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Primary School Students' Learning Achievement and Attitudes Towards Inquiry-Based Science Fieldwork with Socio-Demographic Information

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Abstract

This study investigated the impact of school setting, gender, and age on Namibian primary students' learning achievement following an inquiry-based science fieldwork (IBSF) intervention and examined how attitude towards IBSF varied by these factors. A mixed-methods approach was used with 100 seventh-grade students from two socio-demographically different schools. From this group, 20 students were purposively selected for semi-structured interviews. Thus, multiple linear regression, exploratory factor analysis, multivariate analysis of variance, and Pearson correlation coefficients were conducted. Our quantitative results showed that school setting—but not gender or age—significantly influenced post-test learning achievement, underlining the critical role of the school environment in meeting learning outcomes. In contrast, school setting had no significant effect on students' attitudes toward IBSF. Gender differences emerged in attitudes: boys reported more positive views of IBSF's importance and greater eagerness to participate in future fieldwork, whereas girls expressed some reluctance despite strong performance. Content analysis of qualitative data confirmed that most students valued IBSF and were eager to engage again. These findings suggest that introducing IBSF at the primary level enhances students' understanding of science and its relevance to their futures. The study recommends that interventions also address gender stereotypes to promote equity and sustained interest in science education.

Introduction

In the current era of the educational revolution, where science knowledge is increasing rapidly, more students are adopting new learning methods to develop and improve their learning achievements (Ngana & Van Hong, 2021). However, there has been increasing public concern that many students perform poorly in science education (Mamili, 2017). Poor performance has been attributed to a lack of learning resources, overcrowded classes (Ndjangala et al., 2021), and unfavourable school classroom settings (Kibga et al., 2021). School settings refer to the school environment, number of students in the classes, and the diverse physical locations, contexts, and cultures in which students learn (Malik & Rizvi, 2018). Besides poor performance, teaching and learning methods contribute to students' poor attitudes to science education (Ndjangala et al., 2021; Çetin & Türkan, 2022). These students' poor attitudes generally do not apply to all countries but are very common in African countries such as Southern Africa (Marais, 2016). Thus, there is a need to investigate the African context in more detail and find different approaches to hinder the factors related to poor performance and attitudes. That is why it is necessary to improve students' learning achievement and attitudes to open the door to higher education, scholarships, and other competitive educational programs. In this study learning achievement refers to the measurable outcomes of a students' academic performance or mastery of specific science learning content (Aljermawi, 2024). It is typically assessed through standardized tests, exams, quizzes, assignments, or other evaluation tools that quantify a student's understanding, progress, and proficiency in the learning objectives (Kızıkan, 2024). In science education, learning achievement could also be defined as the score students receive on a science test, measuring their comprehension of key concepts covered during inquiry-based science learning (IBSL) (Ghimire, 2024). IBSL is a method aimed at engaging students in science through active participation and presentation (cf., Jaber & Hammer, 2016; Sim & Liow, 2021; Odhiambo, 2022).

In South African countries, it has been discovered that primary schools find it difficult to engage their students in science fieldwork, including practical work (Ngema, 2016), affecting students' learning achievement. Learning achievement is a product of the learning process attained by students after studying a particular subject (Sullivan

& Glanz, 2013). Thus, teaching and learning methods, such as IBSF, can directly or indirectly contribute to students' learning achievement and attitudes in science education.

In science education, 'attitude may be viewed as an emotional disposition of an individual which influences his or her behavioural intention as well as the commitment towards a given phenomenon' (Chata et al., 2019, p. 571). Some studies indicated that the role of attitude toward IBSF could be influenced by the students' age and gender (Roccatello et al., 2024). A study conducted by Cermik and Fenli-Aktan (2020) in Turkey revealed that the students' attitude towards science do not differ statistically according to their gender but are influenced by their upbringing, such as students' parental involvement in science activities. To the best of our knowledge, only a few studies in Namibia have investigated the quantitative part of the students' attitudes in fieldwork in science education (Uugwanga, 2020) and students are not used to working in groups outside lessons. Therefore, this paper investigates primary school students' learning achievements and attitudes towards IBSF, considering the impact of the school setting and students' gender and age on learning achievements and attitudes. Furthermore, investigates IBSF importance and future participation and examines the relationship between students' achievements and attitudes towards IBSF.

The Role of the School Setting, Gender, and Age in Informing Primary School Students' Learning Achievements in Inquiry-based Science Fieldwork

The school setting significantly shapes students' learning achievements and academic success (Korir, 2014; Hanaysh et al., 2023). Students encounter different school settings that can decrease or increase their performance (Wang & Eccles, 2013). Therefore, changes in students' academic success are accomplished by changing the school setting, including the school's structure and operations (MacNei et al., 2019). Harris (2018) outlined that the school shapes students' experiences as they engage in learning outside the classroom. Thus, the inquiry-based science fieldwork may offer possibilities to improve science learning as a positive and enjoyable learning environment (see Zaragoza & Fraser, 2017).

In terms of learning achievements in science, gender differences vary worldwide (Mullis et al., 2020). Boys have been found to receive better marks and outperform girls (Ma et al., 2022; Pongsophon, 2023). However, some studies have shown that girls become more fascinated by science activities than boys, leading to better results (Maison et al., 2020; Aznam, 2022). On the other it has been argued that students' learning achievements are not affected by gender, but by the amount of time they invest in learning and their working memory capacity, which shows learning gained improved attitudes towards fieldwork because of the experience and time invested in setting up educational fieldwork (Riggs, 2005; McKinley et al., 2023).

Age-related factors can play a role in learning achievement. For example, poor performance has been associated with relatively older (older in age) students who know their capabilities better than younger students (Gualtieri & Finn, 2022; Rawlings et al., 2023) in the same grade. In contrast, some studies outlined that older students demonstrate relatively better academic achievement than younger students, implying that younger students face more difficulty in this regard (Navarro et al., 2015). Moreover, some older students in the same grade have a better level of learning ability, which affects their learning achievement (Boateng-Nimoh & Nantwi, 2020). If a class has students in different age groups, it is necessary to understand how age affects their learning progress. Younger students can lose interest in fieldwork activities because they find the connection between science and the real world dry and boring (DeWitt & Archer, 2015; Said et al., 2016).

The Role of the School Setting, Gender, and Age in Primary School Students' Attitude towards Inquiry-based Science Fieldwork

A recent study indicated that a school setting affects students' attitude towards IBSF in science education (cf., Haynes et al., 2023). Thus, different school settings, such as the school environment, influence students' attitudes towards IBSF and allow them to develop new knowledge, arousing their curiosity and creative abilities (Carrier et al., 2013; Iskrenovic-Momcilovic, 2020; Kim, 2022). Furthermore, IBSF promotes active participation, which boosts student engagement when they explore and become more invested in their learning, helping them retain knowledge effectively (Peasland et al., 2024; Chalmeau & Julien, 2023). Moreover, a study conducted in Britain with primary students signifies that exposure to fieldwork settings may impact on students' environmental attitudes, environmental awareness, and science learning (Thompson et al., 2008). Additionally, different teaching and learning methods increase students' commitment to schoolwork (Küçük & Yıldırım, 2020), and fieldwork increases primary school students' inclination to ask questions and explore science related to the school

environment (Matawali et al., 2019) and stimulates their engagement and active learning (Owens et al., 2020). For example, if students are interested in science, IBSF can influence their attitudes to that subject because they have more clarity on what the subject entails. Some researchers have found that having a good attitude profoundly improves students' learning (Jones & Washko, 2021), which can also increase their interest in IBSF (Bascope et al., 2023) and related career choices. Therefore, interactions with nature are crucial to fostering a sustainable future and environmental consciousness (Jeronen et al., 2009). Fieldwork also enables students to experience nature with all their senses (Palavan et al., 2016; Li et al., 2024) and their attitudes to and capabilities toward learning about fieldwork (Zhu, 2022). IBSF enhances students' attitudes by offering hands-on learning experiences that deepen their understanding of scientific concepts and processes (Chalmeau & Julien, 2023). Moreover, students actively engage with their natural surroundings, nurturing a sense of environmental appreciation (Nazir & Pedretti, 2016). Primary school boys have been found to have better attitudes when learning outside than inside the classroom (Carrier, 2009; Ashjae et al., 2024). Randler et al. (2005) found that involvement in a fieldwork activity heightened interest in well-being and lower levels of anger, anxiety, and boredom among elementary school boys. Furthermore, the relationship between the teacher and the student was positively realigned through a shared outdoor learning experience (Scott et al., 2013; Erickson et al., 2024).

Reasons for gender differences in childhood and adolescence differ in terms of their attitudes towards IBSF (cf., Nation & Muller, 2023). Research finds that boys receive more reinforcement than girls to get involved in fieldwork activities and are more likely to be active in high school and pursue degrees in college (Posselt & Nuñez, 2022). Therefore, masculinity is associated with fieldwork (Vanderbeck, 2005; Bartholomaeus, 2013). Although a field-based environmental summer camp revealed that girls found the fieldwork interesting and felt they were helping to complete valuable research (Nation & Muller, 2023). Moreover, a study conducted in Namibia revealed that students develop autonomy through hands-on practical activities as they conduct inquiry activities (Shivolo & Mokiwa, 2024).

A study conducted in the United Kingdom on fieldwork in earth sciences and environmental sciences argued that stimulating effective approaches to learning during fieldwork happens regardless of age (Boyle et al., 2007). Accordingly, Lowe (2004) stated that younger students' attitudes towards fieldwork are more positive than older ones. Where else, Goulder et al. (2013) argued that older students had a more positive perception of fieldwork because they enjoy themselves while participating in fieldwork, feel safe, believe that they are making good use of their time because it provides first-hand experience of recording and interpreting scientific data, the ability to work in a team.

The ideas of exploration and investigation can be viewed as part of IBSF and valuable in science education. Subsequently, the IBSF learning method creates and improves students' positive learning achievements and attitudes (Bogut et al., 2017). Fieldwork engages students' intellectual, emotional, interpersonal, intrapersonal and physical abilities (Pamulasari, 2017), allowing them to perform academically well in science subjects (Talib et al., 2009). Therefore, the role of fieldwork challenges students to take responsibility for their learning, permitting them to discover new ways to think and not rely only on the textbook (Hill & Woodland, 2002; Hirsch & Paczyńska, 2024). Therefore, a strong positive correlation exists between academic achievement and attitude towards fieldwork, especially the enjoyment of science lessons (Afari, 2011; Haynes et al., 2023). A recent study by Lee (2020) asserted that while conducting the field tasks, students became more active, adventurous, talkative, and responsible for what was happening compared to classroom learning.

Research Aim and Questions

In Namibia, primary science education is referred to as integrated natural science and health education (INSHE) (Namibian Ministry of Education, Arts and Culture, NMoEAC, 2016). Consequently, primary school students' learning achievements have declined (Ndjangala et al., 2021), since they are not performing well, and current teaching and learning methods have encountered obstacles (Mashebe & Zulu, 2022). A decline in students' positive attitudes towards different teaching methods in science at the primary level was reported (Çokadar & Külçe, 2008). The factors responsible for this decline include the quality of instruction, classroom setting, and medium of instruction (Liem et al., 2008). Implementing IBSF remains less practiced by teachers in Namibian science education, particularly in poorly resourced schools (Shinana et al., 2021). However, it is believed that the use of inquiry-based learning to examine fieldwork has an impact on students' attitudes and improves academic performance and the acquisition of new skills (Iskrenovic-Momcilovic, 2023). Conversely, when students do not perceive the value of explorative teaching and learning methods such as IBSF, they use other kinds of surface learning methods (e.g., memorization) to learn (Liem et al., 2008). The results of this study may extend the current understanding of school settings, gender, and age in order to increase students' learning achievements and attitudes

toward IBSF. Although a few studies have looked at students' learning achievements in science education, to the best of our knowledge, none have explored how primary school students' learning achievements and attitudes towards IBSF differ according to the school setting, gender, and age. Hence, the following research questions guide this research:

RQ1. To what extent do school setting, gender, and age impact primary school students' learning achievement after an IBSF intervention?

RQ2. To what extent do primary school students' attitudes toward IBSF vary by school setting, gender, and age?

RQ3. To what extent are primary school students' learning achievements and their attitudes toward IBSF related?

Method

Research Design

This study used a quasi-experimental case study design in which socio-demographic variables such as school setting, gender and age were measured with regard to learning achievements after an IBSF learning experience. Quasi-experimental study is a type of research design that attempts to establish a cause-and-effect relationship (Rogers & Revesz, 2019). In this study, we wanted to determine how the IBSF intervention affects students' learning achievements and attitude towards IBSF after experiencing it. The design provided opportunities to understand the impact of experiencing IBSF learning among selected students to regulate external variables. In addition, the study supports further developments in using the IBSF teaching approach in the Northern Namibian context.

The study was implemented in a school setting, and the first author selected the participating schools based on her local knowledge to find appropriate, well-representative public schools from the savannah ecosystem. Savannah ecosystem is a mixed grassland ecosystem characterized by a combination of open grassy areas and scattered trees, which is typically found in tropical and subtropical regions, such as Africa, it is known for its unique climate and wide range of plants and animal species (Williams et al., 2022). At the same time, classes were randomly assigned as the "control" and "experimental" groups. Random sampling was used in this study to select a subset of individuals from a larger student community each individual has an equal chance of being chosen. This technique is crucial for ensuring that the sample accurately represents the population being studied, which enhances the validity and reliability of the research findings (Stratton, 2021). Data were collected from learning achievement tests before and after the IBSF learning experience, from questionnaires on students' attitude and semi-structured interviews. Moreover, the selection of the schools had been done through purposive sampling. In this case purposive sampling (Kelly, 2010, p. 317) was necessary to obtain data from the schools located in the savannah ecosystem. All seventh-grade classes were assigned to participate in study by the school principal, and students' participation depended on their guardians signing a consent form. Moreover, the interview participants were selected based on students' requirements, such as participation in the intervention and completion of the attitude questionnaire, as students were able to express themselves well in the English language based on the teacher's observation.

IBSF Intervention

As far as the intervention was concerned, the researchers designed the curricular activities based on the science learning objectives (cf. NMoEAC, 2016). The general aim of the intervention lessons was for students to share their environmental experiences of the different types of ecosystems they lived in and the kinds of plants and animals within the Savannah ecosystem. However, before the implementation of the intervention, the activities were thoroughly and critically reviewed by the researchers and science teachers in terms of their perceived feasibility and efficacy. The interventions were implemented over a period of approximately four weeks for each school. In terms of the social aspects of the learning environments, the students were not used to working in groups outside lessons and making inquiries, which, to some extent, caused challenges for the teacher.

Introduction (Six Lessons, 10 Minutes)

This part of the intervention involved making students aware of the learning competencies, the division of groups, and completing the worksheets via guided inquiry. Guided inquiry is considered beneficial and was recommended over other types of inquiry strategies (Bunterma et al., 2014).

Development of the Intervention Part (Six Lessons, 80 Minutes)

This part involved solving the science learning objectives within IBSF group work. The students worked collaboratively as a group guided by the teacher. They completed the learning materials (worksheet), which directed them to develop knowledge and competencies using stimuli within the environment. In this study the type of IBSF activities implemented involved observation, investigating and collecting data. As such students completed the worksheet with answers during IBSF intervention and report the findings based on the competencies (cf., Appendix 1). The students discussed questions raised by other students and compared them with the textbook content. In addition, the teacher clarified the misconceptions.

Evaluation of the Learning Process (Six Lessons, 20 Minutes)

The students reflected and presented their findings from the IBSF using poster presentations, textbooks and internet research. Post-test for learning achievement and attitudes was administered four weeks after the students' initial participation in the pre-test. The learning achievement test was a paper–pencil test, and the attitude questionnaire was completed online, and the participants' names, grade, age and name of the school were written on the test paper but were omitted during the reporting of results in this study for confidentiality purpose. The interviews of 20 students at the schools were audiotaped, and each one took approximately 15–20 minutes. The study was conducted following the guidelines of the ethics committee of the National Board on Research Integrity (2019) and of the executive director of the NMoEAC. All stakeholders were informed about the study, and their voluntary participation and the confidentiality of the data used were highlighted. All stakeholders, such as the school principals, teachers, guardians, and students, consented to the study. Fortunately, none of the guardians refused their children to participate in the study because they were provided with the content of the study and how it aligned with the revised school curriculum.

Measurements**Pre- and Post-Learning Achievement Tests**

Before and after an IBSF learning experience, students' learning achievements were measured using a prepared paper-pencil test (cf., Appendix 4). The authors created the pre-and post-tests following the INSHE syllabus for seventh grade students in Namibia (cf. Appendix 2). According to the syllabus, the tests should be out of 20 marks and feature different types of questions, from easier multiple-choice questions to more explanatory types of questions with pictures that students can identify. The measure consisted of nine closed and open-ended questions in total. The marking scheme was formulated using the INSHE platinum textbook in Namibia. The school's science teacher reviewed and approved the pre-and post-tests and the marking scheme.

Questionnaire and Interview

Students' attitudes to IBSF in science education were determined based on the revised attitude questionnaire by Barmby et al. (2008). The instrument consists of 14 statements (see Appendix 2), and a Likert scale with five options was used (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). The semi-structured interviews were to determine students' attitude towards IBSF after participating in an IBSF intervention. Semi-structured interviews were chosen to allow the respondents to explain their viewpoints (Creswell & Creswell, 2017) and to obtain more information from them. The interviews consisted of two questions (see Appendix 3), the first focusing on the students' views on the importance of IBSF and the second tapping into students' future participation in the IBSF. All authors validated the interview questions and agreed on the related themes.

Participants

A total of 100 primary school students from Northern Namibia participated in the study. They were all seventh graders (grade 0-7th grade is part of elementary school in Namibia) who were considered to have had satisfactory year-end exam performances in their subjects of choice after completing sixth grade. All the students from the two schools used the same national curriculum in science education; however, every school environment is set up based on the teachers' preferences and students' needs. For example, the arrangement of chairs in the class and the

type of teaching and learning strategy performed. Table 1 shows the participants' socio-demographic information whereby students were 12–14 years old, including those who were repeating seventh grade for the second time > 14 years old.

Table 1. Demographic information of the participants

Item	IBSF (f) N = 100
<i>First time seven graders' age (years)</i>	
12	43
13	36
<i>Repeaters of seven graders' age ≥ 14</i>	21
<i>Gender</i>	
Boys	44
Girls	56
<i>Participants per school</i>	
School 1	53
School 2	47
<i>Interviewed students</i>	
Boys	11
Girls	9

Data Collection and Research Ethics

The study design was piloted in spring 2021 with 50 seventh-grade Namibian students who did not form part of the main study group. Based on the results of the pilot study, we removed three low-validity attitude factors ($\alpha < .70$) from the current study and the remain items had acceptable Cronbach's alpha. Furthermore, all students were given the same amount of time to complete the questionnaire which is 10-15 minutes. All students completed within the given time.

The main study data from the pre-and post-learning achievement tests and attitude questionnaires were collected in spring 2022. The pre-and post-test data were collected during INSHE lessons, which took 45 minutes. Pre-test were carried out individually in each class as a paper–pencil task. After that, the students participated in the IBSF attitude questionnaire and interview.

The IBSF was based on three topics from the Namibian INSHE syllabus: ecosystem, plants and animals (cf. NMoEAC, 2016; see Appendix 1). Paper–pencil science tests on the three topics were administered to the students before and after the IBSF intervention. Prior to the intervention, students mostly associated IBSF with school field trips, such as to museums, aquariums and animal parks. For this intervention, all students were new to this method of learning, and they learned in environments near to the schools in a village.

Data Analysis

The study used a mixed-methods approach, combining both quantitative and qualitative data analysis. Quantitative methods were applied to assess students' learning achievements, while qualitative methods provided deeper insights into students' attitude towards IBSF. This combined approach enhanced the overall understanding of the research findings (Tashakkori & Creswell, 2007). Quantitative data were analyzed using SPSS version 25. Since data were collected from two different schools, variations in students' school setting, gender (with unequal group sizes), and age were taken into account (see Table 1). Prior to analysis, the data were cleaned to remove duplicates from the pre- and post-test learning achievement and attitude questionnaires, ensuring result accuracy. Data analysis began with the calculation of descriptive statistics, providing a foundational understanding of the data and its relationships. Next, the validity and reliability of the questionnaire and interviews were assessed using inferential analyses. Before proceeding with more advanced analyses, assumptions were tested for appropriateness. Finally, multiple linear regression, exploratory factor analysis (EFA), multivariate analysis of variance (MANOVA), and Pearson correlation coefficients were conducted.

Qualitative data from the interviews were analyzed using content analysis. Content analysis in the study was to develop a valuable coding framework that could be enhanced by categories emerging from the data (cf. Schreier,

2012). The lead analyst (first author) thoroughly reviewed the transcripts to comprehensively understand the data. Consequently, the research team familiarized themselves with the information gathered from students' interviews and observations, which provided them with initial insights. Initial codes were derived directly from the data, reflecting concepts related to students' responses about positive learning experiences in IBSF (PLE-IBSF) and future engagement and valuing in IBSF (FEV-IBSF). Categories were formulated based on research questions and defined according to the outcomes of the coding process. Codes were created based on the frequency of phrases identified in the students' responses while also considering variables such as school setting, gender, and age. Similar codes were subsequently grouped under corresponding categories and interpreted using a tabular format (see Tables 13, 14, 15). In this stage, each student's IBSF transcript, which typically contained multiple sentences, was treated as a unit of content analysis. A systematic approach was utilised for coding, beginning with identifying and labelling meaningful data units within the transcripts. The codes were then compiled into a list and continuously refined through peer review. This collaborative effort enhanced the trustworthiness and credibility of the findings, ensuring consistency across the dataset.

Results

RQ1. Impact of school setting, gender, and age on primary school students' learning achievement following an IBSF intervention

To answer the first research question, we conducted regression analysis to quantify the relationship between the independent variables (school setting, gender, and age) and the dependent variable (post-test scores). Assumption checks revealed no violations of linearity, and the scatterplot confirmed a linear relationship between the covariate (pre-test scores) and post-test scores. Assumptions of independence (Durbin–Watson = 1.37), homoscedasticity, and absence of multicollinearity (VIF values < 10) were met. Skewness (−0.622, SE = 0.241) and kurtosis (−0.463, SE = 0.478) fell within acceptable limits, suggesting no major departures from normality. Although the Kolmogorov–Smirnov test was significant ($p < .001$), indicating non-normality, we proceeded with the regression analysis, nonetheless, noting that no outliers were present. Tables 2, 3, and 4 present the mean, median, standard deviation, and range of post-test scores across the categories of school setting, gender, and age.

Table 2. Post-test scores by school setting

	Mean	Median	Standard Deviation	Range of post-test scores
School 1	10.89	11.00	4.24	1.50-20.50
School 2	17.47	18.00	2.400	10.00-20.50

Table 3. Post-test scores by students' gender

	Mean	Median	Standard Deviation	Range of post-test scores
Boys	13.70	14.50	5.43	1.50-20.00
Girls	14.21	14.75	4.37	2.50-20.50

Table 4. Post-test scores by students' age

	Mean	Median	Standard Deviation	Range of post-test scores
12	14.52	16.50	4.98	2.50-20.00
13	13.83	13.50	4.69	2.50-20.00
14	12.22	12.00	4.35	5.50-19.00
above 14	18.83	18.50	1.53	17.50-20.50

Table 5 presents multiple regression results predicting post-test scores from school setting, gender, and age. The overall model was significant ($F(4, 95) = 27.69, p < .001$), with an adjusted R^2 of .538. The effect size ($f^2 = 1.17$) was moderately large, indicating that these predictors had a substantial impact on student performance. After controlling pre-test scores, school setting was found to be a significant predictor of learning achievement (post-test) ($\beta = .693, t = 9.856, p < .000$).

Specifically, students in setting 2 ($M = 17.47, SD = 2.40$) outperformed those in setting 1 ($M = 10.89, SD = 4.24$). In contrast, gender ($\beta = .005, t = 0.076, p = .940$) and age ($\beta = -.140, t = -1.959, p = .053$) were not significant predictors. Pre-test scores also significantly predicted post-test performance ($\beta = .219, t = 3.121, p = .002$), indicating that higher pre-test scores were associated with higher post-test scores.

Table 5. Multiple linear regression analysis examining the impact of school setting, gender, and age on students' learning achievement

Intercept	B	SE	β	t	p
Pre-test scores	.414	.133	.219	3.121	.002
School setting	6.63	.673	.693	9.856	.000
Gender	.052	.688	.005	0.076	.940
Age	-.800	.408	-.140	-1.959	.053

RQ2. Primary School Students' Attitudes Toward IBSF Differed by School Setting, Gender, and Age

Before addressing the second research question, we assessed the validity and reliability of the students' attitude scale via exploratory factor analysis (EFA) using principal axis factoring with oblimin rotation (Kaiser normalization), followed by Cronbach's alpha tests. According to the EFA results, there were two distinct factors. The items in the first factor mainly gauged students' positive learning experiences, which increased their interest and confidence in IBSF.

The second factor measured students' willingness to engage in IBSF and the extent to which they valued their IBSF experiences. Thus, we named the factors Positive Learning Experience in IBSF (PLE-IBSF) and Future Engagement and Valuing IBSF (FEV-IBSF). All items loaded above .40 on their respective factors. Cronbach's alpha values were .911 for PLE-IBSF and .886 for FEV-IBSF (see Appendices 4 and 5), indicating high internal consistency. Given these two dependent variables, we selected MANOVA to examine group differences in both simultaneously.

Prior to analysis, we confirmed that all dependent measures were continuous with no outliers. The independent variables were all categorical, consisting of two dichotomous factors (school setting and gender) and one three-level factor (age group), with an adequate sample size ($n > 50$). Box's test of equality of covariance matrices was non-significant at the .001 level (Box's $M = 57.466$, $p = .005$; Pallant, 2010), meeting the homogeneity-of-covariance assumption. Levene's tests showed homogeneity of variances for PLE-IBSF ($F(13, 86) = .958$, $p = .499$) but not for FEV-IBSF ($F(13, 86) = 2.193$, $p = .016$). Consequently, we used Pillai's Trace for the MANOVA, as it is robust to variance-homogeneity violations (Finch, 2005). Tables 6–8 present descriptive statistics for PLE-IBSF, stratified by participants' background characteristics. Similarly, Tables 9–11 show descriptive statistics for FEV-IBSF across the same background variables.

Table 6. Descriptive statistics of PLE-IBSF by school setting

	Mean	Median	Mode	Standard Deviation	Range of attitude scores	Frequency Distribution
School 1	29.00	30.00	28.00	3.90	14.00-34.00	53
School 2	29.70	30.00	30.00	3.12	21.00-35.00	47

Table 7. Descriptive statistics of PLE-IBSF by gender

	Mean	Median	Mode	Standard Deviation	Range of attitude scores	Frequency Distribution
Boys	29.95	30.00	33.00	3.22	22.00-35.00	44
Girls	28.84	30.00	31.00	3.75	14.00-35.00	56

Table 8. Descriptive statistics of PLE-IBSF by gender

	Mean	Median	Mode	Standard Deviation	Range of attitude scores
12	29.00	30.00	28.00	3.16	21.00-35.00
13	28.67	28.50	28.00	4.21	14.00-35.00
14	30.11	30.50	31.00	2.85	24.00-35.00
above 14	28.33	28.00	24.00	4.51	24.00-33.00

Table 9. Descriptive statistics of FEV-IBSF by school setting

	Mean	Median	Mode	Standard deviation	Range of attitude scores	Frequency distribution
School 1	28.58	29.00	28.00	3.09	20.00-33.00	53
School 2	29.38	29.00	31.00	3.67	21.00-35.00	47

Table 10. Descriptive statistics of FEV-IBSF by gender

	Mean	Median	Mode	Standard Deviation	Range of attitude scores	Frequency Distribution
Boys	29.45	29.00	28.00	3.01	23.00-34.00	44
Girls	28.57	29.00	31.00	3.63	20.00-35.00	56

Table 11. Descriptive statistics of FEV-IBSF by age

	Mean	Median	Mode	Standard Deviation	Range of attitude scores
12	29.19	30.00	31.00	3.00	22.00-35.00
13	28.17	28.00	28.00	3.40	20.00-34.00
14	30.28	31.00	31.00	3.58	21.00-35.00
above 14	27.33	24.00	24.00	5.77	24.00-34.00

Finally, a MANOVA was conducted to examine whether primary students' attitudes toward IBSF varied by school setting, gender, and age. According to the result, the overall model was significant, (Pillai's Trace = .132, $F(27, 3926.50) = 1.850$, $p = .005$). To be specific, the effect of school setting on students' attitude towards IBSF was not significant (Pillai's Trace = .013, $F(2, 85) = 0.555$, $p = .576$, $\eta^2 = .013$), indicating a small effect size. In contrast, a significant effect of gender was observed with boys ($M = 4.27$, $SD = 0.48$) scored higher than girls ($M = 4.13$, $SD = 0.52$) on PLE-IBSF (Pillai's Trace = .073, $F(2, 85) = 3.357$, $p = .041$, $\eta^2 = .073$), indicating a moderate effect size, suggesting that boys displayed a more positive learning experiences in IBSF compared to girls. A similar pattern emerged for FEV-IBSF, with boys ($M = 4.21$, $SD = 0.45$) slightly above girls ($M = 4.09$, $SD = 0.52$).

Table 12 between-subjects effects confirmed a significant gender difference on PLE-IBSF ($F(1, 86) = 4.218$, $p = .043$, $\eta^2 = .047$) and a stronger effect on FEV-IBSF ($F(1, 86) = 6.490$, $p = .013$, $\eta^2 = .070$), suggesting gender plays a larger role in students' willingness to participate and valuing IBSF. Age did not significantly influence overall attitudes (Pillai's Trace = .095, $F(6, 172) = 1.427$, $p = .207$, $\eta^2 = .047$). However, LSD post hoc tests on FEV-IBSF revealed that 13-year-olds ($M = 4.33$, $SD = 0.50$) scored significantly higher than 14-year-olds ($M = 3.95$, $SD = 0.79$), $p = .025$, indicating specific age-group differences despite the non-significant omnibus test.

Table 12. Results of the MANOVA test for the effects of school setting, gender, and age on PLE-IBSF and FEV-IBSF

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
School setting	PLE-IBSF	.105	1	.105	.407	.525	.005
	FEV-IBSF	.234	1	.234	1.121	.293	.013
Gender	PLE-IBSF	1.088	1	1.088	4.218	.043	.047
	FEV-IBSF	1.357	1	1.357	6.490	.013	.070
Age	PLE-IBSF	1.152	3	.384	1.489	.223	.049
	FEV-IBSF	1.660	3	.553	2.646	.054	.085
Error	PLE-IBSF	22.184	86	.258			
	FEV-IBSF	17.977	86	.209			
Total	PLE-IBSF	1781.163	100				
	FEV-IBSF	1734.735	100				
Corrected Total	PLE-IBSF	25.553	99				
	FEV-IBSF	23.140	99				

To further address RQ2, the qualitative findings were used to explain the results of the attitudes questionnaire. Similar to the quantitative findings, two categories emerged: Positive Learning Experiences in IBSF (PLE-IBSF), and willingness to participate and valuing IBSF (FEV-IBSF). Accordingly, the two interview categories were identified based on research questions to complement the quantitative results. According to the students' responses to the question 'How does IBSF affect your learning?', the PLE-IBSF category was generated (see Table 13). Six students in School 1 indicated that IBSF had a positive role in their learning because it allowed them to experience science and understand that learning was not exclusive to the classroom, which increased their knowledge and learning. On the other hand, nine students enrolled in School 2 considered IBSF to be good and responded positively to it because they could recall the things they had learned, learn more outside class, and get fresh air while participating in IBSF. For example, one student responded that *"It affected my learning in a positive way because going out in the field give us an opportunity to experience compared to when taught in the classroom, we*

saw birds flying". Regarding FEV-IBSF, it is notable that students from Schools 1 and 2 acknowledged that they wanted to participate in IBSF in the future because they considered life to be all about learning and could explain what they were taught after engaging in IBSF. Moreover, science was fun, as they could explore and learn more. For examples, one student responded that *"IBSF is a lot of fun to be outside and experience nature"*.

