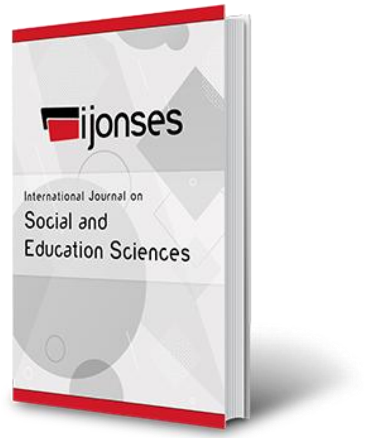

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Banu Avsar Erumit
Recep Tayyip Erdoğan University, Türkiye

Zeliha Yerlikaya
Recep Tayyip Erdoğan University, Türkiye

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Enhancing Pre-service Science Teachers' Views on the Nature of Science through QR Code Activities

Banu Avsar Erumit, Zeliha Yerlikaya

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Abstract

This study explores the potential of QR code technology in enhancing preservice science teachers' understanding of astronomy topics and their views on the Nature of Science (NOS). Using QR codes, the study focused on teaching complex concepts like the Kuiper Belt, dwarf planets, and Pluto's reclassification, while fostering an explicit and reflective approach to NOS dimensions such as tentativeness, creativity, subjectivity, and empirical observation. Designed as qualitative research, data collection included pre- and post-implementation interviews, reflective evaluations, and QR code-based activities developed by participants. The findings demonstrate that QR codes effectively improved conceptual understanding and facilitated the integration of NOS dimensions into teaching practices. Participants identified QR code activities as engaging and innovative, despite expressing concerns about technological infrastructure and accessibility in professional settings. The results highlight the importance of supporting technology integration in teacher education to maximize the pedagogical potential of digital tools. Future research should examine the application of QR codes across diverse science topics and grade levels, as well as investigate their long-term impact on NOS understanding and retention. By addressing barriers to implementation and providing targeted professional development, QR code technology can serve as a transformative tool for NOS instruction and broader science education.

Introduction

One of the primary goals of science education is to cultivate scientifically literate individuals (Roberts & Bybee, 2014). Scientific literacy encompasses the ability to understand, evaluate, and apply scientific knowledge (Miller, 1983). In today's society, where science and technology profoundly influence every aspect of life, fostering scientific literacy is paramount. Consequently, developing scientifically literate individuals has become a cornerstone of educational policies worldwide. Scientifically literate individuals not only comprehend the role of science in human life but also appreciate its dynamic relationship with technological advancement (Özden & Cavlazoğlu, 2015).

Understanding the nature of science (NOS) is a fundamental component of scientific literacy (DeBoer, 1991).

NOS refers to the epistemological underpinnings of science, the values and beliefs inherent in scientific inquiry, and the processes involved in the generation of scientific knowledge (Lederman, 1992). A robust grasp of NOS equips individuals to engage in meaningful learning and fosters the development of scientific reasoning (Abd-El-Khalick & Lederman, 2000). In this regard, science teachers hold a pivotal role in cultivating scientifically literate individuals.

Effective NOS instruction can be achieved through various approaches, including the history of science, socioscientific issues, and inquiry-based learning (Mulvey & Bell, 2017). Teaching NOS in contextualized ways allows students to connect scientific principles with real-world applications, enriching their understanding beyond traditional classroom boundaries (Akerson et al., 2011; Avsar Erumit & Yuksel, 2023; Avsar Erumit et al., 2024). This study integrates NOS dimensions with astronomy topics and the history of science, utilizing QR code technology to create an innovative learning experience.

Science teachers are tasked not only with teaching fundamental concepts and laws but also with explaining the historical and developmental processes of scientific knowledge (Türkmen & Yalçın, 2001). This dual focus helps students understand the nature, history, and philosophy of science. However, classroom practices often reveal that teachers struggle to convey NOS effectively, frequently presenting scientific knowledge based on their limited understanding (Türkmen & Yalçın, 2001). Thus, it is critical for educators themselves to have a deep understanding of NOS.

NOS encompasses what science is, how it operates, how scientists work, and how society interacts with scientific endeavors. It extends beyond simple observations and experiments, incorporating social, cultural, and cognitive dimensions (McComas et al., 1998). Key NOS elements include the tentativeness of scientific explanations, the subjectivity of scientists, the role of imagination and creativity, the empirical nature of science, and the societal and cultural influences on scientific knowledge (Lederman & Zeidler, 1987). These characteristics help demystify the complexities of science and foster critical thinking skills.

Despite its importance, teaching NOS effectively remains challenging. Factors such as limited teacher knowledge and insufficient emphasis on NOS in science curricula contribute to these difficulties (Akerson et al., 2019b; Özden & Cavlazoğlu, 2015). Research has shown that preservice science teachers often have misconceptions or insufficient understanding of NOS (Gürses et al., 2005; Mıhladız & Doğan, 2017). These findings underscore the need for courses like "Nature of Science" and "Philosophy of Science" to be incorporated into teacher training programs.

The omission of NOS in science curricula often implies that students are expected to acquire this knowledge implicitly through classroom practices (Lederman, 2019). However, research indicates that the indirect approach is inadequate for fostering a thorough understanding of NOS. Studies advocate for the explicit-reflective approach, which involves direct emphasis on NOS elements and encourages students to reflect on these aspects in depth (Akerson et al., 2014; Akerson et al., 2019b; Khishfe & Abd-El-Khalick, 2002). This method fosters active engagement, helping students connect theoretical NOS concepts with practical applications.

Astronomy, a significant yet abstract branch of science, presents unique challenges for students. To enhance retention and understanding, diverse methods and techniques must be employed in its teaching. Integrating technology into astronomy lessons can significantly enhance their effectiveness. Technology-supported lessons, such as those employing visual and auditory stimuli, promote enduring learning by simplifying complex concepts (Başçı, 2019).

In this study, topics such as "Our Solar System," the discovery of the Kuiper Belt, and Pluto's reclassification as a dwarf planet were taught to preservice science teachers using QR code technology and an explicit-reflective approach. These activities were enriched with NOS dimensions, including tentativeness, empirical evidence, imagination, and creativity. The aim was to help preservice teachers develop a better understanding of NOS in the context of astronomy and enable them to design similar activities for their future classrooms.

While the use of QR codes in science education is gaining traction, their integration into the instruction of the Nature of Science (NOS) remains underexplored. This study aims to address this gap by incorporating QR code technology into lessons on astronomy and NOS for preservice science teachers. The study has two primary objectives. The first is to evaluate preservice science teachers' conceptual understanding of topics such as the Kuiper Belt, dwarf planets, and Pluto's reclassification, along with their perspectives on NOS, both before and after engaging in QR code-based activities. The second is to analyze how preservice teachers integrate and reflect on NOS dimensions in the QR code activities they create. By integrating QR code technology with NOS instruction, this study aims to provide a foundation for innovative teaching strategies that enhance both scientific literacy and digital competence in science education.

