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Changes in academic achievement in environmental topics and in environmental attitudes and social skills among fourth grade students following environmental education supported by Canva

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Abstract

This study examined changes in fourth-grade students' academic achievement in environmental topics, environmental attitudes, and social skills following Canva-supported environmental education. A convergent mixed methods design was used. The participants were 25 fourth-grade students attending a public primary school in Kastamonu, Türkiye, during the 2023–2024 academic year. Quantitative data were collected using the Environmental Academic Achievement Test, the Environmental Attitude Scale, the Social Skills Scale, and a structured classroom observation form; qualitative data were obtained through semi-structured interviews and a researcher journal. After two weeks of introductory Canva training, students worked in five heterogeneous groups for 10 weeks to design and present digital posters addressing soil, water, air, noise, and light pollution. Quantitative data were analyzed using paired-samples t tests and Wilcoxon signed-rank tests. Mean academic achievement scores increased from 14.92 to 19.40, mean change = 4.48, 95% CI [3.36, 5.60], $t(24) = 8.26$, $p < .001$, $\eta p^2 = 0.74$, $dz = 1.65$. Mean social skills scores increased from 59.92 to 70.12, mean change = 10.20, 95% CI [7.87, 12.53], $t(24) = 9.02$, $p < .001$, $\eta p^2 = 0.77$, $dz = 1.80$. Significant posttest-favoring rank changes were also found for every environmental attitude subscale and the total score, Bonferroni-adjusted $\alpha = 0.0125$, all $p < .001$, $r = .88$. Evidence from interviews, observations, and the researcher journal generally converged with the direction of the quantitative changes: students reported new learning, greater attention to environmental issues, and predominantly positive experiences of group work. The qualitative findings also revealed that some students already had an awareness of environmental issues, while others experienced difficulties with basic computer use. Differences in group dynamics were also observed, highlighting the importance of clear roles and constructive feedback throughout the process. Overall, the study provides an integrated understanding of the cognitive, affective, social, and process-related aspects of using Canva to support environmental education at the primary school level.

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Keywords Environmental education, Canva, Collaborative digital posters, Mixed methods, Environmental attitudes, Social skills

1 Introduction

Living organisms are constantly connected to both the biotic and abiotic elements of their surroundings, and any disruption in these relationships can affect environmental balance [42]. Human activities have increasingly contributed to environmental problems, including soil, water, air, noise, and light pollution. The effects of industrialization, population growth, and unsustainable consumption have further intensified these problems. At the same time, limited environmental knowledge and insufficiently developed pro-environmental orientations may make it more difficult for individuals to take preventive action [39]. In this context, education has an important role in promoting preventive approaches and encouraging more positive environmental attitudes [37].

Environmental education seeks to help students understand environmental systems, become aware of their responsibilities, and develop the knowledge, values, and skills needed to address environmental problems [28]. In Türkiye, the Environmental Law [11] also emphasizes the importance of providing environmental education beginning in the early years of life. Environmental learning should therefore not be viewed solely as the acquisition of factual information. It also involves affective and social processes that shape how students understand environmental problems, assign meaning to them, and determine how they will respond [10].

At the primary school level, environmental education can be more effective when it extends beyond direct transmission of information and gives students opportunities to investigate, communicate, and participate actively. Previous studies indicate that although primary school students may express sensitivity toward environmental issues, their knowledge may remain relatively superficial, and they may have difficulty transferring their environmental awareness into everyday practices [5, 12]. For this reason, researchers have also examined environmental education practices that incorporate different activities and instructional materials, particularly with fourth-grade students [3, 17, 19].

Web 2.0 tools offer additional possibilities for active learning by facilitating interaction, collaborative content creation, and the communication of ideas through multimedia [27]. Among these tools, Canva is an online visual design platform that allows users to bring together text, images, and other visual elements to create digital products. Studies carried out in different educational settings suggest that digital production activities can contribute to student participation, perceived usefulness, digital competence, and motivation when they are integrated into a purposeful instructional process [8, 16, 31, 35, 43].

Environmental education was chosen as the focus of the present study because it provides an opportunity to connect scientific understanding of soil, water, air, noise, and light pollution with values, responsibility, and collective action. Fourth grade was considered an appropriate curricular and developmental level for engaging students in activities through which they could examine the causes and consequences of pollution, work collaboratively over an extended period, design digital posters, and share environmental messages with their peers. Within this framework, academic achievement was

considered to reflect the cognitive dimension, environmental attitudes to represent the affective dimension, and social skills to capture the collaborative dimension through which students could discuss and negotiate issues related to shared environmental problems [2, 33, 41].

Recent studies further underscore the value of students producing their own environmentally themed digital products. Ergül and Demirci Güler [13], reported fourth-grade students' experiences of creating digital stories about environmental problems, whereas Kayır and Akyol [20] reported positive changes in children's environmental attitudes and awareness in an environmental learning context supported by digital storytelling tools. Although previous studies have examined environmental education, digital learning tools, and student outcomes from different perspectives, less is known about how cognitive, affective, and social changes relate to the classroom processes through which primary-school students investigate environmental problems, collaboratively develop digital products, present their work, and respond to feedback. Evidence linking pre–post outcome measures with students' own accounts and process-level classroom data remains particularly limited in primary environmental education. The present study addresses this gap by examining both the changes observed across the implementation and the classroom experiences and processes that accompanied those changes.

The purpose of this study was not to establish the independent causal effect of Canva. Rather, it sought to examine the changes observed following a classroom intervention that combined brief content instruction, online inquiry, collaborative digital poster production, peer presentation, and feedback, and to explore the processes through which those changes were experienced. The following research questions guided the study:

1. Is there a significant difference between fourth-grade students' pretest and posttest scores for academic achievement in environmental topics following Canva-supported environmental education activities?
2. Is there a significant difference between fourth-grade students' pretest and posttest environmental attitude scores following Canva-supported environmental education activities?
3. Is there a significant difference between fourth-grade students' pretest and posttest social skills scores following Canva-supported environmental education activities?
4. How did the study groups' structured observation scores vary across the instructional cycles addressing different forms of pollution?
5. How did fourth-grade students evaluate the Canva-supported environmental education process?
6. According to the researcher journal, what pattern of change over time was observed in the implementation of Canva-supported environmental education?
7. How do the quantitative findings and the evidence from interviews, structured observations, and the researcher journal jointly explain changes in students' academic achievement in environmental topics, environmental attitudes, and social skills?

2 Method

2.1 Research design

A convergent mixed methods design was used in this study. Quantitative, qualitative, and observational data were collected at different stages of the implementation. Each type of data was analyzed separately using procedures appropriate to that form

of evidence, and the findings were brought together during interpretation [9, 32]. The quantitative strand followed a one-group pretest–posttest design. The qualitative strand followed a qualitative descriptive design, selected to provide a direct and practice-oriented account of students' experiences and of how the classroom process unfolded [36]. Structured observation scores were treated as quantitative process indicators rather than as an additional experimental outcome.