Table 13. Students' attitudes towards IBSF by school setting

Category	School 1	<i>f</i>	School 2	<i>f</i>
PLE-IBSF	Understanding	1	Good	5
	Knowledge	2	Learning more	3
	Positivity	3	Positivity	1
FEV-IBSF	Learning more	4	Exploring	1
	Fun	5	Remembering	3
	Remembering	1	Performing much better	2
			Interesting	4

Table 14 summarises the qualitative interview responses by gender. Concerning PLE-IBSF, seven girls expressed that they understood science better due to IBSF because it affected their learning in a very positive way. In addition, going out in the field allowed them to experience new things, compared to when they were taught in the classroom, and they could learn that the environment provided them with oxygen and shelter; as a result, they learned more about things they did not know. However, two girls expressed that IBSF did not affect their learning. Where else, eight boys stated that IBSF positively affected their learning because it allowed them to learn more, understand the outside world better and connect what they had been taught. Lastly, one boy stated that going out allowed students to get fresh air. Regarding FEV-IBSF, two girls stated that IBSF would not impact their futures, as they believed they would gain more knowledge once they moved on to higher grades. Moreover, two boys said that they could not focus when they were outside and that IBSF does not upgrade their learning.

Table 14. Students' attitudes towards IBSF by gender

Category	Girls	<i>f</i>	Boys	<i>f</i>
PLE-IBSF	Understanding and learning more	7	Learn and understand more.	8
	Has no effect	2	Fresh air	
	Delayed Learning		IBSF does not upgrade learning	1
FEV-IBSF	Perception	2		2

The qualitative findings, as illustrated in Table 15, suggest that students' perceptions of IBSF varied by age. To be specific, among the 12-year-olds, four students expressed that they learned more during IBSF than in the classroom. IBSF allow them to experience nature beyond what was taught in textbooks, get a better and more robust understanding and knowledge of science and get fresh air. Among the 13-year-olds, three students found IBSF to be beneficial and could recall the things they had learned because they connected what was being taught with what was outside the classroom.

Table 15. Students' attitude towards IBSF based on age

Category	12 years	<i>f</i>	13 years	<i>f</i>	14 years	<i>f</i>
PLE-IBSF	Opportunity to learn more	4	Recall the subject content	2	Get more knowledge	2
	Understand better	2	Connecting what has been taught	1		
	Get fresh air	1				
FEV-IBSF	Focus outside	4	Learn more.	4	Gain more information.	2
	Job related	1	Work well with people.	1	Learn what is taught.	1
	Learn more	2	Fresh air	1		
	Take care of the environment	1	Perform well			

For the 14-year-old students, two students expressed that they obtained more knowledge from learning outside and were positive. Concerning FEV-IBSF, all 12-year-old students wished to take part in IBSF in the future because it allowed them to see animals and plants and how they interact, and one wanted to learn more about science. Moreover, 13-year-old students stipulated that they learned more outside than in class, knew how to work

with other people and got fresh air. The 14-year-old students gained more information during IBSF and considered learning outside to be better than in the classroom because they tended to know what they were being taught.

RQ3. The Relationship Between Primary School Students' Learning Achievements and Attitude Towards IBSF

We conducted Pearson correlation analyses between two attitudinal factors (PLE-IBSF and FEV-IBSF) and students' post-test scores to explore the relationship between attitudes and achievement. Before analysis, several assumptions were checked. First, post-test scores, PLE-IBSF, and FEV-IBSF were measured on continuous scales, fulfilling the requirement for correlation. Scatterplots for each variable pair revealed a consistent directional trend, confirming linearity. Univariate normality was assessed via skewness and kurtosis: post-test scores (skewness = $-.622$, SE = $.241$; kurtosis = $-.463$, SE = $.478$), PLE-IBSF (skewness = -1.080 , SE = $.241$; kurtosis = 2.550 , SE = $.478$), and FEV-IBSF (skewness = $-.469$, SE = $.241$; kurtosis = $-.258$, SE = $.478$). Levene's test for equality of variances showed no significant differences for post-test scores and PLE-IBSF ($p = .413$) but did for FEV-IBSF ($p < .001$), indicating a homoscedasticity violation; however, Pearson correlation is robust to this, so analyses proceeded. Finally, the independence of observations assumption was met, as each student contributed only one set of data.

A Pearson correlation analysis was conducted to examine the relationship between primary school students' post-test learning achievement and their attitudes toward IBSF. The results indicated a non-significant negative correlation between post-test scores and PLE-IBSF ($r(100) = -.022$, $p = .830$), as well as a non-significant positive correlation between post-test scores and FEV-IBSF ($r(100) = .044$, $p = .667$). These findings suggest that students' attitudes toward IBSF—whether related to their learning experiences or their motivation and values—may not be directly associated with their immediate academic performance.

Discussion

Socio-Demographic Differences in Learning Achievement

Our results showed that school setting significantly influenced post-test learning outcomes, underscoring the critical role of students' learning environment, which aligns with Hanushek and Woessmann (2011), who demonstrated that school context can directly influence student performance. Consequently, curriculum developers should strive for uniform implementation of educational content across all schools to ensure equitable learning opportunities (Cheung & Wong, 2012). In Namibia, urban schools generally benefit from superior infrastructure, more qualified teachers, and richer educational resources, whereas rural schools contend with overcrowded classrooms, limited materials, and teacher shortages (NMoEAC, 2018), which may explain the differences we observed across school settings.

In our study, gender did not influence post-test learning achievements, indicating that the IBSF intervention benefited boys and girls equally, the finding contradicts the study by Wieselmann et al. (2020) which observed fifth-grade students engaged in integrated STEM activities, the findings revealed that boys predominantly assumed leadership roles, directing experiments and handling materials, while girls often took on supportive roles such as observing and recording. Likewise, Meece et al. (2006) observed that urban schools often employ teaching methods and resources that advantage one gender over another. Despite the absence of gender differences in our results, the Namibian Environmental Education Policy should continue to monitor and ensure equitable access to fieldwork opportunities for both boys and girls (Simasiku, 2020). Interestingly, our results showed that age did not significantly predict post-test learning achievement, despite a trend in which younger students outperform older ones who have a bigger age in a small grade. This contrasts with Boateng-Nimoh and Nantwi (2020) and Robinson et al. (2014), who reported that older students tend to have stronger learning abilities and higher academic performance. However, those studies did not account for grade repetition—a factor that may explain our findings, since older students in our sample were more often repeaters. These results emphasize that, in the Namibian context, grade repetition should be considered when designing educational content to ensure lessons remain appropriately challenging and aligned with students' learning needs (Ndjangala et al., 2021).

Impact of Socio-Demographic Factors on IBSF Attitudes

The quantitative and qualitative results revealed that students in both schools held positive attitudes toward IBSF, with no significant differences between settings. This suggests that students develop positive attitudes toward IBSF regardless of their school environment. Chalmeau and Julien (2023) reported that most primary and lower secondary students enjoy fieldwork because of the physical activities involved, the opportunity to engage with nature, and the novelty of learning experiences. Considering the limited experience of Namibian teachers with inquiry-based science fieldwork (IBSF), it is essential that both pre-service and in-service training programs equip all educators with uniform fieldwork skills to maintain consistently positive attitudes (Shivolo, 2024).

In terms of gender, boys reported more positive attitudes toward both interest and confidence in IBSF and willingness to participate and valuing IBSF, indicating that they value IBSF and are more eager to participate in future fieldwork than girls, in line with Ribeirinha et al. (2024) which found that boys generally report higher interest and confidence in inquiry-based science activities compared to girls, boys also expressed greater willingness to participate in future field investigations, suggesting they value hands-on, exploratory science learning more highly. However, it contrasts with Chetcuti and Kioko (2012), who found that Kenyan schoolgirls held more favorable attitudes toward science than boys. To address these gender differences, Mashebe and Zulu (2022) recommend mixed-gender rather than single-gender groupings during fieldwork; however, because our study already employed mixed-gender groups, we cannot evaluate the effectiveness of this strategy. Our qualitative data further revealed some girls' reluctance to engage in future IBSF despite strong performance, Nation and Müller (2023) study conducted with high school students suggest inviting females' fieldwork experts into the classroom to help girls feel more connected to these activities.

Concerning the age differences, our quantitative results revealed that 13-year-olds were more willing to participate in IBSF than 14-year-olds, implying that younger students hold more positive attitudes toward IBSF than older ones. This finding aligns with Chalmeau and Julien (2023), who reported that younger students are more interested in fieldwork, whereas older students primarily enjoy general outdoor activities. Buchanan et al. (2022) argue that this age-related decline in attitude may stem from younger learners' sensory-based engagement, which enhances their appreciation for science fieldwork compared to older students. Chalmeau and Julien (2023) further noted that students at different age levels value fieldwork for different reasons: upper-secondary students cite well-being factors—such as fresh air and tranquillity—and view it as a valuable learning experience, while primary students appreciate the physical activities and their affinity for nature. Accordingly, Burns (2023) recommends incorporating more physical, hands-on activities at all grade levels to bolster both learning and positive attitudes toward fieldwork.

Correlation Between Learning Achievement and IBSF Attitudes

While many studies (Boyle, 2007; Brackney, 2008) report a positive relationship between students' learning achievement and attitudes toward fieldwork, this was not the case in our study, this result implies that students' favorable attitudes toward IBSF may not automatically translate into higher achievement, suggesting a need for targeted instructional support that helps learners convert their engagement into concrete learning gains and to figure out their interest towards IBSF. Although the IBSF topics used in this study were well received, incorporating additional content, such as different soil types, could further expand students' knowledge and deepen their appreciation of IBSF in science education.

Conclusion

This study investigated primary school students' learning achievements in science education, considering the impact of school setting, gender, and age which indicated that IBSF contributes to students' learning achievement. It also examined how students' attitude towards IBSF vary based on school setting, gender, and age, as such the quantitative and qualitative results revealed that through IBSF, students have fun observing and indulging in different science learning activities. Additionally, students recognized IBSF as essential, and their positive attitude towards IBSF will encourage them to consider participating in IBSF in the future. Finally, the results did not indicate any relationship between students' learning achievements and attitudes.

Recommendations

The current study focused on two schools located in the same region which limit the generalization of results to the entire population, which has positively responded to the letter of consent to carry out the study. However, this study aimed to reach students in science education mainly in the Savannah ecosystem as it provides opportunities to achieve relevant learning experiences. Thus, future researchers are recommended to use different schools from

different regions to make the results stronger and generalize them to the whole country and different school settings. We believe that this work supports the results of similar studies by providing compelling evidence that can be used to influence decision-making by principals, teachers, and policymakers to promote IBSF in primary schools in the broader learning context. The implication of adopting IBSF orientation for primary school students is to employ real-world problems and include controversial topics in the curriculum to allow students to apply disciplinary knowledge to current affairs of science, critical thinking and reasoning skills to formulate educated judgments as IBSF fosters student discussion, interactions and direct engagement with the experiences of others. The positive attitude towards IBSF will encourage students to participate in IBSF in the future. Moreover, a contextual essay (Morales-Doyle, 2023) might be a great instrument for examining students of different ages in different schools' attitude towards IBSF.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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Appendix 1. Example of pre-test and post-test

Name: _____

Grade: _____

Name of the school: _____

Gender (boy/girl): _____

Subject: Integrated Natural Science and Health Education

Years in grade 7: _____

Age: _____

Instructions

- Circle one correct answer in the multiple-choice.
- Answer the structured questions on the question paper.

Topic: Plants

1. Monocots have flower petals in groups of _____

A. 2

B. 3

C. 4

D. 5

(1)

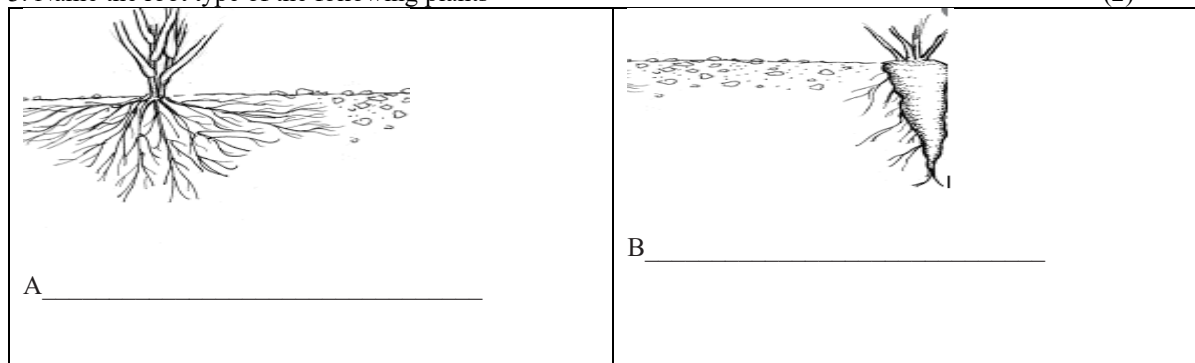
2. State three differences between the characteristics of flowering and non-flowering plants

—

(3)

3. Name the root type of the following plants

(2)



Topic: Animal

4. Explain one physical difference between amphibians and reptiles

(2)

5. In your own words describe the living environment of the butterfly

(3)

6. Describe how birds are adapted to the environment for survival

(2)

Topic: Ecosystem

7. Define the term ecosystem

(1)

8. Describe the energy flow of living organisms within Savannah

(2)

9. Construct a food chain using organisms in your environment

(4)

Total marks: 20

Appendix 2. The content of teaching and learning sequences and aims of the 7th- grade lessons.

Lesson	Content of the lessons	Aims of the lessons
Plants	- Identify the structure of a flowering and non-flowering plant (take pictures). - Describe the difference and similarities between flowering and non-flowering plants. - Describe the species of different plants. (Make use of small plants to identify the flowers, leaves, fibrous and tap roots).	- To understand the structure of flowering and non-flowering plants. - To understand the differences and similarities of flowering plants. - Describe the species of plants.
Animals	- Explain the physical difference between amphibians and reptiles. - Describe in your own words the living environment of the butterfly and what it is doing. - Describe how animals adapt the environment for survival.	- Understand the physical difference between amphibians and reptiles. - Describe the living environment of the butterfly. - To understand how animals are adapted to the environment.
Ecosystem	- Define the term Ecosystem - Describe the energy flow of living organisms within the Savannah Ecosystem. - Describe how birds are adapted to the environment for survival. - Construct a food chain using organisms in your environment.	- To gain knowledge of the Ecosystem. - Understand the flow of energy in the Ecosystem. - To understand how birds are adapted to the environment. - Construct a food chain

Adapted from Namibia. Ministry of Education, Arts and Culture. (2016). Integrated Natural Science and Health Education, (INSHE), Grade 7.

Appendix 3. Interview Questions

- How does IBSF affect your learning?
- Would you like to take part again in IBSF in future?

Appendix 4. Exploratory factor analysis of students' attitude scale and students' attitude towards IBSF in science education measure

Item	Factor		Items
	1	2	
1. FEV-IBSF		.802	I look forward to my IBSF lesson
2. FEV-IBSF		.910	I would like to do more IBSF at school
3. FEV-IBSF		.752	I would like more practical work in my IBSF
4. FEV-IBSF		.574	IBSF is important for society
5. FEV-IBSF		.562	IBSF helps the poor learning learners
6. FEV-IBSF		.565	The benefits of IBSF are greater than the harmful effect
7. FEV-IBSF		.497	Practical work in IBSF is good because I can decide what to do myself
1. PLE-IBSF	.872		I learn interesting things in IBSF lessons
2. PLE-IBSF	.796		I get good marks in IBSF
3. PLE-IBSF	.843		In my IBSF class, I understand everything
4. PLE-IBSF	.709		Practical work in inquiry-based science fieldwork is exciting
5. PLE-IBSF	.728		I like IBSF practical work because you do not know what will happen
6. PLE-IBSF	.691		We learn science better when we do practical work
7. PLE-IBSF	.620		There are many exciting things happening in IBSF

A Systematic Review Study on the Use of Artificial Intelligence in Environmental Education

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Abstract

Environmental education is the solution to the environmental problems caused by technological advancements. Technological advancements make human life easier in many aspect. Today, artificial intelligence is one of the current technological advancements. The purpose of this research is to determine the general trend in studies on the use of artificial intelligence in environmental education, identify gaps in the relevant literature, and explain how current developments in educational technologies impact environmental education. This research is a systematic review. In this research, studies on the use of artificial intelligence in environmental education were systematically compiled to reveal how new developments in artificial intelligence affect the environmental education process. Seventeen studies were included in the review process. This research has two main conclusions. First, artificial intelligence in environmental education is a relatively new and current topic in literature. Second, the use of artificial intelligence tools causes water waste and carbon emissions. Therefore, the conscious use of artificial intelligence is essential for both teachers and students to be aware of it.

Introduction

Unusual temperatures, unstoppable forest fires, melting glaciers, the disruption of life cycles, loss of biodiversity, drought, and hunger... Today, environmental problems, with their underlying causes and consequences, have escalated into unavoidable environmental disasters. These issues affect not only the physical environment but also all of humanity, creating numerous economic and social challenges. Addressing environmental problems has become a priority on the global agenda. The key to solving these problems lies in transforming environmentally harmful behaviors into environmentally friendly ones. This transformation is not a simple, linear process; rather, it is a complex undertaking involving multiple disciplines, encompassing cognitive, affective, and psychomotor domains, and depending on both knowledge and positive attitudes. The foundation of this process is environmental education. Environmental education seeks to cultivate environmentally conscious individuals who strive for sustainable solutions to environmental problems (Tilbury, 1995; Erten, 2004; UNESCO, 2017).

Environmental problems began with the developments that followed the Industrial Revolution. After this period, technology advanced rapidly, living standards improved, and the population grew significantly. The needs of this expanding population also increased, leading to the reckless exploitation of natural resources (Köseoglu, 2023). Technology has transformed many aspects of daily life, particularly human behavior (Akgün, 2019). Education is undoubtedly one of these areas. The integration of technology into education is a widely studied topic today. Factors such as the rapid advancement of technological products, the widespread availability of internet access, and the expansion of online education during the COVID-19 pandemic (UNESCO, 2023) have begun to reshape the education systems of countries worldwide (Arslan et al., 2022). One of the most prominent technological innovations today is artificial intelligence. The use of artificial intelligence in education often involves developing new curricula and producing teaching materials such as virtual reality tools and robotics. While artificial intelligence is recognized for enabling more lasting and effective learning experiences for students, the question of how best to integrate it into education remains a highly debated issue (Chen et al., 2020). Consequently, there appears to be no consensus in the literature on how educational processes can most effectively benefit all stakeholders (Güzey et al., 2023).

Artificial intelligence plays a crucial role in addressing many global crises, particularly climate change. It accelerates the process of describing current situations and obtaining existing data. Teaching processes incorporating artificial intelligence have brought many benefits. However, when it comes to environmental education, the issue becomes more complex. The primary goal of environmental education is to find solutions to

environmental problems. One of the root causes of environmental problems is technological advancements itself. When the use of ChatGPT, one of the most widely adopted artificial intelligence applications, is examined in the context of its carbon and water footprint, the picture that emerges is concerning: A 2023 study by Cheng et al. found that a short conversation (20–50 questions and answers) with ChatGPT consumed approximately half a liter of water. Considering its global use, with billions of questions asked daily, this clearly points to significant water consumption. The same study also reported that a single training session in a data center required about 700,000 liters of fresh water. A similar situation exists regarding carbon footprints. To further analyze this issue, the researcher asked ChatGPT the question: “Does using you harm the environment?” (queried on July 28, 2025). ChatGPT’s response is summarized as follows (Table 1):

“Using me consumes a small amount of energy with each query, which indirectly leads to carbon emissions. However, this harm is minimal for single uses but becomes significant for millions of uses. If 100 million ChatGPT queries are made per day, this translates to tons of CO₂ emissions.

Table 1. Approximate estimated data

	Carbon Emissions (CO ₂)
Making a single ChatGPT query	~1-5 gram
Google search	~0.25 gram
Watching YouTube for 1 hour	~150 gram
Send 1 email	~4 gram

"If the purpose of an AI is to benefit humans and increase productivity, this benefit must be achieved without harming nature and the environment. By using me responsibly and consciously, I will help make this process more sustainable."

A similar concern exists regarding cryptocurrency mining. Cryptocurrency is a product of new technology and is used by a wide range of investors as a payment product. This process consumes significant energy. It is known that cryptocurrency mining consumes the same amount of energy as a small country, thus significantly increasing fossil fuel use. The intensive use of cryptocurrencies means more fossil fuels and causes serious environmental damage (Elbir-Mermer & Kurtulgan, 2024). Therefore, it can be considered a new generation environmental problem. The unlimited use of artificial intelligence will create a similar situation. Carbon emissions are one of the most significant factors disrupting the fundamental balance of the environment and are the root cause of many environmental problems. With the widespread use of artificial intelligence today, and its integration into education proving controversial, it is neither possible nor logical to isolate children from this technology. Therefore, incorporating these current technologies, which are among the root causes of environmental problems, into environmental education is a challenging process.

In summary, environmental education is the solution to the environmental problems caused by technological advancements. Technological advancements make human life easier in many aspect. Today, artificial intelligence is one of the current technological advancements. Many studies have investigated the role of artificial intelligence in education, both nationally and internationally. However, a detailed examination of this literature reveals an absence of research specifically addressing its role in environmental education (Ateş, 2025; Yeşilyurt et al., 2024; Kutlucan & Seferoğlu, 2024; Çavuş, 2024; Meço & Coştu, 2022; Güzey et al., 2023; Akdeniz & Özdiñç, 2021; Chen et al., 2020; Huang et al., 2021). Therefore, conducting a systematic review on the use of artificial intelligence in environmental education will fill a gap in the literature and offer a current perspective on this emerging topic. Identifying the trends in studies conducted on this topic will also provide insight into how artificial intelligence is being incorporated into environmental education from an environmentally friendly perspective. The purpose of this research is to determine the general trend in studies on the use of artificial intelligence in environmental education, identify gaps in the relevant literature, and explain how current developments in educational technologies impact environmental education. To this end, the research problem was defined as "What are the general trends and characteristics of studies on the use of artificial intelligence in environmental education?"

Method

This research, conducted to determine the general trend in studies on the use of artificial intelligence in environmental education, is a systematic review. When conducting systematic reviews, a core topic is first identified. Research on this topic is scanned in detail and examined based on inclusion/exclusion criteria. At the end of this process, studies to be included in the review are identified and analyzed in depth (Higgins & Green,

2011). In this research, studies on the use of artificial intelligence in environmental education were systematically compiled to reveal how new developments in artificial intelligence impact the environmental education process. The systematic review process was conducted in five steps (Table 2). This process was conducted under the supervision of an expert with publications in the field of environmental education.

Table 2. Systematic review process

Step	Name	Explanation
1	Determining the Purpose of the Research	1. The research objective has been established. 2. The research problem related to the purpose of the research has been determined.
2	Creating the Review Protocol	1. Keyword definitions were determined. 2. Databases were selected. 3. Inclusion and exclusion criteria were established.
3	Literature Search	1. Studies were searched in specific databases. 2. Reviews were conducted based on inclusion and exclusion criteria.
4	Finding Studies to be Included in the Review	1. The studies to be undertaken have been finalized. 2. The studies have been summarized in an Excel spreadsheet. 3. The studies have been reviewed.
5	Analysis of Research	1. The summary table was analyzed using content analysis. 2. Trends and gaps in the literature were identified. 3. The research text was written.

Determining the Purpose of the Research (Step 1)

In compiling studies, it is first necessary to determine the topic, purpose, and problem of the research. The topic chosen for this systematic review is the use of artificial intelligence in environmental education. The aim of this research is to "determine the general trend in studies on the use of artificial intelligence in environmental education, identify gaps in the relevant literature, and explain how current developments in educational technologies impact environmental education."

Creating the Review Protocol (Step 2)

After determining the research purpose, it is necessary to identify studies to be included in the review. A review protocol should be developed to facilitate this process. This will create a roadmap. First, the keywords that will shape the literature review were identified. The keywords identified for this research were "environmental education, artificial intelligence," "environmental education, artificial intelligence tools," "environmental education, ChatGPT," "education for sustainable development, artificial intelligence," "education for sustainable development, artificial intelligence tools," and "education for sustainable development, ChatGPT."

Alternatively, a search was conducted using the keyword "artificial intelligence in education." The databases to be searched were then determined. Scopus, ERIC, Web of Science, ProQuest, TR Index, and YÖKTEZ were selected. After determining the keywords and databases, inclusion and exclusion criteria were determined. All studies combining environmental education and/or education for sustainable development with artificial intelligence technologies were included in this search. Studies written on environmental protection but related to disciplines such as engineering, health, technology, and economics that included a dimension of AI were not included in the review. Similarly, existing studies on the use of AI in education were not included if they did not emphasize environmental education and/or education for sustainable development.

Literature Search (Step 3)

A literature search was conducted using relevant keywords in the identified databases. The studies identified through the literature search were examined in detail based on the inclusion and exclusion criteria described above. At the end of this process, 17 studies were identified. The number of studies retrieved from all databases during the literature search was 920. When duplicates (identical studies found in different databases) were removed from these databases, the remaining number of studies decreased to 210. A review of the inclusion and exclusion criteria, as well as the titles and abstracts of the studies, determined that 30 studies were suitable for the scope of the study. A detailed review of these studies revealed that the content of 13 articles was not suitable for educational research. At the end of this process, a total of 17 studies were included in the systematic review process.

Finding Studies to be Included in the Review (Step 4)

Following the literature search process, a summary Excel file was created listing the 17 studies to be included in the systematic review and their characteristics. The studies were recorded in a summary table by examining and evaluating the characteristics required for scientific research. This way, the data was created, organized, and made ready for content analysis.

Analysis Process (Step 5)

Content analysis was deemed appropriate for analyzing the data from the 17 studies included in the review. Content analysis is an analysis conducted to identify concepts that explain the data and the relationships between these concepts. This process involves conceptualizing the data, organizing these concepts, deriving themes that explain the data, and then numerically explaining the codes and themes (Yıldırım & Şimşek, 2016).

During the data analysis, studies from national and international literature were analyzed individually to reveal trends related to the characteristics specified in the research subproblems. The studies were then considered as a whole to determine the general trend in literature. Following this analysis, gaps in literature were also identified, in addition to the general trends of studies. The findings of the analysis were explained using frequencies and percentages as predicted by the content analysis and summarized in tables. The analysis process was conducted under the supervision of a researcher with publications in the field of environmental education. Relevant information is described under the Findings section of the study.

Results and Discussion

The research problem for this article was defined as "What are the general trends and characteristics of studies on the use of artificial intelligence in environmental education?" The characteristics of studies on the use of artificial intelligence in environmental education are described by article type, year of publication, method, sample, and sample size. The general trends of the relevant studies include an analysis of the articles' aims and results. The relevant findings are presented in tables below.

Table 3. Type of article

Type of article	f	%
Research	13	76.5
Theoretical	4	23.5

All of the studies included in the review were articles. Thirteen (76.5%) of the articles were research articles and four (23.5%) were theoretical articles (Table 3).

Table 4. Publication year of articles

	f	%
2018	1	5.9
2021	2	11.8
2022	1	5.9
2023	3	17.6
2024	4	23.5
2025	6	35.3

The first example of research focusing on environmental education and artificial intelligence was seen in 2018. 1 study (5.9%) was published in 2018. No research was found on this topic published in 2019 and 2020. 2 studies (11.8%) were found in 2021 that investigated environmental education and artificial intelligence together, and 1 (5.9) in 2022. It has been observed that there has been an increase in research on the place of artificial intelligence in environmental education since 2023. 4 studies (23.5%) were conducted in 2024 and 6 (35.3%) in 2025. This can be interpreted as that the place of artificial intelligence in environmental education has just started to attract attention with the developments in technology (Table 4).

Table 5. Articles methods

Method	f	%
Experimental	4	23.5
Case study	2	11.8
Survey	2	11.8
Mixed	1	5.9
Design development	2	11.8
None (theoretical paper)	4	23.5
Not specified	2	11.8

Of the 17 articles included in the review, 4 (23.5%) were theoretical and therefore lacked methodological information. Of the 13 articles that were research articles, 2 (11.8%) did not specify any methodology. Of those with methodological information, 4 (23.5%) were experimental, 2 were case studies, design development, and screening (11.8%), and 1 (5.9%) was a mixed methods study. All these findings indicate that the research conducted focused primarily on quantitative methods (Table 5).

Table 6. Sample of articles

Sample	f	%
Students	8	47.1
Documents (programs-key case studies, AI tools)	3	17.6
Experts	2	11.8
Faculty members	1	5.9
Teachers	1	5.9
People	1	5.9
Green Entrepreneurs	1	5.9
None (theoretical article)	4	23.5

Of the studies included in the review, 8 (47.1%) were conducted with students. Among these, 3 involved university students, 2 involved college students, 2 involved elementary school students, and 1 focused on children in early childhood. In 3 studies (17.6%), data were collected from documents such as curricula, notable case studies, and AI tools. In 2 studies (11.8%), expert opinions were gathered on projects developed within the scope of the research. In 1 study (5.9%), data were collected from faculty members; in another (5.9%) from teachers; in another (5.9%) from green entrepreneurs; and in one (5.9%) from the people (Table 6).

Table 7. Sample number of articles

Sample number	f	%
1-49	4	23.5
50-99	1	5.9
100-149	0	0.0
150-199	1	5.9
200-249	1	5.9
250 and more	3	17.6
None (theoretical article)	4	23.5
Not specified	2	11.8

When the sample size of the studies included in the review is examined, it is seen that the density is 1-49 people and 250 and above. There are 4 articles (23.5%) working with sample sizes in the range of 1-49, and 3 articles (17.6%) working with sample sizes of 250 and above. The sample size of 1 article (5.9%) is in the range of 150-199, and 1 article (5.9%) is in the range of 200-249 (Table 7).

Table 8. Purposes of articles

Purposes of the articles	f	%
<i>Demonstrating the benefits of AI</i>		
Helping to gain awareness of sustainable development	3	17.6
Supporting green education	3	17.6
Facilitate the development of environmentally friendly projects/curriculum	2	11.8
Ensuring efficient use of resources	1	5.9
<i>The impact of AI-supported teaching processes</i>		
Sustainable development awareness	2	11.8
Environmental awareness		
Positive attitude towards the environment	3	17.6
Ecological knowledge	2	11.8
Environmentally friendly behavior	2	11.8
Gaining individual experiences	2	11.8
<i>Demonstrate their intention to accept AI technologies in environmental protection</i>	2	11.8

An examination of the objectives of the studies included in the review revealed that all data were grouped under three themes: "Exposing the benefits of AI," "Impact of AI-supported teaching processes," and "Exposing intentions to accept AI technologies in environmental protection." There are four codes under the theme of "Exposing the benefits of AI." Raising awareness of sustainable development and supporting green education are the most frequently mentioned codes (17.6%). These studies also observed benefits of AI, such as facilitating the development of environmentally friendly projects/curriculum (11.8%) and ensuring the efficient use of resources (5.9%). Most of the studies discussing the benefits of AI are theoretical articles.

