their own truths; but if you don't have any evidence to support these, spreading these might be wrong.	Response
21	Figen	Well, he says he didn't provide any evidenceabout his claims, we should not make claims about such serious matters without evidence or information.	Evaluation

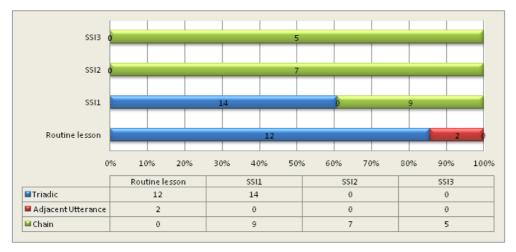


Figure 4. Discourse Patterns Observed in Seda's Routine and SSI Courses.

Table 11. An Example of A Triadic Discourse Pattern Recorded in Seda's Routine Lesson.			
Line	Speaker		Discourse Indicators
1	Seda	Now let's look at electron configuration of hydrogen. How many electrons does it have?	Question
2	S1	One.	Response
3	Seda	There's only one. It does not have any other electrons. Now, hydrogen says that "I offer my only electron" And chlorine says, "If you share your only electron, I will share one of seven electrons in my last orbit with you."	Evaluation

tioned as a facilitator of the discourse in that she asked students to deepen their answers and rephrased their answers while providing feedback. **Table 10** presents a sample chain discourse pattern dialogue recorded in Figen's SSI2 lesson.

In the dialogue presented in **Table 10**, having presented a newspaper article about building new nuclear power plants, Figen initiated the discourse by asking about the reliability of claims presented in the article regarding nuclear power plants (Line 1). A student answered negatively (Line 2), and Figen asked the reason for the answer (Line 3), asking the student to expand his answer. In Line 9, Figen expanded the interaction by using the phrase "Any other opinion?" This is one of the chain discourse pattern words to get other students' answers. As seen in the table, Figen provided feedback and asked new questions to expand and continue the discourse (Lines 5, 11 and 19).

#### Seda

Seda conducted both routine and SSI lessons in an 8th-grade class. **Figure 4** shows the discourse patterns observed in Seda's routine and SSI lessons.

As seen in **Figure 4**, Seda used only the triadic and adjacent utterance discourse patterns in her routine lesson. While the chain discourse pattern was not used in her routine lesson, it became the dominant pattern in the SSI lessons (nine times in SSI1, seven times in SSI2 and five times in SSI3). **Table 11** provides an example of a triadic discourse pattern observed in Seda's routine lesson.

As seen in **Table 11**, Seda asked students, "Now let's look at the electron configuration of hydrogen. How many electrons does it have?" (Line 1). This question started the dialogue and a student answered: "One" (Line 2). When Seda heard the expected answer, she evaluated the answer and ended the triadic pattern.

She also used the adjacent utterance discourse pattern twice in her routine lesson, to check and recall previous learning. **Table 12** presents one of the adjacent utterance discourse patterns observed in Seda's routine lesson.

As presented in **Table 12**, Seda initiated the dialogue with a question on covalent bonds: "... lets' think about this. How many electrons in total will they share?" (Line 1). Having received the correct answers from the students (Lines 2 and 4), she posed new questions without any evaluation or feedback (Lines 3 and 6). Thus, the adjacent utterance discourse pattern occurs in the form of Initiation-Response-Initiation-Response in the dialogue.

Seda continued to use the triadic discourse pattern in the SSI1 lesson, where previous learning was reviewed and repeated. However, the chain discourse pattern was the dominant strategy in all SSI lessons, in which students presented and explained their perspectives on controversial topics. **Table 13** presents a chain discourse pattern observed in Seda's SS3I lesson.

As seen in **Table 13**, Seda started the dialogue with an initiation sentence: "Now, finally, I'm going to ask you this. So far, we've talked about organic farming. Now, what can be done for the people who live around Lake Seyfe if they cannot live on farming? Let's think about it. One of your friends said they should sell their farms" (Line 1). The student repeated his answer to the class (Line 2) and Seda requested more explanation (Line 3). This dialogue constitutes a pattern of chain discourse with no evaluation until Line 13. The dialogue continued with a new initiation question in Line 13 without evaluating the answers from the students (Line 11 and Line 12). Concerning the student's answer, "Miss, in organic farming, the environment does not get dirty" (Line 14), Seda provided feedback "You are saying the environment does not get polluted when it is organic. What about waste materials?" (Line 15) and then provided an evaluation (Line 17). The dialogue

### Table 12. An Example of the Adjacent Utterance Discourse Pattern Recorded in Seda's Routine Lesson.

Line	Speaker		Discourse Indicators
1	Seda	Come on, lets' think about this. How many electrons in total will they share?	Initiation
2	S1	Two.	Response
3	Seda	How many electrons each atom going to share?	Initiation
4	S2	One.	Response
5	S1	Not one, two!	Response
6	Seda	The more the need, the more it will be put out there. How much is the need?	Initiation