Research Questions

1. What are the conceptual understandings of preservice science teachers regarding the Kuiper Belt, dwarf planets, and Pluto's reclassification, as well as their views on NOS, before and after engaging with QR code-based activities?
2. Which NOS dimensions have preservice teachers explicitly and reflectively addressed in the QR code activities they created?
3. What are the reflective views of preservice science teachers on teaching science topics using QR code technology?

The Role of Technology in Advancing Science Education

In the 21st century, often referred to as the digital age, technology is advancing at an unprecedented pace, continuously bringing about innovative tools and methodologies. This rapid transformation underscores the need for fostering knowledgeable and well-equipped individuals, enhancing teaching and learning methods, and effectively integrating technological innovations into educational programs (Gül, 2023).

As technology becomes increasingly intertwined with everyday life, its integration into education has proven to be not just beneficial but essential. The ongoing advancements in technology offer new teaching and learning opportunities, particularly in educational environments, where they help bridge the gap between theoretical concepts and practical understanding (Durak & Yılmaz, 2019; Koehler & Mishra, 2009).

In science education, the active and effective use of technology is widely recognized for its potential to improve both the quality and efficiency of lessons. By leveraging technology to make scientific topics more tangible, abstract concepts become more accessible to students, fostering deeper understanding. For example, interactive and visually engaging tools can simplify complex topics, such as cellular processes or astronomical phenomena, making them more relatable and easier to grasp (Başçı, 2019). These approaches not only capture students' attention but also encourage their active participation in lessons, leading to more meaningful learning experiences. Furthermore, integrating technological applications into science education enhances the development of 21st-century skills, such as critical thinking, collaboration, and communication (Atalay et al., 2016; Mishra & Kereluik, 2011).

Enriching science education with technology also promotes students' conceptual understanding by connecting scientific concepts to real-life contexts, thereby increasing retention and fostering engagement. Research highlights that such integrations increase interest and motivation in science lessons (Başçı, 2019; Durak & Yılmaz, 2019; Gül, 2023). For instance, Gül (2023) investigated the self-efficacy of preservice science teachers in technology-oriented teaching and found that participants developed proficiency in using technological tools tailored to specific topics and grade levels. Similarly, Başçı (2019) demonstrated that activities enriched with technological tools, such as mobile planetariums, Stellarium, animations, videos, simulations, and QR code technologies, significantly enhanced students' understanding of astronomy concepts.

The role of augmented reality (AR) in education is another area of growing interest. Durak and Yılmaz (2019) emphasized that AR applications positively influenced middle school students' attitudes and motivation toward science lessons, offering immersive learning experiences. Similarly, Azuma et al. (2001) argue that AR facilitates active learning by merging virtual and physical environments, enabling students to visualize and interact with complex scientific phenomena. Recent studies have also shown that gamified educational tools and simulations can further enhance learning outcomes by making lessons engaging and interactive (Gee, 2003; Vos et al., 2011). Moreover, technology's integration into science education positively impacts students' daily lives by equipping them with the skills needed to navigate and contribute to a knowledge-based society. Mishra and Koehler (2006) emphasize the importance of Technological Pedagogical Content Knowledge (TPACK) as a framework to guide teachers in effectively integrating technology into their teaching practices. This approach ensures that students are not only learning scientific concepts but are also developing digital literacy skills that will serve them in diverse contexts.

Building on these advancements, specific technologies such as QR codes have emerged as powerful tools to enhance teaching and learning, particularly in science education. With their ability to seamlessly connect physical resources to digital content, QR codes exemplify how simple yet innovative technologies can transform educational practices. The next section delves into the use of QR codes in science education, exploring their potential to enrich learning experiences and foster greater engagement among students.

The Use of QR Code Technology in Science Education

QR code technology, first developed in 1994 by the Japanese company Denso-Wave, has transformed the way information is accessed and shared (Law & So, 2010). Quick Response (QR) codes are two-dimensional barcodes that can be read by devices such as mobile phones, tablets, or laptops (Ramsden, 2008). These codes store various types of information, including URLs, SMS, and plain text. A key advantage of QR codes is their ability to connect physical media (e.g., posters, printed materials) with digital platforms (e.g., websites, databases), allowing users to seamlessly navigate between physical and digital learning environments. Furthermore, QR codes facilitate communication, such as initiating SMS messages or phone calls, making them versatile tools for diverse applications (Mehendale et al., 2017; Law & So, 2010).

In education, QR codes serve as a dynamic link between learners and digital resources, providing immediate access to curated information. Codes generated through online platforms can be scanned via free QR code reader apps on mobile devices, often without the need for an active internet connection (Karahan & Canbazoğlu Bilici, 2017). This feature enables students to access reliable content efficiently, bypassing the misinformation that can often occur during unstructured online searches (Aktaş & Çaycı, 2013). QR codes can enhance science literacy by making abstract concepts more accessible and engaging. Savitri et al. (2021) demonstrated this through the Real Science Mask with QR Code, which significantly improved students' digital literacy skills and facilitated interactive, flexible learning by linking science content to digital platforms like Google Classroom.

By embedding QR codes into teaching materials, educators can create interactive and streamlined learning environments that encourage engagement and self-directed learning (Al-Sababha, 2024). The integration of these tools into education shifts the focus from teacher-centered instruction to student-centered approaches, empowering learners to actively participate in their own educational journey— a key principle of constructivist pedagogy (Köksal, 2019; Yılmaz & Canbazoğlu Bilici, 2017). QR codes also facilitate access to a variety of multimedia resources, including texts, videos, images, and audio, catering to diverse learning preferences and making lessons more inclusive and engaging (Aktaş & Çaycı, 2013). Furthermore, their cost-effectiveness, ease of use, and compatibility with gamified learning environments have significantly contributed to the widespread adoption of QR codes in education (Tajudeen et al., 2013).

Although the integration of QR codes into science education is relatively new, research highlights their potential to enhance teaching practices and improve students' understanding of scientific concepts. Bonifacio (2012), for instance, embedded podcast links into QR codes to create an alternative representation of the periodic table. These links provided detailed information about chemical elements, making the resource particularly beneficial for visually impaired students.