There are two codes under the theme of "Impact of AI-supported teaching processes." These are sustainable development awareness and environmental awareness. The proportion of studies examining sustainable development awareness is 11.8%. The number of studies on environmental awareness is higher and also addresses environmental awareness elements. Of the relevant articles, 17.6% addressed positive attitudes toward the environment, while 11.8% addressed acquiring ecological knowledge, environmentally friendly behavior, and personal experience. The aims of the research articles were largely concentrated around the theme of the impact of AI-supported learning processes. Another theme was "Exposing intentions to accept AI technologies for environmental protection." The proportion of studies under this theme was 11.8% (Table 8).

Table 9. Results of the articles

Results of the articles	f	%
<i>Raising environmental awareness</i>		
Increasing attitudes towards the environment	7	41.2
Increasing environmental knowledge	4	23.5
Environmentally friendly behavior		
Proposing sustainable solutions to environmental problems	2	11.8
Protecting the environment	1	5.9
<i>Accessing information about environmental issues</i>		
More	4	23.5
Easier	4	23.5
Simplifying complex ecological concepts	2	11.8
<i>Making environmental education interdisciplinary</i>		
Creating environmentally friendly STEM projects	4	23.5
Meaningful learning	4	23.5
<i>Raising awareness of sustainable development</i>		
Developing environmental ethics	3	17.6
Creating a future-oriented learning environment	3	17.6
Supporting inclusive/quality education	3	17.6
Supporting the SDGs	2	11.8
Eco-citizenship	1	5.9

An examination of the results of the articles included in the review revealed that artificial intelligence technologies increase environmental awareness, facilitate access to information about environmental issues, make environmental education interdisciplinary, and foster sustainable development awareness. Overall, while the articles' purposes and types vary, their results appear to be supportive. Articles claiming that artificial

intelligence technologies increase environmental awareness also mentioned elements of environmental awareness. 41.2% of these articles indicated an increase in positive attitudes toward the environment, while 23.5% indicated an increase in environmental knowledge. Furthermore, there is a dimension of environmentally friendly behavior. These behaviors include proposing sustainable solutions to environmental problems (11.8%) and protecting the environment (5.9%). The articles' results indicate that accessing information about environmental issues is more frequent (23.5%) and easier (23.5%) thanks to artificial intelligence technologies. Furthermore, it is said that the complex nature of ecological knowledge has become simpler (11.8%) with artificial intelligence. According to the articles, environmental education is becoming more interdisciplinary with the support of artificial intelligence. Creating environmentally friendly STEM projects (23.5%) and thus developing meaningful learning (23.5%) becomes possible. The incorporation of artificial intelligence technologies into environmental education raises awareness of sustainable development, as does environmental awareness. The articles' results also emphasize the societal and social dimensions of sustainable development. It is stated that artificial intelligence improves students' environmental ethics (17.6%), creates future-focused learning environments (17.6%), and supports quality education (SDG Goal 4) (17.6%). In other words, 11.8% of these articles also support the 2030 UN Sustainable Development Goals by integrating artificial intelligence into environmental education. One study also mentioned the concept of ecological citizenship (5.9%, Table 9).

Conclusion

This research is a systematic review that aims to determine the general trend in studies on the use of artificial intelligence in environmental education. The review identified 17 studies combining environmental education and artificial intelligence, all of these studies were published in the form of articles. No articles on the subject were found in national literature; all of the articles belong to international literature. The publication years range from 2018 to 2025. The first article was published in 2018, and there has been an increase since 2023. These findings indicate that artificial intelligence was gaining a new place in the relevant literature. The fact that 4 of the articles on artificial intelligence in environmental education in the relevant literature were theoretical articles also supports this interpretation. Many of the research articles were experimental or involved in new product design. Overall, the articles either present theoretical knowledge on the subject or demonstrate the effectiveness of new interventions or products.

A review of the literature revealed multiple compilations on artificial intelligence in education. These studies suggested that the integration of artificial intelligence into education increases student achievement and learning motivation, facilitates teachers' instructional design processes, and individualizes student experiences (Baker & Inventado, 2014; Luckin et al., 2016; Holmes et al., 2019; Zawacki-Richter et al., 2019). The findings of this study align with these interpretations in the context of environmental education. The objectives of the articles included in the systematic review indicate the importance of examining the effects of artificial intelligence-supported teaching processes on environmental awareness and sustainable development awareness. Three fundamental elements are mentioned in the theoretical context of environmental awareness: environmental knowledge, positive attitudes toward the environment, and environmentally friendly behavior (Erten, 2004). In parallel with this information, the reviewed articles also provided specific information on the knowledge, attitude, and behavior dimensions of environmental awareness. The research aims to explain the benefits of artificial intelligence specifically in environmental education. Particularly in theoretical articles, the aim was to explain how sustainable development awareness is fostered through artificial intelligence, how artificial intelligence supports environmentally friendly (green) education processes, and how it facilitates the development of environmentally friendly projects and curriculum. While the articles' objectives vary, their results offer a common picture. The articles' results suggest that artificial intelligence increases environmental awareness, particularly its attitude dimension. As for environmentally friendly behavior, they demonstrate its benefits in proposing sustainable solutions to environmental problems and protecting the environment. However, the research appears to focus more on the knowledge and attitude dimension. The article results also demonstrate that artificial intelligence increases the environmental knowledge dimension of environmental awareness and facilitates access to more and easier information about environmental issues. Indeed, as environmental knowledge increases, positive attitudes toward the environment also increase. More research is needed on environmentally friendly behavior. While the results of relevant studies highlight the benefits of artificial intelligence in environmental education, no information was available on the environmentally friendly use of artificial intelligence. Another observation in the research results was that some of the studies included in the review emphasize environmental education as a transdisciplinary process. Artificial intelligence made the process transdisciplinary and provided meaningful learning with environmentally friendly STEM projects.

Another result offered by research was that it raises awareness of sustainable development. It was said that artificial intelligence makes it easier to create learning environments based on the future. Another significant finding was that Quality Education, one of the 2030 UN Sustainable Development Goals, supports the context of inclusive education. Quality Education emphasizes equal opportunities in education and forms the basis of all Sustainable Development Goals. AI-based technologies facilitate access to teaching materials for disadvantaged children and children with special needs (Good, 2021). Furthermore, according to a 2019 UNESCO report, they also provide appropriate learning opportunities for children who have difficulty integrating into society, those with disabilities, migrants and refugees, and those who are out of school. Indeed, the results of relevant research were known to support the implementation of the 2030 UN Sustainable Development Goals. This clearly demonstrates that artificial intelligence has a significant place both in teaching sustainable development approaches and in achieving the goals of the global sustainable development agenda.

The ethical context of artificial intelligence is also a topic of debate. It is believed that artificial intelligence can have a misleading effect on data privacy, access to accurate information, and impartiality. For all these reasons, information obtained from artificial intelligence must be integrated into teaching processes as a facilitator and continuously monitored (Baker & Inventado, 2014; Luckin et al., 2016; Holmes et al., 2019; Zawacki-Richter et al., 2019). In addition to the ethical concerns in the findings of this research, relevant articles have concluded that it can improve environmental ethics. A report by the Council of Europe on artificial intelligence states that teachers' literacy on this topic must be improved so that they can use artificial intelligence more consciously in teaching processes. It also emphasizes that teachers must be decision-makers in every process they use artificial intelligence and question all information. This will ensure that artificial intelligence is reliably incorporated into education (Holmes et al., 2022). Both teachers and students should be aware that the use of artificial intelligence tools causes water waste and carbon emissions, and therefore, their conscious use is essential. In this context, consideration should be given to whether artificial intelligence is a solution to environmental problems or a new factor that will exacerbate them. Carbon and water footprints are increasing due to new environmental problems. While carbon emissions can be reduced through the use of renewable energy sources, reducing the water footprint in this way does not seem possible. The 2030 UN Sustainable Development Goals and the 2015 Paris Climate Agreement are two recent developments aimed at addressing all environmental problems, especially climate change. The primary goal of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping global temperature rise to 2 degrees Celsius above pre-industrial levels this century and to strive to limit the temperature increase to 1.5 degrees Celsius. The most fundamental step to this goal is to reduce carbon emissions globally. It is imperative to be aware of this global effort when using emerging technologies like artificial intelligence.

Recommendations

In light of all this information, the following recommendations have been reached:

This article is a systematic review of research on the use of artificial intelligence in environmental education. 17 articles were identified that focused on this topic. This demonstrates the emerging position of this topic in the relevant literature. Future studies should expand research on this topic. The majority of studies reviewed are theoretical, while research articles are mostly experimental in design. Future research should employ a wider variety of methods to strengthen sample selection, sample size, and the generalizability of findings. The correct and conscious use of artificial intelligence is considered a necessity. The integration of artificial intelligence into education is also an important and current issue. It is recommended that faculty members be supported in this area. This can increase both the use of artificial intelligence in education and the number of research on the subject. Simply using artificial intelligence to access accurate information and conscientiously address privacy will be insufficient. Artificial intelligence must be used in an environmentally friendly manner. Experts in the field should inform faculty members, principals, teachers, students—in short, all stakeholders in the educational process.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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A Phenomenological Exploration of Pre-service Science Teachers' Perspectives on Artificial Intelligence

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Abstract

Artificial intelligence (AI) in science education offers significant advantages to pre-service teachers in lesson planning, developing teaching resources, and implementing personalized learning. Simulations, visualizations, and intelligent assessment systems contribute to the concretization of abstract concepts and increased student participation. This phenomenological study aims to determine preservice science teachers' views on AI. To this end, semi-structured interviews were conducted with 13 preservice teachers from different grade levels who had prior experience with AI, including virtual laboratory applications. A semi-structured interview form was used for this purpose, and the data were evaluated using content analysis. Strategies such as in-depth data collection, expert review, and member check were employed to ensure internal validity. The findings indicate that preservice teachers view AI as a tool that supports lesson planning and teaching processes. However, they also believe that excessive reliance on AI may limit teachers' creativity. Participants' views were grouped into the following categories: AI use in educational processes, the effects of AI on students, reliability, and the role of the teacher. One emerging finding is that preservice teachers often do not verify the information they obtain from AI. The study highlights the potential of AI as a pedagogical tool in science education and the factors teachers should consider when using AI.

Introduction

In the 21st century, rapid technology-driven developments have led to fundamental transformations in education systems. Web 2.0 technologies and advances in AI have reshaped learning and teaching (Baidoo-Anu & Ansah, 2023). During this transformation, as machine learning and deep learning-based systems have advanced, generative artificial intelligence (GenAI)—a subset of AI focused on creating content—has emerged, and the importance of innovative applications in education has increased (Tyson & Sauers, 2021). GenAI tools can produce meaningful, contextually relevant, and human-like text, images, and other digital content in response to user input (Söğüt, 2024). In this regard, GenAI has the potential to generate knowledge and offer personalized learning experiences in teaching. GenAI learns patterns from large datasets using statistical and probabilistic models, enabling it to generate original content based on these patterns (Baidoo-Anu & Ansah, 2023). Advances in AI technology have enabled these tools to analyze multiple data types, such as text, audio, images, and video; understand complex structures; and produce content based on this analysis. AI-based tools provide preservice teachers with access to information, assist them in developing teaching resources, and offer personalized support according to their individual learning needs (Nyaaba et al., 2024). These features have made AI a valuable learning tool, supporting preservice teachers' academic development and strengthening their research, inquiry, and production skills (Lee & Zhai, 2024).

Research in teacher education has focused on preservice teachers' awareness (Akanzire et al., 2025). Preservice teachers will play a key role in future educational environments, going beyond mere information conveyors to become learning facilitators integrating technology with pedagogy. In this context, it is worth noting that preservice teachers' attitudes towards GenAI tools are closely related to how useful and easy these tools are perceived to be (Yang & Chen, 2023). For instance, AI-supported applications can visualize abstract scientific concepts, thereby deepening conceptual learning and facilitating meaningful learning for students. This perceived benefit may encourage preservice teachers to use AI tools more willingly. Teachers' views largely determine whether technological tools will be used in the classroom. The increasing awareness and usage of GenAI applications, such as ChatGPT, Google Bard, and DALL·E, indicate that preservice teachers recognize the potential of these technologies in education (Alhumaida et al., 2022; Nyaaba et al., 2024). Furthermore, it has been suggested that these tools could significantly support students by providing feedback, evaluating their learning, and designing instruction to meet their individual needs (Yıldırım & Akçan, 2024). This situation has

made it vital to examine preservice teachers' views, opinions, and experiences with these technologies in their scholarly and professional practices (Alhumaida et al., 2022; Nyaaba et al., 2024). As preservice teachers will be at the center of education, it is strategically important to thoroughly examine preservice science teachers' perceptions of GenAI, not only to understand current technological developments but also to shape future teaching models. Such an investigation would provide valuable insights into the practical, ethical, and pedagogical use of AI in education (Aldosari, 2020; AlKanaan, 2022). In this regard, the present study aims to examine preservice science teachers' views on AI and to develop recommendations for integrating these technologies into teacher education.

Theoretical Framework

This section provides a thorough review of the use of artificial intelligence in educational settings, particularly in science education, and of how it is discussed in existing literature.

Artificial Intelligence in Education

AI holds significant potential to revolutionize personalized learning, lesson preparation, and research for preservice teachers (Li & Ironsi, 2024; Nyaaba et al., 2024). For instance, Li and Ironsi (2024) highlighted the advantages and disadvantages of utilizing AI in education. It has been stated that AI is useful for mathematical operations in education but is generally insufficient for large groups due to cost, ethical concerns, usability issues, and other factors (Yavuz-Bostanci et al., 2025; Zhai et al., 2021). Numerous AI technologies are designed with a wide-ranging focus, thereby failing to address the specific instructional practices or educational goals of particular domains. (Lee et al., 2023). However, integrating AI technologies can enable personalized distance learning, especially in regions experiencing teacher shortages, where a single teacher can instruct students from multiple regions online. This enables students to interact with expert instructors and take advantage of learning opportunities (Li & Ironsi, 2024). Furthermore, advanced homework systems powered by AI can autonomously evaluate students' assignments from various locations, enabling educators to personalize instruction for each learner (Azad et al., 2020). The capacity of AI to augment personalized learning is a persuasive justification for incorporating these technologies into education, facilitating a more individualized and effective learning experience for students.

Teachers' and pre-service teachers' attitudes towards AI influence their use in education (Li & Ironsi, 2024). Inadequate, misguided, aimless, or outdated professional development programs may cause teachers to either reject AI completely or become overly dependent on it. Therefore, relevant, up-to-date, and effective professional development programs are needed to enable teachers to use AI consciously and in a balanced manner (Mnguni, 2025). Teachers should learn how to use AI as an educational tool and apply it in a balanced way, without becoming overly dependent on it or rejecting it entirely. Teachers play a crucial role in teaching AI literacy (Park et al., 2023). Nevertheless, since many educators lack AI expertise and are already constrained by their existing teaching tasks, it might be difficult for them to evolve into AI-literate instructors. Integrating AI into the curriculum requires teachers to make a significant effort. AI enables teachers to implement personalized learning and practical assessment methods in their lessons. Developing AI literacy among teachers and pre-service teachers is a critical step towards successful educational transformation (Azad et al., 2020). Science education inherently involves many abstract concepts, so AI technologies have significant potential to present these concepts to students in more concrete, understandable ways. The ability of AI to make these abstract concepts more accessible and easier to understand is a fascinating aspect of its potential in education (Holder et al., 2018). Science education often requires students to understand natural phenomena and processes that they cannot directly experience or observe (Hamed, 2025). Such abstract information can be challenging to learn using traditional methods. However, AI technologies, particularly simulations and visualizations, can make these concepts more accessible and easier to understand (AlKanaan, 2022).

Artificial Intelligence in Science Education

The acceptance of new educational reforms depends on the attitudes of science teachers (Lee & Zhai, 2024). Teachers who are resistant to technology and prefer traditional methods may find integration of AI tools into the classroom problematic (Bizim et al, 2025; Darayseh, 2023). This can lead to a prejudiced approach to technology and resistance to change. However, the use of AI in science education does not guarantee practical application or

improved teaching quality (Mnguni, 2025). For AI to fully demonstrate its potential benefits in science education, teachers must be prepared to use this technology effectively.

Integrating artificial intelligence tools into science education can significantly improve teaching methods (Darayseh, 2023; Lee & Zhai, 2024; Yilmaz, 2024). Teachers benefit from these tools, as they make classroom interactions more efficient and provide personalized education. Using AI in science lessons can stimulate students' interest and motivation and improve their learning (Yilmaz, 2024; Konstantinos, 2025). For instance, AI systems can analyze student responses in real time, providing rapid, personalized feedback tailored to each student's level of understanding. This is particularly important in subjects such as science, where grasping abstract concepts is essential (Kim & Kim, 2022). AI can adapt materials to students' learning styles, enabling them to progress at their own pace (Almasri, 2024). Furthermore, AI enables students to better understand scientific concepts by providing safe, interactive experiences through virtual laboratories and simulations (Ibáñez & Delgado-Kloos, 2018). GenAI also facilitates the exchange of scientific ideas between students and teachers from different regions, fostering a global perspective (Almasri, 2024; Deveci Topal et al., 2021).

However, the success of this process relies on teachers' ability to select and use these technologies effectively (Mnguni, 2025). Teachers' attitudes towards technology and their knowledge are crucial to its successful use in education (Lee & Zhai, 2024). Teachers' behavioral intentions regarding AI adoption are important for determining the potential of AI-supported instruction in science education and the future direction of educational technologies (AlKanaan, 2022). Generally, individuals have limited awareness of and understanding of AI applications in science education (Kim & Kim, 2022). Some teachers recognize the benefits of AI but lack knowledge of it in education (Yilmaz, 2024). These issues hinder teachers' ability to use AI in education and prevent its widespread adoption in science classrooms (Rana et al., 2025). AI-supported simulations can improve teaching by offering teachers and preservice teachers more effective teaching methods. Teachers can use AI-supported simulations to improve their teaching skills and adopt more innovative, practical methods in science education. Mnguni (2025) noted that participants had mixed attitudes: they believed that AI is pedagogically beneficial but expressed concerns about its effectiveness (Kim & Kim, 2022).

AI-supported science education is an important tool for developing pre-service teachers' teaching skills (Cooper & Tang, 2024; Zhang et al., 2024). Darayseh (2023) reported in his descriptive study that science teachers highly accept AI, and that this level of acceptance is related to self-efficacy, ease of use, perceived usefulness, and attitudes towards AI. Kim and Kim (2022) stated that while AI applications can limit thinking, teachers who use these applications broaden thinking by providing sources that support their claims in class and by reflecting participants' expectations and concerns about AI. Furthermore, themes such as support, difference, learning, teacher role, and transparency stand out (Ayanwale et al., 2024). Deveci Topal et al. (2021) taught science concepts through AI-supported chatbots. The research results revealed that this positively affected students' experience of AI-supported online learning. Students evaluated the chatbot as a valuable, enjoyable, and easy-to-repeated learning tool. Haseski (2019) examined preservice teachers' views on AI, revealing that they have mixed feelings about it and do not want to live in a world managed by AI. Furthermore, preservice teachers believe that AI carries both benefits and risks in education and can have positive and negative effects (Nyaaba, 2024). Therefore, activities such as research, experimentation, and observation should be encouraged, particularly in fields such as technology and science (Kartal, 2024).

Kim and Rachmatullah (2025) argue that teachers have integrated AI into science education in three ways: as a digital tool, an inquiry partner, and an epistemic system. These approaches have enabled students to develop basic AI skills, as well as scientific thinking and ethical awareness. The study demonstrates that AI can be used in science education across technical, knowledge-production, and critical-thinking contexts. Lee and Zhai (2024) examined lesson plans developed by pre-service teachers using AI. Concerns were raised in this context about the accuracy of AI-supported science lesson plans and the risk of students becoming overly dependent on ChatGPT. Furthermore, they proposed solutions for more systematically organizing classroom dynamics between teachers and students. Yilmaz (2024) noted the various advantages of AI in science education, such as the creation of virtual environments and its ability to increase inclusivity, strengthen motivation, and create personalized learning environments. However, he also emphasized that AI-supported science teaching has various disadvantages. These include dependence on technology, data privacy and security issues, infrastructure requirements, the need for teacher training, access inequality, and a reduced human touch.

The use of AI in science education can increase students' motivation to learn and participation (Konstantinos, 2025). However, teachers' perceptions of this technology and their level of preparation to use it are critical factors in determining the success of this process (Darayseh, 2023). Science teachers' hesitant attitudes towards AI tools stem from a lack of awareness and preparation (Mnguni, 2025). This has the potential to hinder the full benefits

of technology in education from being realized. Teachers require sufficient knowledge and skills to use AI-supported teaching tools effectively (Li & Ironsi, 2024). This study is essential for examining preservice teachers' views on AI and the factors that will directly affect the success of integrating these technologies into teaching processes.

Method

Research Design

This phenomenological study aims to gain a deeper understanding of preservice science teachers' experiences when using AI-supported applications in innovative teaching environments and the meanings they assign to these experiences. The phenomenological approach focuses on describing how individuals perceive, feel, and interpret a phenomenon (Creswell & Poth, 2016). This study provides an important framework for understanding how preservice science teachers make sense of their beliefs and perceptions of personal efficacy regarding technology, science, and instructional processes through their experiences with GenAI. This study can contribute both theoretically and practically to the role of artificial intelligence-based learning environments in science teacher education programs.

Participants

The participants were selected using a purposive sampling method, which consciously selects individuals who can provide in-depth information about a specific phenomenon (Patton, 2014). In this context, the key criterion was that participants were students in the science education teacher education program who had experience with artificial intelligence-supported virtual laboratory applications. The participants were 13 pre-service science teachers studying in the second, third, and fourth years of the science education teacher education program at a state university's Faculty of Education in the Central Anatolia region of Turkey. This approach aimed to enrich and enhance the representativeness of participants' data and to explore the phenomenon across multiple dimensions, thereby contributing to a multifaceted understanding. Of the preservice teachers, six (one male and five female) were in the second year, four (two male and two female) in the third year, and three (all female) in the fourth year.

Data Collection Process

Participants at different grade levels took courses on virtual laboratory applications. While studying the theoretical content, preservice teachers also had the opportunity to practice in virtual laboratories. These laboratories enabled them to simulate physical experiments in a digital environment, reinforcing their theoretical and practical knowledge. AI-supported tools not only helped preservice teachers perform experiments but also provided feedback on procedures conducted in the virtual environment, thereby helping personalize the teaching process. Through this process, preservice teachers integrated theoretical knowledge with virtual laboratory practices, gaining a deeper understanding with the support of AI. Following this experience, qualitative data were collected through semi-structured interviews to examine the preservice teachers' attitudes and opinions in greater depth. Preservice teachers were informed about the study, and participation was voluntary. The interviews took place in a comfortable environment at a time chosen by the participants. The interviews lasted between 30 and 45 minutes. Lincoln and Guba (1985) stated that credibility is a crucial criterion in qualitative research and that several steps must be taken to achieve it. These are: i) prolonged engagement; ii) in-depth data collection; iii) expert review; and iv) participant confirmation. The data collection process, analysis, and reporting were carried out under the supervision of field experts. Additionally, immediately after the interviews, researchers made preliminary interpretations based on notes taken during the interviews and later confirmed them with the participants. These strategies are among the most important factors in ensuring the validity of a qualitative study.

The data were collected through semi-structured interviews, specifically designed to align with the research objectives and structured around open-ended questions to gain in-depth insights into participants' experiences and perspectives. This allowed the researchers to guide discussions on specific themes while enabling participants to express their experiences freely (Tisdell et al., 2025). During the interviews, the primary researcher aimed to reach the core of the participants' experiences through pre-determined questions and employed probing follow-up questions as needed (Seidman, 2006). A conducive environment was established to facilitate comfortable expression, and participation was voluntary. A voice recording device was used to ensure the integrity and

accuracy of the data collected. The recordings were subsequently transcribed in detail to prepare for analysis. The transcriptions maintained the authenticity of the participants' statements. To analyze the data, MAXQDA software was used, known for enhancing the systematic and transparent nature of qualitative research.

Interview transcripts were first transcribed verbatim, and researchers identified units of meaning by repeatedly reading the texts. These units of meaning were then coded, and themes and categories were created by grouping similar meanings. This resulted in a comprehensive description of the essence of the phenomenon (Patton, 2014). To avoid bias and deepen their understanding of participants' experiences, researchers adhered to the bracketing principle (Creswell & Poth, 2016). In addition, to increase the reliability of the analysis results, feedback was obtained from participants (member checking), making them active participants in the research. Researchers also conducted the analysis independently, ensuring diverse perspectives. At the end of the study, the coders met to compare codes, fostering collaboration. When differences arose between coders, a mutual discussion was held, and the process continued until 100% agreement was reached. Codes on which consensus could not be reached were not included in the study (Miles & Huberman, 1994). This method increased the reliability of the analysis process and strengthened the scientific validity of the study's findings.

Results

This section presents the findings from the content and descriptive analysis in the format of codes, categories, and quotations. Table 1 illustrates preservice teachers' views on artificial intelligence and educational processes.

Table 1. Artificial intelligence and educational processes

Category	Definition	Sample quotes
Planning and Preparing Teaching Resources	Preservice teachers' use of artificial intelligence to develop lesson plans and enrich teaching resources	<i>"So, I think it makes our lives easier. It provides lesson plans and content, creates visuals, and outlines how to proceed."</i> <i>"I was going to talk about force. I asked the AI how to introduce the topic. It had me design an activity involving Play-Doh."</i> <i>"I need to teach a class during my student teaching. When I ask the AI about that, it gives me some great ideas."</i>
Applications for Artificial Intelligence	Applications of artificial intelligence in education, such as preparing teaching resources, visualization, and virtual laboratories	<i>"I use artificial intelligence by conducting simulations, performing experiments, and implementing virtual laboratories."</i> <i>"It can draw graphs for you or directly present a lot of details or examples for you."</i> <i>"It can show the stages of mitosis and create those visuals and diagrams for me."</i> <i>"I believe it will be much more useful in situations where physical experiments are unlikely to be conducted."</i>
Student Participation	The impact of artificial intelligence on interest in the science course and student participation	<i>"I think it will negatively affect student participation."</i> <i>"Students are becoming more enthusiastic and motivated."</i> <i>"When I give students a prompt, they will already be engaged in a kind of research."</i>
Prompt Writing	Experiences regarding how to formulate queries to obtain more accurate and detailed responses from artificial intelligence	<i>"I ask questions with question marks, begging for answers, and that way I get more responses."</i> <i>"I want to set some limits on certain things. He, on the other hand, asks for things. His answers are more detailed, while mine are more superficial and briefer."</i> <i>"I try to write in more detail each time to get more detailed information."</i> <i>"I explain my students' situation according to the class I am entering; I want him to provide content... I even give details like this: I elaborate so that when my teacher asks, he will not realize I had AI do it; I guide him in terms of content."</i>

As shown in Table 1, pre-service teachers perceive artificial intelligence as a tool that can facilitate and enrich the educational process. They stated that it helped them to complete time-consuming tasks, such as lesson planning and preparing teaching resources, more quickly and creatively. They also indicated that they had used it to assist with such tasks during their teaching experience. For instance, one participant said, *"I need to teach a class during my student teaching. When I ask the AI about that, it gives me some great ideas"*, demonstrating that they found AI helpful for generating preliminary ideas. Another participant described their approach, saying: *"I explain my students' situation according to the class I am entering; I want him to provide content... I even give details like this: I elaborate so that when my teacher asks, he will not realize I had AI do it; I guide him in terms of content."* This indicates that preservice teachers provide supplementary prompts to ensure that the content does not appear to have been created by AI. Furthermore, AI is also used to create engaging lesson introductions and research-focused tasks to increase student participation. Additionally, it is possible to note that participants developed skills such as 'prompt engineering' to produce higher-quality output. This highlights their efforts to use technology more consciously and effectively. It is also noteworthy that preservice teachers give AI polite and directive commands to make the content more detailed and accurate. Table 2 presents the preservice teachers' opinions on the effects of artificial intelligence on students, as revealed by data analysis.

Table 2. The effects of artificial intelligence on students

Category	Definition	Sample quotes
Creativity and Imagination	The potential of artificial intelligence to increase or decrease students' creativity and imagination	<i>"It hinders creativity."</i> <i>"It definitely affects and degrades students' creativity."</i> <i>"I think artificial intelligence is very creative; it can come up with very different things based on something I say or a command I give."</i> <i>"This brings out something far beyond my imagination."</i>
Thinking Skills	The impact of artificial intelligence on students' critical thinking and problem-solving skills	<i>"I think it will take away our ability to think creatively and critically."</i> <i>"I think it will prevent us from thinking more straightforwardly...."</i> <i>"Artificial intelligence... is hindering our thinking."</i> <i>"It will slow down our problem-solving skills."</i> <i>"We do not question; we do not scrutinize. We do not think about whether it is right... I do not think it will develop many skills; it will have a negative impact."</i>
Encouraging Complacency and Laziness	The risk that artificial intelligence may lead to accepting information without questioning it, and adopting a complacent approach	<i>"I think it makes our lives easier, but on the other hand, it also seems to lead to laziness."</i> <i>"For example, we used to go to the library or do research when we had homework. However, now, even I can ask artificial intelligence almost anything right away"</i> <i>"We are taking the easy way out, myself included... I often use the information as it comes, and I think it makes us lazy."</i> <i>"People can become a bit, excuse me, foolish, whether they want to or not."</i>

Table 2 shows that preservice teachers are seriously concerned about the potential negative effects of AI. While AI is seen as offering opportunities to support and develop imagination, pre-service teachers also perceive it as a threat that could hinder students' cognitive skills, such as creative and critical thinking and problem-solving. In this context, pre-service teachers emphasize that AI support may limit students' thinking and make learning more superficial. For instance, one pre-service teacher stated, *"I think it will take away our ability to think creatively and critically."*, suggesting that AI could eliminate the cognitive skills of both teachers and students. One pre-service teacher, for instance, stated that *"I think it will take away our ability to think creatively and critically,"* in reference to artificial intelligence as a tool that can limit educators' and students' cognitive abilities. Similarly, a significant number of participants noted that AI carries the risk of creating a 'shortcut mentality' and a 'ready-made approach'. This situation could result in students becoming mentally lazy in the long term, as they may become discouraged from making the effort. Indeed, one pre-service teacher shared their own experience: *"We are taking the easy way out, myself included... I often use the information as it comes, and I think it makes us lazy."* This example clearly shows that overconfidence in AI poses a risk not only to students but also to pre-

service teachers. Pre-service teachers' views indicate that AI has a dual impact on the students. On the one hand, it is seen as a tool that supports and facilitates learning. On the other hand, it is perceived as a threat that could undermine individuals' ability to think for themselves. Therefore, participants are concerned that uncontrolled use of AI in the classroom could have negative consequences, such as reducing the mental productivity of both students and teachers. On the one hand, AI is seen as a supportive and facilitating learning tool; on the other hand, however, it is perceived as a threat that could undermine individuals' authentic thinking. Table 3 presents pre-service teachers' views on the final category that emerged from the data analysis: reliability and the role of the teacher.