### Table 13. An Example of the Chain Discourse Pattern Recorded in Seda's SSI3 Lesson.

Order	Speaker		Discourse Indicators
1	Seda	Now, finally, I'm going to ask you this. So far, we've talked about organic farming. Now what can be done for the people who live around Lake Seyfe if they cannot live on farming? Let's think about it. One of your friends said they should sell their farms.	Initiation
2	S1	No, they may sell those lands to scientists. And with that money, they can buy fertile lands somewhere else.	Response
3	Seda	Well, is that your alternative solution?	Feedback
4	S1	Then they may do fishing. If they can't make a living with it, a lot of people have migrated from villages to cities, and they can do as well.	Response
5	S2	But life is very difficult in cities.	Response
6	S1	Well, everyone can manage it.	Response
7	Seda	But, Samet, think of it this way. How do they live in the city if they can only know farming?	Feedback
8	S1	They should think about the fish, too. If they are farmers, they should think of other creatures living in Lake Seyfe. They should do organic farming, then.	
9	S2	Then, we are not in favor of fishing.	Response
10	Seda	Why aren't you?	Feedback
11	S2	It damages the ecosystem.	Response
12	S3	Because those birds feed on fish.	
13	Seda	Omer, what do you think of the people in the villages there? For example, you think they should do organic farming. There may be some downsides to that. Like environmental pollution? What are your solutions for these?	Initiation
14	S2	Miss, in organic farming, the environment does not get dirty.	Response
15	Seda	You are saying the environment does not get polluted when it is organic. What about waste materials?	Feedback
16	S2	Recycling.	
17	Seda	Yes, recycling is important. But how can we promote recycling?	
18	S1	By informing people.	Response
19	Seda	We have to inform them. How is that going to work?	Feedback
20	S1	There can be places to collect waste material, too, about recycling.	Response
21	Seda	Places to collect waste material. Well, then, these materials could sent to the relevant places.	

Table 14. Frequencies and Ratios of Discourse Patterns Used by the Participant Teachers in Their Routine and SSI Lessons.

Teacher	Lesson Type	Frequency and Ratio of Discourse Patterns Used		
reacher		Adjacent Utterance	Triadic	Chain
Kayra	Routine	0	36 (100%)	0
	SSI1	1 (10%)	7 (70%)	2 (20%)
	SSI2	0	0	6 (100%)
	SSI3	0	0	2 (100%)
Sevil	Routine	3 (8%)	37 (92%)	0
	SSI1	0	17 (71%)	7 (29%)
	SSI2	0	15 (60%)	10 (40%)
	SSI3	0	5 (29%)	12 (71%)
Figen	Routine	5 (10%)	42 (88%)	1 (2%)
	SSI1	0	14 (59%)	11 (41%)
	SSI2	0	1 (10%)	9 (90%)
	SSI3	2 (8%)	5 (19%)	19 (73%)
Seda	Routine	2 (14%)	12 (86%)	0
	SSI1	0	14 (61%)	9 (39%)
	SSI2	0	0	7 (100%)
	SSI3	0	0	5 (100%)

continued with a new chain discourse pattern that took the form of Initiation-Response-Feedback-Response-Evaluation (Lines 17, 18, 19, 20 and 21).

In **Table 14**, frequencies and ratios of discourse patterns used by the teachers in SSI lessons are presented in comparison with their routine lessons.

As outlined in **Table 14**, Kayra spent her entire routine lesson using the triadic discourse pattern for review and to assess whether the students had understood the subject. The chain discourse pattern was never used in this lesson. In her SSI lessons, however, the number of adjacent utterance discourse patterns and triple discourse patterns decreased while the use of chain discourse patterns became dominant, especially in SSI2 and SSI3 lessons. Although the number of uses of these chain discourse patterns may seem small (two and six times), these dialogues were lengthy and covered almost all the lesson time.

**Table 14** shows that Sevil conducted her routine lesson using mostly the triadic (37 times) and adjacent utterance (three times) as a discourse pattern. Sevil did not use the adjacent utterance discourse pattern in her lessons in the context of the SSI, reduced the use of the triple discourse pattern (SSI1, SSI2, and SSI3, respectively; 17, 15, and five times), and increased the use of chain discourse pattern (SSI1, SSI2, and SSI3, respectively; seven, ten, and 12 times).

As seen in **Table 14**, Figen dominantly used the triple discourse pattern (42 times) in her routine lesson. She used the adjacent utterance five times, and the chain discourse pattern was used only once, which constituted only a small part of the lesson time. Figen continued to use each of the discourse patterns in SSI lessons. However, the chain discourse pattern became the most used strategy compared to the routine lesson.

Lastly, the triple discourse pattern was the major strategy (12 times) in Seda's routine lesson. However, the chain discourse pattern appeared for the first time and became the major strategy in the context of SSI.

#### **Discussion and Conclusion**

In this study, the change in discourse patterns used by science teachers in their routine and SSI lessons was examined. Routine lessons and lessons conducted in the context of SSI of four science teachers were analysed in terms of classroom discourse.

According to the results of the research, the participating teachers routinely used the triadic and adjacent utterance discourse patterns in their everyday lessons. Studies in this line of research confirm that teachers predominantly use the triadic discourse pattern in their classrooms (Kaya & Kilic, 2010; Lemke, 1990; Molinari & Mameli 2010; Nassaji & Wells, 2000). According to Lemke (1990), teachers often prefer the triadic discourse pattern as it provides advantages such as ensuring classroom management and establishing authority. In traditional classroom environments, the teacher transmits the knowledge, which the students are expected to remember later. Teachers often use methods of telling and showing in their lessons for this purpose. In this teaching model, knowledge is a collection of information independent of personal interpretation, while students are passive recipients who receive this information. The findings of this study indicated that teachers used the triadic and adjacent utterance discourse patterns in this traditional approach. They used these strategies to transmit new knowledge, to get students to remember and repeat previously learned knowledge, to measure whether students understood the subject and to combine new learning with previous knowledge in students' minds.

In many science classes, like those in participants' routine lessons in this study, the students have little room in classroom discourse. Many students do not speak at all, ideas arise but are not interpreted, and those that do not conform to the scientific perspective are ignored or corrected. Putman (2006) states that such teacher-centred authoritarian dialogues are preferred because it makes it easier to control class time and student behaviour. In such an environment, even though the teacher asks leading questions, the responses from the students tend to be limited to odd words here and there, interspersed in the teacher's delivery (Mortimer & Scott, 2003). Although

the teacher and students communicate in such interactions, the teacher's goal is to hear the correct information from the students. Often teachers even ignored wrong answers from students and only evaluated the correct answers. In addition, students' participation in the course decreases when the teacher responds to the student's answers (Nassaji & Wells, 2000). According to Alexander (2013), the consequences of this type of dialogic exchange, in which talk is essentially one-sided and cognitively unchallenging, are three-fold: first, children may not learn as effectively as they should; second, children's potential to engage in dialogic interactions that challenge current perspectives or demonstrate their explanatory capacities may be inhibited or less developed; and third, teachers may be unaware of their students' understanding.