Canbazoğlu Bilici, Tekin, and Karahan (2016) explored the use of QR codes in laboratory settings, asking preservice science teachers to create posters incorporating QR codes. The findings revealed that these QR code-enhanced posters improved students' attitudes toward laboratory activities and encouraged creativity in presenting scientific data. Similarly, Yılmaz and Canbazoğlu Bilici (2017) developed QR code-based educational games to teach seventh-grade students about the solar system, which significantly increased engagement and facilitated the comprehension of complex concepts.

Uçak and Usta (2023) investigated the perceptions of students, teachers, and preservice teachers regarding the use of QR codes in education. Their results indicated that QR code-based games made science lessons more enjoyable, supported retention of information, and increased curiosity and motivation among students. Furthermore, Smith et al. (2018) compared traditional teaching methods with QR code-supported activities and found that students in the QR code group performed better in achieving learning objectives. These students also reported that QR code activities were interactive and enjoyable while enhancing their practical skills.

Köksal (2019) integrated QR codes into plant anatomy experiment worksheets, making the activities more interactive and accessible. Similarly, Lai et al. (2013) utilized QR codes in outdoor learning environments, where students accessed multimedia resources to learn about plant biology. The study found that students developed positive attitudes toward technology and appreciated its role in facilitating informal and experiential learning.
While the use of QR codes in science education is increasing, their application within formal classroom settings remains underexplored. By bridging the gap between traditional teaching methods and modern technological tools, QR codes can enrich learning experiences, improve conceptual understanding, and foster critical thinking.

Methodology

In this study, a qualitative research method was employed to deeply examine the conceptual understanding of preservice science teachers regarding astronomy topics and the nature of science. The qualitative approach is effective in uncovering complex thought processes and experiences in detail (Merriam & Tisdell, 2015). This research specifically investigates how preservice teachers learn scientific concepts through activities incorporating QR code technology and how their views on the nature of science evolve. The analysis, particularly through the activities designed by the teachers themselves and their reflective insights, provided a deep understanding of their thought processes and conceptual comprehension. Therefore, the qualitative method, which offers an in-depth analysis of participants' experiences, was chosen as the most suitable approach for achieving the objectives of this study (Patton, 2015).

The qualitative research design used in this study was phenomenology. Phenomenological design aims to deeply explore how individuals perceive and make sense of a particular phenomenon or experience (Creswell & Poth, 2018). In this study, the focus was on examining the conceptual understanding of preservice science teachers regarding astronomy topics and their views on the nature of science through QR code technology. In this context, phenomenology is the most appropriate approach for exploring participants' personal experiences, perceptions, and the meanings they derive during this process (Moustakas, 1994).

Phenomenology prioritizes understanding participants' subjective experiences of a specific phenomenon and the impact of these experiences on them. In this study, the preservice teachers' experiences with QR code activities, as well as their evolving views on the nature of science, were examined. This analysis provided a deep exploration of participants' individual awareness and learning processes (Merriam & Tisdell, 2015).

Participants

The sample for this study consisted of 10 preservice science teachers enrolled at a public university in the Eastern Black Sea region during the 2022–2023 academic year. Of these participants, two were third-year students, and eight were fourth-year students. While presenting the findings, the participants were coded as P1, P2, and so on. Specifically, P9 and P10 were third-year students, whereas the rest were fourth-year students. The demographic characteristics of the preservice teachers are presented in Table 1.

Table 1. Demographic Characteristics of the Preservice Teachers

College Year	Gender
3rd year	2 female
4th year	7 female, 1 male

This study was conducted as part of the second author's project under the TÜBİTAK 2209-A Research Projects Support Program for University Students, with the first author serving as the project advisor. The research was carried out with preservice science teachers enrolled in the Interdisciplinary Science Teaching course taught by the project advisor. The primary reason for selecting this course for the implementation was its interdisciplinary nature, which allowed for the integration of various disciplines, including the nature of science, the history of science, technology, and astronomy. Additionally, the project advisor teaching this course during the relevant semester provided a practical opportunity to conduct the study within this group.

The participants were selected from preservice teachers enrolled in this course using the convenience sampling method. Convenience sampling involves selecting participants that are easily accessible to the researchers, making it a practical choice for this study (Patton, 2015). This method is especially useful when research is conducted under time and resource constraints. During the period in which the study was conducted, the preservice teachers had not yet taken a course specifically on the nature of science. Therefore, foundational information on the nature of science was provided before the implementation. This introductory knowledge helped participants enhance their conceptual understanding during the study activities.

Data Collection Tool

The data collection tools for this study included interviews conducted with preservice teachers before and after the implementation, reflective feedback gathered from the preservice teachers following the implementation, and the QR code activities they developed themselves.

Preservice Teacher Interviews

In this study, a set of 12 open-ended interview questions was developed to assess preservice science teachers' conceptual understanding of topics such as the Solar System and planets, the Kuiper Belt, dwarf planets, and Pluto's reclassification from planetary status, as well as their views on the nature of science related to these topics. The same interview questions were administered both before and after the implementation to identify changes in the participants' knowledge levels and understanding.

The interview questions included items aimed at evaluating the preservice teachers' conceptual understanding of astronomy topics emphasized during the implementation, such as: *"How many planets are there in the Solar System? Is Pluto a planet? What is the Kuiper Belt?"* Additionally, the form contained questions developed by the researchers to assess preservice teachers' views on the nature of science. These questions were designed to explore dimensions such as the tentativeness of scientific knowledge, the use of observation and inference in scientific work, the role of imagination and creativity in the work of scientists, and how scientists' characteristics influence their research. Table 2 provides sample questions designed to assess the nature of science and specifies the dimensions of the nature of science that each question measures.

Table 2. Sample Interview Questions Related to the Nature of Science

Interview Questions	NOS Dimensions
How did scientists discover these planets?	*Observation and inference, empirical NOS*
How do scientists acquire knowledge about space, the universe, and our Solar System? Please explain.	*Empirical NOS rooted in observation and experimentation.*
What do scientists rely on when modeling planets? Do you think imagination and creativity play a role? If so, how?	*Imagination and creativity, empirical NOS rooted in observation and experimentation.*
Do scientists' explanations about space and the universe, such as the characteristics of our Solar System and planets, change over time? Can you explain your answer with examples?	*Tentativeness of scientific knowledge.*
Is there always tentativeness in science? Can you provide an example?	*Tentativeness of scientific knowledge.*

Implementation

During the four-week implementation process, the preservice teachers were first administered a pre-interview form. Subsequently, a QR code activity developed by the researchers was conducted. After the activity, to help the preservice teachers reinforce the topic and understand its historical development, they were asked to work in groups and create a timeline.

In the following week, the researchers provided training on creating QR codes. The preservice teachers were then tasked with designing a QR code activity similar to the one implemented the previous week, focusing on astronomy topics. They were instructed to explicitly and reflectively incorporate dimensions of the nature of science into their activities.