Table 3. Artificial intelligence, reliability, and the teacher's role

Category	Definition	Sample quotes
Accuracy and Reliability of Information	Verifying the accuracy of information provided by artificial intelligence and the uncertainties surrounding this issue.	<i>"Sometimes it provides incorrect information, and I have noticed that too."</i> <i>"We are not sure whether the information is correct."</i> <i>"Artificial intelligence can present information it has received from someone else as if it knew it itself, which is a very serious and unethical situation."</i> <i>"I do not think I can determine whether content from artificial intelligence is accurate."</i> <i>"If it is something I care deeply about, I check it; if it is a weekly assignment, however, I generally do not check for accuracy or errors."</i>
Teacher Role and Responsibilities	The teacher's responsibility for guidance and control in the use of artificial intelligence	<i>"Our education system wants us to be guides. I think I will serve as a guide in artificial intelligence as well."</i> <i>"How will you verify the accuracy of the image it creates? I will take on that role here too; as their teacher and guide, I will show them the way in the classroom."</i> <i>"I actually think artificial intelligence could be much better in the hands of teachers rather than students."</i>
Artificial Intelligence Education	The need for training for teachers and preservice teachers to effectively use artificial intelligence	<i>"I would really like every teacher to use artificial intelligence and for students to explain it, that is, to actively apply it."</i> <i>"I think preservice teachers really need to be informed about this."</i> <i>"There is talk of making artificial intelligence education a compulsory course in undergraduate education."</i> <i>"You can get training on this subject on its own. Not as part of a course, but short training courses can be taken over a period of a month."</i>
The Future of Artificial Intelligence	The potential benefits and challenges of AI in science education	<i>"I think it will play a crucial role in science education."</i> <i>"I believe it will be at a much more advanced level in 10 years."</i> <i>"I think it is a somewhat stalled issue in our country."</i> <i>"Since I prefer the traditional approach, I do not think the use of artificial intelligence will have much impact on science classes."</i> <i>"I think that in the future, we may not even be guides anymore."</i>

Table 3 shows that pre-service teachers are concerned about the reliability of information and the ethical issues that arise from the widespread adoption of AI. Participants stated they cannot always verify the accuracy of information generated by AI, suggesting that the use of such tools poses significant ethical risks. The statement

'Artificial intelligence can present information it has received from someone else as if it knew it itself, which is a very serious and unethical situation' suggests that AI poses a risk similar to plagiarism in the production of information. This phrase emphasizes how pre-service instructors are now discussing the dependability of AI. In this context, the teacher's guiding role is emphasized. Pre-service teachers stated that AI alone is not a sufficient learning resource and that teachers need to guide students to make the most of this tool. One participant expressed this view as follows: *"Our education system wants us to be guides. I think I will serve as a guide in artificial intelligence as well."* This statement reveals that participants view teaching as both the transmission of knowledge and the guidance of learning processes. The pre-service teachers also stated that compulsory courses or short-term training should be provided during undergraduate education to ensure the correct use of AI tools. This demonstrates that the ability to use technology consciously must become an integral part of the teaching profession. Participants' expectations for the future vary. One group believes that AI will transform subject teaching, particularly in science. However, another group is concerned that the traditional structure of the education system may limit this potential, leaving the opportunities offered by AI underexploited. This situation reveals that pre-service teachers are seeking a balance between their expectations and concerns about artificial intelligence.

Conclusion and Discussion

This study examines pre-service science teachers' views on AI, including a group of participants from second, third, and fourth grades at a university in the Central Anatolia region of Turkey. Participants were selected based on their previous experiences with artificial intelligence and virtual laboratory applications. The views of pre-service science teachers on AI revealed a multidimensional understanding of its applications in education, its impact on pre-service teachers, and its implications for their roles and expectations. The participants' responses clearly demonstrate the opportunities and potential risks presented by AI. This suggests that pre-service teachers view AI not only as a time-saving tool but also as a supportive element that fosters creativity and enhances pedagogical processes. While AI reduces the workload for lesson planning and material preparation, it provides pre-service teachers with different perspectives and creative ideas through features such as content delivery, visualization, and activity design. Similarly, Avşar Erümit and Yılmaz (2024) found that ChatGPT helps pre-service teachers, especially in idea generation and the development of digital materials. Abualrob (2025) found that pre-service teachers primarily use AI for lesson plans, teaching materials, assessments, tables, pictures, drawings, and teaching strategies. Perceiving AI as an additional tool, particularly when encountering material deficiencies during student teaching and lectures, encourages pre-service teachers to adopt a more flexible and creative approach to pedagogical processes. This finding highlights the importance of using AI as a supportive tool in teacher education. According to Yılmaz Can and Durmuş (2024), AI can enrich lesson planning by offering creative and differentiated approaches and by facilitating the development of assessment criteria and rubrics that align with lesson plans.

In their study examining the ability of AI to plan lessons and prepare teaching resources, Kahraman and Kıyıcı (2025) evaluated ChatGPT-generated lesson plans using a question-based lesson plan rubric. Their findings suggested that the lesson plans generally received moderate to high scores. However, the study emphasized that, when it came to providing feedback and determining where to start the lesson, the prompts needed to clarify the existing curriculum trends. The findings of this study stressed the importance of the effective use of prompts. Participants learned how to structure prompts to elicit accurate, detailed responses from AI. The form of the question, the language used, and the level of detail all directly affect the quality of the response. Some participants stated that they received more effective responses when they communicated with AI as they would with a human, using a polite or respectful style. They also mentioned a previous experience in which two people gave the same command in different styles from different devices at the same time. They observed that the AI provided more accurate and detailed responses to the person who used a more polite prompt. Abualrob (2025) stated that prompts can enhance the effectiveness of AI-generated outputs by eliciting creative ideas from pre-service teachers. This suggests that pre-service teachers need to develop new skills, such as prompt writing, to use AI effectively in teaching. Hamed et al., (2025) found that prompts were more explicit, detailed, and instructive in the teacher role than in the student role. In other words, they had greater control over the content in the teacher's role. Participants obtained high-quality responses from AI by using clear, detailed prompts and created multiple representations (such as visuals, tables, and graphs) to explain concepts. The findings revealed that the ability to create prompts is a critical skill in teacher education, supporting the learning process when interacting with AI.

Participants indicated that AI can be advantageous in practical applications, such as virtual laboratories, simulations, and the development of visual resources. They emphasized that AI could play a supportive role in education when physical experiments are not possible. This demonstrates that technology can support learning

processes, particularly given the experimental and observational nature of science education. Similarly, Pope et al. (2025) found that pre-service teachers preferred AI for visualizing abstract concepts. Cooper and Tang (2024) also stated that visualization facilitates understanding of abstract concepts in science education and promotes conceptual learning. AI-supported visuals attract students' attention and facilitate long-term learning by making microscopic processes, experiments, and scientific events more tangible.

Pre-service teachers have stated that AI can increase both interest in lessons and student participation. It can be said that pre-service teachers perceive AI as a motivating and interactive tool in the learning process. AI applications that offer personalized content, gamification, and instant feedback can engage students and encourage participation in the lesson. These findings reveal that pre-service teachers generally have a positive attitude towards AI and regard it as an important pedagogical opportunity. However, this positive perception may be influenced by factors such as access to technology during implementation, teachers' digital literacy, and the compatibility of AI tools with pedagogy. Preparedness and willingness to use AI increase pre-service teachers' engagement with AI applications (Ayanwale et al., 2024). AI-supported tasks or prompts given to students motivate them to conduct their research and inquiries. This demonstrates that AI can function as both a teacher-centered tool and a student-centered one. Pope et al. (2025) stated that AI applications make abstract concepts concrete through visualization, thereby deepening students' understanding and supporting their learning motivation. Ayanwale et al. (2024) also found that a positive attitude towards AI increases pre-service teachers' participation in AI-related educational activities and their sense of self-efficacy.

Pre-service teachers noted that the impact of AI on students' creativity and critical thinking skills is mixed. While some mention that AI can generate creative ideas and boost imagination, others express concern that it may restrict students' thinking processes and promote laziness by relying on ready-made information. These perspectives highlight the need for careful planning in the pedagogical use of AI and underscore the importance of teacher supervision. In their study, Habib et al. (2024) stated that AI allows for the rapid generation of numerous ideas, which students enjoy during brainstorming and initial idea generation. However, they also found that some students worry that AI might take over the thinking process and limit their individual creativity. This underscores the importance of using AI as a supportive tool in creative tasks and raises awareness that excessive dependence on technology could weaken students' thinking skills. After the pandemic, students used technology more than before, making them more reliant on it (Şeker et al., 2023). Consequently, the question of how, in what manner, and for what purposes AI should be used in education has become a key area of discussion. Rana et al. (2025) stated that, when thoughtfully integrated, AI can support students' creativity, critical thinking, and ethical reasoning.

Pre-service teachers have stated that information generated by AI is not always reliable and that they cannot be sure of its accuracy. The fact that AI sometimes produces incorrect or incomplete information raises not only technical problems, but also ethical and pedagogical concerns. This situation highlights the need for teachers to critically evaluate their teaching and support their students in doing the same. Furthermore, some pre-service teachers mentioned that they felt the need to verify information. They described this process as follows: If a topic needs urgent attention, they use the information without verifying its accuracy, but if they have more time, they verify the accuracy of information obtained from AI. They still tend to use AI unconditionally, even if they are concerned about the reliability of information. Here, the issue of the source of knowledge raises epistemological concerns. This is because, although pre-service teachers have taken courses such as 'The Nature of Science' and can question the source of the knowledge, they do not seem to critically evaluate or verify information obtained from AI when necessary. Determining the relationship between technology and epistemology is of great importance (Kartal et al., 2022; Kartal, 2024). Furthermore, participants argued that they should be taught about AI through informative courses integrated into teacher education programs. Indeed, Ramnarain et al. (2024) found that, while preservice teachers were willing to use generative AI tools, they had serious concerns about the accuracy of the information produced by these tools. Participants emphasized that providing incorrect information could lead to misconceptions and faulty learning among students (Bizim et al, 2025). Similarly, Lee and Zhai (2024) highlighted examples of ChatGPT misuse in lesson planning, such as the use of invented internet sources and technically unsupported visual prompts. These findings demonstrate the importance of teachers using AI alongside critical scrutiny and pedagogical adaptation, rather than as a direct source of information.

Participants emphasized that AI should only be used as a classroom tool and that teachers should continue to provide guidance. Participants said that the teacher's role as a guide is one of the goals of the MoNE curriculum. They also said that teachers should take a leadership role in the use of AI. However, some stated that, even with AI, teachers would not be able to play a guiding role in the future (Yavuz-Bostanci et al., 2025). They also mentioned that Turkey lags behind in AI development. It is possible to say that this may be why they still prefer traditional methods. Teachers are responsible for verifying information, guiding students, and supporting the

learning process. This finding suggests that AI should support teachers in their roles rather than replace them. Similarly, Nyaaba (2024) emphasized that AI plays multifaceted roles, directly addressing resistance to change, increasing access to resources, and supporting teachers' professional development. In their study, Liu and Wang (2020) stated that AI will support teachers in planning, but the main task will remain teacher-centered.

According to these findings, pre-service science teachers view AI as a creative, motivating, and supportive educational tool. They state that it reduces the workload associated with processes such as lesson planning, preparation of teaching resources, and visualization. However, they emphasized that information produced by AI is not always reliable and drew attention to the importance of accuracy control. The tendency to use information without verifying it, especially in time-critical situations, suggests a limited understanding of knowledge. Teachers should use AI as a complementary tool in guidance and pedagogical adaptation processes, developing new skills such as prompt writing and critical evaluation. In conclusion, while AI offers opportunities in education, the need to maintain teacher guidance and a critical approach comes to the fore.

Limitations and Recommendations

Pre-service science teachers' views on AI revealed that it presents both opportunities and risks in education. This study examined these views through qualitative interviews and content analysis. The findings show that participants considered AI to be an effective tool for lesson planning, preparing teaching resources, visualization, increasing student participation, and supporting the learning process. However, they are also aware of limitations such as the potential unreliability of AI, its capacity to generate misinformation, and the risk of restricting students' creative thinking. These results highlight the importance of planned, conscious use of AI as a pedagogical tool. Future studies could build on these findings and explore their various aspects more thoroughly in depth. Firstly, the selection of participants in future research may be broader, including a wider range of pre-service teachers, disciplines, and educational institutions. This would increase the transferability of the findings and reveal how AI is perceived in different contexts. For instance, examining differences in AI use across disciplines such as science, mathematics, the social sciences, and language education could illuminate subject-specific pedagogical practices. The effectiveness of teacher training programs related to AI could also be investigated. The findings suggest that pre-service teachers require training in new AI-related skills, such as prompt writing, content verification, and pedagogical adaptation. Future research could therefore evaluate how AI training develops pre-service teachers' technological proficiency, pedagogical approaches, and creative thinking skills. Furthermore, research could examine how teachers apply ethical decision-making and critical evaluation processes when using AI tools. Additionally, although pre-service teachers are concerned about the accuracy of information when using AI, they still tend to use it without verifying it. In this context, there is a need for studies that connect technology, AI, and epistemology. While this study presents important findings regarding pre-service teachers' use of AI, future studies might focus on increasing participant diversity, ensuring methodological diversity, evaluating teacher education programs, and detailing classroom pedagogical practices. This will reveal the potential of AI as a pedagogical tool in education more comprehensively and reliably.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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Examining Biology Teachers' Cognitive Structures Regarding Artificial Intelligence Using a Word Association Test

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Abstract

In recent years, artificial intelligence has attracted great attention worldwide, particularly due to its impact on all areas of human life. The reasons for this interest include the rapid increase in the changes that artificial intelligence applications may bring to individuals' lifestyles and the structure of society, and the potential problems that may accompany these changes. As in many other fields, artificial intelligence has quickly entered educational settings and has become a focal point for both students and teachers. In this respect, revealing teachers' cognitive structures regarding artificial intelligence is of great importance, as their approaches to this development will directly influence their students. The aim of this study is to examine the conceptual frameworks of biology teachers regarding artificial intelligence. The data were collected from 126 participants using a free word association test. The analysis of the free word association test demonstrates various aspects of the participants' conceptual frameworks concerning artificial intelligence. The participants emphasized the potential benefits of artificial intelligence in terms of advanced technologies, education, benefits to humanity, and contributions to the cultural and economic life of society. However, they also expressed the view that artificial intelligence may entail potential drawbacks, including ethical issues, security risks, and the risk of promoting laziness.

Introduction

Artificial intelligence, one of the leading technological developments of the twenty-first century, has become a concept encountered in nearly every aspect of life in recent years. Artificial intelligence is defined as the imitation of human cognitive abilities and skills by machines (Nabiyev, 2010). In this context, the 4-1 victory of AlphaGo, developed by Google DeepMind, over world Go champion Lee Sedol in 2016 marked a global turning point in the field and significantly increased interest in artificial intelligence research (Borowiec, 2016).

The rapid advancement of artificial intelligence technologies has also manifested itself in educational settings. Artificial intelligence tools, used formally and informally in schools and out-of-school learning environments, have become invisible participants in classrooms. While students are expected to conduct research, inquiry, and reasoning processes, many now complete assigned tasks quickly through artificial intelligence tools. This raises questions about the quality of teacher-student interactions: What role will the teacher assume in this evolving learning environment? What are teachers' perceptions and attitudes toward artificial intelligence? How can traditional teaching models be applied within this new technological context? Such questions constitute the current focal points of discussion in educational research.

Artificial intelligence in education (AIED) is defined not only as a tool forming the basis of "intelligent" educational technologies, but also as a powerful instrument that aims to open the "black box of learning" by revealing how learning actually occurs (Luckin et al., 2016). Stanford University's 2024 Artificial Intelligence Index Report shows that the number of artificial intelligence-related educational programs offered in English has nearly tripled since 2017. This increase indicates a rising demand for and awareness of artificial intelligence literacy in education (Maslej et al., 2024).

According to Zhou and Peng (2025), artificial intelligence has the potential to enhance students' creativity; however, this can only be achieved when it is used in pedagogically meaningful ways by teachers. They further emphasize that AI-supported creativity emerges from human-machine collaboration, and the strength of this effect depends on the extent to which students perceive their teachers as AI-literate.

According to the report of the U.S. Department of Education, artificial intelligence offers significant opportunities for increasing teacher productivity, monitoring student progress, and supporting individualized learning processes. However, unsupervised use of artificial intelligence tools also bring certain risks, such as weakening the teacher's authority in classroom management (USDOE, 2023). Since artificial intelligence cannot perform human-specific functions such as empathy, ethical understanding and actions, and emotional attitudes, teacher control or supervision is of critical importance. The study conducted by Lahdesmäki, Väisänen, and Hyytinen (2025) revealed that teachers who received artificial intelligence training felt much more motivated and confident, showing that openness to learning, rather than experience, makes the real difference. Although teachers have begun to view artificial intelligence as a partner rather than a threat, they continue to emphasize that ethical responsibility ultimately lies with them.

The literature contains numerous studies on the use of artificial intelligence in education. Artificial intelligence provides personalized learning environments, increases the efficiency of learning processes by offering learners instant and adaptive feedback (Shute, 2008), and facilitates assessment and evaluation processes for teachers (Benhamdi, Babouri & Chiky, 2017; Begum, 2024; Chen, Chen & Lin, 2020; González-Calatayud, Prendes-Espinosa & Roig-Vila, 2021; Jukiewicz, 2024). However, challenges remain, such as inadequate infrastructure, poor access to information, insufficient resources, data security and ethical issues, and the fact that teachers have not yet reached the desired level of competencies required to effectively use artificial intelligence pedagogically. In this context, a study (Uygun et al., 2024) reported that teachers' levels of artificial intelligence awareness are moderate and that they require more training and resources for integration. Furthermore, the increasing use of artificial intelligence also raises potential risks, such as the weakening of students' social communication skills (Begum, 2024; Huang, Saleh & Liu, 2021).

It has been noted that preservice teachers perceive artificial intelligence as a "source of information" and often associate it with the metaphor of a "teacher" (Eroğlu, 2024; Gölbaşı & Okul, 2024). However, it has been stated that artificial intelligence cannot replace teachers; rather, the future of education can be enriched through the combination of teachers' unique expertise and the capabilities of artificial intelligence (Crovello, 1974; Luckin et al., 2016).

There is a limited number of studies in literature examining teachers' perceptions of artificial intelligence. Dişlioğlu Ateş, and Medeni (2025) found that the majority of teachers have a positive view of using artificial intelligence in education; however, they also stated that it may negatively affect students due to reasons such as "becoming accustomed to ready-made information and failing to learn how to conduct research." Similarly, Cruz, Duque and Carvalho (2024) reported that teachers generally agree on the integration of artificial intelligence into teaching, while at the same time acknowledging their need for further training in this area. Gökçe (2024), on the other hand, investigated pre-service science teachers' perceptions of artificial intelligence using a word association test and found that artificial intelligence was most frequently associated with the concepts of "robot, convenience, technology, ChatGPT, and smart assistant."

One of the fundamental goals of biology education is to encourage students to understand the nature of the technologies that will shape the future. In this regard, it is known that both teachers and students utilize artificial intelligence tools to develop their scientific knowledge-building practices. Lidiastuti et al. (2025) noted an increasing trend in the use of artificial intelligence in biology education over the years. In this regard, understanding ideas about artificial intelligence technologies can enhance teachers' abilities to participate in future scientific developments and current scientific debates, as well as to benefit from the products of science and technology and critically evaluate scientific claims. Therefore, it is important to examine conventional representations of artificial intelligence and the image of artificial intelligence in people's minds. Biology teachers' images of artificial intelligence can shape their biology teaching methods and, in turn, influence students' perspectives on biology and technology. Considering the strong influence teachers have on students' understanding, revealing the cognitive structures of biology teachers regarding artificial intelligence is expected to provide guidance for possible improvements in teacher training programs.

Significance

Today, artificial intelligence technologies have permeated nearly every aspect of life, and it is inconceivable for the education system to remain outside this transformation. However, achieving technological transformation in schools cannot be accomplished merely by introducing tools such as smart boards or tablets into classrooms. The primary determining factor is the perceptions and approaches of teachers who will use these technologies. At this point, biology teachers hold a unique position. Concepts such as "intelligence," "learning," and "the

nervous system” constitute fundamental areas of study in biology, and the structure of artificial intelligence, which mimics the human mind, may lead biology teachers to interpret artificial intelligence differently from teachers in other subject areas. This study makes an original and valuable contribution to the literature by thoroughly examining biology teachers' cognitive structures related to artificial intelligence using data obtained from both verbal expressions and drawings.

Purpose

The primary purpose of this study is to examine the cognitive structures of biology teachers regarding artificial intelligence through a free word association test. In line with this aim, the following research questions were addressed: (1) *Which concepts do biology teachers associate artificial intelligence with and how frequently?* (2) *Under what categories can these associated concepts be classified?*

Method

This study aims to examine biology teachers' cognitive structures related to "artificial intelligence" through drawing and a free-word association test. In line with this aim, the research was designed in accordance with qualitative research patterns. Qualitative research is defined as an approach that employs qualitative data collection methods such as observation, interview, and document analysis, and follows a qualitative process aimed at revealing perceptions and events in a realistic and holistic manner in natural settings. In other words, qualitative research is an approach that prioritizes investigating and understanding social phenomena within their context, with an approach based on theory formation (Yıldırım and Şimşek, 2016, p. 39). A fundamental principle of qualitative research is the holistic nature of the data collected. Based on the understanding that a whole is more meaningful than the sum of its parts, the research topic is determined through a holistic approach, and the data collected are analyzed accordingly.

Participants

This study was conducted with 126 biology teachers, 97 female and 29 male, working in high schools in Konya province. The average age of the participants was 43, and their average professional experience was 13 years. The research data were collected over a one-month period during the spring semester of the 2024-2025 academic year. Participation in the study was voluntary. A word association test was used as the data collection tool.

Data Collection Tool

In this study, a free word association test was used as the data collection tool to reveal the cognitive structures of biology teachers regarding “artificial intelligence.” Before the implementation, participants were verbally informed about the purpose, duration, and procedure of the free word association test, and several examples and practice activities were provided. In the test, the term “artificial intelligence” was presented to the participants as a stimulus term, written 10 times under one another as shown below, and they were asked to respond within 30 seconds.

Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:
 Artificial intelligence:

Draw the first image that comes to your mind when you think of artificial intelligence and write a sentence about it:

The reason for writing the stimulus term ten times consecutively is to prevent the risk of chain reactions. If a participant does not return to the stimulus term after writing a response, they tend to write words associated with their previous response rather than with the stimulus word itself. This undermines the purpose of the test. Participants were asked to write the first ten words that came to mind when they heard or read the term "artificial intelligence." The word association test is a data collection technique used to determine the conceptual structure of an individual or group. This technique involves presenting a stimulus word and asking participants to freely associate it with ideas that come to mind within a short period of time. This stimulus term is assumed to provide relatively unrestricted access to participants' mental representations (Bahar, Johnstone & Sutcliffe, 1999). In its simplest form, participants are presented with a stimulus word, either verbally or in writing. Participants are required to provide feedback using the response words evoked by the stimulus term. Following this procedure, participants were asked to draw the first image that came to mind within 30 seconds when artificial intelligence was mentioned, and then to write one sentence about it within the next 30 seconds. After analyzing the content and calculating the frequency of response words, it becomes possible to derive conclusions about the associative meanings of the stimulus words and thereby describe participants' conceptual structures. The drawings and sentences obtained through association were evaluated together and categorized. Free word association test that reveals the associative meanings of various concepts has been used in several studies (Dikmenli, 2010; Torkar & Bajd, 2006).

Data Analysis

In the free word association test, the analysis and interpretation of the word associations provided for the key word were carried out through the following stages:

- 1- Coding and extraction stage,
- 2- Category development stage,
- 3- Ensuring validity and reliability stage.
- 4- Transferring the data into the SPSS package program for quantification of the qualitative data.

1- Coding and Extraction Stage: The associations generated by 126 biology teachers for the keyword "artificial intelligence" were coded into concepts. During data analysis, associations that were deemed illogical, unrelated to "artificial intelligence," and were not repeated at least three times were excluded. No response sheets lacking associations were encountered in the study. 208 response words, initially assumed to be valid, were identified in the data collection tools. However, only 113 response words were included in the analysis. The remaining 95 response words were excluded from the study because they were repeated only once or twice. Of the excluded words, 78 were used only once, and 17 were used only twice. For example, the words "Deep seek" and "chip" were excluded because they were used only once, and the word "feedback" was excluded because it was used only twice. Thus, response words that were repeated once or twice were excluded. In addition, drawings and sentences about artificial intelligence from 126 participants were semantically evaluated and categorized.

2-Category development stage: After excluding 95 response words, 113 valid response words were obtained. At this stage, these words were listed from highest to lowest according to their frequency and reviewed for the third time. Semantically similar response words were grouped and categorized into a single cluster. For example, the words "robot," "technology," and "computer" were placed in the same cluster. Through this process, eight distinct categories were created.

The participants' drawings and sentences related to artificial intelligence were grouped according to their similarities, and four separate categories were created: (1) Artificial intelligence is a useful tool for humanity, (2) Artificial intelligence is useful when used correctly but dangerous when used incorrectly, (3) Artificial intelligence is a dangerous tool for humanity, and (4) Artificial intelligence is an ordinary technology.

3-Ensuring Validity and Reliability: Validity and reliability are the two most important criteria used to ensure or increase the credibility of research findings. In this regard, providing a detailed report of the collected data and explaining how the researcher reached the results are considered key indicators of validity in qualitative research (Yıldırım & Şimşek, 2016, p. 270). In this study, two major procedures were carried out to ensure the validity of the research findings: (1) The data analysis process, specifically how the eight separate categories were reached, was explained in detail. (2) The eight categories, consisting of 113 words and 1069 frequencies, were included in the findings section.

Three key strategies were employed to ensure the reliability of the study. First, the four researchers who are the authors of this article studied collaboratively and consistently at every stage of the research process (e.g., developing the research design, formulating the research questions, collecting data, analyzing data, developing categories, and interpreting the results). In the event of disagreement, they sought consensus to reach a decision. The eight conceptual categories developed in the study were submitted to two separate experts for review. Each expert, both of whom are faculty members specializing in biology education, was provided with a list containing the eight conceptual categories along with the associated response words and their frequencies, and they were asked to evaluate whether the response words in each category were semantically appropriate. The categorizations made by the experts were then compared with those of the researchers. In all comparisons, the numbers of agreement and disagreement were determined, and the reliability of the study was calculated using Miles and Huberman's (2016) formula (i.e., $[\text{Agreement} / (\text{Agreement} + \text{Disagreement}) \times 100]$). In the reliability study conducted specifically for this study, an agreement (reliability) rate of 93% and 96% was achieved, respectively. The first expert reported disagreements for eight response words, yielding a reliability score of $(105/113) \times 100 = 93\%$, while the second expert reported disagreements for five response words, yielding a reliability score of $(108/113) \times 100 = 96\%$. These results indicate that the study achieved the desired level of reliability.

The four categories created for the participants' drawings and sentences about artificial intelligence were evaluated by two independent experts. Each expert, both of whom are faculty members specializing in biology education, was provided with a list containing the four categories and their frequencies, along with all 126 participants' drawings and sentences regarding artificial intelligence. The experts were asked to match each drawing and sentence with the categories and to indicate if they had a different opinion outside of these categories. Their categorizations were then compared with those of the researchers, and the numbers of agreements and disagreements were determined. The reliability of these categorizations was calculated using Miles and Huberman's (2016) formula. In the reliability study conducted specifically for this study, agreement (reliability) rates were achieved at 91% and 88%, respectively. The first expert disagreed on 11 drawings or sentences, yielding a reliability coefficient of $(115/126) \times 100 = 91\%$, while the second expert disagreed on 15 items, yielding a reliability coefficient of $(111/126) \times 100 = 88\%$. These calculations indicate that the study achieved the desired level of reliability.

4- Transferring Data to SPSS for Quantification of Qualitative Data: After coding a total of 113 associations and developing eight conceptual categories formed by these associations, all data were transferred to SPSS statistical software. Additionally, the categories obtained through semantic analysis of the participant's drawings and sentences related to artificial intelligence were transferred to SPSS statistical software. Following this process, the number (f) and percentage (%) of concepts representing each category were calculated.

Results

A total of eight response word categories were generated as a result of data analysis: (1) advanced technologies, (2) education and training, (3) benefit, (4) society, culture and economy, (5) human mind and cognition, (6) ethics and safety, (7) personal emotions, and (8) harm. These categories and the response words within each category are shown in Table 1. The participating biology teachers associated artificial intelligence with 113 different response words, producing a total of 1,069 word frequencies. According to the findings, the dominant category associated with artificial intelligence was advanced technologies (398 response words, accounting for 37.23% of all response words). 27 different concepts were represented in this dominant category with 398 frequencies. The most frequently repeated concepts were "Robot" (63), "Technology" (61), "ChatGPT" (44), "Computer" (32), "Internet" (23), "Data Mining" (20), "Coding" (18), "Software" (17), "Informatics" (13), and "Virtual Reality" (13). These results indicate that the participants made direct associations between artificial intelligence and advanced technologies. These mental associations reflect the strong conceptual link between artificial intelligence and technology. The response words obtained reflect participants' expectations that humanity will further advance artificial intelligence technologies both today and in the future.

The second category of response words indicates that the participating teachers associated artificial intelligence with education and training (151 response words, accounting for 14.13% of all response words). 18 different concepts were represented in this category with 151 frequencies. The most frequently repeated concepts were "information" (32), "education" (14), "assignment" (14), "information access" (12), "science" (11), "learning" (10), "research" (9), "inquiry" (8), "idea" (7), "language learning" (5), "accessibility" (5), and "problem solving" (5). In this category, it was observed that many of the participants focused on ways to access information, producing scientific information, and the instructional aspects of artificial intelligence, while others

focused on aspects such as problem solving, satisfying curiosity, and scientific discovery. These results reflect the teachers' ideas, shaped by their profession, regarding the potential impacts of artificial intelligence on biology teaching.

Table 1. Associations with the term “artificial intelligence” (categories and responses included in each category and the cumulative frequency of response words).