In classrooms where dialogical discourses are prioritised, however, the situation is the opposite. The teacher considers student ideas, enabling different ideas to be explored and combined (Scott et al., 2006). In addition, the teacher is not expected to give the student ready-made information, but to wait for the student to discover, encourage discussion of different ideas and guide them where necessary (Akpinar & Ergin, 2005). The results of this study show that the class atmosphere becomes dialogical with the use of SSI contexts. The participant teachers used the triadic and adjacent utterance discourse patterns in their SSI lessons, and the purpose was the same as that of routine lessons. However, their use of the adjacent utterance and triadic discourse patterns decreased dramatically in lessons in which SSI was used as a teaching and learning context compared to their routine lessons, while the use of the chain discourse pattern increased. Similarly, Bosser and Lindahl (2021) demonstrated that teachers could effectively utilize different communicative approaches in their classrooms to promote students' reasoning skills. It was evident that, as the SSI context allows students to present their ideas and perspectives, the chain discourse pattern emerged naturally in these lessons. In fact, in lessons taught in the context of SSI, the chain discourse pattern was sometimes the dominant approach and was used throughout the lesson.

In these lessons, the nature of classroom interaction changed. Significantly, the types and nature of questions were different compared with those of routine lessons. These questions were generally open-ended and controversial in that the answers varied by person, and the teacher provided continuous feedback. Indeed, it seemed that one of the important differences in SSI-based science teaching was the type of questions that the teacher used in dialogues. It was clear that SSI contexts allowed the teachers ask to thought-provoking questions that allowed students to express their thoughts and compare them with different ideas. Thought-provoking questions such as "Why do you think that? Why is this relevant? Can you explain that a little bit? What if it wasn't? So, what could happen in this situation?" are called

guidance questions (Brooks & Brooks, 1999). The analysis of the classroom discourse indicated that such reflective and thought-provoking questions were frequently used in lessons taught in the SSI context and naturally increased the number of chain discourse patterns.

In learning environments where scientific talk and argumentation are valued and prioritised, students find opportunities to communicate their thoughts freely and compare new ideas with their own (Jiménez-Aleixandre et al., 2000). In cases of no tension between existing and new views, learning progresses is easy for the individual. At other times, conflicts may emerge and will need to be resolved if new and existing ideas are to be integrated. Whatever the path, meaning-making is a fundamentally dialogic process in which different ideas are brought together and worked upon (Mortimer & Scott, 2003). The significance of SSI contexts for science learning appears here since SSI provides important possibilities for social exchange and class-room conversation.

The results of this study show that promoting SSI contexts in science classes is essential to increase the use of dialogical discourse. Sadler (2011) argues that in SSI teaching the teacher is the one who directs the discussion rather than being an authority in the learning environment. The use of dialogical discourse is manifested in the chain discourse patterns, in which dialogue is shaped based on student ideas. In addition, in this study, communication in such dialogues took place not only between teacher and student but also between students. Similarly, Chung et al. (2014) found that SSI instruction could help students to understand the key ideas of others and value their perspectives. Like Gillies's (2016) results, dialogues showed that students changed their minds as they listened to their pairs' opinions.

Indeed, teachers often encounter situations such as crowded classes, time limitations, and discipline problems, which, in turn, negatively affect teaching and learning (Dogan, 2021; Lehesvuori, 2013; Pimentel & McNeil, 2013). All these factors also restrict dialogic exchanges. However, the findings from this study revealed that the SSI context positively diversified the discourse patterns that appear in science courses. This situation suggests that the use of SSI as context will improve communication and interaction in science classes, thus being an important approach to achieving the goal of scientific literacy.

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# Inquiry-based Learning in Junior Secondary Geography Education: A Lesson Analysis of China's Natural Resources Teaching

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Abstract: This paper is a lesson study of the instruction of China's Natural Resources (the third unit of eighth-grade geography), and its objective is to examine the efficacy of inquiry-based learning in geography education. In the experimental lesson, we reorganized the teaching content by integrating the learning materials from the four sections of Natural Resources Overview, Land Resources, Water Resources, and Marine Resources in the unit. With proposed real-world situations and learning tasks, students posed research questions and conducted independent inquiry into issues such as the characteristics, distribution, and utilization of Chinese natural resources, as well as the existing problems. In this procedure, students gained the right methods and skills for geographical study, thereby enhancing their academic competency in geography.

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EOGRAPHY, a subject that combines elements of the natural and rsocial sciences, can not only offer students a wealth of geographical knowledge but also heighten their understanding of the connections between the environment and human activity. China's junior secondary geography education is now plagued by its traditional teaching methodology, which mainly relies on the instructor providing information from textbooks and their own expertise of the subject. In such a mode of instruction, students are passive recipients of knowledge that has limited potential to be transformed into practical abilities; hence, their geographical competence cannot be enhanced. For instance, students may have theoretically mastered a number of methods for identifying directions, but in practice they are unable to recognize the east, west, north, and south. However, students cannot appreciate the complicated relationships between the environment and human activity through lecture alone. Students' perception and comprehension of the disciplinary principles underlying geographical phenomena are enhanced through inquiry-based learning in authentic contexts.

# What Is Inquiry-based Learning?

Instead of experiencing the process of learning new things, experimenting with different teaching strategies, and developing moral principles, students have traditionally been expected to memorize information from textbooks. The development of imaginative skills has become a social need for education in the information age, and all countries have made it their educational objective to help students develop these skills and an exploratory spirit. In this context, inquiry-based learning has received a lot of attention from educators throughout the globe as a pedagogical strategy intended to help students develop their higher-order thinking abilities. In their current reform of education and teaching, Chinese teachers are also aware of it.