In the third week, the groups presented their designed activities and reflected on the activities and the nature of science dimensions they had included. At the end of the implementation process, the pre-interview form administered at the beginning of the study was re-applied to evaluate the impact of the implementation on the preservice teachers' views. Additionally, reflective feedback regarding the design of the QR code activities and their potential application in schools was collected through a reflective feedback form.
The implementation process is summarized in Table 3 and further detailed below the table.

Table 3. Timeline of the Implementation

Weeks	Implementation
Week 1	Administration of the pre-implementation interview form
Week 2	Implementation of the QR code activity by the researchers
Week 3	Training provided by the researchers on the use of QR code applications
Week 4	Presentation of activity plans prepared by preservice teachers using QR code technology, administration of the interview form, and collection of reflective feedback

After the pre-interview, preservice teachers were divided into pairs, with each pair receiving a planet-themed box, as shown in Figures 1 and 2. Each box contained 27 QR code cards with numbers written on the back. Additionally, a "Start" QR code and a "Finish" QR code were displayed on the board. The preservice teachers were instructed to scan the "Start" QR code on the board before scanning any QR codes in their boxes. The "Start" QR code provided instructions for the activity. According to these instructions, the preservice teachers were required to scan the QR codes in their boxes, examine the visuals and information displayed on the corresponding pages, and record key events, milestones in space exploration, and relevant dates on an A4 sheet of paper. They were informed that this information would later be used to create a timeline.

The 27 QR codes included a combination of visual content and videos. The information accessed through the QR codes directed preservice teachers to pages containing details such as Pluto’s reclassification from a planet to a dwarf planet due to specific characteristics, the classification of planets in the Solar System, the discovery of the Kuiper Belt, and updates to the classification of planets and dwarf planets, along with their associated historical processes.

Figure 1. Boxes Containing QR Code Cards

Figure 2. QR Code Cards Arranged by Preservice Teachers

Some of the QR code cards included questions designed to stimulate group discussions about various dimensions of the nature of science, such as the tentativeness of scientific explanations in light of new evidence, the evidence-based foundation of science, the use of observation and inference, and the role of imagination and creativity in scientific work. To differentiate these from other cards, the discussion-focused QR code cards were marked with a red backing, while the cards directing users to astronomy-related web pages were marked with a blue backing. After scanning all the QR codes in their boxes, groups were instructed to scan the "Finish" QR code displayed on the board. This final QR code guided participants to use the notes they had taken on their A4 sheets during the activity to construct a timeline. Blank timeline templates prepared by the researchers were distributed to the groups, and each group was then required to present their completed timeline to the class.

In the following week, the researchers introduced the QR code application used in the previous activity. They provided a detailed explanation of how QR codes are created, the step-by-step process of their development, and how the activity cards were designed. Building on this knowledge, preservice teachers were tasked with working in groups to design their own QR code activities. These activities were required to align with the learning objectives of the *Solar System and Planets/Earth and Space* unit in the science curriculum and to explicitly and reflectively integrate at least one dimension of the nature of science.

The following week, the groups presented their designed activities orally. During these presentations, the researchers posed guiding questions to encourage thoughtful discussion. Questions included how and at what stage of the lesson the QR code activity would be implemented, which dimension of the nature of science was addressed, and how it would be explicitly and reflectively conveyed to students. To foster a collaborative learning environment, other group members were encouraged to ask questions and provide constructive feedback on the presented activities.

At the conclusion of the study, reflective feedback from the preservice teachers on using QR code technology for teaching science and astronomy topics was gathered through an open-ended interview form. Additionally, the pre-test interview form was re-administered to assess changes in their understanding and conceptual development. This multi-faceted approach ensured a comprehensive evaluation of the effectiveness of the QR code-based activities and the integration of the nature of science into teaching practices.

Data Analysis

The responses provided by the preservice teachers during pre- and post-implementation interviews, their post-implementation reflections, and their self-prepared QR code activity plans were analyzed using descriptive analysis. Descriptive analysis involves organizing and summarizing data in alignment with predefined themes (Yıldırım & Şimşek, 2018). In this study, the predefined themes included dimensions of the nature of science (e.g., tentativeness, observation and inference, imagination, and creativity) and conceptual understandings of astronomy topics (e.g., the Solar System, the Kuiper Belt, and dwarf planets).

During data analysis, interviews and reflective feedback from the preservice teachers were coded and examined according to these themes. For instance, a preservice teacher's statement, *"Scientists discover new planets through observation and inference,"* was categorized under the observation and inference dimension of the nature of science. For classifying responses related to the nature of science, the framework provided by Lederman et al. (2002), which distinguishes between "informed" and "uninformed" responses for each dimension, was employed.

Throughout the analysis process, participants' responses and activities were systematically categorized under the identified themes, and the findings were summarized to highlight key insights. The results indicated that the preservice teachers' conceptual understanding of astronomy topics improved and their views on the nature of science matured. For example, their perspectives on Pluto’s reclassification as a dwarf planet were analyzed under the theme of tentativeness in science. Direct quotations from participants were used to support the findings, offering rich insights into their experiences. The descriptive analysis approach facilitated a systematic presentation of participants’ thoughts and experiences, enhancing the comprehensibility of the findings (Creswell, 2013). This method also clarified the study's outcomes by organizing the data into meaningful categories, ultimately enabling a deeper understanding of the preservice teachers' learning processes and conceptual development.

Validity and Reliability

In this study, triangulation was achieved by utilizing multiple data sources, including pre- and post-implementation interviews with preservice teachers, their reflections, and the QR code activity plans they developed. These diverse data sources facilitated a more reliable assessment of the participants' conceptual understanding and their views on the nature of science (Creswell, 2013). During the descriptive analysis, predefined themes related to the nature of science and astronomy topics guided the coding of participants' responses. This alignment of themes with the research objectives supported the validity of the study (Yıldırım & Şimşek, 2018).

The participants' perspectives were substantiated with direct quotations, enhancing the study's credibility by ensuring the authenticity of their experiences. This approach strengthened the internal validity of the study by grounding the findings in the participants' subjective experiences (Patton, 2015). Additionally, the reliability of the study was enhanced by involving multiple researchers in the coding process. Initially, the data were analyzed by the project leader, and the analyses were subsequently reviewed by the project advisor. Any discrepancies in coding were discussed until a consensus was reached, minimizing subjectivity in the analysis process (Creswell, 2013). The study's findings were corroborated through consistent analysis of various data sources, such as interviews, reflections, and activity plans. This consistency further reinforced the reliability of the results (Patton, 2015).