Categories	Associations included in categories and their frequencies	Total frequency of associations in this category	%
1 Advanced Technologies	“Robot” (63), “technology” (61), “ChatGPT” (44), “computer” (32), “internet” (23), “data mining” (20), “coding” (18), “software” (17), “informatics” (13), “virtual reality” (13), “gemini” (12), “smart phone” (10), “machine learning” (7), “system” (7), “application” (7), “information processing” (6), “artificial neural network” (6), “algorithm” (5), “deep learning” (5), “image processing” (5), “space” (4), “robotic coding” (4), “biotechnology” (4), “smart home appliances” (3), “siri” (3), “engineering” (3), “augmented reality” (3).	398	37,23
2 Education And Training	“Information” (32), “education” (14), “assignment” (14), “information access” (12), “science” (11), “learning” (10), “research” (9), “inquiry” (8), “idea” (7), “language learning” (5), “accessibility” (5), “problem solving” (5), “instructional” (4), “course” (3), “critical thinking” (3), “encyclopedia” (3), “discovery” (3), “curiosity” (3).	151	14,13
3 Benefit	“Convenience” (63), “assistant” (18), “speed” (16), “quick access” (12), “benefit” (6), “production” (6), “medical assistance” (6), “time saving” (5), “access” (5), “accessibility” (5), “guide” (3).	145	13,56
4 Society, Culture And Economy	“Development” (31), “future” (26), “innovation” (13), “new world order” (9), “progress” (8), “unemployment” (7), “world domination” (5), “loss of profession” (5), “opportunity” (4), “profession” (4), “revolution” (3), “globalization” (3), “economy” (3), “welfare” (3), “social media” (3), “media” (3), “communication” (3).	133	12,44
5 Human Mind And Cognition	“Analysis” (12), “brain” (10), “creativity” (10), “intelligence” (9), “reason” (6), “not thinking” (6), “decision making” (5), “fuzzy logic” (5), “logic” (4), “imagination” (4), “mind” (3), “genius” (3), “reasoning” (3), “visualization” (3), “perception” (3).	86	8,04
6 Ethics And Safety	“Global threat” (18), “security vulnerability” (11), ‘misinformation’ (8), “end of humanity” (5), “fake” (4), “ethical concern” (4), “control” (4), “inhuman” (4), ‘chaos’ (3), “dark forces” (3), “threat” (3).	67	6,27
7 Personal Emotions	“Fear” (17), “lack of emotion” (10), “conversation” (7), “confidant” (6), “loneliness” (4), “my everything” (3), “anxiety” (3).	50	4,68
8 Harm	“Laziness” (15), “imitation” (6), “seeking ready-made answers” (5), “fakeness” (4), “atrophy” (3), “humanoid” (3), “harm” (3).	39	3,65
Total	113	1069	100

The response words in the third category indicate that the participants associated artificial intelligence with the convenience that could benefit humanity (145 response words, accounting for 13.56% of all response words). Eleven different concepts were represented in this category with 154 frequencies. The most frequently repeated concepts were "convenience" (63), "assistant" (18), "speed" (16), "quick access" (12), "benefit" (6), "production" (6), and "medical assistance" (6). In this category, many participants focused on auxiliary services that make human life easier, while others focused on aspects such as time saving and ease of access. These results show that biology teachers take into consideration the facilitating effects of artificial intelligence on individuals' daily lives.

The response words in the fourth category indicate that the participating teachers associated artificial intelligence with terms related to society, culture, and the economy (133 response words, accounting for 12.44% of all response words). Seventeen different concepts were represented in this category with 133 frequencies. The most frequently repeated concepts were "development" (31), "future" (26), "innovation" (13), "new world order" (9), "progress" (8), "unemployment" (7), "world domination" (5), "loss of profession" (5), "opportunity" (4), and "profession" (4). In this category, many participants focused on developments and innovations in the future of society, while others focused on the aspects such as unemployment, loss of profession, and world domination. These results reflect the belief of biology teachers that although artificial intelligence will bring innovations to social dynamics, it may also lead to challenges such as unemployment and loss of professional roles.

The response words in the fifth category indicate that the participating teachers associated artificial intelligence with terms related to mental processes (86 response words, accounting for 8.04% of all response words). Fifteen different concepts were represented in this category with 86 frequencies. The most frequently repeated concepts were "analysis" (12), "brain" (10), "creativity" (10), "intelligence" (9), "mind" (6), and "not thinking" (6). In this category, many participants focused on human brain activities, analysis, and creativity, while others focused on aspects such as logic, imagination, and perception. These results reflect biology teachers' views on the potential innovations artificial intelligence may bring to human mental processes.

The response words in the sixth category indicate that the participants associated artificial intelligence with ethics and potential security risks (67 response words, accounting for 6.27% of all response words). Eleven different concepts were represented in this category with 67 frequencies. The most frequently repeated concepts were "global threat" (18), "security vulnerability" (11), "misinformation" (8), and "the end of humanity" (5). In this category, many participants focused on global threats to the future of humanity, while others focused on the aspects such as ethical concerns and potential inhumane practices. These results reflect biology teachers' belief that artificial intelligence may pose certain risks for the future of humanity.

The response words in the seventh category indicate that the participants associated artificial intelligence with terms related to personal emotions (50 response words, accounting for 4.68% of all response words). Seven different concepts were represented in this category with 50 frequencies. "Fear" (17), "lack of emotion" (10), "Conversation" (7), "Confidant" (6), and "Loneliness" (4) were the most frequently repeated concepts. Many participants in this category focused on emotions such as fear and loneliness. These findings suggest that while artificial intelligence may serve as a companion for lonely individuals, it may also, over time, contribute to emotional desensitization in humans.

The response words in the eighth category indicate that the participants associated artificial intelligence with aspects that could potentially harm humanity (39 response words, accounting for 3.65% of all response words). Seven different concepts were represented in this category with 39 frequencies. "Laziness" (15), "imitation" (6), and "seeking ready-made answers" (5) were the most frequently repeated concepts. Overall, many participants emphasized the idea that artificial intelligence may lead to negative outcomes for humans, particularly by fostering laziness and an overreliance on ready-made answers.

A semantic analysis of participants' drawings and sentences related to artificial intelligence revealed four distinct categories (Table 2). According to the results, the dominant category associated with artificial intelligence was the idea that it is a useful tool for humanity (46.8%). This was followed by the categories suggesting that artificial intelligence is useful only when used correctly but dangerous when used incorrectly (23%), that it is a dangerous tool for humanity (16.7%), and finally, that it is perceived as an ordinary technology (13.5%).

Examples of drawings and sentences related to the dominant category reflecting the idea that artificial intelligence is a useful tool for humanity are presented below (Figures 1, 2, 3, 4).

Table 2. Categorization of drawings and sentences obtained through association

Categories	n	%
1 Artificial intelligence is a useful tool for humanity	59	46,8
2 Artificial intelligence is useful when used correctly and dangerous when used incorrectly	29	23
3 Artificial intelligence is a dangerous tool for humanity	21	16,7
4 Artificial intelligence is an ordinary technology	17	13,5
Total	126	100

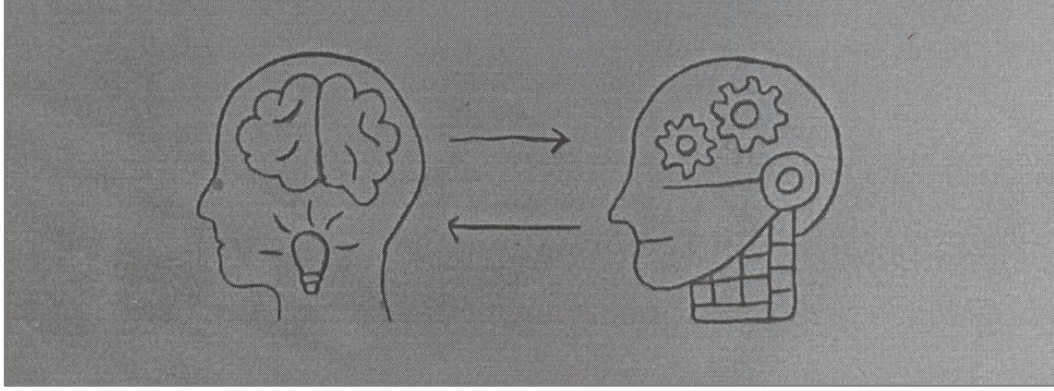


Figure 1. “Artificial intelligence is a technology that enables computers to learn and think like humans” (Participant 107)

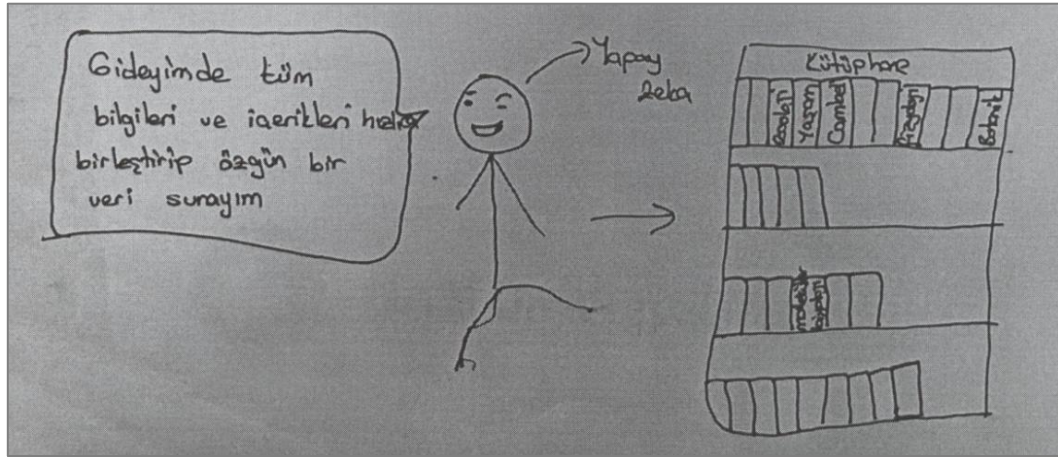


Figure 2. “My assistant who speeds up my work in every field” (Participant 110)

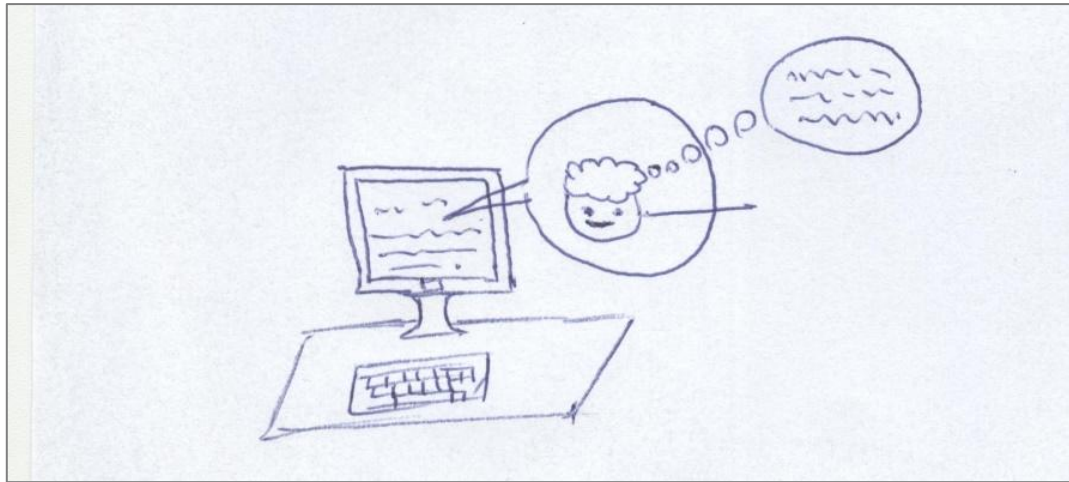


Figure 3. “When artificial intelligence is used in education, it greatly simplifies the process and enables us to use time efficiently” (Participant 114)

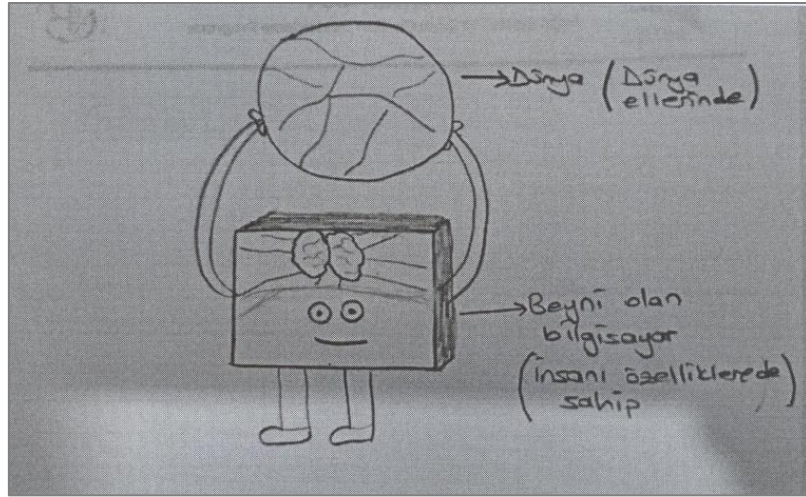


Figure 4. “Thanks to artificial intelligence, all my daily tasks have become much easier. With artificial intelligence, I can access a lot of information I want” (Participant 103)

Examples of drawings and sentences reflecting the idea that artificial intelligence is useful when used correctly and dangerous when used incorrectly are presented below (Figures 5 and 6).

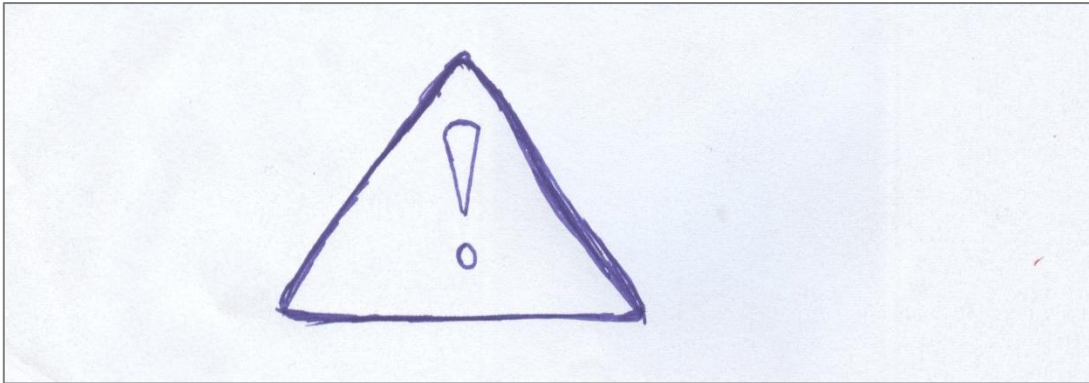


Figure 5. “Artificial intelligence will be like medicine if used correctly, but like poison if used incorrectly.” (Participant 105)

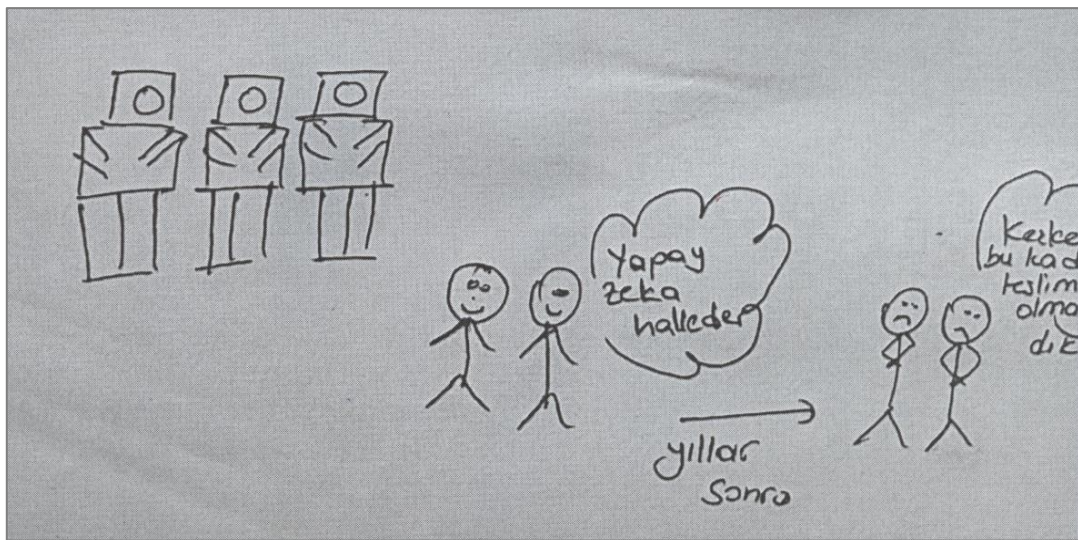


Figure 6. “The weapon of the future; a good tool when used for the right purpose in the right hands, but a bad tool when used for the wrong purposes in the wrong hands” (Participant 112)

Examples of drawings and sentences reflecting the idea that artificial intelligence is a dangerous tool for humanity are presented below (Figures 7, 8, 9, 10, 11, 12).

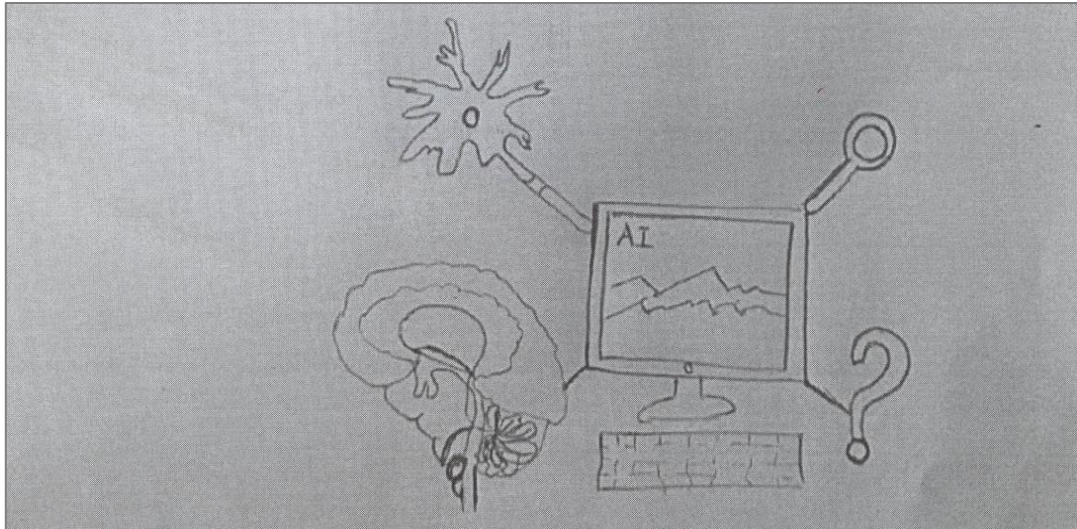


Figure 7. *“As a result of the development of artificial intelligence, humanity may gradually lose its thinking skills and resort to easy solutions, and may also face professional limitations”* (Participant 111)



Figure 8. *“As it makes people’s lives easier, it paves the way for ideas that will turn them into robots”* (Participant 123)

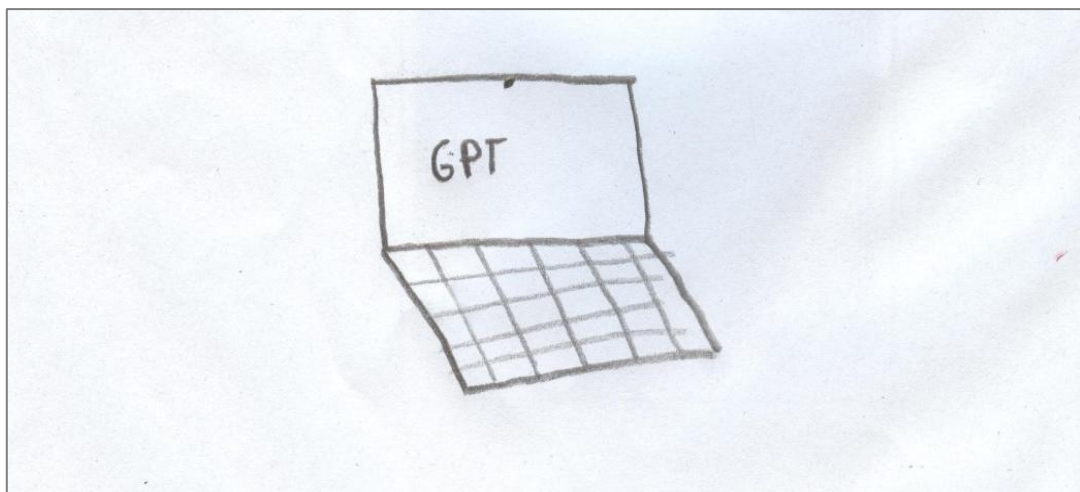


Figure 9. *“One day it may bring about the end of humanity”* (Participant 99)

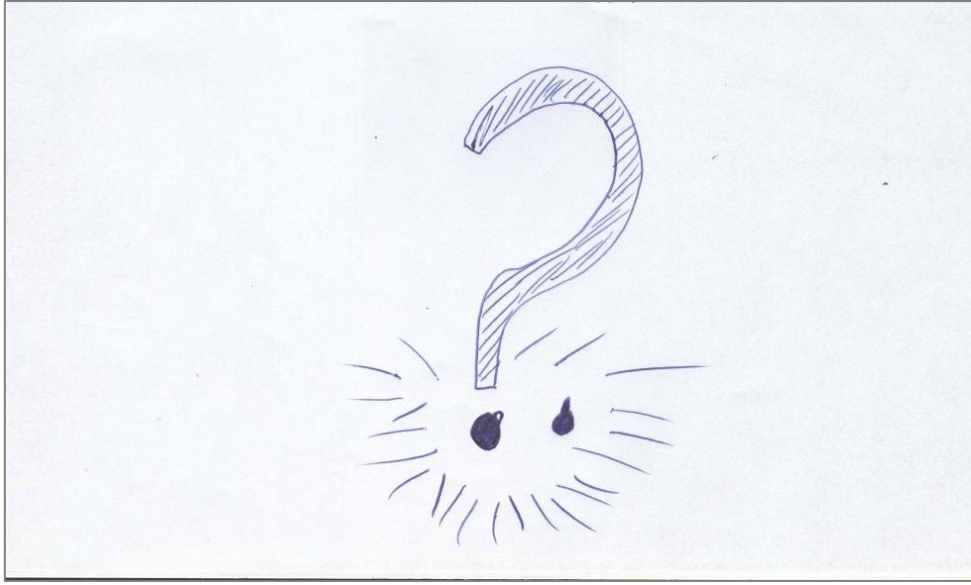


Figure 10. "In my opinion, it's quite dangerous data mining, an innovation that seeks to abstract the human mind, with unknown forces and plans behind it." (Participant 92)

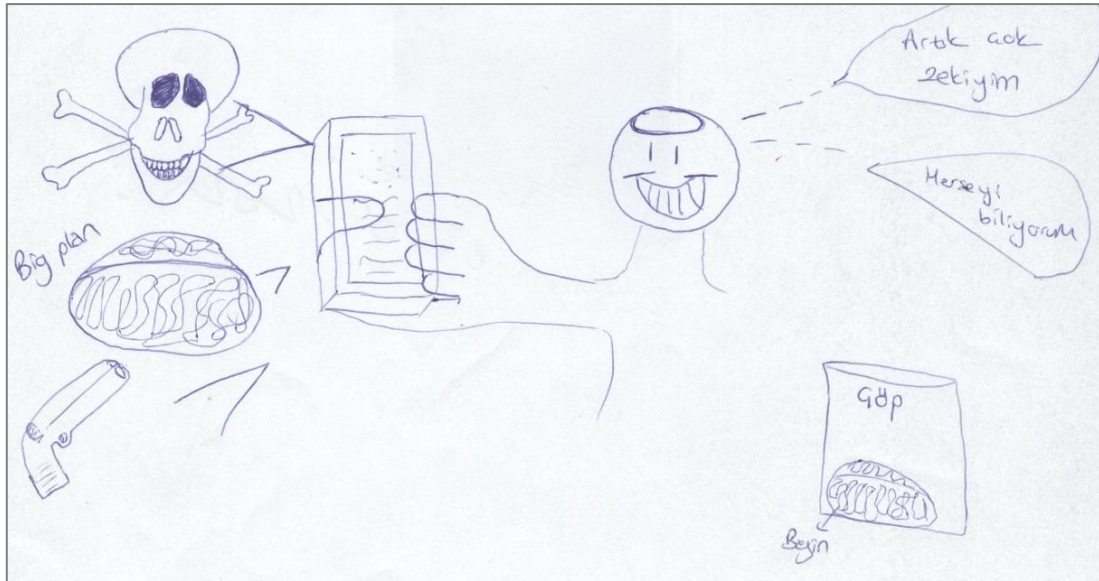


Figure 11. "The secret weapon of today's modern world, which I think leads to social atrophy and may become the most dangerous force in the future" (Participant 14)

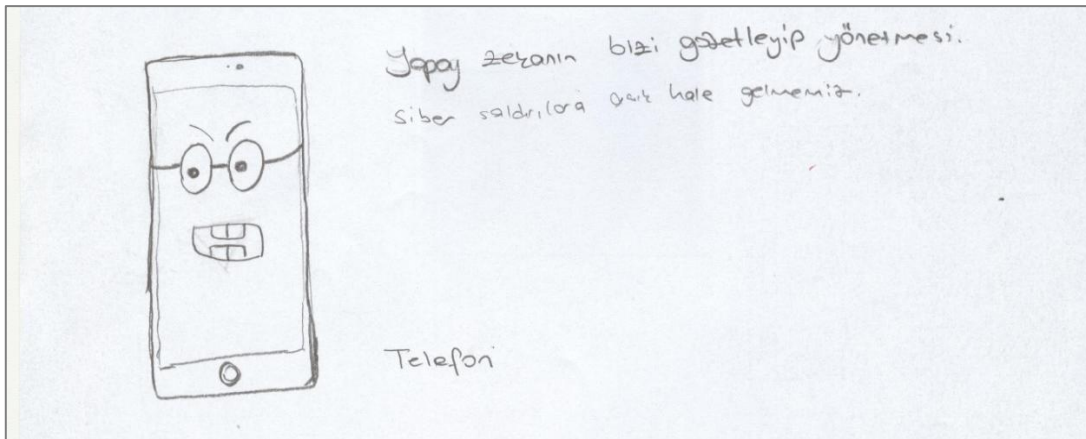


Figure 12. "Artificial intelligence monitoring and controlling us, making us vulnerable to cyberattacks" (Participant 37)

Examples of drawings and sentences related to this category, which reflect the idea that artificial intelligence is an ordinary technology, are presented below (Figure 13).

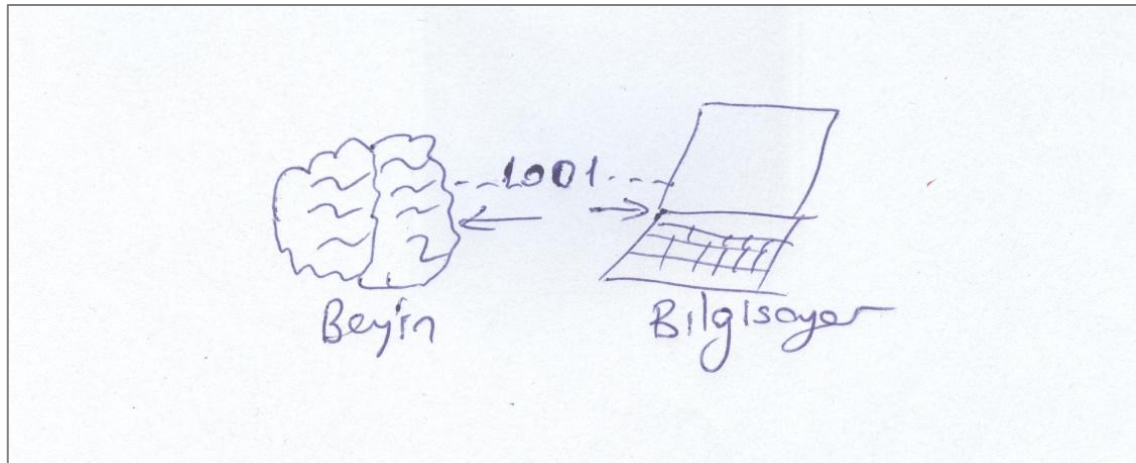


Figure 13. *“It is a computer technology capable of performing behaviors similar to human behaviors”*
(Participant 89)

Conclusion and Discussion

This study aimed to examine the cognitive structures of biology teachers regarding artificial intelligence. The findings revealed that biology teachers evaluate artificial intelligence from a multidimensional perspective, considering technological, educational, socio-cultural, and ethical aspects. A total of 113 response words expressed at a total frequency of 1069 were grouped into eight categories. The analysis of drawings and written explanations further showed that biology teachers’ overall perceptions of artificial intelligence clustered around four main themes. Nearly half of the biology teachers (46.8%) viewed artificial intelligence as a useful tool for humanity. However, a significant portion (23%) emphasized that artificial intelligence can be useful only when used correctly but may pose risks when used incorrectly. While 16.7% of participants viewed artificial intelligence as a directly dangerous element, 13.5% viewed it as an ordinary technology.

In this study, biology teachers predominantly (37.23%) coded artificial intelligence under the category of “advanced technologies.” The fact that the concepts “robot,” “technology,” and “ChatGPT” had the highest frequencies indicates that biology teachers define artificial intelligence primarily through technological tools and current applications. This finding is consistent with similar studies in the literature. In a study conducted with pre-service science teachers, participants most frequently associated the concept of artificial intelligence with the concepts of “robot,” “convenience,” “technology,” “ChatGPT,” and “smart assistant” (Gökçe, 2024). The high frequency of “ChatGPT” in both groups can be interpreted as a common reflection of the rapid dissemination and acceptance of artificial intelligence tools in the field of education. Similarly, another study conducted with education faculty students (Keleş & Aydın, 2021) reported that, as in the present study, the terms “robot” and “technology” reached the highest frequencies. This trend is further supported by another study by Henrich et al. (2025), which found that the most frequently used term was “robot,” followed by “computer” and “ChatGPT,” once again confirming the strong semantic association established between artificial intelligence and technological applications.

The education-training category that emerged from the study indicates that biology teachers' professional roles shape their perceptions of artificial intelligence and reveals their potential to integrate artificial intelligence into their professional practices. Biology teachers' emphasis on concepts such as "information," "education," "assignment," "learning," and "information access" suggests that artificial intelligence is particularly associated with aspects that support learning processes. This finding is consistent with findings in the literature suggesting that artificial intelligence has the potential to personalize learning, provide rapid access to information, and enrich teaching materials (Baker et al., 2019; Hashim et al., 2022; Akyel & Tur, 2024).

In this study, biology teachers’ perception of artificial intelligence as a tool that provides “convenience,” “assistance,” and “speed” in human life indicates that the practical benefits of AI in daily life have become embedded in their mental representations. This finding is also consistent with the drawing analysis results, in which “Artificial intelligence is a useful tool” emerged as the dominant category (46.8%). Biology teachers

positioned artificial intelligence as an assistant that accelerates access to information and saves time. This finding is supported by numerous studies demonstrating that artificial intelligence helps individuals save time, particularly by automating routine tasks (Telaumbanua, 2025). Similarly, Poola (2017) emphasized that artificial intelligence saves time, which in turn increases the efficiency of human activities.

The study found it noteworthy that, in the category of social, cultural, and economic impacts, biology teachers focused on concepts of development, innovation, and opportunity, while simultaneously emphasizing concerns such as unemployment, loss of profession, and global domination. This dual structure aligns with the frequently emphasized argument in the literature that "artificial intelligence poses both opportunities and threats" (Groumpos, 2019; Bozkurt & Gursoy, 2025). The apparent presence of concerns about loss of profession and unemployment among teachers demonstrates that the potential of artificial intelligence to transform working life in many areas, including the education sector, has raised teachers' awareness. This economic concern is consistent with other findings in the literature. In a study conducted with university students by Ghotbi, Ho, and Mantello (2022), the term "unemployment" was identified as the most common negative association with artificial intelligence.

One of the noteworthy findings of the study is that biology teachers directly associated artificial intelligence with human mental and cognitive activities (8.04%). The prominence of concepts such as "analysis," "brain," "creativity," "intelligence," and "reason" indicates that teachers perceive artificial intelligence not merely as an external technology but also as an extension of the human mind. Biology teachers' direct engagement with topics such as the functioning of the human brain suggests that associations in this category may be a reflection of their professional knowledge. Chen et al. (2020) argued that future research should not only focus on artificial intelligence itself, but also on innovations that facilitate the development of technologies with human-like intelligent capacities, such as decision-making, adaptive learning abilities, and cognitive functions.