Inquiry-based learning is a type of active learning that begins by providing questions, challenges, or scenarios and is dominated by students' independent, explorative research, according to the experience of the discovery learning movement (Wang, 2019). It includes coming up with questions, making observations, looking into information that already exists, designing experimental techniques, gathering, analyzing, and interpreting data, writing potential explanations, etc.

The status of geography education, where direction instruction and rote learning are predominant, can be changed by including inquiry-based learning, and students' abilities to recognize issues, process information, research, and analyze can be improved. In our investigation of inquiry-based learning in junior secondary geography instruction, phenomena are proposed by the teacher, research questions are raised by students, and study groups

are formed to collaboratively carry out learning tasks with the aim of developing students' critical thinking and problem-solving skills.

# **Teaching Practice Based on Inquiry-Based Learning**

# Requirements of the Course Standards and Learning Situations

Chinese Natural Resources Overview, Land Resources, Water Resources, and Sea Resources are the four sections that make up the China's Natural Resources subject in Volume One of the eighth-grade geography textbook. Students should be able to describe the key features of China's water, land, mineral, and marine resources, among other resources, using maps and pertinent materials, to illustrate the relationship between natural resources and human production and life with examples, and to comprehend the significance of natural resource exploitation, utilization, and preservation, all through the study of this unit, in accordance with the Compulsory Education Course Standards for Geography 2022 (Ministry of Education of China, 2022). Evidently, the national course standards set quite high standards for academic ability for the study of this unit, emphasizing that students need to understand the current state of China's natural resources, be able to explain how human activities and natural resources relate to one another from a regional perspective, and initially establish a scientific outlook on development that is suitable to local conditions.

The use of natural resources is essential to human existence, and students may have some limited knowledge of them via personal experience. Student comprehension of the true state of China's natural resources, however, is limited due to their lack of education and life experience. The distribution of natural resources across all areas and nations was discussed in a global geography lesson from the previous grade (grade seven), but it did not go into great detail. In general, students have very basic prior knowledge of natural resources, and they have not yet fully grasped the connections between natural resources and human activities. In order to assist students to meet the learning objectives of this unit through inquiry-based learning, teachers must construct research scenarios depending on their cognitive abilities, encourage them to pose research questions, and support them in doing so.

### Reorganizing Teaching Contents

The unit on China's Natural Resources is highly informative, particularly for junior secondary school students who are forming their values at this vital juncture in their lives. As a result, we not only emphasize students' mastery

of China's natural resources in lesson design and implementation but also attempt to draw their attention to actual social issues, raise their awareness of the importance and urgency of saving and protecting natural resources, and guide them to develop proper views of resources, the environment, and social development. We blended instructional materials from the four main portions of the unit and designed two learning challenges based on students' life experiences and cognitive abilities. (i) Investigating whether China is rich in natural resources or deficient in them; (ii) Making recommendations for the responsible use and preservation of natural resources. To provide students with richer subject matter for their inquiry-based learning, the lesson also included a series of hot topics of public concern, such as the carbon emission peak, carbon neutrality, renewable energy development, new energy vehicles, across-regional resource allocation, and tiered water and electricity prices.

## Setting Learning Objectives for Students

- To express their understanding of the idea that "natural resources are an important prerequisite for human activities" and to summarize the two fundamental characteristics of natural resources—existing in the natural world and helping humans—using examples from real life,
- To determine whether China is a resource-rich nation by describing the fundamental characteristics of its natural resources using maps and pertinent data.
- To collect information, explain why China's national policy gives priority to the protection and preservation of natural resources as well as natural restoration, and make suggestions for how to do so by citing practical examples.

### **Instruction Processes**

# Task One: Looking for Evidence of Whether China Is Rich or Wanting in Natural Resources

#### • Introductory Situations

The teacher brought up the point that China has a vast land with a wide diversity and quantity of natural resources. At the same time, it has a large population and is experiencing significant economic development, which implies that natural resources are in high demand. What is the state of our resource reserves? Is China's natural resource base abundant or depleted? A variety of reading materials were distributed to students, including "A Comparison of World Rankings of China's Main Natural Resources and Its Per

Capita Quantity of Resources," "A Diagram of China's Oil Consumption and Production," "A Chart of China's Automobile Sales Growth," and "China's Coal, Oil, and Natural Gas Resources Distribution."

#### Question-based Cooperative Study

Students submitted questions based on their personal experiences and attempted to complete the learning task through autonomous and collaborative inquiry.

### i. Question One: "What are natural resources?"

Students made a list of as many common objects in life as they could, such as books, desks, rice, salt, lightning, air, sunlight, water, and so on, and then determined whether or not they are natural resources and explained why. Following that, group members discussed those undecided issues with one another and came up with the two basic characteristics of natural resources, which are that they exist in the natural world and benefit humans.

#### ii. Question Two: "Is China a naturally resource-rich country?"

The students first conducted independent research to learn more about the fundamental characteristics of China's key natural resources before formulating their own opinions on "whether China is a strong country in natural resources." They next engaged in in-group discussions to further their comprehension of how natural resources, the environment, and human activities are related.

#### Group Presentation and Debate

Each group provided their reasoning for their answer to the topic of whether China is a country rich in natural resources. Following inter-group discussion and debate, students agreed that China is rich in natural resources in total quantity, but its per capita share is small; that China has an unbalanced geographical distribution of natural resources; and that China has a large gap between supply and demand for natural resources.