Findings

In this section, the findings will be presented in alignment with the study's research questions. First, examples of preservice science teachers' conceptual understanding of the Kuiper Belt, dwarf planets, and Pluto's reclassification as a dwarf planet, as well as their views on the nature of science related to these topics, will be shared using excerpts from pre- and post-implementation interviews. Next, examples will illustrate the dimensions of the nature of science that preservice teachers explicitly and reflectively incorporated into the QR code activities they designed. Finally, the preservice teachers' reflective perspectives on teaching science topics using QR code technology will be presented.

Preservice Teachers' Conceptual Understandings of the Solar System, Planets, Kuiper Belt, and Dwarf Planets

During the pre-activity interviews, it was observed that preservice teachers had significant knowledge gaps regarding dwarf planets, the Kuiper Belt, Pluto's planetary status, and even the planets in the Solar System. However, their responses in the post-activity interviews indicated notable improvements in their conceptual understanding. Below are examples of their responses before and after the activity.

For instance, when asked, *"How many planets are there in the Solar System? Can you name them?"* only three out of ten pre-service teachers correctly identified the number and sequence of planets in the Solar System. Three others failed to name all eight planets, while four incorrectly stated that there are seven planets in total. In the pre-interview, most preservice teachers admitted they did not know why Pluto was reclassified as a dwarf planet. While two preservice teachers correctly explained that it was because *"it could not clear its surroundings,"* one participant provided a misconception, stating, *"It was removed because it is small and primitive."* This response disregards the fact that smaller planets in the Solar System were not removed due to their size.

During the post-interview, pre-service teachers' responses demonstrated improvement. Three preservice teachers partially but not fully correctly stated, *"It was removed in 2006 because it did not meet the criteria to be a planet."* Seven participants provided the accurate explanation, stating, *"It is not considered a planet because it could not clear the other celestial objects in its surroundings."*

When asked about the Kuiper Belt with the question, *"What is the Kuiper Belt? Have you heard of this term before?"* during the pre-interview, two preservice teachers gave incomplete responses such as, *"I've heard of it; it's a belt between the Sun and Earth,"* while eight admitted, *"I haven't heard of it, I don't recall."* In the post-interview, their conceptual understanding of the Kuiper Belt showed significant improvement. Two preservice teachers acknowledged, *"I had not heard of it before, but I learned about it through this activity,"* while eight gave more informed responses, such as, *"It is a belt of icy objects and dwarf planets located between Neptune and the Oort Cloud, forming a ring of icy bodies surrounding the Solar System."*

The QR codes provided detailed information on how scientists discovered the Kuiper Belt. In the post-interview, when asked, *"How did scientists discover the Kuiper Belt?"* preservice teachers offered responses such as, *"Through new developments and observations," "By using spacecraft sent into space," "Thanks to New Horizons,"* and *"Through the discovery of icy celestial bodies."*

To assess their knowledge of regions beyond the Solar System, pre-service teachers were asked, *"Starting from the Sun, draw and label the components and structures within the Solar System, including any discovered regions beyond."* In the pre-interview, nine preservice teachers only drew the Solar System (the Sun and planets), while only one included the Kuiper Belt. These responses revealed limited knowledge about areas beyond the Solar System. In the post-interview, pre-service teachers' drawings reflected notable improvements: three preservice teachers included the Solar System and the Kuiper Belt, three included the Solar System and the Oort Cloud, and three incorporated dwarf planets into their Solar System drawings. These responses demonstrated an enhanced understanding of regions beyond the Solar System, with pre-service teachers incorporating details about the Kuiper Belt and Oort Cloud into their visuals.

Preservice Teachers' Contextual Views on the Nature of Science

In this study, five open-ended questions were posed to evaluate preservice teachers' views on the nature of science, particularly concerning topics of astronomy such as the Solar System, planets, dwarf planets, and the Kuiper Belt. Comparisons between their pre- and post-activity interview responses revealed significant improvements in their understanding of the nature of science.

To assess their grasp of dimensions such as "science is based on evidence from observation and experiments," "tentativeness," "observation and inference," and "imagination and creativity," pre-service teachers were asked, "*How did scientists discover these planets?*" In the pre-interview, one preservice teacher admitted having no idea, while six responded with, "*through spacecraft and space observations*". In the post-interview, two pre-service teachers elaborated with responses like, "*through scientific calculations and observations, they made inferences*" emphasizing the role of inference in scientific discovery. Four participants added, "*through observation and creativity*", highlighting the combination of imagination and observation. Two others reiterated, "*spacecraft and space observation,*" and another two mentioned, "*mathematical calculations and observation-based inferences*".

For the question, "*How do scientists acquire knowledge about space, the universe, and our Solar System? Please explain!*" pre-interview responses were limited to, "*through spacecraft and space research*". Post-interview responses reflected a broader understanding, with participants stating, "*through scientific methods and observations*", "inspired by space photographs," and "*drawing insights from previous studies*". This shift indicates that participants began incorporating dimensions of the nature of science into their responses following the activity.

When asked, "*What do scientists use when modeling planets? Do you think imagination and creativity are important? How?*" all participants in the pre-interview agreed that creativity plays a role, but their responses about the tools and methods for modeling were more superficial compared to their post-interview answers. Four participants stated, "*from observations and examinations*", while another four mentioned, "*making space models*" or "*creating models about planets*". Only one participant offered a more nuanced response, stating, "*They examine the sky with telescopes and create models using their creativity"*. Post-interview responses demonstrated deeper integration of the nature of science. For example, one participant explained, "*It is important. To produce something, one must design it mentally, and the environment can also influence modeling*".

Another remarked, "*Science is in constant interaction and change, so it influences modeling*" A third participant added, "*They combine observations and previous research; they do not create models that contradict their ideas*". Two participants noted the use of telescopes and other space tools combined with imagination to create models, reflecting a deeper understanding of tentativeness and the role of environmental influences in science.

For the question, "*Do scientists' explanations about space, the universe, and the Solar System change over time? Can you provide examples?*" one participant in the pre-interview stated, "*No, they do not change*". However, in the post-interview, none of the participants maintained this view. Seven participants correctly identified Pluto's reclassification as an example of scientific change, stating, "*Yes, they change. Pluto was initially considered a planet but was later excluded"*. Two participants cited, "*Discoveries about Venus and Mars and signs of life on these planets*" as examples.

When asked, "*Is science always tentative? Can you provide examples?*" most pre-interview responses cited atomic models. In the post-interview, nine participants referenced Pluto's reclassification, illustrating a deeper understanding of the tentativeness of scientific explanations. One participant added, "*Yes, it is. For example, the progression of beliefs about Earth's shape from flat to spherical to geoid*".