Another important finding of the study is the emphasis biology teachers place on issues related to "Ethics and Safety." Concepts with negative associations such as "global threat," "security vulnerability," "misinformation," and "the end of humanity" indicate that technophobia and ethical concerns are prevalent among biology teachers. These findings suggest that biology teachers perceive artificial intelligence as a force that is difficult to control and potentially capable of endangering the future of the human species. Furthermore, as teachers of a discipline that prioritizes the accuracy and reliability of scientific knowledge, biology teachers also appear to be concerned that fabricated information generated by artificial intelligence could harm scientific literacy. In other words, teachers are not only concerned about physical robot invasion but also about information pollution.

In the literature, this situation is explained through the myth that artificial intelligence could turn into a "malignant" force and turn against humanity (Sheikh et al., 2023). It is noteworthy that views similar to those held by teachers are also shared by some scientists. For example, Prof. Stephen Hawking stated that although the primitive forms of artificial intelligence developed so far have been very useful, he feared the consequences of creating something that could match or surpass human intelligence. According to him, the development of full artificial intelligence could spell the end of the human race (Cellan-Jones, 2014). Similarly, in his speech at the Nobel Prize Ceremony on December 10, 2024, Prof. Geoffrey Hinton emphasized that the rapid advancement of artificial intelligence brings numerous short-term risks and that, in the near future, artificial intelligence could be used to develop terrifying new viruses and lethal weapons that can autonomously decide who to kill or injure (Hinton, 2024). In a study conducted by Bagir et al. (2022) with science teachers, it was reported that teachers had serious concerns and ethical worries about "malicious individuals entering the system" and the security of personal data. Velander et al. (2024) similarly noted that the characteristics of artificial intelligence may lead to fear and anxiety about the future, causing some teachers to perceive artificial intelligence as "bad" (or threatening) and reducing their professional interest in the subject.

One of the significant findings of the study is that the relationship biology teachers establish with artificial intelligence has not only a technical dimension but also a deep psychological dimension. The fact that "fear" ranked first in this category demonstrates the extent to which teachers' distrust of technology is deeply embedded in their individual emotions. However, the most striking and unique aspect of this category is the coexistence of the concepts of "confidant" and "conversation" with "lack of emotion" and "loneliness" in participants' mental representations. This suggests that teachers tend to perceive artificial intelligence as a nonjudgmental, always-accessible digital confidant with whom one can share thoughts, while at the same time expressing concern that such an artificial bond might gradually desensitize individuals and detach them from genuine social relationships. The predominance of the concept of "fear" in the study findings parallels other studies in literature. For instance, Gökçe (2024) found that preservice teachers associated artificial intelligence with fear and anxiety. The paradoxical coexistence of the "confidant/ conversation" perception and the "lack of

emotion/loneliness” concern observed in this study is also supported by Karşlı (2024), who noted that people seek not only information but also a sense of emotional understanding from artificial intelligence, pointing to the psychological roots of this digital-confidant tendency.

According to the results of the study, the “harm” category was characterized particularly by the emphasis on “laziness” and “seeking ready-made answers.” This reflects biology teachers’ pedagogical concern that students’ critical thinking skills may deteriorate. By its nature, biology education requires observing the natural world, analyzing data, and engaging in process-oriented thinking. However, the findings revealed that biology teachers fear that the instant and effortless information provided by artificial intelligence may free students from the burden of thinking, thereby leading them into a state of cognitive laziness. This finding is in full alignment with the theme of “useful when used correctly, dangerous when used incorrectly.” Similar concerns have been expressed in literature. For example, Seyrek et al. (2024) found that the use of artificial intelligence in education carries serious risks, such as diminishing creativity, encouraging laziness among students, causing data breaches, and generating inequalities stemming from differences in access to technology. Additionally, the concept of imitation, prominent in this category, reflects a sensitivity to academic honesty and originality. Biology teachers may perceive the direct copying and pasting of AI-generated outputs by students as a threat that undermines productivity and authentic learning. Slimi et al. (2025) warned that excessive reliance on artificial intelligence could hinder the development of students’ independent critical thinking skills. Similarly, Uygun’s (2024) study with teachers reported concerns that artificial intelligence may render individuals passive, dull their investigative qualities, and potentially contribute to teachers’ own professional complacency.

In conclusion, the cognitive perceptions of biology teachers regarding artificial intelligence appear to exhibit a complex structure balanced between benefits and threats. While technological and utilitarian aspects dominated the word association test, traces of pessimistic future-oriented scenarios were also observed in the emotional and ethical dimensions. The drawing analyses further concretized this mental complexity; although the majority of biology teachers positioned artificial intelligence as a functional tool that serves the benefit of humanity, a considerable proportion also expressed serious reservations about the uncontrolled use of the technology.

Recommendations

Artificial intelligence technology should be integrated into educational settings based on data obtained from educational psychology, educational sociology, and contemporary teaching models. An AI system that lacks foundational educational principles may cause more harm than benefit to students; therefore, it should be embedded in ways that align with the field of educational sciences. It is unrealistic to expect humans and educators to detach themselves from technology; however, technology should not overshadow the fundamental aims of education and must be used cautiously. Artificial intelligence should not replace the teacher, who serves as a guide in the learning process.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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Development of Four Tier Misconception Test on Electrochemistry

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Abstract

The purpose of this study was to develop a valid and reliable measurement tool that can be used to identify pre-service teachers' misconceptions about electrochemistry. The Electrochemistry Concept Test (ECT) developed for this purpose consists of a total of 12 questions, each containing four tiers. The Electrochemistry Concept Test (ECT) was applied to a total of 307 science teacher candidates from 10 different universities in seven regions of Türkiye. The data were analyzed using Excel, SPSS, and Factor programs. A four-factor structure with 12 questions was determined using EFA, and the KMO value of the test was calculated as 0,682, indicating that this four-factor structure explained 48% of the total variance. As a result of the reliability analyses, the KR-20 reliability coefficient for the scientific knowledge score obtained from correct answers was calculated as .819, and the KR-20 reliability coefficient for the misconception score obtained from wrong answers was calculated as 0,702. The item analyses revealed that the difficulty and discriminative indices of the test were at an intermediate level. Positive and negative wrong values were calculated for content validity. The validity and reliability analyses confirm that the developed test is a valid and reliable measurement tool. As a result of the analysis of the data collected in the study, it was determined that the pre-service teachers had misconceptions above 10% for each question related to electrochemistry - activity, reduction-oxidation, galvanic cell reactions, and cell potential - and that their scientific knowledge was not at a sufficient level. As a result of the study, a total of 37 misconceptions related to the topic of electrochemistry were identified, among which 9 misconceptions with a prevalence of over 10% were determined, thereby contributing new misconception statements to existing literature. In conclusion, a valid and reliable measurement tool has been developed that researchers can use to determine pre-service teachers' misconceptions and achievement levels in electrochemistry.

Introduction

Concepts are abstract units of thought that are understood by the human mind. They exist alongside concrete examples from the real world, as well as abstract concepts such as love and affection, whose meanings vary from person to person. In concept teaching, students' prior knowledge, misconceptions, and experiences can significantly impact their subsequent learning and negatively affect the acquisition of new knowledge. Conceptual misconceptions are mental definitions and designs related to elements in individuals' mental processes that differ from scientifically accepted truths (Yakışan et al., 2007). According to existing studies in the literature, one reason for failure in chemistry is that chemistry topics often contain abstract and complex concepts. This makes chemistry difficult for students to understand. Since electrochemistry involves more abstract concepts, students find it challenging to understand this subject. Many studies have reported that students have numerous misconceptions about electrochemistry, which is one of the important topics in chemistry education (Sanger & Greenbowe, 1997a; Sanger & Greenbowe, 1997b; Garnett & Treagust, 1992a; Garnett & Treagust, 1992b; Birss & Truax, 1990; Garnett & Treagust, 1990; Sanger & Greenbowe, 1999; Geban et al., 1999; Morgil et al., 2002; Yılmaz et al., 2002; Şen et al., 2017; Yılmaz, 2012; O'Grady-Morris, 2008; Özkaya, 2000; Erdoğan, 2009; Ercan, 2009).

Books & teachers are among the primary sources of information that students can access directly. Gaps in teachers' knowledge or their misunderstandings can cause misconceptions in students. For this reason, it is essential to identify and address pre-service teachers' lack of knowledge and misconceptions in electrochemistry. Methods such as interviews, open-ended questions, multiple-choice tests, and various test formats, including two-tier, three-tier, and four-tier tests, are used to identify misconceptions held by individuals. Interviews and open-ended questions, which are frequently used to identify students' misconceptions, offer the opportunity to examine participants' thoughts in depth, but they also have some limitations (Lee & Schneider, 2015; Karaarslan & Çetin,

2018). Marshall & Rossman (2006) state that the main disadvantages of these methods are that they are carried out with a limited number of participants, the data may be subject to subjective influences due to the researcher's direct involvement in the process, the application process is time-consuming, and the analysis of the data obtained is relatively more complex and time-consuming.

Multiple-choice tests, on the other hand, can be considered a more efficient and practical measurement tool compared to other data collection methods due to their ability to reach a broad sample, be administered in a short time, and be easily scored (Haladyna, 1997). However, it is often impossible to distinguish whether student responses obtained in such tests are due to lack of knowledge, simple wrongs, chance, or external factors such as copying. Two-tier tests, which aim to minimize the disadvantages of multiple-choice tests while retaining their advantages, enable more in-depth analysis of the misconceptions that students may hold (Karataş et al., 2003). However, two-tier tests are also insufficient in determining whether the answer stems from a lack of knowledge or a misconception.

According to Kaltakçı (2012), three-tier tests were developed by incorporating a third tier into the test, which aims to assess the level of confidence in the answers provided in the first two tiers, thereby overcoming the limitations of two-tier tests. The primary advantage of three-tier tests over two-tier and multiple-choice tests is that they enable researchers to identify the causes of students' misconceptions and assess the degree of their confidence in their answers. Additionally, these tests offer an opportunity to determine whether wrong answers result from misconceptions or a lack of knowledge. However, in three-tier tests, students' confidence levels regarding their answers are asked for both tiers together. This makes it difficult to determine whether the student's confidence or lack thereof, as expressed in the third tier, is related to the answer given in the first tier, the justification provided in the second tier, or both. Four-tier tests were developed to overcome the limitations of three-tier tests.

In four-tier tests, the first tier represents the content tier, describing the knowledge level of the respondents. The second tier questions the level of certainty about the content tier and thus forms the confidence tier. The third tier, which forms the reason tier, includes the justification for the answer given to the main question. The fourth tier is the confidence tier, which questions the confidence level of the answer given to the reason tier (Kaltakçı, 2012). If the student is "not confident" at any tier of their answer, i.e., if there is doubt at any tier, then it is concluded that there is a "lack of knowledge". Table 1 compares the possible outcomes of students' decisions on four-tier tests (Kaltakçı-Gürel et al., 2015).

Table 1. Comparison of decisions from four tier tests

1. Tier	2. Tier	3. Tier	4. Tier	Decision of four-tier test decision
True	Confident	True	Confident	SK
True	Confident	False	Confident	FP
False	Confident	True	Confident	FN
False	Confident	False	Confident	M
True	Confident	True	Not Confident	LK1
True	Not Confident	True	Confident	LK2
True	Not Confident	True	Not Confident	LK3
True	Confident	False	Not Confident	LK4
True	Not Confident	False	Confident	LK5
True	Not Confident	False	Not Confident	LK6
True	Confident	True	Not Confident	LK7
False	Not Confident	True	Confident	LK8
False	Not Confident	True	Not Confident	LK9
False	Confident	False	Not Confident	LK10
False	Not Confident	False	Confident	LK11
False	Not Confident	False	Not Confident	LK12

SK: Scientific Knowledge, LK: Lack of Knowledge, M: Misconception, FN: False Negative, FP: False Positive

Four-tier diagnostic tests provide more comprehensive information than two- and three-tier tests because they can separately reveal which option participants chose, why they chose it, and how confident they are in both their choice and their reasoning. In this study, a four-tier concept misconception diagnostic test developed by the researcher was used as a measurement tool to identify misconceptions in electrochemistry among pre-service science teachers.

Problem Statement

Printed materials and teachers are among the primary sources of information for students. Teachers' lack of knowledge or misunderstandings can lead to misconceptions among students. For this reason, it is important to identify and eliminate pre-service teachers' misconceptions and knowledge levels in electrochemistry. This study aims to develop a valid and reliable measurement tool to identify misconceptions of pre-service science teachers regarding electrochemistry. In this context, a four-tier diagnostic test was developed to identify misconceptions. It is believed that this diagnostic test can be used to identify pre-service teachers' misconceptions about electrochemistry and the reasons behind these misconceptions. Additionally, this research is of great importance in guiding future studies aimed at addressing these misconceptions. In light of this information, the following sub-problems were addressed in the study:

1. Is the test developed to identify misconceptions of pre-service science teachers about electrochemistry a valid measurement tool?
2. Is the test developed to identify pre-service science teachers' misconceptions about electrochemistry a reliable measurement tool?
3. What are the factor-based values of pre-service science teachers' misconceptions about electrochemistry, their scientific knowledge levels and their lack of knowledge?

Method

Research Design

In this study, a concept test was developed to identify pre-service teachers' misconceptions about electrochemistry, and a quantitative test development and validation was employed as the preferred quantitative research method. Quantitative research is defined as the process of collecting data using scientific research principles and expressing the results in numerical data or symbols to understand a phenomenon or problem better, or to contribute to the solution of an existing problem (Büyüköztürk, 2013).

The primary objective of survey designs is to generate various statistical results about events and situations using quantitative data collected from large sample groups. In this way, the relevant phenomena or situations are described (Creswell, 2009). Especially in cross-sectional survey designs, the variables under study are evaluated with a single measurement (Büyüköztürk, 2013). For these reasons, the survey design was selected as an appropriate method for the test development process aimed at identifying misconceptions related to electrochemistry.

Data Collection

The target population of this study was comprised of pre-service science teachers from universities across Türkiye. The accessible population consisted of pre-service science teachers studying at 10 different universities in Türkiye, and the sample consisted of 307 pre-service science teachers. Due to various reasons, including transportation difficulties, application challenges, and cost, it was not feasible to apply the study to the entire population; therefore, a sample was created. In the sample selection process, 10% of the accessible population, at least 10 times the number of items in the measurement tool, or the sample size obtained from the G-Power analysis was considered (Pallant, 2020). Accordingly, the study aimed to reach participants that are at least 10 times the number of items included in the test and as a result a sample of 307 participants was selected. Since the sample determination process is a fundamental element in survey research, this study employed a rigorous process to ensure representativeness of the target population. The study sample was created by selecting participants from universities in all seven regions of Türkiye. To enhance the reliability coefficient of the test results, a heterogeneous sample was selected, comprising pre-service teachers from all grade levels.

Of the pre-service teachers who voluntarily participated in the study, 246 (80,13%) were female and 61 (19,87%) were male. In terms of class level, 123 (40,07%) pre-service teachers were in the first grade, 114 (37,13%) were in the second grade, 32 (10,42%) were in the third grade, and 38 (12,38%) were in the fourth grade. Demographic data regarding gender distribution and grade level are presented in Table 2. Data for this study were gathered during the spring semester of the 2023–2024 academic year through the Electrochemistry Concept Test, which was developed by the researcher and administered at designated universities.

Table 2. Gender distribution and class levels

Gender	Number	Percentage %
Female (F)	246	80,13%
Male (M)	61	19,87%
Total	307	100%
Class Level		
1st grade	123	40,07%
2nd grade	114	37,13%
3rd grade	32	10,42%
4th grade	38	12,38%
Total	307	100%

During the test development process, open-ended questions were prepared by combining the observations of teachers and instructors in theoretical and practical lessons, the answers given by students on their exam papers, and findings related to misconceptions about electrochemistry in the literature and a pool of questions was created. Three subject matter experts reviewed the item pool, and 17 questions were selected that were considered to contain all possible misconceptions on the subject. The selected questions were read to five pre-service teachers who were not included in the study to obtain information about the questions' visual, linguistic, and comprehension levels, and feedback was obtained on the suitability of the test. The researcher applied these questions to 64 pre-service science teachers. The researcher analyzed the data from their responses and identified misconceptions. After this tier, the answers given by the pre-service teachers on their exam papers and the findings related to misconceptions in the literature on electrochemistry were combined. The test was converted into a multiple-choice format. The test consisted of three tiers: the first tier contained a three-choice knowledge question (content), the second tier contained the confidence level of the answer given to the knowledge question, the third tier asked for the reason (justification) for the knowledge question, and the fourth tier consisted of a confidence question indicating whether the candidate was confident in their justification. With the addition of confidence tier to the knowledge tier and justification tier to the reasoning tier, the test was converted into a four-tier concept test. The four-tier draft test was sent to three subject matter experts for content and face validity, and the necessary revisions were made based on their feedback, resulting in the final version with 12 questions. The Electrochemistry Concept Test (ECT) consists of 12 questions, each divided into four tiers. The Electrochemistry Concept Test (ECT) was administered to a total of 307 pre-service science teachers from 10 different universities across 7 regions of Türkiye during the spring semester of 2023-2024.

Data Analysis

The validity and reliability analyses of the developed Electrochemistry Concept Test (ECT) were performed using Excel, SPSS, and Factor software packages. During the data analysis process, the data were assigned separate scores based on possible results, including scientific knowledge, misconceptions, false positives, and false negatives. In the calculations, correct answers were coded as "1" and wrong answers as "0" for all questions. In tiers where the level of confidence was questioned, the "I am sure" option was coded as "1" and the "I am not sure" option as "0".

When calculating scientific knowledge scores, data with a 1-1-1-1 coding, where all tiers were answered correctly, were included. In concept misconception scoring, a 0-1-0-1 coding was used for cases where participants gave wrong answers in the first and third tiers, but were confident in both confidence levels. In cases of false positive (answer correct, justification wrong), the calculation was made based on the 1-1-0-1 coding, where the answer was correct in the first tier, wrong in the third tier, and confident in both confidence levels. False negative (answer wrong, justification correct) scores were calculated based on the 0-1-1-1 coding, where the answer was wrong in the first tier, correct in the third tier, and confidence was expressed in both confidence levels. All other possibilities were coded as missing information.

Reliability Analysis of the Test

The developed Electrochemistry Concept Test (ECT) can be used to identify students' misconceptions and determine their level of scientific knowledge. In this context, the reliability scores of the four-tier test can be calculated using two different methods:

Reliability 1: Scientific Knowledge Reliability

The first type of reliability coefficient for the ECT was calculated based on students' correct answers in the first and third tiers and their "I am sure" responses in the second and fourth tiers (1-1-1-1) scoring, resulting in the KR-20 reliability coefficient for the test. In the literature, a reliability coefficient of 0,70 or higher is generally considered sufficient for data reliability (Fraenkel & Wallen, 2006). However, it is also stated that this coefficient may be below 0,70 in concept misconception tests (Eryılmaz, 2010; Kaltakçı, 2012, p.118).

Reliability 2: Concept Misconception Reliability

The second type of reliability coefficient of the ECT was calculated based on questions where students answered "I am sure" in the second and fourth tiers and answered wrong in both the first and third tiers (0-1-0-1). This coefficient determined the test's ability to reveal misconceptions. The KR-20 reliability coefficient was calculated to determine the test's ability to identify conceptual misconceptions. If the reliability coefficient of the developed test was 0,70 or above, it indicated that the test was reliable.

Validity Analysis of the Test

Not all reliable data may be valid. For this reason, the validity of the test was determined using data obtained from four different methods (Taban & Kiray, 2022).

Validity-1: Factor Analysis

One of the most basic statistical methods used to collect evidence of construct validity is factor analysis (Cronbach, 1984; Pedhazur & Pedhazur Schmelkin, 1991; Turgut, 1980; Urbina, 2004). Factor analysis is structured on the relationships between test items and can be applied in two different types: exploratory and confirmatory. The test items were grouped according to misconceptions, and factor analysis was performed according to the total scores obtained. In this study, the suitability of the data obtained from the ECT for factor analysis was examined using Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) test. Information regarding the exploratory factor analysis data of the four-tier conception test is presented in a table. As a result of the item analyses, the difficulty and discriminative indices of the test were calculated.

Validity-2: Correlation Between Correct Answer Scores and Confidence Scores

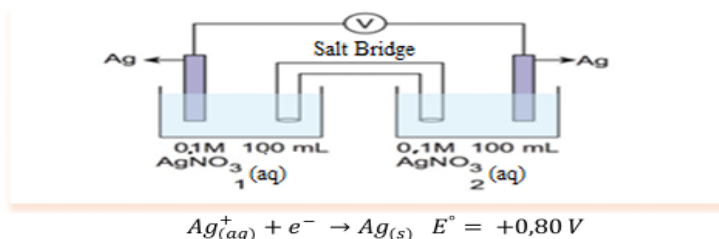
Three different correlation coefficients were calculated to examine the correlation between the correct answers and the confidence scores of the teacher candidates. These were the correlation coefficients between the first and second tier scores, between the third and fourth tier scores, and between the first and third tier scores and the second and fourth tier scores.

Validity 3: False Positive and False Negative

In terms of content validity, the possibilities of lack of knowledge, false negative and false positive were examined, and expert opinions were consulted. For the validity of concept misconception tests, it has been stated that the averages of false positive and false negative should be below 10% (Hestenes & Halloun, 1995).

Validity 4: Expert Opinion

Expert opinions were obtained from teachers and instructors in the field of chemistry education during the development of open-ended questions. The four-tier draft test was sent to three subject matter experts for content and face validity, and necessary revisions were made based on the experts' feedback, resulting in the final version shown in Figure 1.



11.1. If a small amount of 0.1M $AgNO_3$ solution is added to the battery setup shown in the figure, how does the battery voltage change compared to its initial state?

- a) Increases
- b) Decreases
- c) Remains unchanged

11.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

11.3. Why did you select the above option?

- a) If a substance is added to reversible battery reactions, the battery voltage increases.
- b) If $AgNO_3$ solution is added to the first container, the concentration of the solution will increase, causing a concentration difference and increasing the battery voltage.
- c) If a coarse $AgNO_3$ solution is added, the volume of the solution increases, causing a concentration difference between the cells and reducing the battery voltage.
- d) If a substance is added to reversible battery reactions, the battery voltage decreases.
- e) If a coarse $AgNO_3$ solution is added, the concentration does not change, so the battery voltage remains unchanged.
- f) In batteries made up of the same electrodes, the battery voltage is constant and does not change.

11.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

Figure 1. The four-tier electrochemistry concept test question sample

Findings and Discussion

Results of the Exploratory Factor Analysis (EFA) for the Electrochemistry Concept Test

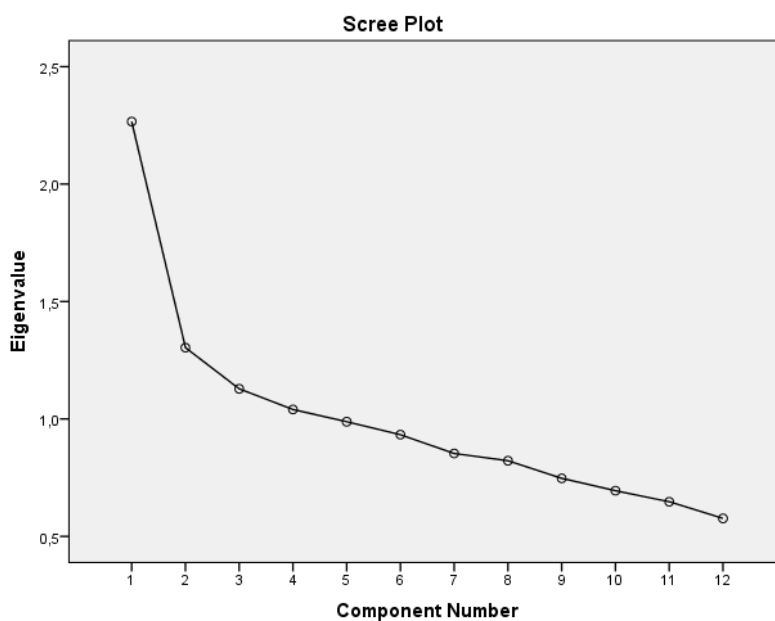


Figure 2. Slope accumulation graph

According to the EFA results based on concept misconception results, the KMO value was 0,682, indicating that the sample size was sufficient for factor analysis. According to Bartlett's sphericity test, the correlation matrix obtained for EFA is not a unit matrix, thus it was suitable for factor analysis ($X^2 = 251.310$, $df = 66$, $p = .000$). Figure 2 shows the slope accumulation graph from the EFA results, which measure misconceptions in the electrochemistry concept test. Upon examination of the graph, it can be seen that it begins to flatten from the fifth point onwards, indicating that the test had four factors.

The factor loadings and the total variance explained are presented in Table 3. According to the factor analysis results, the effect factor value of all items was greater than 1. If the total variance value of a test developed in the fields of education, measurement-evaluation, or science education is 40% or higher, the test is generally considered adequate (Tabachnick & Fidell, 2007). However, the higher this ratio is, the stronger the construct validity of the scale is interpreted to be.

Table 3. ECT factor load table

Test Questions	Factor 1	Factor 2	Factor 3	Factor 4
Question 6	0,738			
Question 1	0,627			
Question 7	0,578			
Question 9	0,446			
Question 11		0,751		
Question 12		0,726		
Question 5			0,725	
Question 8			0,629	
Question 4			0,529	
Question 3				0,821
Question 10				0,648
Question 2				0,318
Eigenvalue	2,266	1,304	1,128	1,04
Explained Variance	18,884	10,864	9,402	8,669
Explained Total Variance	47,819			
Overall Scale Reliability	0,702			

As a result of the EFA conducted on the concept of success test misconception, eigenvalues ranging from 1,04 to 2,266 were obtained, and four factors greater than 1 were identified. The first factor included 4 items (1, 6, 7, 9) and explained variance of 18,884; the second factor included 2 items (11, 12) and explained variance of 10,684; the third factor included 3 items (4, 5, and 8) and explained variance of 9,402; and the fourth factor included 3 items (2, 3, and 10) and explained variance of 8,669. In the success test, the total variance explained by all four factors was determined to be 47,819%. The factor loadings for the first factor ranged from 0,446 to 0,738; for the second factor, they ranged from 0,721 to 0,756; for the third factor, they ranged from 0,529 to 0,725; and for the fourth factor, they ranged from 0,318 to 0,821. All factor loadings were greater than 0,30. As a result, a four-factor structure was identified in the Electrochemistry Concept Test based on the EFA results, which were examined according to concept misconceptions. The correlations between the scores of the first and second tiers, between the third and fourth tiers, and between the first and third tiers and the second and fourth tiers are presented in Table 4.

Table 4. Correlation values

		Second Tier Scores
First Tier Scores	r	,301
	p	0
		Fourth Tier Scores
Third Tier Scores	r	,214
	p	0
		Second and Fourth Tier Scores
First and Third Tier Scores	r	,485
	p	0

Büyüköztürk (2013) states that a correlation coefficient of 1,00 indicates a perfect positive relationship between two variables, while a coefficient of -1,00 indicates a perfect negative relationship. If the coefficient is 0,00, this

indicates that there is no relationship between the variables. Although there is no definitive consensus regarding the magnitude of the correlation coefficient, according to the generally accepted classification, a relationship is considered strong if the absolute value of the coefficient is between 0,70 and 1,00, moderate if it is between 0,30 and 0,70, and weak if it is between 0,00 and 0,30. Baykul (2010) states that a correlation coefficient of $r < 0,40$ indicates a weak relationship. A low positive correlation was found between the first and second tier scores ($r=,301$, $p<,05$). A low level of positive correlation was found between the third and fourth tier scores ($r=,214$, $p<,05$). A moderate level of positive correlation was found between the first and third tier scores and the second and fourth tier scores ($r=,485$, $p<,05$).

As a result of the reliability analyses, the KR-20 reliability coefficient for the scientific knowledge score obtained from correct answers was calculated as ,819, and the KR-20 reliability coefficient for the misconception score obtained from wrong answers was calculated as ,702. As a result of the item analyses, it was determined that the test's difficulty and discrimination indices were at a moderate level. In terms of data reliability, a reliability coefficient of 0,70 or higher indicates that the test is reliable (Fraenkel & Wallen, 1993, p.149). Kiray and Şimşek (2021) state that a reliability coefficient of 0,50 or higher in four-tier tests indicates that the test can be considered reliable. For the validity of concept misconception diagnosis tests, it has been stated that the averages of false positive and false negative answers should be below 10% (Hestenes & Halloun, 1995). In the analyses conducted with the data obtained from teacher candidates within the scope of the study, the calculated average of false positive answers was found to be 4,78%, and the average of false negative answers was found to be 1,89%. Both values are below 10%.

Findings Regarding Misconceptions

Tablo 5. Classification of teacher candidates' understanding of electrochemistry

Item Number	1	6	7	9	Mean	11	12	Mean	4	5	8	Mean	2	3	10	Mean
Content Grouping	Cell Reactions				Factor 1	Cell Potential		Factor 2	Activity			Factor 3	Oxidation-Reduction			Factor 4
% First Tier	40,4	43,4	50,6	30,6	41,2	26,3	35,4	30,8	27,3	42,3	39,2	36,2	47,0	28,6	28,6	34,7
% First Two Tiers	26,6	30,8	31,3	15,5	26,1	8,9	10,3	9,6	11,0	27,8	24,5	21,1	36,0	15,4	16,8	22,7
% First Three Tiers	11,6	20,1	23,7	12,5	17,0	6,9	6,3	6,6	7,2	17,5	15,4	13,3	19,6	8,9	5,6	11,3
% Four Tiers Together	9,7	16,3	21,4	11,1	14,7	3,8	5,6	4,7	5,9	15,5	14,1	11,8	18,3	7,6	4,5	10,1
% Scientific Knowledge	9,7	16,3	21,4	11,1	14,7	3,8	5,6	4,7	5,9	15,5	14,1	11,8	18,3	7,6	4,5	10,1
% Misconception	22,0	15,5	20,3	18,2	19,0	17,0	15,0	16,0	32,7	25,5	20,6	26,2	14,4	19,4	37,6	23,8
% All Lack of Knowledge	45,8	56,1	51,0	68,2	55,3	75,9	75,8	75,8	57,6	49,5	54,1	53,7	50,4	64,9	45,5	53,6
% False Positive	13,4	7,5	7,2	2,3	7,6	3,1	3,0	3,0	3,0	7,2	7,0	5,7	12,3	4,8	9,4	8,8
% False Negative	9,2	4,7	0,1	0,3	3,6	0,1	0,7	0,4	0,8	2,4	4,2	2,5	4,6	3,2	3,0	3,6
% Lack of Knowledge 1	1,8	3,8	2,3	1,4	2,3	1,0	0,7	0,8	1,3	2,0	1,3	1,5	1,3	1,3	0,8	1,1
% Lack of Knowledge 2	2,8	0,8	2,0	1,3	1,7	1,4	1,1	1,3	1,5	0,7	0,4	0,9	1,7	0,8	1,7	1,4
% Lack of Knowledge 3	3,8	3,2	10,1	7,9	6,3	8,9	15,2	12,0	9,4	7,9	7,7	8,4	4,1	4,5	4,2	4,3
% Lack of Knowledge 4	1,7	3,2	0,4	2,0	1,5	1,0	1,0	1,0	0,8	3,1	2,1	2,0	4,1	1,7	2,0	2,6
% Lack of Knowledge 5	3,2	1,0	1,0	0,6	1,4	0,4	1,3	0,8	0,3	0,3	0,6	0,4	1,3	0,6	2,1	1,3
% Lack of Knowledge 6	4,0	7,5	6,2	5,3	5,7	6,8	7,5	7,1	5,1	5,6	6,0	5,5	4,1	7,3	3,8	5,1
% Lack of Knowledge 7	0,3	2,2	0,0	0,3	0,7	0,3	0,1	0,2	0,1	0,4	1,1	0,6	0,8	0,4	0,8	0,7
% Lack of Knowledge 8	3,8	0,3	0,1	0,0	1,1	0,1	0,4	0,3	0,1	0,1	0,6	0,3	0,4	1,1	0,6	0,7
% Lack of Knowledge 9	3,5	6,5	0,6	1,3	3,0	1,8	1,5	1,7	1,8	3,8	7,0	4,2	4,1	3,8	2,1	3,3
% Lack of Knowledge 10	3,4	3,2	3,0	4,1	3,4	5,2	3,5	4,4	5,6	3,1	4,2	4,3	6,6	7,2	5,3	6,4
% Lack of Knowledge 11	5,1	3,7	3,0	5,1	4,2	5,3	3,1	4,2	3,7	2,9	4,1	3,5	5,0	5,2	4,6	4,9
% Lack of Knowledge 12	12,4	20,1	22,4	40,3	23,9	43,7	40,3	42,0	27,8	19,6	19,0	22,1	17,0	31,0	17,3	21,8

The developed electrochemistry concept test was administered to 710 pre-service science teachers. The percentages for the categories of the first tier, first two tiers, first three tiers, all four tiers combined, scientific knowledge, misconception, False Positive, False Negative, and lack of knowledge—related to the four sub-dimensions of the 12-item test, namely activity, oxidation–reduction, cell reactions, and cell potential—are presented at both the item and factor levels in Table 5.