#### Summary and Reflection

The application of inquiry-based learning requires real-world contexts and insightful questions. Students' interest in research, the development of an active learning environment, and their comprehension of the two fundamental characteristics of natural resources (natural and social attributes) could all be sparked by the classification of common resources. To gain a general understanding of China's natural resources, students conducted relevant data searches, recognized the key issues and their root causes, and learned the fundamental conditions of China's natural resources. In the interim, both the students' verbal communication skills and their capacity to extract pertinent information from texts and figures have significantly increased. Their

awareness of the value of and need to protect the environment emerged on its own.

# Task Two: Proposing Suggestions for Reasonable Utilization and Preservation of Natural Resources

#### Introductory Situations

As a result of its expanding population and rapid economic development, China's lack of resources has become increasingly acute, impeding the country's ability to sustainably develop its economy and society. How to protect and make judicious use of natural resources is a critical issue that requires immediate attention (Cai & Zhou, 2013).

#### Question-based Cooperative Study

Students divided themselves into several groups based on the questions they were interested in exploring, and they carried out their research in groups.

i. Question One: "What is the status quo of China's natural resource utilization?"

Students gathered and studied national policies on the exploitation and utilization of natural resources to determine the importance of governmental regulation of this issue; they looked for specific cases to examine the problems in China's natural resource exploitation and utilization; and they proposed solutions for rational resource use from both the national and individual perspectives. Individual opinions were expressed in group discussions, and it was eventually agreed that both developing renewable resources and conserving conventional ones are critical to managing natural resource limitations.

ii. Question Two: "What is the water and electricity consumption of our school like?"

The study group spoke with the teacher in charge of school logistics to learn more about how much water and power the school uses and consumes. The next step was to document the phenomenon of water and electricity waste in schools by visiting all locations where water and electricity were required. Finally, a group discussion was held to generate workable ideas for conserving water and electricity in the school. The topic was "what I can do to save water and electricity on the campus."

#### Group Presentation and Debate

With an emphasis on the current issues with resource use in China and potential improvement measures for resource conservation and preservation, group presentations were made to discuss the investigation's findings.

#### Summary and Reflection

By collecting data on their own, students discovered the true scale of natural resource waste in China and the significance of rational usage of natural resources, which aided in the development of rational perspectives on resources, the environment, and social progress in them.

Using task-based learning, students were able to study real-world geography. By studying the school's water and electricity consumption, students were able to apply theoretical knowledge to real-world scenarios and become more aware of the resource issue on campus. In addition, the process of proposing recommendations for minimizing water and electricity waste in schools could increase students' sense of responsibility towards the school and society.

# **Findings of the Lesson Study**

### An Evaluation of Instructional Results

According to the set arrangement of chapters and parts, geography teachers often explain the fragmented knowledge points in the textbook one at a time. When taught about China's natural resources in a traditional classroom, for instance, most students struggle to explain the country's overall natural resource situation or to use examples to explain the connections between natural resources, the environment, and human activities, let alone to understand the country's current resource policies and regulations in the context of historical development. In inquiry-based learning, which is guided by learning tasks and questions, students carefully read the text and figures in the textbook and actively seek out additional material to find answers to predetermined questions and establish their own judgments on resource-related issues. To deepen their understanding of key ideas like "Natural resources are fundamental to human activities," "Exploitation, utilization, and preservation of natural resources are interconnected aspects in holistic planning," and "Developing new sources of resources and conserving reserves are both crucial to addressing natural resource shortages," students are guided to discuss hot topics of public concern in the interim. Moreover, students' favorable attitudes about resources, the environment, and human growth are greatly fostered by this inquisitive learning approach.

### Observers' Comments

"Is China wealthy or impoverished in terms of natural resources?" Such difficult questions led to students properly understanding the essential topic—natural resources—and established a link between conceptual knowledge and the real world. They also piqued students' interest in geography. This class was dominated by inquiry-based learning, with students serving as the primary actors. Students do learning exercises based on research topics in an

open learning environment with extra learning materials. Students constructed a thinking route for tackling resource concerns by combining independent learning and group study, which consists of the following steps: raising questions, researching questions, and solving problems. This way of thinking is applicable in different circumstances. As a result, students' academic ability improves on its own.

## Comments from the Lesson Evaluation Specialist

In this case of inquiry-based instruction on China's natural resources, students have been actively engaged in identifying and investigating topics and problems to create knowledge and solutions. Students had a relatively full comprehension of the categories of natural resources and the relationships between natural resources, the environment, and human activities as a result of the learning activity "searching for evidence to determine if China is rich or poor in natural resources." Students realized, for example, that the uneven distribution of water resources in China is related to its unbalanced precipitation in terms of time and space, and that the distribution of land resources is determined by its topography; that water resources and land resources in most regions are mismatched to varying degrees; and that the same natural resource conditions have distinct effects on the economic development of different regions in China. The "proposing suggestions for reasonable utilization and preservation of natural resources" learning task was successful in drawing students' attention to resource issues in real life and reality, motivating them to collect information via multiple media and use concrete examples to present the current state of resource exploitation and utilization, and educating them to consciously conserve resources in everyday life to align their knowledge with their behavior. The pedagogical method of inquirybased learning has been properly implemented to achieve the learning objectives of this lesson, which are to acquire preliminary knowledge of the basic condition of China's natural resources and cultivate an initial awareness of the prudent use and preservation of natural resources.

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# Environmental Sustainability in Science Education in the Anthropocene: A View from STEAM Education

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Abstract: Environmental problems in the age we live in require us to think differently, to question them, and to do something corrective. The role of science education in the transformation of education and its adaptation to the age is perhaps more than in previous periods. Because at the end of the day is the continuity of our planet. This article examines science education and higher-order thinking skills in the Anthropocene era and presents examples from studies on environmental sustainability as a prominent concept in this field. In addition, it argues that STEAM education is one of the ideal approaches that can meet this goal by presenting examples of what can be done with a holistic and interdisciplinary view of environmental sustainability within the framework of STEAM education. Suggestions are made through STEAM training, with the assumption that environmental sustainability in an intricately connected network structure rather than linear chains can only be understood with an interdisciplinary approach and solutions can be found only in this way.