Quantitative measures were administered before and after the intervention, structured observations and researcher journal entries were recorded during the implementation, and individual interviews were conducted after the posttests. The datasets were first analyzed independently and were then compared around shared cognitive, affective, social, and implementation-related domains. At the design level, the different forms of evidence addressed a common overall purpose. At the analysis and interpretation stages, findings from the separate datasets were merged through side-by-side comparison and a joint display [14]. Because the qualitative and observational evidence was generated within the same classroom context and largely by the same researcher, agreement across sources was not treated as independent validation of the quantitative results. Instead, the sources were examined for convergence, complementarity, divergence, and evidence that qualified or contextualized the overall pattern of findings.

2.2 Participants

The participants were 25 fourth-grade students attending a public primary school in a district of Kastamonu during the 2023–2024 academic year. Convenience sampling was used because the study required regular access to the students throughout the extended implementation period. None of the students had received formal training in Canva before the study. To create balanced and diverse groups, students were assigned to five heterogeneous groups of five based on their third-grade science achievement records, ensuring that students with different initial achievement levels were represented in each group. All 25 students were included in the pretest-posttest and individual interview analyses; no student was excluded because of missing outcome or interview data.

Fourth grade was selected because the environmental topics addressed in the intervention aligned with outcomes in the 2018 Science Curriculum and because students at this level were able to participate in a sequence of inquiry, digital poster creation, and presentation activities. In the Ministry of National Education's 2018 science curriculum, air, water, and soil are introduced in third grade as nonliving components of the environment, and students are expected to participate actively in keeping their environment clean and to investigate and propose solutions for protecting the natural environment (F.3.6.1.1, F.3.6.2.2, and F.3.6.2.6). In fourth grade, students are explicitly expected to investigate the causes and effects of light and noise pollution and propose ways to reduce them (F.4.5.3.1-F.4.5.3.3 and F.4.5.5.1-F.4.5.5.3). The curriculum also emphasizes the economical use of resources and awareness of recycling (F.4.6.1.1-F.4.6.1.2; [25], pp. 18–19, 23–24). In line with this curricular continuity, the intervention topics connected students' third-grade foundations in recognizing and protecting the environment with fourth-grade learning outcomes related to pollution and resource use.

The small sample drawn from a single public school limits the statistical generalizability of the findings. Therefore, the study focused on explaining changes and

implementation within the specific classroom context rather than attempting to generalize the findings to a broader population.

2.3 Data collection instruments

After the Canva training was completed during the first two weeks, the researcher administered the pretests in Week 3. The posttests were administered in Week 14, following the completion of the intervention. At both measurement points, the quantitative instruments were administered on days when all students were present, and each instrument was completed during a separate class period. The quantitative data collection instruments used in the study are described below.

2.3.1 Environmental Academic Achievement Test

Kara's [19] 25-item multiple-choice test uses a scoring system of 1 point for each correct answer and 0 points for each incorrect answer, resulting in total scores ranging from 0 to 25. The author reported a Cronbach's alpha coefficient of 0.73 for the instrument. In the present study, the test was piloted with 204 fourth-grade students who were not included in the main study, and the analysis yielded a Cronbach's alpha coefficient of 0.86.

2.3.2 Environmental Attitude Scale

Peker's [30] 15-item scale consists of three subscales: Pollution, Love of Plants and Nature, and Love of Animals. The items are rated on a three-point scale, with total scores ranging from 15 to 45, where higher scores reflect more positive environmental attitudes. Peker [30], reported a Cronbach's alpha coefficient of 0.87. In the present study, the scale was piloted with 191 fourth-grade students who were not included in the main study, resulting in a Cronbach's alpha coefficient of 0.89.

2.3.3 Social Skills Scale

The 20-item scale developed by Kocayörük Yaya [22] uses a four-point response format and yields total scores from 20 to 80. Kocayörük Yaya [22], reported a Cronbach's alpha coefficient of 0.75. In the present study, the instrument was piloted with 190 fourth-grade students outside the study group, yielding a Cronbach's alpha coefficient of 0.83. These reliability estimates refer to the independent fourth-grade pilot samples described above rather than to the 25 students in the intervention group, and all exceeded the 0.70 criterion commonly used in educational research [7].

2.3.4 Structured observation form and observation procedure

The researcher-developed observation form comprised 21 group-level criteria: seven related to group work and 14 related to Canva-based design production. The group-work criteria addressed respectful communication, task allocation, exchange of ideas, democratic decision making, and the accurate and timely completion of tasks. The design criteria addressed willingness to participate, arranging text and images, locating appropriate information, searching the internet, changing the background, positioning text and images, adding a title and group information, controlling text density, and producing an original product. The form was reviewed by two academics and three primary school teachers to evaluate the appropriateness and relevance of its items. Expert

agreement, calculated using the Miles and Huberman [24] formula, was 76.47%. Items on which the experts disagreed were revised before the final version of the form was prepared.

The researcher observed each group once at the end of each of the five pollution cycles, resulting in five observations for each group. Each criterion was rated as poor (1), moderate (2), or good (3), with the scores combined to produce a composite score ranging from 21 to 63. The composite score was retained because the form had originally been developed and administered as a single process-monitoring instrument covering two related aspects of the implementation: group functioning and Canva-based product development. The two sets of criteria were not treated as independently validated subscales. Because the ratings were completed by the researcher rather than by independent observers, the scores were used descriptively to characterize group-level implementation patterns rather than as independently validated outcome measures.

2.3.5 Semi-structured interview form and interview procedure

A semi-structured interview form was used to explore fourth-grade students' experiences during the intervention and the changes they perceived. The form was developed in four stages. First, draft questions were prepared based on the relevant literature and the research questions. Second, the wording was revised to ensure that the questions were clear and accessible for fourth-grade students, taking into account their developmental characteristics and language level. Third, the draft form was reviewed by five experts, including two academics in environmental and science education and three primary school teachers. The experts evaluated the questions in terms of their alignment with the study purpose, scope, clarity, and age appropriateness. Finally, the form was revised based on the feedback received.

The final form included three broad, open-ended questions. The questions were deliberately phrased in child-accessible language so that students could describe aspects of the experience that were meaningful to them without being directed toward predetermined positive or negative judgments about achievement, environmental attitudes, or social interaction:

1. What do you think about using Canva?
2. What do you think about using Canva in lessons that address environmental topics?
3. Did this process lead to any changes for you? If so, in what ways? If not, why not?

When necessary, nonleading probes were used to help students elaborate on and provide examples for their responses.