When the responses of the pre-service science teachers to the first item of the test presented in Table 5 were analyzed, the percentage of correct responses to the first-tier question was found to be 40.4%. In other words, if the first item had been a single-tier question, it would have been concluded that approximately 60% of the pre-service teachers held misconceptions based solely on their incorrect responses. However, the four-tier test demonstrates that not all incorrect responses necessarily indicate the presence of a misconception. These individuals may instead exhibit misconceptions, False Positive responses, False Negative responses, or a lack of scientific knowledge. The percentage of participants who answered all four tiers of the first item correctly and with confidence was 9.7%, indicating that only 9.7% of the pre-service teachers possessed scientific knowledge regarding this concept. Of the remaining 90.3%, only 22% were identified as having misconceptions. Furthermore, 45.8% exhibited a lack of knowledge, 13.4% demonstrated False Positive responses, and 9.2% demonstrated False Negative responses.

A total of 37 misconception statements were identified from the four-tier diagnostic misconception test developed for the topic of electrochemistry. Items measuring the same misconception were grouped together and reorganized into a single statement. The table clearly indicates which misconceptions are identified based on specific response patterns to each item. The electrochemistry-related misconceptions of pre-service science teachers and their corresponding percentages obtained from the four-tier diagnostic test are presented in Table 6.

Table 6. Misconception statements about electrochemistry and percentages

Mis-conception	Perc. (%)	Misconception statements	Answer	
M1	%11,8	All chemical reactions occur through the transfer of electrons.	1.1.a	1.3.a
			1.1.a	1.3.b
			1.1.a	1.3.e
			1.1.a	1.3.c
M2	%8,3	A species that gains electrons is reduced, whereas a species that loses electrons is oxidized.	2.1.b	2.3.d
M3	%0,1	All chemical reactions are redox reactions.	1.1.c	1.3.a
M4	%3,9	A species that gains electrons is oxidized, while a species that loses electrons is reduced.	2.1.b	2.3.a
			2.1.b	2.3.c
M5	%0,4	In a chemical reaction, both species involved in electron transfer exhibit both oxidation and reduction behavior.	2.1.c	2.3.b
M6	%10,1	Metalloids react only with strong acids.	3.1.a	3.3.a
			3.1.a	3.3.b
M7	%5,6	Metalloids react only with aqua regia.	3.1.a	3.3.c
M8	%2,4	Metalloids react only with oxygen-rich acids and bases.	3.1.b	3.3.d
M9	%0,1	Metalloids react only with oxygen-poor acids and bases.	3.1.b	3.3.e
M10	%7,7	The interaction of metalloids with an HClO solution results in the formation of O ₂ gas.	4.1.a	4.3.a
			4.1.a	4.3.d
M11	%24,2	The interaction of metalloids with an HClO solution results in the formation of H ₂ gas.	4.1.c	4.3.b
			4.1.c	4.3.e
M12	%21,5	If the activity of an ion in a solution is greater than that of the immersed metal, the metal rod undergoes corrosion.	5.1.b	5.3.b
			5.1.b	5.3.f
			5.1.b	5.3.a
M13	%1,2	The corrosion tendencies of metals are the reverse of their positions in the activity series.	5.1.c	5.3.d
M14	%9,1	In an electrochemical cell, the sum of the standard oxidation potentials of the electrodes gives the standard cell potential.	6.1.a	6.3.c
M15	%1,2	In an electrochemical cell, the difference between the standard cell potentials of the anode and the cathode gives the standard cell potential.	6.1.a	6.3.d
M16	%2,5	The electrode with the higher reduction potential is the anode.	6.1.b	6.3.a
M17	%1,5	The electrode with the lower oxidation potential is the anode.	6.1.b	6.3.e

M18	%14,8	The mass of the electrode with the lower oxidation potential decreases over time.	7.1.a	7.3.a
M19	%1,8	While the mass of the anode electrode increases over time, the mass of the cathode electrode decreases over time.	7.1.a	7.3.b
M20	%3,3	Hydrogen gas is released because hydrogen has a greater tendency to be reduced than copper.	7.1.c	7.3.c
M21	%14,9	The schematic representation of an electrochemical cell is written according to the net cell reaction.	8.1.a	8.1.b
M22	%1,8	The schematic representation of an electrochemical cell is written according to the anode half-cell reaction.	8.1.a	8.3.a
M23	%0,4	The schematic representation of an electrochemical cell is written according to the cathode half-cell reaction.	8.1.b	8.3.c
M24	%1,9	In the schematic representation of an electrochemical cell, the cathode half-cell reaction is written to the left of the salt bridge and the anode half-cell reaction to the right.	8.1.b	8.3.e
M25	%1,7	In reversible cell reactions, an increase in temperature affects the cell potential because it changes the volume.	9.1.b	9.3.c
M26	%10,2	In cell reactions, as temperature increases, the kinetic energy of particles increases; therefore, the cell potential increases.	9.1.b	9.3.b
M27	%5,6	Cell reactions are reversible (bidirectional); therefore, they are not affected by temperature changes.	9.1.c	9.3.a
M28	%5,9	In an electrochemical cell, the container on the left is always the anode and the container on the right is the cathode.	10.1.a	10.3.a
M29	%3,8	In an electrochemical cell, the direction of electric current is from the anode to the cathode.	10.1.a	10.3.c
M30	%20,8	In a galvanic cell, electrons move through the salt bridge.	10.1.c	10.3.d
M31	%0,7	In the electrolyte solution, anions migrate toward the cathode and cations toward the anode.	10.1.a	10.3.e
M32	%11,4	In reversible cell reactions, adding the same solution at the same concentration increases the cell potential.	11.1.a	11.3.a
M33	%3,8	Adding the same solution at the same concentration to an electrolytic cell increases the solution volume; therefore, the cell potential decreases.	11.1.b	11.3.c
M34	%0,2	The addition of substances to electrochemical cell reactions decreases the cell potential.	11.1.b	11.3.d
M35	%4,9	In electrochemical cells composed of identical electrodes, the cell potential is constant and does not change.	12.1.c	12.3.e
M36	%6,1	In a concentration cell, the addition of a second substance that affects the solution concentration to the reaction vessel does not affect the cell potential.	12.1.b	12.3.c
M37	%2,7	As the amount of solid AgCl increases due to precipitation in the vessel while the volume of the AgNO ₃ solution decreases, the cell potential decreases	12.1.b	12.3.d

Tablo 7. Percentage table of misconceptions

N=710	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10
Mean	84	59	1	28	3	72	40	17	1	55
%	11,83	8,31	0,14	3,94	0,42	10,14	5,63	2,39	0,14	7,75
N=710	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19	M 20
Mean	172	153	9	65	9	18	11	105	13	24
%	24,23	21,55	1,27	9,15	1,27	2,54	1,55	14,79	1,83	3,38
N=710	M 21	M 22	M 23	M 24	M 25	M 26	M 27	M 28	M 29	M 30
Mean	106	13	3	14	12	73	40	42	27	148
%	14,93	1,83	0,42	1,97	1,69	10,28	5,63	5,92	3,80	20,85
N=710	M 31	M 32	M 33	M 34	M 35	M 36	M 37			
Mean	5	81	27	2	35	43	19			
%	0,70	11,41	3,80	0,28	4,93	6,06	2,68			

In Table 7, the mean values and percentages of the identified misconception statements are presented. The graphical representation of the misconception percentages given in Table 7 is shown in Figure 3. An examination of Table 7 and Figure 3 reveals that 9 misconceptions were observed at a rate of 10% or higher among pre-service science teachers. These misconceptions are listed below:

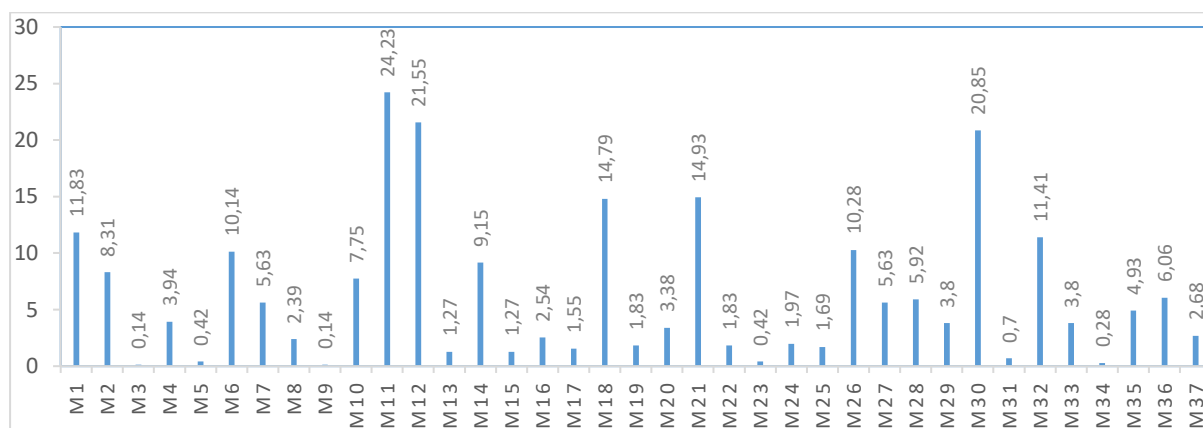


Figure 3. Percentages of misconceptions

M1 (%11,83): All chemical reactions occur through the transfer of electrons.

M6 (%10,14): Metalloids react only with strong acids.

M11 (%24,23): The interaction of metalloids with an HClO solution results in the formation of H₂ gas.

M12 (%21,55): If the activity of an ion in a solution is greater than that of the immersed metal, the metal rod undergoes corrosion.

M18 (%14,79): The mass of the electrode with the lower oxidation potential decreases over time.

M21 (%14,93): The schematic representation of an electrochemical cell is written according to the net cell reaction.

M26 (%10,28): In cell reactions, as temperature increases, the kinetic energy of particles increases; therefore, the cell potential increases.

M30 (%20,85): In a galvanic cell, electrons move through the salt bridge.

M32 (%11,41): In reversible cell reactions, adding the same solution at the same concentration increases the cell potential.

When the literature was reviewed, although there are studies indicating that various methods have been used to identify misconceptions, it was observed that in recent years the most commonly used approach in this field is the multi-tier diagnostic test. Among these tests, four-tier diagnostic tests are preferred more frequently because of their potential to reveal the causes of individuals' misunderstandings (Dewi et al., 2020; Kiray & Şimşek, 2021; Kural, 2021; Ranggu et al., 2023; Yan & Subramaniam, 2018). Four-tier tests, with respect to determining false positive, false negative, lack of knowledge, misconceptions, and levels of scientific knowledge, yield more effective results compared to other methods such as two- or three-tier tests. However, in the existing literature there is no four-tier diagnostic test specifically addressing misconceptions in electrochemistry. In this context, the four-tier Electrochemistry Concept Test developed in this study can be regarded as a suitable instrument for addressing the identified gap in the literature. Additionally, using the developed test, experimental studies can be designed, and the effectiveness of different teaching methods, techniques, or tools on misconceptions can be determined.

Conclusions and Recommendations

The purpose of this study was to develop a valid and reliable measurement tool for identifying pre-service science teachers' misconceptions about electrochemistry. To this end, a four-tier misconception diagnosis test was developed. The positive and negative wrong answer rates of the developed test were calculated to be below 10%. Correlation analysis, to determine the validity of the four-tier diagnostic test, was applied. A moderate and significant positive correlation was observed between the first and third tier scores and the second and fourth tier scores ($r = .485$, $p < .05$). The developed four-tier misconception diagnosis test consisted of four sub-dimensions, as determined by the factor analysis results. The sub-dimensions of this four-tier test, which consisted of a total of 12 items, were supported by exploratory factor analysis. According to the factor analysis results, items 1, 6, 7, and 9 in the test are consistent with the first sub-dimension; items 11 and 12 are consistent with the second sub-

dimension; items 4, 5, and 8 are consistent with the third sub-dimension; and items 2, 3, and 10 are consistent with the fourth sub-dimension. Within the scope of reliability analysis, two different reliability coefficients were calculated. These coefficients were KR-20 reliability coefficients calculated for the scientific knowledge and misconception scores. Both coefficients indicated that the test is a reliable measurement tool. The findings obtained from the analyses revealed that the developed electrochemistry misconception diagnostic test is a valid and reliable measurement tool for assessing pre-service science teachers' misconceptions and scientific knowledge in electrochemistry. This diagnostic test was applied to pre-service science teachers. It is recommended that validity and reliability studies fort his test to be repeated for research conducted with different study groups. Four-tier diagnostic tests are preferred over two-tier and three-tier tests because they can reveal the causes of individuals' misconceptions more effectively. Four-tier diagnostic tests are more effective than other methods and two- and three-tier tests in terms of determining false positive, false negative, lack of knowledge, misconceptions, and scientific knowledge.

Although various studies have been conducted on identifying misconceptions related to electrochemistry in the literature, no four-tier diagnostic test has been identified. In this context, it is believed that the four-tier electrochemistry misconception diagnostic test developed in this study can fill this gap in the literature. Thanks to the developed test, the areas where pre-service teachers' misconceptions in electrochemistry are concentrated can be identified, their causes analyzed, and corrective measures implemented. Additionally, experimental studies can be designed using the developed test to evaluate the impact of methods or tools on misconceptions.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors

* The research was conducted by scientific ethical rules. Furthermore, we declare that we accept all ethical and legal consequences that may arise from any violation of this statement and that we are responsible for these consequences. Ethical approval was obtained from the Hacettepe University Ethics Committee, as per the decision dated 10 February 2023 and numbered E-35853172-300-00002683846.

Conflict of Interest

* There is no conflict of interest among the authors regarding this study.

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* This study is based on the first author's doctoral thesis.

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ELECTROCHEMISTRY CONCEPT TEST

Dear Students,

This study aims to determine the misconceptions of pre-service science teachers about electrochemistry. Please read each item below carefully and answer accordingly. Your honest answers are crucial for the scientific validity of this study. I sincerely thank you for your contributions to my doctoral research through your sincere answers.

Best regards, Fatma ŞENER

Gender: Female: ☐ Male: ☐
Grade: 1 ☐ 2 ☐ 3 ☐ 4 ☐

- I. $NaOH_{(aq)} + HCl_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(s)}$
II. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
III. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

1.1. Which of the above reactions are redox reactions?

- a) I and II
b) II and III
c) All of them

1.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
b) No, I am not sure

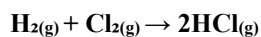
1.3. Why did you choose the above option?

- a) All chemical reactions involve the exchange of electrons, therefore they are redox reactions.
b) Combustion reactions and acid-base reactions involving electron transfer are redox reactions.
c) Reactions involving particles that reduce by gaining electrons and oxidize by losing electrons are redox reactions.
d) Reactions involving particles that reduce by gaining electrons and oxidize by losing electrons are redox reactions.
e) Combustion reactions involving reduction and oxidation, and neutralization reactions involving oppositely charged ions are redox reactions.

1.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
b) No, I am not sure

2.1. Which of the following statements about this reaction are correct?



- I H_2 is a reducing agent
II. Cl_2 is an oxidizing agent
III. It is a synthesis reaction

- a) I and III b) II and III c) All of them

2.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

2.3. Why did you select the above option?

- a) In the formation reaction, Cl_2 gains electrons and is oxidized to its anion, while H_2 loses electrons and is reduced to its cation.
- b) In the formation reaction, there is an exchange of electrons between the H_2 and Cl_2 molecules, so both exhibit reduction and oxidation properties.
- c) In the formation reaction, Cl_2 donates an electron and is reduced to an ion, while oxidizing the substance opposite to it, thus exhibiting oxidizing properties.
- d) When the HCl molecule, a new type of molecule, is formed between the H_2 and Cl_2 molecules, H_2 exhibits reducing properties because it gains an electron.
- e) In the formation reaction, H_2 exhibits reducing properties because it oxidizes the substance opposite to it by losing an electron.

2.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

3.1. Merve, a senior science teacher, wonders if the ring her fiancé bought her is really silver (Ag). To find out, she decides to go to the chemistry lab and conduct an experiment using what she learned in chemistry class. Which concentrated solutions do you think Merve should use?

- I. Salt acid (HCl)
- II. Caustic soda (NaOH)
- III. Nitric acid (HNO_3)

- a).I and III
- b) II and III
- c) Only III

3.2. Are you sure about your answer to the previous question?

- a).Yes, I am sure
- b).No, I am not sure

3.3. Why did you select the above option?

- a).Silver is a semi-noble metallic element, so it reacts with all acids.
- b).Silver is a semi-noble metallic element, so it only reacts with strong acids.
- c).Because silver is a semi-noble metallic element, it reacts only with aqua regia ($\text{HCl} + 3\text{HNO}_3$).
- d).Because silver is a semi-noble metallic element, it reacts only with strong acids and bases rich in oxygen.
- e).Because silver is a semi-noble metallic element, it reacts only with strong acids and bases poor in oxygen.
- f).Silver is a semi-noble metallic element, so it only reacts with strong acids rich in oxygen.

3.4. Are you sure about your answer to the previous question?

- a).Yes, I am sure

b).No, I am not sure

4.1. Mete Han, a senior student studying to become a science teacher, is disappointed when he cannot find a glass beaker to hold the concentrated HClO solution he needs for his chemistry lab experiment. He immediately looks around. Seeing the shiny, sterile bags on the shelf in front of him, he is delighted to find some copper containers that have not yet been removed from their packaging. He takes one of them and adds the concentrated HClO solution to it. Which of the following statements about the situation he observes in the container is correct?

- a).O₂ gas is observed coming out of the copper container.
- b).No change is observed in the copper container.
- c).H₂ gas is observed coming out of the copper container.

4.2. Are you sure about your answer to the previous question?

- a).Yes, I am sure
- b).No, I am not sure

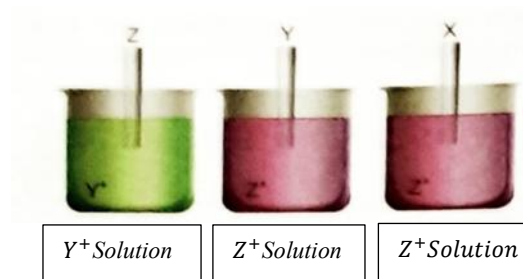
4.3. Why did you choose the above option?

- a).HClO is an oxygenic acid solution, so it reacts with the semi-noble metallic copper container to form salt, water, and O₂ gas.
- b).HClO is an oxygenic acid solution, so it reacts with the semi-noble metallic copper container to form salt, water, and H₂ gas.
- c) Although HClO is an oxygen-containing acid solution, it is a weak acid, so it does not react with the semi-noble metallic copper container.
- d).HClO is a strong base solution, so it reacts with the semi-noble metallic copper container to form salt, water, and O₂ gas.
- e).Since HClO is a strong base solution, it reacts with the semi-noble metallic copper container, forming salt, water, and H₂ gas.
- f).Since HClO is a base solution, it does not react with the semi-noble metallic copper container.

4.4. Are you sure about your answer to the previous question?

- a).Yes, I am sure
- b).No, I am not sure

5.1. The activity order of metals X, Y, and Z is $X > Y > Z$. According to this, which of the metals X, Y, and Z immersed in the following solutions will corrode?



- a) X and Y
- b) Only Z
- c) All of them

5.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

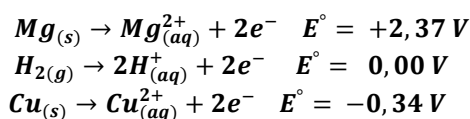
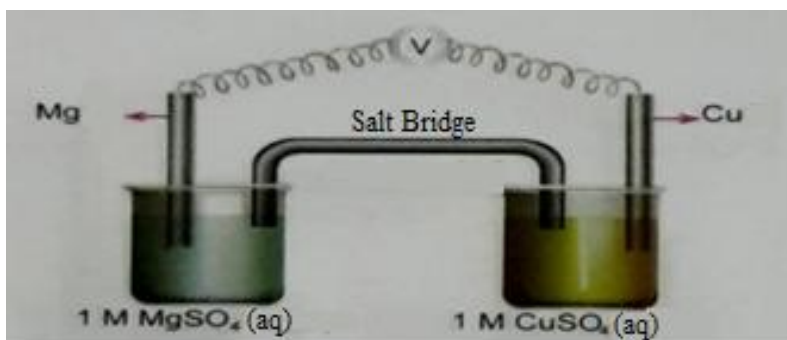
5.3. Why did you select the above option?

- a) The activity of the solution containing ions is greater than the activity of the immersed Z metal, so the metal rod corrodes over time.
- b) The solution containing ions is less active than the Z metal immersed in it, so the metal rod corrodes over time.
- c) The most active X metal corrodes the most, followed by the less active Y metal, and the least active Z metal corrodes the least.
- d) Since the corrosion activity order is the exact opposite, the Z metal corrodes the most, followed by the Y metal, and the X metal corrodes the least.
- e) Since the activity of the solution containing ions in the container is lower than the activity of the X and Y metals immersed in it, the metal rods corrode over time.
- f) The solution containing the ions in the container has a higher activity than the X and Y metals immersed in it, so the metal rods corrode over time.

5.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

Answer questions 6 and 7 based on the Mg-Cu battery shown in the figure.



6.1. Which of the following statements about the Mg – Cu battery setup shown in the figure is correct?

- a) The battery potential is +2.03 volts
- b) The Cu electrode is the anode
- c) The Mg electrode is the anode

6.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

6.3. Why did you select the above option?

- a) The electrode with the higher reduction potential is the anode.

- b) The electrode with the lower reduction potential is the anode.
- c) The sum of the standard oxidation potentials of the electrodes gives the cell potential.
- d) The difference between the standard cell potentials of the anode and cathode gives the cell potential.
- e) The electrode with the smaller oxidation potential is the anode.

6.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

7.1. Which of the following statements about the **Mg – Cu** battery shown in the figure is correct?

- a) The mass of the Cu electrode decreases over time.
- b) The mass of the Cu electrode increases over time.
- c) The mass of the Cu electrode remains unchanged.

7.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

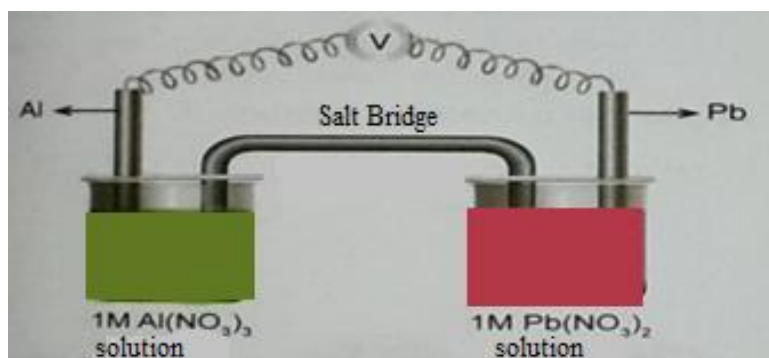
7.3. Why did you select the above option?

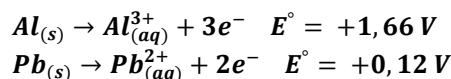
- a) Since there will be corrosion at the anode and deposition at the cathode, the mass of the Cu electrode decreases over time.
- b) Since there will be an increase at the anode and a decrease at the cathode, the mass of the Cu electrode decreases over time.
- c) As the mass of the anode increases, the mass of the cathode remains constant, and H_2 gas is observed to exit the cathode chamber.
- d) As the mass of the anode decreases, the mass of the cathode remains constant, and H_2 gas is observed to exit the cathode chamber.
- e) Since there will be corrosion at the anode and deposition at the cathode, the mass of the Cu electrode increases over time.
- f) Since there will be an increase at the anode and a decrease at the cathode, the mass of the Cu electrode increases over time.

7.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

Answer questions 8 and 9 based on the Al-Pb battery shown in the figure.





8.1st According to the battery arrangement shown in the figure, which of the following is the schematic representation of the battery?

- a). $\text{Al}_{(s)}/\text{Pb}_{(1M)}^{+2} // \text{Al}_{(1M)}^{+3}/\text{Pb}_{(s)}$
- b). $\text{Pb}_{(s)}/\text{Pb}_{(1M)}^{+2} // \text{Al}_{(1M)}^{+3}/\text{Al}_{(s)}$
- c). $\text{Al}_{(s)}/\text{Al}_{(1M)}^{+3} // \text{Pb}_{(1M)}^{+2}/\text{Pb}_{(s)}$

8.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

8.3. Why did you select the above option?

- a) The schematic representation of the battery is written according to the anode half-cell reaction.
- b) The schematic representation of the battery is written according to the net cell reaction. The reactants are written to the left of the salt bridge (//) and the products are written to the right.
- c) The schematic representation of the battery is written according to the cathode half-cell reaction.
- d) In the schematic representation of the battery, the anode is written to the left of the salt bridge (//) and the cathode half-cell reaction is written to the right.
- e) In the schematic representation of the battery, the cathode is written on the left side of the salt bridge (//) and the anode half-cell reaction is written on the right side.

8.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

9.1. In the battery circuit shown in the figure, how does the voltage of the battery change when the temperature increases?

- a) The voltage decreases
- b) The voltage increases
- c) The voltage remains unchanged

9.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

9.3. Why did you select the above option?

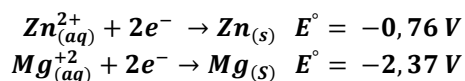
- a) Battery reactions are reversible (two-way), so an increase or decrease in temperature does not affect the battery voltage.
- b) As temperature increases, the kinetic energy of the particles increases, so the reaction rate increases and the battery voltage increases.
- c) As temperature increases, the volume of the electrolyte solution decreases while its concentration increases, causing the battery voltage to increase.

- d) As temperature increases, the volume of the electrolyte solution decreases, causing the battery voltage to decrease.
 e) Since battery reactions are exothermic reactions, the battery voltage decreases as temperature increases.

9.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
 b) No, I am not sure

10.1. Which of the following statements about the battery circuit below is correct?



- a) The Zn electrode is the anode.
 b) The direction of the electric current is from the positively charged electrode to the negatively charged electrode.
 c) Electrons move through the salt bridge.

10.2. Are you sure about your answer to the previous question?

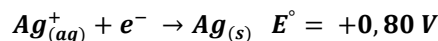
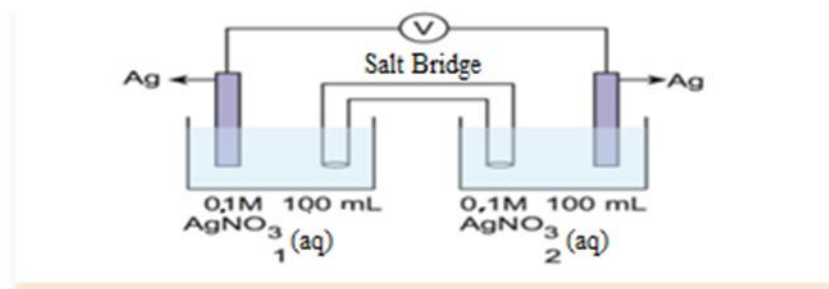
- a) Yes, I am sure
 b) No, I am not sure

10.3. Why did you select the above option?

- a) In a battery circuit, the left container is always the anode and the right container is always the cathode, so the Zn electrode is the anode.
 b) In a battery, the direction of electric current is opposite to the direction of electron movement.
 c) In a battery, the direction of electric current is from the anode to the cathode.
 d) In the battery, the movement of electrons is from the negatively charged anode to the positively charged cathode through the salt bridge.
 e) In the solution, anions migrate toward the cathode and cations toward the anode.

10.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
 b) No, I am not sure



11.1. If a small amount of 0.1M AgNO₃ solution is added to the battery setup shown in the figure, how does the battery voltage change compared to its initial state?

- a) Increases
- b) Decreases
- c) Remains unchanged

11.2. Are you sure about your answer to the previous question?

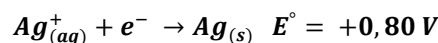
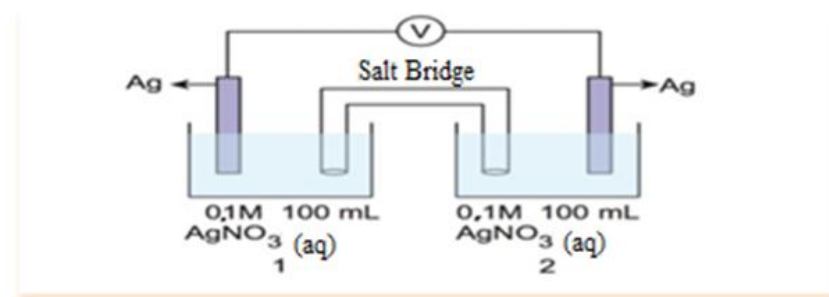
- a) Yes, I am sure
- b) No, I am not sure

11.3. Why did you select the above option?

- a) If a substance is added to reversible battery reactions, the battery voltage increases.
- b) If AgNO₃ solution is added to the first container, the concentration of the solution will increase, causing a concentration difference and increasing the battery voltage.
- c) If a coarse AgNO₃ solution is added, the volume of the solution increases, causing a concentration difference between the cells and reducing the battery voltage.
- d) If a substance is added to reversible battery reactions, the battery voltage decreases.
- e) If a coarse AgNO₃ solution is added, the concentration does not change, so the battery voltage remains unchanged.
- f) In batteries made up of the same electrodes, the battery voltage is constant and does not change.