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#### Introduction

THE Concept of Sustainability that has come to the Forefront in the Anthropocene Era. Anthropocene, it comes from the Greek words "anthro" meaning "human" and "cene" meaning "new (geological age)" and refers to the end of the Holocene age and a new geological age in which human activities have had a great impact on the world (Gilbert, 2016). So anymore human; it is trying to improve and change the world he lives in, and this effect is more than in the previous geological periods of the world. It is also obvious that the effect of change is mostly in the direction of harming the world. Many argue that we are in a "climate emergency" and that urgent action is necessary if we want to prevent a sudden catastrophic change (Gilbert, 2022). With the declaration of 2005-2014 as the Education Period focused on Sustainable Development by the United Nations; It is aimed to improve the cognition, perception and behavior of individuals on a sustainable lifestyle and to realize social transformations in the long term (Ozturk, 2017). In the OECD Education 2030 report, "children starting school in 2018 abandon the notion that resources are unlimited and exist to be exploited; they will need to value shared well-being, sustainability and well-being." with this expression, attention was drawn to the environmental, economic and social challenges for the future of the world (OECD, 2018). In its press release published on 14 January 2022, the European Union called for environmental sustainability to be at the center of EU education and training systems (EU Press Release, 2022). The new vision of K-12 education is that instead of telling students what the phenomenon is and then expecting them to recreate the phenomenon, it should include the role of the confounders of nature and human activity through actions, making the nature of phenomena clear (Milne et al., 2022). So much so that today there is no need to produce disaster scenarios and brainstorm with dystopian fictions, especially environmental disasters exist in our lives. In this case, the problem scenarios turned away from fiction and turned into real problems waiting for an urgent solution.

The damage caused to the ecosystem by the economic and social development experienced in the 20th century has led to the discussion of the concept of sustainability in the last half century (Bazin, 2012). Sustainability consists of three dimensions: environmental, economic and social (Bazin, 2012; Clark et al., 2019). For economic sustainability, a radical new model, the Circular Economy, is proposed instead of the linear economy based on the "buy-build-use-dispose" consumption model since the Industrial Revolution (Andrews, 2015). For social sustainability, the importance of integrating multicultural education, inclusive teaching and learning approaches into education systems emerges (Skrefsrud, 2022). The environmental dimension

is more prominent than these two concepts (Clark et al., 2019). This article also focuses on the environmental sustainability dimension.

Sustainability is a system of systems that requires a high level of understanding beyond concepts and principles (Clark et al., 2019). There are three themes (universalism, scientism, and technocentrism) common to the scientific discourse on sustainability (Feinstein & Kirchgasler, 2015). Sustainable development is shaped according to the needs in different parts of the world and in different historical periods in relation to supply and demand elements (Arslan, 2021).

Education for Sustainability is about providing real-world learning opportunities related to the change of current thinking, practice and values, and this should be a fundamental research question for all educational institutions and fields (Jacobi et al., 2016). Education for sustainability is a goal, not a tool (Albe, 2013). Education for sustainability reveals the necessity of a critical scientific education (de Freitas et al., 2022). On the other hand, there are also criticisms against the theme of sustainability. Kopnina (2020) criticizes the economy-centeredness of sustainable development and emphasizes teaching for sustainability with various examples of alternative education (indigenous learning, ecopedagogy, ecocentric education, education for steady state and circular economy, empowerment and liberation) emphasizing planned ethics and degrowth.

Doğru et al. (2019) found that interest in the field has increased since 2015, when they made a bibliometric analysis of 7 thousand studies in the field of sustainable development and education. Yıldırım (2020), who examined the educational researches in Turkey on sustainability, stated that the subject was mostly dealt with in relation to science and social studies education. Arslan (2021) as a result of his interviews with the participants (teachers, academics, non-governmental organizations, policy makers/practitioners) who have roles and responsibilities in STEM education in the context of Turkey, he made policy proposals for STEM education. Besides he suggested increasing teacher competencies, integrating STEM approach into curriculum, establishing physical infrastructure, ensuring that all stakeholders are involved in the process, the students participate in STEM careers, direct them to STEM careers, and make effective dissemination activities with an inclusive policy.

# **Sustainability Concept in Science Education**

One of the fundamental assumptions of science education is to provide citizens with a critical reading of the world and to reflect on their own circumstances as they face the challenges of science and technology (de Freitas et al., 2022). Although science education has been shaped by different ideas over the years, it has brought pre-vocational education to future scientists,

worked with methods familiar to twentieth-century scientists, and raised willing "science literate" citizens (Gilbert, 2016). For sustainability, it is necessary to improve science education and scientific literacy of society worldwide (Johnson, 2012).

In the Science Education Eligibility (ROSE) project, in which students in the 15-year-old age group are come up in approximately 40 countries; in many industrialized countries, it has been reported that students are suspicious of the objectivity of scientists, science is less popular than other subjects, and these negative perceptions are more common in girls (Gough, 2008). For this reason, since the role of science education is directly proportional to the perception of science and scientists, it is also important in terms of the position of science in society.

The globalization of the world and the changes in the Anthropocene age require a rethinking of science education (Gray & Colucci-Gray, 2014). Considering the end of carbonized modernity, science education is on the verge of transformation (Gilbert, 2016). To ensure sustainability, redesigning science education has become a necessity, not an option (Bateman et al., 2021). Stating that the Anthropocene can be used as an analytical lens in history and philosophy of science, Moura and Guerra (2022) stated that the nature of science studies have not yet taken the Anthropocene into account. By connecting cognitive and affective domains, it can associate understandings in the physical world with attitudes and values in the social world and provide a process that can facilitate the motivation to take conscious action (Quinn et al., 2015). At this point, environmental education issues, which can be considered as one of the dimensions of science education, come to the fore. Since there is a promising synergy between science education and environmental education, it should be ensured that environmental issues are more integrated into the learning process in science education rather than seen as a separate learning content or intermediate topics, so that both efforts enrich each other (Schönfelder & Bogner, 2020).