These responses indicate that preservice teachers developed a more advanced and nuanced understanding of the nature of science over the course of the activity. Their improved responses reflect deeper critical thinking and a better comprehension of the dimensions of the nature of science.

Preservice Teachers' Reflective Opinions on the QR Code Activity Implementation

In response to the question, *"How else can QR codes be integrated into science teaching? Can you provide an example?"*, one preservice teacher suggested, *"QR codes can be integrated into search-and-find activities."* Five preservice teachers responded, *"QR codes can be used to show example videos during experiments."* Another teacher proposed, *"Exams can be conducted using QR codes, which would save paper and eliminate time loss in evaluation."* Additionally, one preservice teacher mentioned, *"They can be used in the assessment phase. A QR code could be added to each question".*

To gather opinions about activities prepared with QR codes, the question, *"Do you think activities prepared with QR codes would be beneficial for students?"* was posed. In the pre-interview, nine preservice teachers believed such activities would be beneficial, while one disagreed, citing school facilities and grade level as limiting factors. However, in the post-interview, five preservice teachers found QR code-based activities functional, whereas four considered them impractical. Those who viewed them as impractical mentioned, *"I might not use them due to the lack of technological devices that students can use."*

When asked, *"Would you use activities designed with QR codes for your students in the future? If so, how would you implement them?"*, eight preservice teachers responded positively, stating, *"I would use them in experiments, while explaining topics, or in the assessment phase"*. Conversely, three preservice teachers expressed reluctance, saying, *"I wouldn't use them because not every student may have a tablet, and I might not be familiar with QR code techniques"*. Their responses reflect hesitation regarding the practical implementation of QR code technology.

Regarding the question, *"What are your thoughts about the activity we conducted using QR codes? Please discuss its strengths and weaknesses,"* preservice teachers identified strengths such as, *"The activity made the topic interesting, effective, and enjoyable"*. Another example included, *"It increased retention and was beautifully and carefully prepared"*. However, weaknesses highlighted included, *"Insufficient facilities in schools and time constraints"*.

These reflections suggest that while preservice teachers recognize the potential of QR codes for making science lessons engaging and effective, concerns about accessibility, technological resources, and time limitations remain significant barriers to broader implementation.

Dimensions of the Nature of Science Used by Preservice Teachers in QR Code Activities

In the activities presented by preservice teachers working in pairs, one group successfully integrated the dimensions of *observation and inference* and *tentativeness*, while three groups effectively incorporated the dimensions of *creativity and subjectivity.* The final group addressed the *tentativeness* dimension in their activity.

A group that designed a QR code activity on the phases of the Moon integrated the dimension of *imagination and creativity in science* by stating, *"Scientists observed the phases of the Moon, but they used their creativity when developing a model and naming the phases of the Moon."* Another group working on the same topic and learning objective emphasized the subjectivity of scientists and making inferences based on observations in science by explaining, *"Observations were made about the formation and phases of the Moon, and each scientist made inferences based on their own work, which relates to the subjectivity of science."*

A group that prepared an activity on the Solar System highlighted the *tentativeness* of scientific knowledge by stating, *"Earth was once considered the center of the universe, and all planets were thought to orbit around Earth. However, over time, Copernicus proposed that the Sun, not Earth, is at the center of the universe, and all planets orbit around the Sun. Scientific explanations can change with the help of new evidence."*

These examples illustrate how preservice teachers integrated various dimensions of the nature of science into their QR code activities, demonstrating their understanding of the roles of creativity, observation, inference, subjectivity, and tentativeness in scientific processes.

Discussion

The findings of this study corroborate the existing literature regarding the potential of QR code technology in enhancing science education. The activities designed with QR codes demonstrated a notable improvement in preservice teachers' conceptual understanding and articulation of astronomy topics, including the Solar System, the Kuiper Belt, and Pluto’s reclassification as a dwarf planet. As highlighted by Başçı (2019), integrating technology into the teaching of astronomy enhances instructional effectiveness by making abstract concepts more accessible. Additionally, Güntepe and Usta (2019) emphasized that QR code technology contributes to the development of pedagogical content knowledge by fostering a deeper understanding of scientific concepts. Similarly, Atalay et al. (2016) underscored the role of QR codes as effective tools in cultivating 21st-century skills, aligning with Gül's (2023) findings on technology's role in deepening students' conceptual understanding.

This study also revealed that preservice teachers, despite not having taken formal coursework on the "Nature of Science and Its Teaching," were able to successfully integrate dimensions of the nature of science into their QR code activities. This finding aligns with previous research indicating that an explicit and reflective approach enables a more meaningful and durable understanding of the nature of science (Akerson et al., 2014; Khishfe & Abd-El-Khalick, 2002; Akerson et al., 2019a; Avsar Erumit et al., 2019; Avsar Erumit & Akerson, 2022). For instance, the integration of dimensions such as "tentativeness" and "imagination and creativity" into activities designed by preservice teachers reflected their growing understanding of the epistemological underpinnings of scientific inquiry.

Moreover, the participants reported that using QR codes in science teaching was both enjoyable and effective in enhancing content retention. Similar observations were made in Uçak and Usta's (2023) study, where space-themed QR code-integrated games were found to make science lessons more engaging and enjoyable, thereby supporting long-term learning. Likewise, Yılmaz and Canbazoğlu-Bilici (2017) demonstrated that QR code-based educational games increased seventh-grade students' interest and curiosity about the Solar System while making learning more enjoyable. These results are consistent with Smith et al. (2018), who reported that students participating in QR code activities perceived them as interactive and engaging.

However, despite their enthusiasm for QR code technology, preservice teachers expressed concerns about its practical application in professional settings. The most cited challenges included inadequate technological infrastructure in schools and limited access to essential resources such as tablets and computers. These findings align with Karahan and Bilici's (2017) research, which identified technological limitations, wireless connectivity issues, and insufficient access to mobile devices as major barriers to the classroom implementation of QR codes. Furthermore, Traser et al. (2015) reported similar challenges in medical education, where students valued the interactive features of QR codes but were reluctant to use their personal devices in laboratory settings. These challenges highlight the critical need for investments in technological infrastructure to ensure equitable access and effective integration of digital tools in education.

Given these findings, addressing the barriers to technology integration is essential. Schools must prioritize the development of robust technological infrastructure and provide educators with the necessary training to utilize tools like QR codes effectively. Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPACK) framework offers a valuable guideline for integrating technology into teaching practices in a manner that aligns with pedagogical goals and content requirements.

Finally, while this study focused on astronomy topics, the versatility of QR code technology suggests its potential applicability across various domains of science education. Future research should explore its use in other subjects, compare its effectiveness with alternative digital tools, and investigate its long-term impact on student learning outcomes in diverse educational settings. By addressing these areas, QR code technology can further contribute to the advancement of both scientific literacy and digital competence in the 21st century.