The final form was administered after the intervention. Following the posttests, the researcher conducted an individual interview lasting approximately 15–20 min with each of the 25 students in a quiet, unoccupied classroom at the school. With written parental or legal-guardian consent and student assent, the interviews were audio-recorded.

2.3.6 Researcher journal

Throughout the intervention, the researcher kept a journal to document students' participation, distribution of roles, conflicts, adaptation to computers and Canva, information-seeking activities, design choices, feedback, presentations, and other noteworthy classroom events. These records were used as qualitative process data to provide context

Table 1 Implementation process for Canva-supported environmental education

Week	Topic/focus	Related curriculum outcome or intervention learning outcome	Activity	Process emphasis
1	Canva training	Intervention learning outcome: Recognizes Canva's basic features and performs operations for adding images and text and arranging the page.	Introduction to Canva's basic features and to adding images and text and arranging the page.	Recognizing the digital tool's basic features
2	Canva training	Intervention learning outcome: Creates a sample digital poster containing text and images in Canva.	Hands-on Canva practice and preparation of a sample digital poster.	Developing digital poster creation skills
3	Pretests and grouping	No direct learning outcome was targeted; data collection and grouping were completed.	Administration of the Environmental Academic Achievement Test, Environmental Attitude Scale, and Social Skills Scale as pretests; formation of five heterogeneous groups based on third-grade science achievement records.	Establishing baseline levels and forming groups
4	Soil pollution	Related Grade 3 outcomes: F.3.6.1.1 classifies entities as living or nonliving using examples from the environment; F.3.6.2.2 participates actively in keeping the local environment clean; F.3.6.2.6 investigates and proposes solutions for protecting the natural environment. Intervention learning outcome: Investigates the causes and effects of soil pollution and develops solutions for reducing it.	After a brief introduction, groups conduct online inquiry, evaluate information, and begin developing posters in Canva.	Knowledge acquisition, inquiry, joint decision making, peer interaction, and digital product creation
5	Soil pollution	Related Grade 3 outcomes: F.3.6.2.2 and F.3.6.2.6. Intervention learning outcome: Organizes information about soil pollution, prepares and presents a digital poster containing solutions, and evaluates it in light of feedback.	Continuation of inquiry; completion and presentation of posters; receipt of feedback; structured observation.	Peer interaction, collaborative completion, presentation, questions and answers, and feedback
6	Water pollution	Related Grade 3 outcomes: F.3.6.1.1, F.3.6.2.2, and F.3.6.2.6. Intervention learning outcome: Investigates the causes of water pollution and its effects on living organisms and develops solutions for reducing it.	After a brief introduction, groups conduct online inquiry, evaluate information, and begin developing posters in Canva.	Knowledge acquisition, inquiry, joint decision making, peer interaction, and digital product creation
7	Water pollution	Related Grade 3 outcomes: F.3.6.2.2 and F.3.6.2.6. Intervention learning outcome: Organizes information about water pollution, prepares and presents a digital poster containing solutions, and evaluates it in light of feedback.	Continuation of inquiry; completion and presentation of posters; receipt of feedback; structured observation.	Peer interaction, collaborative completion, presentation, questions and answers, and feedback
8	Air pollution	Related Grade 3 outcomes: F.3.6.1.1, F.3.6.2.2, and F.3.6.2.6. Intervention learning outcome: Investigates the causes of air pollution and its effects on living organisms and develops solutions for reducing it.	After a brief introduction, groups conduct online inquiry, evaluate information, and begin developing posters in Canva.	Knowledge acquisition, inquiry, joint decision making, peer interaction, and digital product creation

Table 1 (continued)

Week	Topic/focus	Related curriculum outcome or intervention learning outcome	Activity	Process emphasis
9	Air pollution	Related Grade 3 outcomes: F.3.6.2.2 and F.3.6.2.6. Intervention learning outcome: Organizes information about air pollution, prepares and presents a digital poster containing solutions, and evaluates it in light of feedback.	Continuation of inquiry; completion and presentation of posters; receipt of feedback; structured observation.	Peer interaction, collaborative completion, presentation, questions and answers, and feedback
10	Noise pollution	Grade 4 outcomes: F.4.5.5.1 investigates the causes of noise pollution; F.4.5.5.2 explains its adverse effects on human health and the environment; F.4.5.5.3 develops solutions for reducing it.	After a brief introduction, groups conduct online inquiry, evaluate information, and begin developing posters in Canva.	Knowledge acquisition, inquiry, joint decision making, peer interaction, and digital product creation
11	Noise pollution	Grade 4 outcomes: F.4.5.5.1-F.4.5.5.3. Intervention learning outcome: Prepares and presents a digital poster addressing the causes, effects, and solutions of noise pollution and evaluates it in light of feedback.	Continuation of inquiry; completion and presentation of posters; receipt of feedback; structured observation.	Peer interaction, collaborative completion, presentation, questions and answers, and feedback
12	Light pollution	Grade 4 outcomes: F.4.5.3.1 investigates the causes of light pollution; F.4.5.3.2 explains its adverse effects on wildlife and observation of celestial bodies; F.4.5.3.3 develops solutions for reducing it.	After a brief introduction, groups conduct online inquiry, evaluate information, and begin developing posters in Canva.	Knowledge acquisition, inquiry, joint decision making, peer interaction, and digital product creation
13	Light pollution	Grade 4 outcomes: F.4.5.3.1-F.4.5.3.3. Intervention learning outcome: Prepares and presents a digital poster addressing the causes, effects, and solutions of light pollution and evaluates it in light of feedback.	Continuation of inquiry; completion and presentation of posters; receipt of feedback; structured observation.	Peer interaction, collaborative completion, presentation, questions and answers, and feedback
14	Posttests / interviews	No direct learning outcome was targeted; data were collected to determine postintervention outcomes and student experiences.	Administration of the three quantitative instruments as posttests, followed by individual semi-structured interviews.	Determining postintervention levels and student experiences

for the interview findings and observation patterns. The researcher journal was not treated as an independent measure of the intervention's effectiveness.

2.4 Implementation process and research setting

The study was conducted over a 14-week period, with three class periods allocated to the intervention each week. The intervention took place in the school's computer laboratory, which was equipped with 15 computers. Students worked in five groups of five, with two computers available to each group. This shared computer arrangement was intended to encourage students to work collaboratively as they searched for information, evaluated sources, discussed ideas, and developed their digital posters.

During the first two weeks, students received a total of six class periods of Canva training. This training was designed to develop the basic technical skills required to use the digital tool during the intervention. Students received hands-on, individual instruction in Canva's basic functions, adding images and text, page layout, and digital poster

creation. No instruction was provided at this stage on the study topics of soil, water, air, noise, or light pollution.

In Week 3, the researcher administered the Environmental Academic Achievement Test, Environmental Attitude Scale, and Social Skills Scale as pretests. All quantitative instruments were administered on the same day when every student was present, with one instrument completed in each class period. After the pretests, students were assigned to five heterogeneous groups of five based on their third-grade science achievement records.