The basic framework of science education dedicated to sustainability; change in purpose refers to changes in the subject-object relationship, changes in content and methodological choices (Albe, 2013). Principles to be adopted in environmental education, interdisciplinarity, integrity, continuity, questioning, experientialism, inclusiveness, flexibility, local-global interaction, participation, constructivism, learning by doing-living, predictive learning and innovation (Özdemir, 2007). Scientific literacy is essential to understanding many sustainability issues and especially possible solutions to the environment (Quinn et al., 2015). Science education based on sustainability can offer channels for understanding human's relationship with the world beyond ecological benefits (Jeong et al., 2021). Science literacy for sustainability; means the development of evaluative systems thinking ability in the context of science, technology, environment and society, which requires the

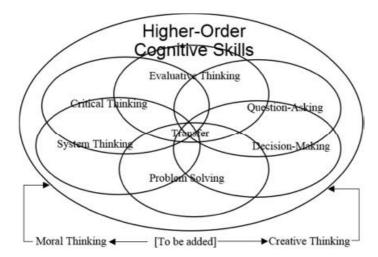


Figure 1: Conceptual Model of Higher-Order Thinking Skills in the Context of Science Education and Sustainability (Zoller, 2015, p. 4476).

development of students' high-level cognitive skills (HOCS), systems critical thinking, and questions (Zoller, 2012).

# High-Level Thinking Skills in the Context of Sustainability in Science Education

Core competencies in sustainability; are high-level skills such as systems thinking, forward thinking, exemplification, strategic competence, and interpersonal competence. These competencies are above the basic competency such as critical thinking and communication (Wiek et al., 2011). High-level thinking skills are skills that cause teachers to push and expand their abilities in flexible and rich teaching environments and require radical changes in teaching practices (Zohar, 2013). As seen in **Figure 1**, high-level cognitive skills such as critical thinking, systems thinking, problem solving, decision making, asking questions, evaluative thinking, and transferring; considered within the framework of moral thinking and creative thinking.

System thinking, community participation, multidisciplinary thinking, cross-discipline transfer, and strong foundations of discipline should be involved in order to solve the problems of the 20th century with the understanding of the 21st century (Rogers et al., 2015). It can be thought that systems thinking and interdisciplinary thinking are particularly prominent concepts.

# What can Science Education do for Environmental Sustainability?

Few studies have focused on the future-thinking potential and futurism of science education (Rasa et al., 2022). Scientific studies in recent years. It increasingly emphasizes the diversity and locality of scientific practices, moving away from the idea of a single scientific method approach or universal method (Albe, 2013). Locality should be addressed in science education and culture should be comprehensively included in science education (Zidny et al., 2020). When Ateş (2018) examined the Science 2018 curriculum in Turkey, he stated that the achievements related to sustainable development were 10.82 percent and should be increased.

One of the important fields of study in which environmental sustainability can be discussed in science education is socio-scientific issues. As socio-scientific issues bring up the science-human interaction, students' tendencies are at the center of curriculum outcomes (Tytler, 2012). Socio-scientific issues are influential in the potential role of science education in thinking and acting about the future (Rasa et al., 2022). Colucci-Gray et al. (2006) have combined the term socio-scientific issues one step further with systems thinking using the term socio-environmental.

Science education practices that center sustainability has been on the agenda for a long time. Sustainable Schools in Australia such as Eco Schools, Green Schools; it deals with waste, energy, water and biodiversity (Gough, 2008). Birdsall (2013) determined that as a result of the sustainability education program he conducted with New Zealand students, their understanding of sustainability and science literacy developed and they showed behavior as activists. Laird (2017) gave the Montessori-inspired Edible School Garden project as an example and suggested the project to sustainability education by giving children a chance to meet with the open air. Seker (2017) concluded in his experimental study with secondary school fifth grade students that the science education program for sustainable development had a positive effect on academic achievement and views on sustainable development. In an experimental study conducted in a kindergarten in Sweden, it was pointed out that children's imaginations offer different solutions that can be beneficial to sustainability-related problems (Caiman & Lundeg ård, 2018). Levrini et al. (2019) stated that the climate change teaching module they conducted with 12th grade students in Italy improved students' perceptions of building the future. In a study conducted in Iran, it was revealed that when primary and secondary school students were asked to draw pictures for the future, children who thought they could have an impact on the environment drew optimistic utopian pictures, while sedentary children who did not accept responsibility drew dystopian pictures (Demneh & Darani, 2020). Trott

and Weinberg (2020) concluded that thanks to sustainability-based science education, children's attitudes towards science improve, understanding the scientific and social dimensions of climate change expands their view of science, and the urgency of climate change solutions makes it more interesting and important for children. As seen in these examples, "what kind of future awaits us and what solutions?", "we can create for future solutions on problems?" like questions are closely related to the sustainability perception of today's children.

A science education that addresses the challenges of today can be decisive in creating the future when children are provided with the space to be critical actors for sustainability in their society (Trott & Weinberg, 2020). To put it more bluntly, the world of tomorrow may be just as much in the minds of today's children. Evans & Marianne Achiam (2021) drew attention to out-of-school learning environments in sustainability education and stated that museums, science centers, zoos and aquariums have strong potential for promoting sustainability.