Conclusion and Recommendations

The integration of QR codes into science education offers a promising approach for effectively teaching the Nature of Science (NOS). By facilitating access to multimedia resources and interactive activities, QR codes provide unique opportunities to explore key NOS dimensions, such as tentativeness, observation and inference, creativity, and subjectivity. This study highlights that even preservice teachers with limited prior exposure to NOS can successfully design activities that explicitly and reflectively incorporate these dimensions when supported by QR technology. Beyond enhancing conceptual understanding, QR codes engage learners, promote critical thinking, and make abstract NOS concepts tangible within diverse science contexts.

Future research could expand on these findings by exploring the application of QR codes in teaching additional NOS dimensions or contextualizing them within different science topics, such as genetics, climate change, or physics. Longitudinal studies could further examine the sustained impact of QR code technology on students' understanding of NOS, providing insights into how these tools influence long-term retention and skill development. Additionally, comparative experimental studies involving control groups without QR codes or groups using alternative technologies could offer deeper insights into the relative effectiveness of QR codes in science education.

Expanding the use of QR codes to diverse educational levels could provide a clearer picture of how technology supports NOS learning across age groups and curricula. Professional development programs tailored to preservice and in-service teachers could further equip educators with the skills to effectively integrate QR technology into their classrooms. Such training should focus on aligning QR activities with pedagogical goals and science content, leveraging frameworks like Technological Pedagogical Content Knowledge (TPACK) to foster innovative and effective teaching practices.

Addressing barriers such as insufficient technological infrastructure and inequitable access to devices is critical for the successful implementation of QR code activities. Strengthening school infrastructure, ensuring access to digital tools, and offering targeted teacher training can help overcome these challenges and maximize the potential of QR technology.

Ultimately, QR codes represent a powerful tool for enriching NOS instruction, making science more interactive, engaging, and accessible. By aligning technology with sound pedagogical practices and addressing practical challenges, QR codes can transform science education, helping students develop a nuanced understanding of NOS while fostering essential 21st-century skills such as digital literacy and creativity. With strategic investment and research, QR codes can play a pivotal role in advancing science education in a technology-driven world.

Notes

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References

Abd-El-Khalick, F. & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. International Journal of Science Education, 22(7), 665-701.

Akerson, V. L., Buck, G. A., Donnelly, L. A., Nargund-Joshi, V., & Weiland, I. S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology*, *20*, 537-549.

Akerson, V., Nargund-Joshi, V., Weiland, I., Pongsanon, K., & Avsar, B. (2014). What third-grade students of differing ability levels learn about nature of science after a year of instruction. *International Journal of*

Science Education, *36*(2), 244-276.

Akerson, V. L., Avsar Erumit, B., & Elcan Kaynak, N. (2019a). Teaching nature of science through children's literature: An early childhood preservice teacher study. *International Journal of Science Education*, *41*(18), 2765-2787.

Akerson, V. L., Carter, I., Pongsanon, K., & Nargund-Joshi, V. (2019b). Teaching and learning nature of science in elementary classrooms: Research-based strategies for practical implementation. *Science & Education*, *28*, 391-411.

Aktaş, C., & Çaycı, B. (2013). QR Kodun Mobil Eğitimde Yeni Eğitim Yöntemlerinin Geliştirilmesine Katkısı. *Global Media Journal*, *4*(7), 1–19.

Al-Sababha, K. M. H. (2024). The effect of using a QR code-enhanced brochure on students' knowledge and skill learning outcomes. *Edelweiss Applied Science and Technology*, *8*(2), 84-99.

Atalay, N., Anagün, Ş. S., & Kumtepe, E. G. (2016). Fen öğretiminde teknoloji entegrasyonunun 21. yüzyıl beceri boyutunda değerlendirilmesi: Yavaş geçişli animasyon uygulaması. *Bartın University Journal of Faculty of Education*, *5*(2), 405-424.

Avsar Erumit, B., Fouad, K. E., & Akerson, V. L. (2019). How Do Learner-Directed Scientific Investigations Influence Students' Questioning and Their Nature of Science Conceptions?. *International Journal of Education in Mathematics, Science and Technology*, *7*(1), 20-31.

Avsar Erumit, B., & Akerson, V. L. (2022). Using children's literature in the middle school science class to teach nature of science: Preservice teachers' development of sources. *Science & Education*, *31*(3), 713-737.

Avsar Erumit, B., & Yuksel, T. (2023). Developing and using physical dynamic models on socioscientific issues to present nature of science ideas. *International Journal of Science and Mathematics Education*, *21*(4), 1031-1056.

Avsar Erumit, B., Namdar, B., & Oğuz Namdar, A. (2024). Promoting preservice teachers' global citizenship and contextualised NOS views through role-play activities integrated into place-based SSI instruction on climate issues. *International Journal of Science Education*, *46*(6), 590-619.

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, *21*(6), 34-47.

Başçı, E. (2019). Teknoloji ile zenginleştirilmiş astronomi dersinin öğrencilerin kavramsal anlamalarına ilgi ve tutumlarına etkisi (Yayınlanmamış Yüksek Lisans Tezi). Aksaray Üniversitesi, Fen Bilimleri Enstitüsü, Aksaray. [Unpublished Master's Thesis]

Bonifacio, V. D. B. (2012). QR-coded audio periodic table of the elements: A mobile- learning tool, Journal of Chemical Education, 89(4), 552-554.

Canbazoğlu Bilici, S., Tekin, N., & Karahan, E. (2016). Öğretmen adaylarının fen laboratuarında QR kodlarla zenginleştirilmiş poster kullanımları. 3. Uluslararası Avrasya Eğitim Araştırmaları Kongresi, 31 Mayıs-3 Haziran, Muğla

Creswell, J. W., & Poth, C. N. (2018). Qualitative inquiry and research design: Choosing among five approaches (4th ed.). Sage Publications.

DeBoer, G. E. (1991). A history of ideas in science education: Implications for practice. *Teachers College, Columbia University*.

Denso (2009). Denso Wave Incorporated. Retrieved May 28, 2025, from http://www. denso-wave.com/en/index.html

Dönmez Usta, N. & Turan Güntepe, E. (2019). Öğrenme ortamında QR kod destekli materyallerin kullanımı. Bolu Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 19(3), 923-935

Durak, A., & Yılmaz, F. G. K. (2019). Artırılmış gerçekliğin eğitsel uygulamalari üzerine ortaokul öğrencilerinin görüşleri. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, *19*(2), 468-481.

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE)*, *1*(1), 20.