The intervention conducted from Weeks 4 through 13 comprised five two-week learning cycles addressing soil, water, air, noise, and light pollution in that order. During the first week of each cycle, the researcher provided an approximately 20-minute introduction to the relevant environmental topic. Students then searched for information online in groups, jointly evaluated the information they found, agreed on the text and images to include, and began developing their digital posters in Canva.

During the second week of each cycle, students continued their inquiry and poster development, completed their posters, and presented them to the class. After each presentation, students received feedback from peers and the researcher and evaluated their products in terms of informational accuracy, clarity, and visual organization. Structured observations were also conducted at this stage.

Peer interaction occurred not only during the presentation and feedback stages but throughout all intervention lessons from Weeks 4 to 13. Students interacted with group members while searching for information, evaluating its accuracy, selecting text and images, allocating tasks, making joint decisions, and creating digital posters. During presentation weeks, within-group interaction was supplemented by intergroup presentations, questions and answers, and peer feedback.

Groups were encouraged to distribute tasks such as conducting research, selecting information, drafting text, choosing images, and arranging the poster. The student responsible for presenting rotated across topic cycles so that every student presented once during the intervention. In Week 14, the same quantitative instruments used as pretests were administered as posttests under equivalent conditions. Individual semi-structured interviews were then conducted with all students. Table 1 presents the weekly activities and process emphases.

2.5 Data analysis

The alignment among research questions, data sources, and analytical procedures is presented in Table 2. The quantitative questions were addressed by comparing preintervention and postintervention scores for achievement, attitudes, and social skills. The qualitative questions were addressed through student interviews and the researcher journal, while structured observations supplied quantitative process indicators. In the final stage, quantitative and qualitative findings were compared through a joint display to identify convergence, complementarity, divergence, and qualifying evidence.

This mapping ensured that each research question was addressed using an appropriate data source and analytical procedure and made the mixed methods integration process transparent. The quantitative and qualitative analyses are described in detail below.

Table 2 Alignment of research questions, data sources, and analytical procedures

Research question	Data collection instrument or source	Data type and unit of analysis	Analysis
1. Is there a significant difference between fourth-grade students' pretest and posttest scores for academic achievement in environmental topics following Canva-supported environmental education activities?	Environmental Academic Achievement Test	Quantitative; student-level paired pretest-posttest scores	Paired-samples t test
2. Is there a significant difference between fourth-grade students' pretest and posttest environmental attitude scores following Canva-supported environmental education activities?	Environmental Attitude Scale	Quantitative; student-level subscale and total pretest-posttest scores	Wilcoxon signed-rank tests; Bonferroni correction for four comparisons ($\alpha = 0.0125$)
3. Is there a significant difference between fourth-grade students' pretest and posttest social skills scores following Canva-supported environmental education activities?	Social Skills Scale	Quantitative; student-level paired pretest-posttest scores	Paired-samples t test
4. How did the study groups' structured observation scores vary across the instructional cycles addressing different forms of pollution?	Structured Observation Form	Quantitative process data; five groups × five intervention cycles	Descriptive analysis of composite scores and group and cycle means; chronological comparison
5. How did fourth-grade students evaluate the Canva-supported environmental education process?	Individual semi-structured interviews	Qualitative; verbatim Turkish interview transcripts	Content analysis: identification of meaning units, coding, and categorization
6. According to the researcher journal, what pattern of change over time was observed in the implementation of Canva-supported environmental education?	Researcher journal	Qualitative process data; intervention weeks and cycles	Content analysis and chronological-thematic comparison
7. How do the quantitative findings and the evidence from interviews, structured observations, and the researcher journal jointly explain changes in students' academic achievement in environmental topics, environmental attitudes, and social skills?	Quantitative and qualitative findings from Research Questions 1–6	Mixed methods integration level	Joint display comparing convergence, complementarity, divergence, and qualifying conditions

2.5.1 Quantitative data analysis

To assess the assumptions underlying the parametric tests used to compare academic achievement and social skills scores, difference scores were calculated by subtracting each student's pretest score from their corresponding posttest score. The distributions of these difference scores were examined using the Shapiro–Wilk test together with skewness and kurtosis values. The criteria suggested by Tabachnick and Fidell [38] were used to evaluate the skewness and kurtosis values. Paired-samples t tests were conducted for academic achievement and social skills, as these variables met the assumptions of parametric analysis. In contrast, Wilcoxon signed-rank tests were used for environmental attitude scores because the relevant assumptions were not met.

For the paired-samples t tests, a positive mean difference and a positive t value indicated that posttest scores were higher than pretest scores. Mean differences, 95% confidence intervals, partial eta squared (ηp^2), and Cohen's dz for paired measurements were reported. Partial eta squared was calculated using the formula $\eta p^2 = t^2/(t^2 + df)$, while Cohen's dz was calculated as $dz = |t|/\sqrt{n}$.

For the three subscales of the Environmental Attitude Scale and its total score, the Wilcoxon effect size was calculated using $r = |Z|/\sqrt{N}$, where N referred to the number of paired observations with a nonzero difference score. A Bonferroni correction was applied across the four comparisons to control the familywise Type I error rate, resulting in an adjusted alpha level of 0.0125. Composite scores obtained from the Structured Observation Form were analyzed descriptively across the study groups and intervention cycles. Group and cycle means were calculated to examine the pattern of change over the course of the intervention.

2.5.2 Qualitative data analysis

The verbatim Turkish interview transcripts and researcher journal entries were analyzed using content analysis. The data were read several times to become familiar with the content, after which meaningful units were identified and initial codes were assigned to relevant statements. Related codes were then grouped into broader categories. These categories were subsequently examined in relation to students' experiences with Canva, environmental attitudes, social interaction, learning experiences, and the conditions under which the intervention was implemented. All analyses were conducted using the original Turkish data. English translations were prepared only for the participant quotations selected for presentation in the report. Consistent with the qualitative descriptive orientation of the study, the analysis remained close to students' accounts and emphasized descriptive, practice-oriented interpretation rather than the development of abstract theoretical explanations. Categories were used to organize recurring meanings while retaining the substance of what students reported about their classroom experiences. Frequencies were used only to show how often particular codes appeared across participants; they were not treated as indicators of statistical prevalence, representativeness, or the relative importance of qualitative categories.

2.5.3 Credibility of the qualitative findings and coding consistency

The credibility of the qualitative findings was strengthened by expert review of the child-oriented interview form, verbatim transcription of the interviews, comparison of evidence from interviews, observations, and the researcher journal, support for findings through traceable direct quotations, and inclusion of negative or qualifying cases in the analysis.