## **Environmental Sustainability in STEAM Education**

Arguing that environmental education is one of the STEM disciplines, Geidel and Winner (2016) explained the reason for this; they explained that environmental science is based on the scientific method and discovery process, is empirical and predictive, is meticulous in providing certain skills for analytical analysis, and provides students with critical thinking skills. Interdisciplinary dialogue is considered as a necessity for addressing contemporary science issues in society and as a tool for questioning the focus boundaries of thought categories and methodologies (Colucci-Gray et al., 2013). Scientists need to be prepared interdisciplinary both in their field of science and in data science (Pennington et al., 2020). Colucci-Gray et al. (2013) suggest interdisciplinary approaches to sustainability education. Pedagogical design, socio-efficiency and philosophy are the main themes in sustainable interdisciplinary education (Daneshpour & Kwegyir-Afful, 2022). Bateman, Steele & Sexton (2021) stated that students should work as "sustainability engineers" in science classes. Levrini et al. (2019) stated that future-oriented STEM education, which is still in its infancy, should become a new trend. Integrating disciplinary views can contribute to reconnecting with and feeling included in nature (Colucci-Gray et al., 2013). As seen in Figure 2, the integrative approach, as opposed to the reductionist approach, can enable the development of an environmental sustainability view by addressing more than one way of thinking.

There are studies on STEM education that focuses on sustainability. Clark & Button (2011) carried out a study in sustainability that brought together public schools, art museums, non-governmental organizations, gov-

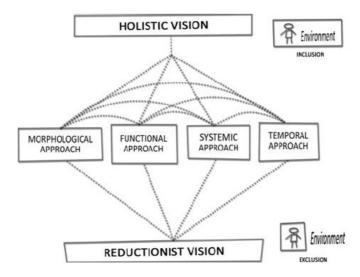


Figure 2: Integrative Approach to Nature (Colucci-Gray et al., 2013).

ernment officials and the general public under the umbrella of STEM. They concluded that by learning from each other, the participants gained a broad and deep understanding of human-environment relationships and the effects of humans on natural resources. Rogers et al. (2015) carried out studies designed to connect perspectives from different disciplines with technical reports from other classes and to write short technical reports summarizing students' results with STEM activities in modules containing inclusive questions. As a result of the studies, they stated that the students' understanding of the characteristics of the twenty-first century problems related to sustainability has improved. Caughman (2017) stated that in STEM education, sustainability education-themed courses affect students' science identities positively and contribute to permanence in science. Kudo et al. (2021) stated that there are four learning outcomes after interdisciplinary sustainabilityoriented courses in higher education: Examining assumptions, managing misunderstanding and miscommunication, mutual learning, being empathetic and looking at life through the eyes of local people. Arisoy (2021), in her research aiming to raise awareness of sustainable life at an early age, implemented a training program in which they tried to find solutions to daily life problems for Sustainable Development Goals in STEM design workshops. Uslu & Boz Yaman (2021) helped secondary school students to come up with an engineering design for the reuse of wastewater in the activity called "Environmental Siphon Activity", which was considered as a STEM project. Campbell and Speldewinde (2022) pointed out that the game-based learning

of young children can be compatible with STEM and sustainability and drew attention to the importance of the subject even in early childhood.

The literature shows the lack of educational models that combine arts and sciences to encourage communities to think about sustainability, and STEM can fill this gap (Clark and Button, 2011). STEM; it deals with the world located at the intersection of science, art and society clusters (Clark & Button, 2011). Heras et al. (2021) set an example for the interdisciplinary collaboration of scientists and artists with their art-based sustainability studies. Trott et al. (2020) propose three methods for combining art and science:

- Interdisciplinary learning focusing on local sustainability challenges;
- Participatory process that combines experiential knowledge with research-based knowledge;
- Co-operative sustainability action that invites community members to design and implement sustainable alternatives where they live.

Smith & Watson (2019), who are critical of STEM education due to its emphasis on economic growth and technology, suggested that it be expanded to include critical reflection and future dimensions and strengthened with STEAM education. Finley (2014) and Feinstein & Kirchgasler (2015) propose an approach that combines the complementary pedagogical strengths of the two fields with a systematic collaboration between science educators and social studies educators for sustainability challenges. STEAM education also emphasizes this. STEAM education has been created with the solution of animation by bringing a new breath to the problems of fragmentation of disciplines and science teaching (Trott et al., 2020). Finley (2014) suggested that 3-4 week interdisciplinary Anthropocene projects can be developed with the cooperation of different fields such as physics, earth sciences, social sciences, and life sciences.

## **Conclusion and Suggestions**

Changes in the vision and mission of science education in the Anthropocene era have led to the concept of environmental sustainability. Addressing environmental sustainability through science education in k-12 grades and being one of the main sources of argument can activate higher-order thinking skills. Environmental sustainability is addressed through approaches such as socioscientific issues, inquiry, out-of-school science teaching, project and problem-based learning, and has a wide coverage in the literature.

As an interesting example, Bateman et al. (2021) likened beavers to an ecosystem engineer, and stated that they created a suitable habitat for others while eliminating the space of some organisms by building a dam. An environment without human influence provides the balance within itself.

However, as a result of the harmful activities of human beings, the balance is disturbed and can lead to irreversible disasters. Considering that man is only one of the parts of the system in the light of systems thinking, the negative perception of dominance over nature can be seen. For this reason, it is important to gain this knowledge, thought and sensitivity from childhood through educational means.

STEM/STEAM education, which has left its mark on the last years of science education with its holistic approach, is also involved in finding solutions to our problems in the Anthropocene and applying it. In particular, the artistic and social emphasis of STEAM education can function as the socioscientific perspective of STEM, providing a humanistic, holistic and developing perspective to our age. By conceptualizing STEAM in the Anthropocene, interdisciplinarity should be approached in a way that enables us to connect with people, try to break down disciplinary hierarchies, and embrace emerging tensions (Guyotte, 2019). In STEAM education at all levels, students should be exposed to many complex and pressing issues of the Anthropocene and interdisciplinary issues (Guyotte, 2019). In this context, it is suggested that STEAM education and the concept of environmental sustainability should be examined interdisciplinary and practices should be carried out with students at the k-12 level.

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