11.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure



12.1. If a small amount of NaCl salt is added to the battery setup shown in the figure, how does the battery voltage change compared to the initial state?

- a) Increases
- b) Decreases
- c) Remains unchanged

12.2. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

12.3. Why did you select the above option?

- a) Sedimentation occurs in the container, causing the $[Ag^+]$ concentration to decrease and the battery voltage to increase.
- b) If a substance is added to reversible battery reactions, the battery voltage increases.
- c) Precipitation occurs in the container, causing the $[Ag^+]$ concentration to decrease, which reduces the cell voltage.
- d) Due to precipitation in the container, the amount of $AgCl$ increases while the volume of the $AgNO_3$ solution decreases, causing the cell voltage to decrease.
- e) Since the anode and cathode are made of the same electrodes, the cell voltage remains constant and does not change.

12.4. Are you sure about your answer to the previous question?

- a) Yes, I am sure
- b) No, I am not sure

The Relationship Between Science Teachers' Self-Efficacy and Anxiety Regarding Out-of-School Learning and Middle School Students' Informal Science Experiences

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Abstract

Pestalozzi emphasised that nature and life outside school are valuable teachers for children, stating, ‘When the birds are chirping beautifully and a worm is crawling on a leaf, stop your language studies immediately. Know that the bird and the worm teach the child better and more.’ All educational activities that take place outside of school throughout an individual's life are defined as ‘out-of-school education,’ and the learning occurring during this process is defined as ‘out-of-school learning.’ The scope of out-of-school learning environments is quite broad, and these environments are often considered as ‘learning laboratories.’ The aim of this study is to determine the relationship between science teachers' self-efficacy beliefs and anxiety levels regarding out-of-school learning and the levels of science experience acquired by the secondary school students taught by these teachers in informal settings. A correlational research design was utilized as a quantitative method in the study. The study sample consisted of 100 science teachers working in state schools in Eskişehir during the academic year of 2022-2023 and 2,767 secondary school students attending these teachers' classes. Convenience sampling was adopted to determine the study sample. The following data collection tools were used: Teacher Self-Efficacy Beliefs Scale for Out-of-School Learning Activities, Anxiety Level Assessment Scale for Out-of-School Learning Environments, a personal information form, and the Science Experience in Informal Settings Scale. The findings indicate a significant relationship between science teachers' self-efficacy beliefs regarding out-of-school learning and their ability to design and organize out-of-school learning activities. However, no significant differences in self-efficacy beliefs were observed with respect to training related to out-of-school learning environments, years of professional experience, or graduation background. Furthermore, science teachers' levels of anxiety toward out-of-school learning did not differ significantly across any of the examined variables. A moderate negative correlation was identified between teachers' anxiety levels and their self-efficacy beliefs. Finally, science teachers' self-efficacy beliefs and anxiety levels were found not to significantly predict students' science experiences acquired in informal learning settings.

Introduction

With the recent rapid developments, the understanding of education and even the perspective on education have changed. With this change in perspective in education, directly imparting knowledge is no longer preferred (Akdağ & Çoklar, 2009). At this point, the goal for individuals who are part of a learning process without boundaries is to benefit effectively from this situation and experience lasting and desirable behavioral change. For individuals, who are expected to gain certain achievements through their social interactions with their environment, to acquire process-oriented and performance-based learning rather than outcome-oriented learning, the environments where lessons are conducted must be diverse (Aydoğdu, Aydoğdu & Aktaş, 2023). In this regard, education and teaching have become a lifelong process that continues everywhere and in every environment (Bozdoğan, Okur & Kasap, 2015). Pestalozzi stated that nature and life outside of school are wonderful teachers for children, saying, “When the birds are chirping beautifully and a worm is crawling on a leaf, stop your language studies immediately. Know that the bird and the worm teach the child better and more” (Akhan & Kaymak, 2020).

According to the effective education approach, students should be active during the learning process, learn by doing and experiencing, and establish connections between what they learn and their lives (Eshach, 2007).

According to Eshach (2007), 85% of the children's time apart from sleep is spent outside the classroom, and this percentage is of great importance. Learning that takes place outside of school provides learning experiences that go “beyond and above” school (Gürbey, Mertoğlu, Sayan & Maroğlu Akgül, 2022). Out-of-school learning environments are effective in relating the knowledge acquired in schools to daily life and adopting it as part of one's lifestyle (Karademir & Tezel, 2010).

The concept of out-of-school education has appeared in the literature under different terms and with a range of definitions. Among them are informal education, out-of-classroom education, out-of-place education, and field education. Although different terms and definitions are used, they all share the common goal of encompassing learning processes that take place outside the school walls, without confining the student within the school (Karamustafaoğlu & Ermiş, 2020). Out-of-school education refers to all education and learning that take place outside of school throughout an individual's life (Tösten, 2020). The boundaries of out-of-school learning environments are quite broad, and these environments are defined as “learning laboratories” (Akhan & Kaymak, 2020). The use of environments outside the school walls in the education and training process is defined as out-of-school learning (Salmi, 1993). Out-of-school learning also encompasses many areas, from various living spaces outside the school boundaries to virtual environments (Eshach, 2007). As stated by Karademir (2018), out-of-school learning environments include museums, science centers, industrial institutions and organizations, zoos, observatories, and nature camps, as well as “digital or virtual out-of-school learning environments” consisting of online spaces such as social media platforms, educational websites, and Web 2.0 tools.

The Ministry of National Education requires that out-of-school learning environments be aligned with education and training programs. In this regard, the Out-of-School Learning Environments Guide has been prepared and published. According to the information in the guide, out-of-school learning environments are defined as a wide range of places, from museums affiliated with state institutions and registered private museums to science and art centers serving within public institutions, from historical and cultural areas determined by the Ministry of Culture and Tourism to public libraries and libraries in literary museum. In addition, natural sites and archaeological sites, technology parks, industrial facilities open to visitors, and universities are also considered within this scope. Furthermore, national and thematic parks, as well as various gardens, are among the other components of out-of-school learning environments (MEB, 2019, p. 4).

Unlike schools and informal classroom settings, out-of-school learning environments are more flexible in terms of allowing individuals and groups to choose what, where, with whom and how they learn since they offer rich learning opportunities and kinesthetic and social experiences (Cooper, 2011; Falk & Dierking, 2013; Wright & Parkes, 2015). Out-of-school learning environments, which enable students to use various types of intelligence, are expected to help students develop the following skills (Eshach, 2007; Worth, 2010):

- They can make observations and draw conclusions.
- They can learn and classify tools and equipment related to the lesson.
- They develop a problem-solving personality.
- They cooperate with their social groups.
- In addition to their discovery skills, they also possess questioning skills.
- They can discover tools and equipment that they cannot see at school or in the classroom.

The effectiveness of teaching activities conducted in out-of-school learning environments depends on the teacher's ability to plan and manage the process correctly. However, implementing such teaching practices on a regular basis poses significant challenges for teachers. This is because the teacher must determine the most appropriate environment and pedagogical method for the content, internalize their responsibilities, and structure the teaching process in detail (Sarioğlu & Küçüközer, 2017). Teachers' self-efficacy levels and attitudes and behaviors play a decisive role in the effectiveness of the teaching programs implemented. In this regard, it is important for teachers to demonstrate positive attitudes towards out-of-school learning activities. In fact, teachers with a positive attitude towards such activities can better encourage students and parents to participate in out-of-school learning. However, factors such as the difficulty of monitoring the teaching process, lack of time, difficulties in ensuring safety and control (Yaşar-Çetin, 2021), economic barriers, avoidance of responsibility (İnce & Akcanca, 2021), and low motivation (Ay, Anagün & Demir, 2015; Çiçek & Saraç, 2017) can cause teachers to develop reluctance and anxiety towards out-of-school learning activities. It can be said that factors such as anxiety and self-efficacy underlie teachers' avoidance of out-of-school learning activities. In this context, the purpose of the present study was to determine the relationship between science teachers' self-efficacy beliefs and their anxiety levels regarding out-of-school learning and the levels of science experience of middle school students in informal settings. In line with this purpose, this study sought answers to the following questions.

1. What is the level of science teachers' self-efficacy beliefs regarding out-of-school learning?
2. What is the level of science teachers' anxiety regarding out-of-school learning?
3. What is the level of informal science experience among middle school students taught by science teachers?
4. What is the relationship between science teachers' self-efficacy beliefs and anxiety levels regarding out-of-school learning, and the levels of science experience of students in informal settings?

Method

Study Design

This study, conducted to examine the relationship between science teachers' perceived self-efficacy regarding out-of-school learning, their anxiety levels related to out-of-school learning processes, and the levels of science-related experiences of the middle school students taught by these teachers in informal learning environments, employed the correlational research method as a quantitative research design. The correlational research method aims to reveal the presence of a relationship between two or more variables and the effect of these variables on each other (Keser-Özmantar, 2019). In this study, since the aim was to determine the degree of relationship between the variables, the explanatory model of the correlational design was deemed appropriate and used (Tekbıyık, 2019).

Study Sample

The study sample consisted of 100 science teachers working in public schools in Eskişehir during the academic year of 2022-2023 and a total of 2.767 middle school students attending these teachers' classes. The convenience sampling method was chosen to determine the study sample. Convenience sampling is based on including individuals accessible to the researcher into the sample, depending on factors such as time, cost, and spatial possibilities. The main reason for choosing this method is to minimize time, cost, and labor loss during the research process, ensuring that the study is conducted more quickly and practically (Fraenkel & Wallen, 2006). Although convenience sampling enabled the researchers to reach participants in a practical and time-efficient manner, this method has certain limitations. Since the participants were selected based on accessibility rather than random selection, the sample may not fully represent the broader population of science teachers and middle school students. Therefore, the findings of this study should be interpreted with caution, particularly in terms of generalizability beyond the study context. In the present study, schools of different achievement levels were included in the sample to ensure maximum diversity in sampling. Information about science teachers and students is provided in Table 1 and Table 2.

Table 1. Demographic information about science teachers

		n	%
Receiving Education about out-of-school learning	Yes	31	31.3%
	No	68	68.7%
Event Design	Yes	68	68.7%
	No	31	31.3%
Organizing Event	I edited it 1-3 times.	37	37.4%
	I edited it 3-5 times.	6	6.1%
	I have organized 5 and more	5	5.1%
	Would like to organize 1-3 times	34	34.3%
	Would like to organize 3-5 times	13	13.1%
	Would like to organize 5 and more	4	4.0%
Work Experience	Less than 10 years	24	24.2%
	11-15 years	35	35.4%
	16 years and over	40	40.4%
Education	Bachelor of Education	84	84.8%
	Postgraduate degree	15	15.2%

Table 1 contains demographic information about science teachers. Of all the teachers, 68.7% had not previously received training on informal (out-of-school) settings. The percentage of the teachers who had previously designed and implemented science activities in informal settings was 68.7%. The percentage of the teachers who were able to organize activities in informal settings 1-3 times during an academic year was 37.4%, while the percentage of

the teachers who said they would like to organize science activities in informal settings 1-3 times was 34.3%. Besides, 40.4% of the teachers had work experience of 16 years or more, and 84.8% had a bachelor's degree.

Table 2. Demographic information on middle school students

	N	%
5th Grade	604	21.8%
6th Grade	645	23.3%
7th Grade	816	29.5%
8th Grade	702	25.4%

Table 2 presents demographic information about middle school students. Eighteen schools were included in the study. Of all the students, 21.8% were in the 5th grade, 23.3% were in the 6th grade, 29.5% were in the 7th grade, and 25.4% were in the 8th grade.

Data Collection Tools

Data were gathered from the science teachers with the “Teacher Self-Efficacy Beliefs Scale for Activities Related to Out-of-School Learning Environments,” developed by Güloğlu-Demir & Çetin (2021), the “Out-of-School Learning Environment Anxiety Level Assessment Scale”, developed by Üner (2019), and a personal information form prepared by the researchers. The “Science Experience Scale in Informal Settings,” adapted into Turkish by Bakioğlu & Karamustafaoğlu (2021), was used to collect data from the students.

The Teacher Self-Efficacy Beliefs Scale for Out-of-School Learning Activities consists of a total of 29 items, of which 15 were negative statements and 14 were positive statements. The scale has a four-factor structure. These four factors are “Preparation Self-Efficacy,” “Implementation and Evaluation Self-Efficacy,” “Learning Support Self-Efficacy,” and “Knowledge and Experience Self-Efficacy.” Cronbach's Alpha was reported to be 0.78 and above for the scale and its four factors (Güloğlu-Demir & Çetin, 2021). In this study, Cronbach Alpha was found to be 0.92 for the scale measuring teachers' self-efficacy beliefs regarding out-of-school learning activities.

The Anxiety Level Assessment Scale for Out-of-School Learning Environments is composed of 25 items. Cronbach Alpha was reported to be 0.94 for the scale (Üner, 2019). In this study, Cronbach Alpha was found to be 0.92 for the teachers' anxiety level assessment scale for out-of-school learning environments.

Informal Science Experience Scale; As a result of the analysis conducted for reliability, Cronbach alpha for the scale and its subscales of observation, collection, activity, and experiment was found to be 0.85, 0.71, 0.87, 0.63, and 0.71 respectively (Bakioğlu & Karamustafaoğlu, 2021). In this study, Cronbach Alpha was found to be 0.84 for the informal setting science experience scale for the middle school students.

Data Analysis

The data obtained within the scope of the research were transferred to a computer environment, organized using Microsoft Excel, and then analyzed using Statistical Package for the Social Sciences 29.0. Before proceeding to the analysis process, the normality of the distribution of numerical variables was evaluated using Kolmogorov-Smirnov and Shapiro-Wilk tests, along with Skewness and Kurtosis values; visual inspections were also performed using Histogram and Q-Q Plot graphs. As a result of these evaluations, it was determined that the data met the assumption of normal distribution. In the study, categorical variables were reported using frequency and percentage values, while numerical data were reported using mean and standard deviation measures. However, the number of observations for some variables was below 30. In this case, the evaluations related to these variables were performed using non-parametric statistical tests. The “Independent Samples T Test” was preferred to compare two independent groups when the data showed a normal distribution and the number of observations was above 30; otherwise, the “Mann Whitney U Test” was preferred. The “Kruskal-Wallis Test” was applied in comparisons involving more than two groups; when a significant difference was detected as a result of this test, post-hoc analyses were used to determine which groups the difference originated from, and group differences were indicated with letter codes. Groups marked with different letters were considered to be significantly different from each other. The Pearson Correlation Test was used to examine the relationship between two numerical variables, while multiple regression analysis was utilized to determine the effect of numerical variables on each other. The significance level for all the statistical tests was set at $p < 0.05$.

Results

Findings Related to the First Sub-Problem

Findings regarding science teachers' self-efficacy beliefs about out-of-school learning activities according to various variables are presented in Table 3.

Table 3. Science teachers' self-efficacy beliefs regarding out-of-school learning activities according to various variables

		Mean	Sd	t ¹ /U ² /K-W ³	p
Receiving Education about out-of-school learning	Yes	109.42	12.27	1.20 ¹	0.23
	No	105.84	14.32		
Event Design	Yes	110.03	13.12	3.47 ¹	0.00*
	No	100.23	12.84		
Organizing Event	I edited it 1-3 times ^a	110.16	14.92	11.18 ³	0.04*
	I edited it 3-5 times ^{ab}	105.50	11.64		
	I have organized 5 and more ^{ab}	100.80	9.44		
	Would like to schedule 1-3 times ^b	102.59	12.20		
	Would like to schedule 3-5 times ^{ab}	109.15	13.76		
	Would like to arrange 5 and more ^a	117.25	13.94		
Work Experience	Less than 10 years	102.50	12.81	3.60 ³	0.16
	11-15 years	107.34	10.38		
	16 years and over	109.30	16.32		
Education	Bachelor's degree graduate	106.07	14.07	1.77 ²	0.08
	Postgraduate	111.93	10.92		

Note: ¹Independent Sample T Test; ²Mann-Whitney U Test; ³Kruskal-Wallis Test

Note: Letters show post hoc analysis results. The differences between different letters were significant (^{a,b,ab,c}).

*p<0.05

Teachers' self-efficacy beliefs regarding out-of-school learning activities were evaluated according to various variables and are presented in Table 3. The difference between self-efficacy beliefs regarding out-of-school learning activities and activity design status was statistically significant ($t=3.47$; $p<0.05$). The self-efficacy beliefs of the teachers who designed activities (110.03 ± 13.12) were higher than those of the teachers who did not design activities (100.23 ± 12.84). A statistically significant difference was found between self-efficacy beliefs regarding out-of-school learning activities and the number of science activities organized in out-of-school settings during an academic year ($\chi^2=11.18$; $p<0.05$). According to the post hoc analysis, the differences were indicated by letters. Statistically significant differences were observed between different letters. Teachers who stated that they would like to organize 5 or more activities had the highest self-efficacy beliefs (117.25 ± 13.94). The self-efficacy beliefs of the individuals who received training and those who did not, as well as those who designed activities and those who did not, were found to be quite similar. Although there was a slight difference, the self-efficacy beliefs of the teachers who received training and designed activities were higher (109.42 ± 12.27). No statistically significant difference was found in teachers' self-efficacy beliefs regarding out-of-school learning in terms of the variables of work experience ($\chi^2=3.60$; $p>0.05$) and education ($U=1.77$; $p>0.05$).

Findings Related to the Second Sub-Problem

Findings regarding science teachers' levels of anxiety about out-of-school learning according to various variables are presented in Table 4. Findings regarding teachers' levels of anxiety about out-of-school learning according to various variables are presented in Table 4. No statistically significant differences were found between various variables and the level of anxiety about out-of-school learning ($p>0.05$). However, as shown in Table 4, the teachers who stated that they had not previously received training on informal (out-of-school) environments were found to have higher levels of out-of-school learning anxiety (74.00 ± 14.04). The teachers who stated that they had not previously designed activities also had higher levels of out-of-school anxiety (75.00 ± 14.08). The anxiety levels were 81.08 ± 15.27 for those with less than 10 years of work experience, 73.06 ± 11.97 for those with 11-15 years of work experience, and 70.02 ± 13.72 for those with more than 16 years of work experience. As years of work experience increased, non-school-related anxiety decreased, without a significant difference. When examining educational backgrounds, the anxiety levels of the teachers with a bachelor's degree (74.26 ± 14.70) were higher than those of the graduate degree holders (71.07 ± 9.87).

Table 4. Science teachers' out-of-school learning anxiety status according to various variables

		Mean	Sd	$t^1/U^2/K-W^3$	p
Receiving Education about out-of-school learning	Yes	73.29	14.40	0.23 ¹	0.82
	No	74.00	14.04		
Event Design	Yes	73.22	14.15	0.58 ¹	0.28
	No	75.00	14.08		
Organizing Event	I edited it 1-3 times	72.03	15,86	4.08 ³	0.53
	I edited it 3-5 times	75.00	10.56		
	I have organized 5 and more	71.40	14.96		
	Would like to schedule 1-3 times	73.65	11.72		
	Would like to schedule 3-5 times	78.38	17.14		
	Would like to arrange 5 and more	77.25	11.35		
Work Experience	Less than 10 years	81.08	15.27	2.83 ³	0.09
	11-15 years	73.06	11.97		
	16 years and over	70.02	13.72		
Education	Bachelor's degree graduate	74.26	14.70	656.00 ²	0.36
	Postgraduate	71.07	9.87		

*¹Independent Sample T Test; ²Mann-Whitney U Test; ³Kruskal-Wallis Test

Findings Related to the Third Sub-Problem

Findings regarding middle school students' science experiences in informal settings according to various variables are presented in Table 5 and Table 6.

Table 5. Descriptive statistics on middle school students' science experiences according to their grades

	N	Mean	Sd
5th Grade	604	58.67	8.48
6th Grade	645	56.66	8.44
7th Grade	816	55.18	8.56
8th Grade	702	54.17	8.80
Total	2767	56.03	8.73

Table 6. ANOVA results for middle school students' science experience according to their grades

	Sum of Squares	df	Mean Square	F	p
Between Groups	7485.12	3	2495.04	33.93	0.00*
Within Groups	2031159.01	2763	73.53		
Total	210644.137	2766			

* p<0.05

The informal science experiences of the middle school students according to their grades are presented in Table 5 and Table 6. Science experiences also showed statistically significant differences according to their grade ($F=33.93$; $p<0.05$). The average science experience scores were 58.67 for the 5th grade students, 56.66 for the 6th grade students, 55.18 for the 7th grade students, and 54.19 for the 8th grade students. Science experiences decreased as grade increased.

Findings Related to the Fourth Research Problem

Table 7. Analysis of the relationship between science teachers' anxiety levels and their self-efficacy beliefs

		Anxiety	Self-Efficacy Beliefs
Anxiety	Correlation Coefficient	1	-0.51
	p		0.00**

*Pearson's Correlation Analysis

** p<0.01

Findings regarding the relationship between science teachers' self-efficacy beliefs and anxiety levels in out-of-school learning environments are presented in Table 7. A moderate negative relationship was found between science teachers' anxiety levels and their self-efficacy beliefs ($r=-0.51$; $p<0.01$). As teachers' self-efficacy beliefs increased, their anxiety levels decreased.

Table 8. The effect of science teachers' anxiety levels and self-efficacy beliefs on students' science experience

	$\hat{\beta}$	SE $\hat{\beta}$	Beta	t	p	R ²	Adj. R ²	F	p
Constant (Students' Science Experiences)	59.81	11.830		5.05	0.00				
Teachers' Anxiety Levels	-0.01	0.07	-0.02	-0.20	0.84	0.00	-0.02	0.02	0.98
Teachers' Self-Efficacy Beliefs	-0.00	0.07	-0.01	-0.05	0.96				

*Multiple Regression Analysis

Findings regarding science teachers' self-efficacy beliefs about out-of-school settings and their anxiety levels about out-of-school learning, as well as their middle school students' science experiences in informal settings, are presented in Table 8. Science teachers' anxiety levels and self-efficacy beliefs did not predict students' science experiences ($F=0.02$; $p=0.98$; $p>0.05$). In other words, teachers' anxiety levels and self-efficacy beliefs did not have a significant effect on students' science experiences.

Conclusion and Discussion

This study examined the effect of science teachers' self-efficacy beliefs and anxiety levels regarding out-of-school learning on the informal science experiences of middle school students in their classes. To our knowledge, the studies reported in the literature have examined self-efficacy beliefs and anxiety levels separately (Demir & Çetin, 2022; Pekin & Bozdoğan, 2021; Çetingüney & Büyük, 2022; Acar, 2023; Temel & Kölemen, 2021; Özbilen, 2023) or focused on the relationship between self-efficacy beliefs and anxiety levels (Güngör & Gül, 2021; Yıldırım & Efendioğlu, 2023; Gönüldaş & Gümüşkaya, 2022).

In the current study, the difference between science teachers' self-efficacy beliefs regarding out-of-school learning and their activity design status was found to be statistically significant. Teachers who designed activities related to out-of-school learning had higher self-efficacy beliefs. A statistically significant difference was found between science teachers' self-efficacy beliefs regarding out-of-school learning and their ability to organize activities in out-of-school settings. The teachers who organized numerous activities were found to have higher self-efficacy beliefs. Pekin & Bozdoğan (2021) determined that the teachers participating in their studies had high self-efficacy beliefs regarding their ability to organize educational trips to out-of-school environments.

Gürsoy (2018) reported that the pre-test and post-test self-efficacy scores of the teacher candidates participating in out-of-school field trip activities changed significantly in favor of the post-test. Similarly, Sarışan Tungaç (2015) also revealed that science teachers' perceived self-efficacy regarding out-of-school environmental education were high. In line with these findings, Temel & Kölemen's (2021) study concluded that as the number of field trips teachers conducted during the year increased, so did their self-efficacy beliefs. It can be suggested that teachers who plan more frequent field trips feel more competent largely because of the experience they gain during the field trip process.

There was no statistically significant difference in science teachers' self-efficacy beliefs regarding out-of-school learning in terms of variables such as training related to out-of-school learning environments, work experience, and education. Temel & Kölemen (2021) concluded in their study that preschool teachers' self-efficacy beliefs did not show a significant difference according to the education status variable. Acar (2023) found no significant difference in science teachers' self-efficacy beliefs regarding out-of-school activities in terms of work experience. In the research conducted by Pelin & Bozdoğan (2021), no statistically significant difference was found between teachers' self-efficacy in organizing educational trips to out-of-school environments and their length of work experience. The self-efficacy scores of the teachers with different durations of work experience were similar, indicating that professional experience does not have a decisive effect on teachers' self-efficacy beliefs. Similarly, studies conducted by Pas, Bradshaw & Hershfeldt (2012) and Yılmaz & Çokluk-Bökeoğlu (2008) also revealed that teachers' self-efficacy beliefs did not change with respect to professional experience. In contrast, Acar (2023) found in his research on science teachers that postgraduates had higher self-efficacy beliefs regarding out-of-school learning environments compared to those with undergraduate degrees. Furthermore, Gönüldaş &

Gümüşkaya (2022) reported a positive relationship between self-efficacy perceptions and educational status among individuals continuing their postgraduate education.

Pekin & Bozdoğan (2021) compared the mean self-efficacy scores of teachers' educational levels with their ability to organize educational trips to out-of-school environments and discovered that middle school teachers with postgraduate education had higher mean self-efficacy scores than middle school teachers without postgraduate education with a statistically significant difference. Sontay & Karamustafaoğlu (2017) found in their study that the self-efficacy beliefs of the teachers with a master's degree were significantly higher than those of the teachers with a bachelor's degree. Temel & Kölemen (2021) observed that preschool teachers' self-efficacy beliefs showed a significant difference in terms of their professional experience. This finding reveals that as teachers' length of education increases, so does their self-efficacy beliefs.

Demirtaş & Akkocaoğlu-Çayır (2021) found in their study that the activities and program developed and implemented as part of the “Out-of-Class Educational Activities for Classroom Teachers” project positively improved classroom teachers' self-efficacy beliefs regarding their ability to organize educational trips to out-of-school environments. Similarly, in İşlek's (2017) research with art teachers, a significant increase in teachers' self-efficacy beliefs was observed after they received in-service training on out-of-school education.

In the present study, no statistically significant difference was found in the anxiety levels of the science teachers regarding out-of-school learning across all variables. However, the teachers who had not received training related to out-of-school learning and had not previously designed activities had higher anxiety levels. The teachers' anxiety levels regarding out-of-school learning decreased as their years of work experience increased without a statistically significant difference. In terms of educational background, the teachers with bachelor's degrees had higher anxiety levels than those with master's degrees. Receiving professional training in a given field increases individuals' levels of knowledge in that area and reduces their anxiety levels (Şahin, 2022).

Uğurlu (2022) reported that the average score obtained by classroom teachers on the anxiety assessment scale ranged from 65.01 to 85, and considered the teachers as “Moderately Anxious”. Similarly, Şahin (2022) found that prospective classroom teachers had moderate levels of general anxiety regarding out-of-school learning. Furthermore, this study observed a statistically significant difference between prospective classroom teachers' anxiety levels and their course enrollment status regarding out-of-school learning. According to the findings, the anxiety levels of the teacher candidates who did not take courses on out-of-school learning were higher than those of the candidates who took these courses.

When the middle school students' science experiences were examined, they showed statistically significant differences according to their grades. As grade level increases, science experiences decrease. This situation has been interpreted as potentially arising from students' anxiety about classes and examinations taking precedence over their daily activities. As students progress to higher grade levels, their exam-related anxiety increases, they become increasingly disengaged from daily life, and their interactions with their surrounding environment diminish. Consequently, this situation leads to a reduction in students' informal science experiences.

Aksoy (2024) found that fifth-grade students' science experience scores in informal learning settings were higher than those of sixth-, seventh-, and eighth-grade students. Similarly, İlik (2023) reported that informal learning is generally a process that begins and develops within the family, whereas formal learning environments and academic achievement tend to replace informal experiences in later years. In addition, Subay (2011) stated that the level of conceptual understanding is inversely related to grade level and reported that eighth-grade students exhibited the lowest level of conceptual understanding. The author attributed this unexpected finding to the influence of national examinations within the education system. A moderate negative relationship was found between science teachers' anxiety levels and their self-efficacy beliefs. That is, as teachers' self-efficacy beliefs increase, their anxiety levels decrease.

In a study conducted by Yıldırım & Efendioğlu (2023), a significant, moderate, negative relationship was found between teachers' overall self-efficacy beliefs and their overall anxiety levels. Similarly, Gönültaş & Gümüşkaya (2022) revealed a negative relationship between individuals' perceptions of competence and anxiety and burnout. These findings show that individuals with high perceptions of professional competence have lower levels of anxiety and burnout. Güngör & Gül (2021) found a high-level negative relationship between teacher candidates' self-efficacy perceptions and their professional anxiety. In a study conducted by Yıldırım (2011), a high-level, statistically significant inverse relationship was found between elementary teacher candidates' professional self-efficacy perceptions and their professional anxiety. Similarly, a study conducted by Dadandı, Kalyon & Yazıcı (2016) also found a significant negative relationship between teacher candidates' self-efficacy perceptions and

their professional anxiety. In contrast, studies conducted by Kafkas, Aak, oban & Karademir (2010) and Deniz & Tican (2017) on teacher candidates showed a low level of significant, positive relationship between self-efficacy beliefs and professional anxiety. In view of the evidence from the present study, it can be suggested that while teacher candidates' self-efficacy beliefs increase, they experience low levels of positive professional anxiety, which is conflicting with the findings from previous studies.

Science teachers' anxiety levels and self-efficacy beliefs do not predict students' science experiences. In other words, teachers' anxiety levels and self-efficacy beliefs have no significant effect on students' science experiences. oban (2022) defines informal learning as a lifelong process through which individuals acquire knowledge, skills, and attitudes from their experiences and environment as part of daily life activities, such as those occurring at home, in the workplace, during leisure activities, while traveling, through observation of the behaviors of family members or friends, and via reading newspapers and books, listening to the radio, or watching films and television. Based on this definition, it may be interpreted that science teachers' anxiety levels and self-efficacy beliefs do not directly influence students' science experiences in informal learning settings. Rather, students' informal science experiences may be more strongly shaped by interactions with family members and peers.

This study is limited to a sample of 100 science teachers working in public schools in Eskiřehir and 2.767 middle school students enrolled in these teachers' classes. In addition, the use of convenience sampling constitutes an important limitation of the study. Although schools with different achievement levels were included to increase diversity, the non-probabilistic nature of the sampling method may have restricted the representativeness of the sample. As a result, the findings may not be generalized to all science teachers and middle school students. Future studies employing probabilistic sampling methods with larger and more diverse samples are recommended to enhance the generalizability of the results.

Recommendations

In light of the results of this study, the following recommendations could be made for future studies:

1. Qualitative research should be conducted to understand the reasons for teachers' anxiety and self-efficacy levels.
2. Educational programs and sample materials encouraging teachers to utilize learning environments outside of school could be planned.
3. Applied learning activities that will increase science experience at upper grade levels should be developed.
4. Continuous cooperation should be established between schools and museums, science centers, technology parks, and universities.
5. Differentiated support programs tailored to teachers at each seniority level should be prepared.
6. Out-of-school learning activities that increase parents' participation should be designed.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors

* Ethical approval for this research was approved by the Scientific Research and Ethics Committee of Hacettepe University with the decision dated April 26, 2022 (No: E-35853172-600-00002165987).

Conflict of Interest

* The authors declare that they have no conflicts of interest

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