To assess coding consistency, the researcher recoded the same qualitative dataset one month after the initial analysis using the same coding framework. The two coding rounds were compared using the same preidentified meaning units. Assignment of the same code to a meaning unit in both rounds was classified as agreement; assignment of different codes, or use of a code in only one round, was classified as disagreement. Percentage agreement was calculated using the formula proposed by Miles and Huberman [24]: agreement / (agreement + disagreement) × 100. Substituting the numbers of agreements and disagreements from the two rounds yielded 91.2% coding agreement; that is, 91.2% of the comparable coding decisions matched across rounds. This value reflects intrarater agreement and the temporal consistency of the coding performed by the same researcher rather than agreement between independent coders [26]. Since percentage agreement does not account for agreement that may occur by chance, this value was not considered sufficient evidence of reliability for the qualitative analysis as a whole.

Instead, it was treated as one indicator of consistency in the researcher's coding across time.

2.5.4 Integration of quantitative and qualitative data

Following the separate analyses, findings from the quantitative measures, student interviews, structured observations, and researcher journal were merged during interpretation. Integration was organized around four shared domains: academic learning, environmental attitudes, social interaction, and implementation processes. The findings were compared side by side and summarized in a joint display to examine where the different sources converged, where they contributed complementary information, where they diverged, and where one source qualified the interpretation of another. The purpose of this comparison was not to determine whether one source validated another, but to develop a more context-sensitive interpretation of the quantitative changes and the classroom processes that accompanied them.

2.6 Research ethics

Ethical approval for the study was obtained from the Gazi University Ethics Committee (No. 2023 – 1387; November 24, 2023). Permission to conduct the implementation was also obtained from the Kastamonu Provincial Directorate of National Education and the school administration. Before the intervention began, students and their parents or legal guardians were informed about the purpose and procedures of the study. Written informed consent was obtained from parents or legal guardians, and student assent was also obtained. The consent and assent procedures included permission for audio-recording the individual interviews.

Students were informed that participation was voluntary and that they could withdraw from the study at any time without facing any negative consequences. Confidentiality was maintained throughout the study, and the data were used solely for research purposes. No identifying information was included in the analysis or reporting, and participants were identified using codes ranging from S1 to S25. The study was conducted in accordance with internationally accepted ethical principles governing research involving human participants.

3 Results

3.1 Quantitative findings

3.1.1 Academic achievement in environmental topics

To address the first research question, a paired-samples t test was conducted to examine the change in students' academic achievement scores from pretest to posttest. The results, together with the corresponding effect-size estimates, are presented in Table 3.

As shown in Table 3, the mean academic achievement score increased from 14.92 (SD = 4.11) at pretest to 19.40 (SD = 3.37) at posttest. The mean increase of 4.48 points was statistically significant, 95% CI [3.36, 5.60], t(24) = 8.26, $p < .001$. The effect-size estimates indicated a large within-group change ($\eta p^2 = 0.74$; dz = 1.65). Because the study

Table 3 Paired-samples t test results for academic achievement in environmental topics

Measure	Pretest M (SD)	Posttest M (SD)	Mean change	95% CI	t(df)	*p*	ηp^2	dz
Achievement	14.92 (4.11)	19.40 (3.37)	4.48	[3.36, 5.60]	8.26 (24)	< 0.001	0.74	1.65

Note. Mean change was calculated as the posttest score minus the pretest score

Table 4 Wilcoxon signed-rank test results for environmental attitudes

Dimension	Positive ranks	Ties	Negative ranks	Z	*p*	*r*
Pollution	24	1	0	4.32	< 0.001	0.88
Love of Plants and Nature	21	4	0	4.04	< 0.001	0.88
Love of Animals	25	0	0	4.42	< 0.001	0.88
Total scale	25	0	0	4.38	< 0.001	0.88

Note. A positive rank indicates that the posttest score exceeded the pretest score. Effect sizes were calculated as r = |Z|/√N, where N was the number of nonzero paired differences. The Bonferroni-adjusted significance level was α = 0.0125

Table 5 Paired-samples t test results for social skills

Measure	Pretest M (SD)	Posttest M (SD)	Mean change	95% CI	t(df)	*p*	ηp^2	dz
Social skills	59.92 (9.45)	70.12 (5.09)	10.20	[7.87, 12.53]	9.02 (24)	< 0.001	0.77	1.80

Note. Mean change was calculated as the posttest score minus the pretest score

used a one-group pretest-posttest design, however, the observed change was not interpreted solely as a causal effect of the Canva-supported intervention.

3.1.2 Environmental attitudes

To address the second research question, Wilcoxon signed-rank tests were conducted to examine changes in students' environmental attitude scores between the preintervention and postintervention measurements. Since four comparisons were made across the three subscales and the total score, a Bonferroni correction was applied to control the familywise Type I error rate, resulting in an adjusted alpha level of 0.0125. The results are presented in Table 4.

As shown in Table 4, statistically significant changes in the ranks favoring the posttest were observed for the Pollution, Love of Plants and Nature, and Love of Animals subscales, as well as for the total scale score (all $p < .001$). All four comparisons exceeded the Bonferroni-adjusted significance threshold of α = 0.0125. Posttest scores were higher than pretest scores for 24 students on the Pollution subscale, 21 students on the Love of Plants and Nature subscale, and all 25 students on both the Love of Animals subscale and the total scale. No negative ranks were observed. The effect sizes were large across all four comparisons (all $r = .88$), indicating substantial within-group changes in favor of the posttest across all dimensions of environmental attitudes examined.

3.1.3 Social skills

To address the third research question, a paired-samples t test was conducted to compare students' preintervention and postintervention social skills scores. Partial eta squared (ηp^2) and Cohen's dz for paired measurements were calculated to estimate the magnitude of within-group change. The results are presented in Table 5.

As shown in Table 5, the mean social skills score increased from 59.92 (SD = 9.45) at pretest to 70.12 (SD = 5.09) at posttest. The mean increase of 10.20 points was statistically significant, 95% CI [7.87, 12.53], t(24) = 9.02, $p < .001$. The effect-size estimates indicated a large within-group change in social skills ($\eta p^2 = 0.77$; dz = 1.80). Because no control group was included, however, this change was not interpreted as the independent causal effect of the Canva-supported intervention.

3.1.4 Structured observation findings

To address the fourth research question, structured observation scores were examined descriptively across the five pollution-topic cycles. Composite scores for the five groups at the end of the soil, water, air, noise, and light pollution cycles were compared in chronological order. Because the composite scores included criteria related both to group functioning and to Canva-based digital poster production, they were interpreted as broad indicators of group-level implementation rather than as measures of either domain in isolation. Table 6 presents the observation scores by group and cycle.