Gül, K. S. (2023). Teknoloji Odaklı Fen Eğitimi Uygulamalarının Teknolojik Pedagojik Alan Bilgilerine ve Teknoloji Entegrasyonu Öz-yeterlik Algılarına Etkisi. *Yaşadıkça Eğitim*, *37*(2), 489-507.

Gürses, A., Doğar, Ç., & Yalçın, M. (2005). Bilimin Doğasi Ve Yüksek Öğrenim Öğrencilerinin Bilimin Doğasina Dair Düşünceleri. *Mill Eğitim Dergisi*, *33*(166), 68-76.

Karahan, E. & Canbazoğlu Bilici, S. (2017). Use of QR Codes in Science Education: Science Teachers' Opinions and Suggestions. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 11*(1). 433-457.

Khishfe, R., & Abd‐El‐Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry‐oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *39*(7), 551-578.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary issues in technology and teacher education*, *9*(1), 60-70.

Köksal, K. (2019). Bitki anatomisi laboratuvarı dersi föyünde karekod uygulamasının kullanılması (Yüksek lisans tezi, Balıkesir Üniversitesi Fen Bilimleri Enstitüsü). [Unpublished Master's Thesis]

Lai, H. C., Chang, C. Y., Wen‐Shiane, L., Fan, Y. L., & Wu, Y. T. (2013). The implementation of mobile learning in outdoor education: Application of QR codes. *British Journal of Educational Technology, 44(2), E57-E62.*

Law, C. Y., & So, S. (2010). QR codes in education. *Journal of Educational Technology Development and Exchange (JETDE)*, *3*(1), 85-100.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331-359.

Lederman, N. G. (2019). Contextualizing the relationship between nature of scientific knowledge and scientific inquiry: Implications for curriculum and classroom practice. *Science & Education*, *28*, 249-267.

Lederman, N. G., Abd‐El‐Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497-521.

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teacher behavior? *Science Education*, 71 (5), 721–734.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), The nature of science in science education: Rationales and strategies (pp. 3–39). the Netherlands: Kluwer.

Mehendale, D., Masurekar, R., Nemade, S., & Shivthare, S. (2017). To study the use of QR code in the classroom to enhance motivation, communication, collaboration and critical thinking. *International Journal Of*

Innovative Research in Computer and Communication Engineering, *5*(4), 6987-6993.

Merriam, S.B.; Tisdell, E.J. (2015). *Qualitative Research: A Guide to Design and Implementation*; John Wiley & Sons: Hoboken, NJ, USA.

Mıhladız, G. & Doğan, A. (2017). Fen bilgisi öğretmen adaylarının bilimin doğası konusundaki pedagojik alan bilgilerinin araştırılması. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 32*(2), 380-395. https://doi.org/10.16986/HUJE.2016017220

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054.

Mishra, P., & Kereluik, K. (2011, March). What 21st century learning? A review and a synthesis. In *Society for Information Technology & Teacher Education International Conference* (pp. 3301-3312). Association for the Advancement of Computing in Education (AACE).

Moustakas, C. (1994). Phenomenological Research Methods. Thousand Oaks, CA: Sage.

Mulvey, B. K., & Bell, R. L. (2017). Making learning last: Teachers' long-term retention of improved nature of science conceptions and instructional rationales. *International Journal of Science Education*, *39*(1), 62-85.

Özden, M., & Cavlazoğlu, B. (2015). İlköğretim fen dersi öğretim programlarında bilimin doğası: 2005 ve 2013 programlarının incelenmesi. *Eğitimde Nitel Araştırmalar Dergisi*, *3*(2), 40-65.

Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice (fourth). Sage Publications, Inc. Qualitative research (pp. 273–290). Sage.

Ramsden, A. (2008) The use of QR codes in education: A getting started guide for academics. Working Paper. University of Bath, Bath, UK. Retrieved 28, May, 2015 from https://researchportal.bath.ac.uk/en/publications/the-use-of-qr-codes-in-education-a-getting-started-guide-for-acad

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In *Handbook of research on science education, Volume II* (pp. 559-572). Routledge.

Savitri, E. N., Dewi, N. R., Amalia, A. V., & Prabowo, S. A. (2021, June). Learning using real science mask with qr code to increase students' digital literacy. In *Journal of Physics: Conference Series* (Vol. 1918, No. 5, p. 052059). IOP Publishing.

Smith, M., Segura-Totten, M., & West, K. (2018). QR code lecture activity as a tool for increasing nonmajors biology students' enjoyment of interaction with their local environment. *Journal of Microbiology & Biology Education*, *19*(1), 10-1128.

Tajudeen, S. A., Basha, M. K., Michael, F. O., & Mukthar, A. L. (2013). Determinant of Mobile Devices Acceptance for Learning among Students in Developing Country. *Malaysian Online Journal of Educational Technology*, *1*(3), 17-29.

Traser, C. J., Hoffman, L. A., Seifert, M. F., & Wilson, A. B. (2015). Investigating the use of quick response codes in the gross anatomy laboratory. *Anatomical Sciences Education*, *8*(5), 421-428.

Turgut, H. (2006). *Yapılandırmacı tasarım uygulamasının fen bilgisi öğretmen adaylarının bilimsel okuryazarlık yeterliklerinden" bilimin doğası" ve" bilim-teknoloji-toplum ilişkisi" boyutlarının gelişimine etkisi* (Doctoral dissertation).

Türkmen, H., Yalçın, M. (2001). Bilimin Doğası ve Eğitimdeki Önemi. *Afyon Kocatepe Üniversitesi Sosyal*

Bilimler Dergisi, *3*(1), 189-195.

Uçak, E. & Usta, S. (2023) Eğitimde Qr Kod Kullanımına Yönelik Öğrenci, Öğretmen ve Öğretmen Adaylarının Görüşleri. *Elektronik Sosyal Bilimler Dergisi*, *22*(87), 889-909.

Vos, N., Van Der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education*, *56*(1), 127-137.

Yıldırım, A. & Şimşek, H. (2018). Sosyal bilimlerde nitel araştırma yöntemleri (11. baskı). Ankara: Seçkin Yayınevi.

Yılmaz, B. & Canbazoğlu Bilici, S. (2017). QR Kodlar ile Tasarlanmış Güneş Sistemi ve Ötesi, Uzay Bilmecesi Etkinliği, *Anadolu Öğretmen Dergisi, 1*(2), 75-82.

Author Information

Banu Avsar Erumit
https://orcid.org/0000-0002-9048-6467
Recep Tayyip Erdoğan University
Türkiye
Contact e-mail: *banu.avsar@erdogan.edu.tr*

Zeliha Yerlikaya
https://orcid.org/0009-0004-7649-6388
Recep Tayyip Erdoğan University
Türkiye