As shown in Table 6, structured observation scores generally increased across the chronological sequence for every group. Mean scores across groups were 26.2 for soil pollution, 34.8 for water pollution, 40.8 for air pollution, 50.2 for noise pollution, and 54.2 for light pollution. Group means ranged from 38.2 to 44.6, with the highest mean observed for Group 1 and the lowest for Group 5. Every group obtained its lowest score during the first topic, soil pollution, and its highest score during the final topic, light pollution, indicating a shared upward pattern across the implementation.

This upward chronological pattern should not be interpreted as evidence of a distinct intervention effect. The pollution topic, implementation order, students' accumulating experience with group work and Canva, repeated exposure to the activity structure, familiarity with the presentation format, and increasing familiarity with the observation criteria changed together across the cycles and cannot be disentangled in these descriptive data. The observation scores were therefore interpreted as descriptive process evidence that contextualized how the implementation unfolded rather than as inferential outcomes.

Figure 1 illustrates the common upward pattern across the five pollution topics.

3.2 Qualitative findings

3.2.1 Student interviews

To address the fifth research question, the semi-structured interview data were analyzed to explore students' experiences with Canva-supported environmental education and the changes they perceived during the intervention. The analysis resulted in four main categories: use of Canva, environmental attitudes and attention, social interaction and group work, and perceived environmental learning. Table 7 presents the codes identified within these categories, together with their frequencies, the percentage of participants represented, and illustrative quotations from the students.

Table 7 shows that students' views of Canva-supported environmental education were generally positive. Fifteen students (60%) described Canva as nice or good, five (20%) as easy, and five (20%) as fun or enjoyable. Four students (16%) said that they had learned to use a digital tool that was new to them, whereas three (12%) reported initial difficulty and one (4%) described the experience as neutral. Because responses in the Canva-use

Table 6 Composite observation scores by group and pollution cycle

Group	Soil	Water	Air	Noise	Light	Mean
Group 1	27	35	48	55	58	44.6
Group 2	25	35	39	52	57	41.6
Group 3	27	36	40	52	55	42.0
Group 4	26	36	36	48	53	39.8
Group 5	26	32	41	44	48	38.2

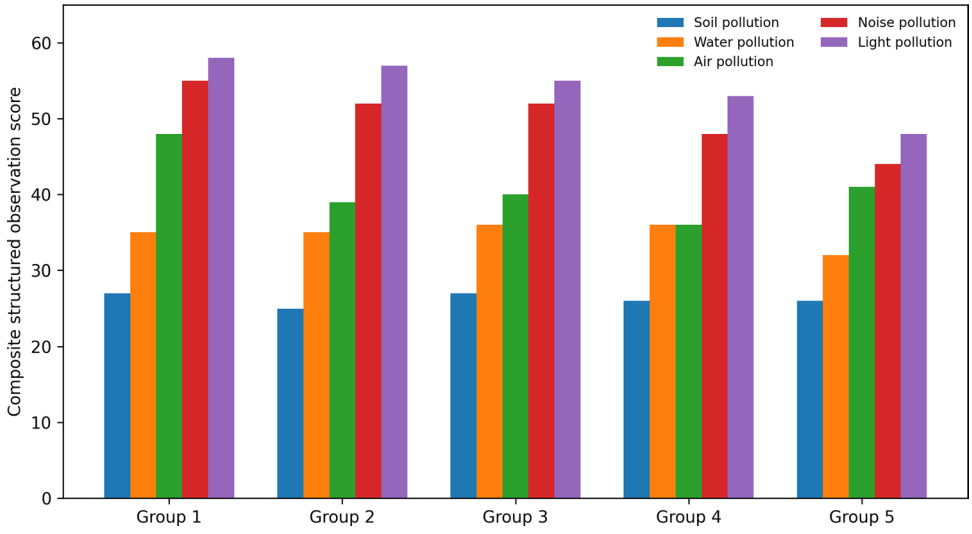


Fig. 1 Composite structured observation scores by pollution topic in chronological order

category could receive more than one code, the frequencies and percentages exceed the number of participants and 100%. The student statements suggest that difficulties were concentrated at the beginning of the intervention and diminished as students became more familiar with the tool.

Regarding environmental attitudes and attention, most students (f = 23; 92%) reported that they paid more attention to environmental issues after the intervention. Two students (8%) did not report a notable change, explaining that they had already been attentive to environmental issues before the intervention. These responses are broadly consistent with the increase observed in the quantitative findings, while also suggesting that the perceived impact of the intervention varied across students and that prior environmental sensitivity may have influenced the extent of perceived change.

In terms of social interaction and group work, 22 students (88%) stated that working together contributed positively to the success of their groups, whereas three students (12%) reported experiencing disagreements or arguments during the process. Thus, although group work was generally perceived positively, the experience was not equally smooth for all students. In addition, all students (f = 25; 100%) reported learning new information about environmental issues. Overall, the interview findings suggest that Canva was positively received and that students generally perceived the intervention as beneficial for environmental learning, attention to environmental issues, and group work. However, technological difficulties, pre-existing environmental sensitivity, and disagreements within groups introduced some variation into this generally positive pattern.

3.2.2 Researcher journal findings

To address the sixth research question, the complete researcher journal was analyzed using content analysis to examine changes in the implementation of Canva-supported environmental education over time. The analysis across the five intervention cycles produced five themes: adaptation to technology use; participation and task responsibility; group functioning and social interaction; engagement in peer presentations and feedback; and digital product development and aesthetic awareness. Overall, the findings

Table 7 Student views of Canva-supported environmental education

Category	Code	f	%	Students reporting the code	Illustrative student quotations
Use of the Canva design tool	Nice or good	15	60.0	S2, S3, S4, S9, S11, S13, S16, S17, S18, S19, S20, S21, S23, S24, S25	"I thought it was very nice." (S2)
	Easy	5	20.0	S5, S7, S10, S13, S22	"Using Canva was easy; I liked making posters." (S7)
	Fun or enjoyable	5	20.0	S1, S8, S11, S14, S16	"Working with Canva was fun; I did not get bored." (S14)
	New learning	4	16.0	S2, S3, S13, S24	"I learned a program that I did not know before." (S24) "I learned new things. I had not known Canva before. We could not finish in the first week, but in the following weeks we completed our posters. Sometimes the colors did not match and we made mistakes, but we still managed to do it." (S2)
	Difficult	3	12.0	S6, S12, S20	"At first I struggled a little, but then I got used to it." (S6)
	Neutral	1	4.0	S15	"It was neither too difficult nor too easy." (S15)
Perceived impact on environmental attitudes	Increased attention to the environment	23	92.0	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S13, S14, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25	"I did not throw litter on the ground before, but now I pay even more attention. For example, I put some things in recycling now that I used to throw in the trash." (S5)
	No impact	2	8.0	S12, S15	"It did not change much; I was already careful not to harm nature." (S12)
Perceived impact on social skills	Positive contribution to group success	22	88.0	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S17, S18, S19, S20, S21, S23, S24, S25	"We did better when we worked together." (S3)
	Disagreement or argument	3	12.0	S12, S15, S16	"Group work was good, but sometimes we argued. In the first week, none of us wanted to present and we could not agree. Later, we decided to take turns presenting. I was a little shy at first when I presented, but then it passed." (S12)
Perceived impact on academic achievement	New learning	25	100.0	All students	"I learned the meanings of some words and wrote the new words in my notebook. For example, I learned about noise pollution. Sometimes I listened to music loudly at home. From now on, I will listen at a normal volume." (S9)

Note. Percentages are based on $N = 25$. Within the Canva-use category, a student response could be assigned to more than one code

showed a progression from initial technical difficulties, uneven task distribution, and disagreements within groups toward more confident technology use, more consistent participation, stronger collaboration, more detailed peer feedback, and greater attention to the quality of digital products. However, this development was not uniform or linear across all students and groups.

Adaptation to technology use During the initial cycles, students' technical difficulties appeared to be related mainly to differences in their familiarity with basic computer operations rather than to difficulties with Canva itself. The researcher recorded the following observation:

> *Students mostly had difficulty using the computer. They were observed to work more comfortably and quickly when using the Canva design tool.*

The journal indicated that some students were comfortable using digital tools from the beginning, whereas students with less prior computer experience required greater support, particularly during the early cycles. As the intervention progressed, students began to use Canva more confidently and efficiently, required less assistance with technical operations, and solved technical problems in less time. Thus, the pattern within this theme reflected a gradual shift from difficulties with basic computer use toward more fluent and independent Canva use.

Participation and task responsibility Journal entries revealed differences in students' participation in research, information selection, poster preparation, and presentation activities during the early cycles. Some students readily assumed tasks such as selecting images, arranging colors, and creating digital products, whereas others were more reluctant to take responsibility or had difficulty completing the tasks assigned to them. In one group, in particular, one student's reluctance to fulfill assigned responsibilities negatively affected the working process and communication of the other group members. As the intervention progressed, clearer task allocation and the rotation of presentation responsibilities contributed to more regular participation and improved task completion. Nevertheless, increases in responsibility and participation were not observed to the same extent among all students.

Group functioning and social interaction During the early weeks, students experienced difficulties related to task distribution, joint decision making, communication, and collaborative product development. In some cases, disagreements resulted in students not speaking to one another, neglecting their responsibilities, and failing to complete their products on time. The change observed over the course of the intervention was summarized in the journal as follows:

> *When students experienced disagreements within their groups, instances of not speaking to one another and not completing their tasks decreased over time; in the final weeks, students who had communicated little before the group work were observed to communicate more.*

As role allocation became clearer and leadership responsibilities were rotated, feedback from the researcher also helped groups organize joint decision making and task completion more systematically. During the later cycles, students resolved problems that had

emerged during the early weeks more quickly and managed the design process more effectively. However, Group 5 continued to experience disagreements and difficulties with joint decision making for a longer period. Ongoing communication problems and incomplete responsibilities prevented the group from completing two products and provided context for its comparatively low scores on the Structured Observation Form.

Engagement in peer presentations and feedback Students' participation in peer presentations became more active over time. The researcher noted improvements in students' listening and note-taking behaviors during presentations, suggesting that their engagement with peers' work increased as the intervention progressed.

> *While listening to their classmates' presentations, students write down their questions or newly learned words and do not interrupt the other groups' presentations.*

During later cycles, students not only listened to presentations but also began to comment on the accuracy of the information presented, the clarity of the explanation, and the visual quality of the posters. The researcher documented this change as follows:

> *While listening to other groups' presentations, students can express opinions about features such as aesthetics and the accuracy of the information included in the presentation.*

These entries indicate that peer participation developed from listening without interruption and noting new concepts into a more elaborated feedback process that evaluated information and product quality. Students' roles in peer presentations thus shifted from passive listening toward asking questions, taking notes, and making evaluative judgments.

Digital product development and aesthetic awareness The researcher journal showed that students incorporated feedback received during peer presentations into the posters they prepared in subsequent cycles. In the early cycles, students were mainly concerned with completing the products, whereas in the later weeks they paid more attention to details such as font type and size, image selection, the placement of text and images, text density, and the inclusion of the group name. The journal also indicated that students began to relate their color choices to the environmental topics addressed in the activities. For example, the researcher noted:

> *In the water pollution activities, students were observed to use predominantly blue tones and to attend to the integration of topic and design.*

As the intervention progressed, students increasingly considered not only aesthetic preferences but also the accuracy of the information presented and the consistency between visual elements and content. Accordingly, digital product development gradually shifted from simply completing the assigned poster to a more deliberate evaluation of informational accuracy, clarity, and visual coherence.

Overall, the researcher journal documented a broad progression from initial difficulties with basic computer use, uneven participation, task-allocation problems, and challenges in group communication toward more fluent technology use, greater consistency in task responsibility, stronger interaction within groups, more substantive peer feedback, and increased awareness of digital product features. Nevertheless, the continuing

communication and responsibility problems observed in Group 5 showed that this development was neither uniform nor continuous across all groups. The researcher journal was therefore used as complementary process evidence rather than as independent confirmation of the Structured Observation Form scores. Its findings helped contextualize the chronological increase in observation scores and the differences observed among the groups.

3.3 Mixed methods integration

To address the seventh research question, findings concerning academic achievement in environmental topics, environmental attitudes, social skills, and group-level implementation were integrated through a joint display. Quantitative results were compared with student interviews, structured observation scores, and process patterns in the researcher journal. Relationships among the data sources were evaluated in terms of convergence, complementarity, divergence, and qualification. The resulting meta-inferences are presented in Table 8.

The joint display in Table 8 indicates broad convergence between the quantitative and qualitative findings while also showing that the observed changes were not experienced in the same way by every student or group. Interviews and the researcher journal helped explain the learning and interaction processes within which the quantitative changes occurred, whereas structured observations documented the chronological development of implementation at the group level. Pre-existing environmental sensitivity, within-group disagreements, differences in basic computer use, and continuing difficulties in Group 5 qualified or contextualized the positive class-level means. Moreover, because topic and implementation order could not be disentangled in the increase in observation scores, that increase was not attributed solely to learning or Canva use. The qualitative and observational evidence was therefore interpreted not as independent confirmation of the quantitative changes but as complementary evidence explaining the processes and conditions under which those changes occurred. Because convergence across data sources does not eliminate the limitations of the one-group design, the findings indicate context-specific changes observed during a structured environmental education process in which Canva was one component, rather than the independent causal effect of Canva.

4 Discussion and conclusion

This study examined changes in fourth-grade students' academic achievement in environmental topics, environmental attitudes, and social skills following Canva-supported environmental education. The quantitative findings showed positive and large within-group changes in all three domains after the intervention. Student interviews, structured observations, and the researcher journal displayed patterns broadly consistent with these changes while also revealing the conditions under which the intervention was implemented and differences among participants.

This multidimensional pattern is consistent with reviews of K-12 research showing that environmental education may be associated not only with environmental knowledge but also with student outcomes such as attitudes, participation, social interaction, and academic learning [1]. Similarly, a meta-analysis of 169 studies involving children and adolescents found that environmental education could produce positive outcomes for environmental knowledge, attitudes, intentions, and predominantly self-reported

Table 8 Joint display of quantitative and qualitative findings

Outcome domain	Quantitative evidence	Qualitative and process evidence	Type of integration and meta-inference
Academic achievement in environmental topics	Mean achievement increased from 14.92 to 19.40 (mean change = 4.48; t(24) = 8.26; $p < .001$; dz = 1.65; Table 3).	All students reported that they perceived themselves as having learned new environmental information. Online inquiry, learning from peer presentations, and note taking were the main processes they described (Table 7). The researcher journal documented increasing attention to information accuracy.	Convergence with qualification: Achievement scores increased, and students also described perceived learning and specific learning experiences in the same general direction. The interview accounts help explain how students experienced the learning process, but perceived learning should not be treated as independent confirmation of test-based achievement. The combined evidence does not establish knowledge retention or Canva's independent effect.
Environmental attitudes	Significant posttest-favoring changes were found for all three subscales and the total score (all $p < .001$; $r = .88$; Bonferroni-adjusted $\alpha = 0.0125$; Table 4).	Twenty-three students reported greater attention to environmental problems, whereas two reported no marked change. Some students described pre-existing environmental sensitivity (Table 7).	Broad convergence with divergence: The quantitative change is consistent with most students' reports of increased environmental attention. Reports of no change and pre-existing sensitivity indicate that the class-level change was not experienced uniformly.
Social skills	Mean social skills increased from 59.92 to 70.12 (mean change = 10.20; t(24) = 9.02; $p < .001$; dz = 1.80; Table 5).	Twenty-two students reported that group work contributed to shared success, while three described within-group disagreement (Table 7). The journal showed that withdrawal from communication and incomplete tasks decreased over time, although these difficulties persisted longer in Group 5.	Convergence with qualifying divergence: The increase in social skills scores aligns with predominantly positive group experiences and improved communication documented in the researcher journal. Disagreements and persistent problems in Group 5 indicate that the positive mean did not reflect the same experience for every student or group. The scale and the process evidence capture related but distinct aspects of social functioning: the scale reflects a broader student-level construct, whereas the observations and journal document context-specific interaction within the classroom groups.
Group-level process and implementation conditions	Mean structured observation scores across the five intervention cycles were 26.2, 34.8, 40.8, 50.2, and 54.2, respectively. All groups received their lowest scores in the first cycle and their highest scores in the final cycle. Across the five cycles, group means ranged from 38.2 to 44.6, with Group 5 having the lowest overall mean (Table 6). Baseline digital literacy and individual computer-use time were not measured quantitatively.	The researcher journal documented a gradual shift from initial difficulties with basic computer use toward faster and more confident use of Canva, clearer task allocation, more detailed peer feedback, and greater attention to the quality of digital products. Most students also expressed positive views about Canva, although a small number reported difficulties or described their experience as neutral (Table 7).	The increase in observation scores was broadly consistent with the process-related changes documented in the researcher journal, indicating complementarity between the two sources. However, this pattern should be interpreted with caution because the order of topics and the implementation process changed simultaneously. Consequently, the observed increase cannot be attributed solely to learning or Canva use; growing familiarity with the tool, experience with group work and presentations, and increasing familiarity with the observation criteria may also have contributed. In addition, the composite observation scores represented group-level indicators of the implementation process rather than independent measures of individual achievement or social skills.

Note. Participants are identified as S1–S25. In the interview analysis, a student could be represented under more than one code. Structured observation scores are composite indicators of group-level processes rather than individual-level measures

behaviors, although effect sizes varied substantially across studies [40]. The changes observed in the present study were therefore interpreted within the structured learning process that combined content instruction, inquiry, collaborative product creation, presentation, feedback, and teacher guidance, rather than as outcomes produced by the digital tool alone.

4.1 Academic achievement in environmental topics

A large within-group increase in academic achievement in environmental topics was observed after the intervention. All students reported learning new environmental information, and the researcher journal documented information seeking, note taking during peer presentations, and increasing attention to information accuracy. These patterns were broadly consistent with the quantitative finding. The result also aligns with K-12 research indicating that environmental education can support not only subject-matter knowledge but also broader outcomes such as academic engagement and problem solving [1]. Previous studies have similarly associated activity-based environmental education in fourth grade with increased academic achievement [3, 19].

Creating digital products with Web 2.0 tools may have provided students with opportunities to select and organize environmental information, connect visual and verbal representations, and explain their learning to others [6]. From a generative learning perspective, reconstructing information through summarizing, visualizing, explaining, and teaching others can help integrate new knowledge with prior knowledge [15]. Digital poster creation may therefore have functioned not merely as the production of a visual artifact but as a process of selecting, organizing, explaining, and presenting information. The study by Ergül and Demirci Güler [13] with fourth-grade students likewise showed that learners can act not only as recipients of digital products on environmental topics but also as investigators, content creators, and sharers of their own products.

These mechanisms were not tested directly in the present study. Canva cannot be isolated as the sole explanation for the increase in academic achievement because the intervention was a composite learning process that included direct content instruction, online inquiry, repeated digital poster creation, peer presentation, feedback, and group work. The increase may therefore have been associated with Canva's visual organization affordances, but it may also have reflected repetition, teacher explanation, peer interaction, preparation for presentation, or time devoted to inquiry. In addition, the one-group pretest-posttest design did not permit the independent contribution of Canva to be tested or alternative explanations such as testing effects, maturation, and other classroom experiences to be ruled out. The finding should therefore be interpreted as evidence of within-group change after a structured classroom intervention in which Canva was one component, not as evidence of Canva's independent causal effect.

4.2 Environmental attitudes

Significant and large posttest-favoring changes were found for every environmental attitude subscale and the total score. In the interviews, most students reported paying greater attention to recycling, resource use, and environmental pollution. This convergence suggests that the attitude changes reflected in the scale scores were also apparent in how students made sense of their experiences with environmental issues.

The findings are consistent with studies linking active-participation environmental education to changes in knowledge and attitudes [3, 29]. The meta-analysis by van de Wetering et al. [40] likewise found that environmental education generally supported environmental knowledge and attitudes among children and adolescents. It also revealed substantial heterogeneity across the studies. This variation suggests that outcomes may be shaped not only by the tool itself but also by factors such as intervention duration, instructional activities, student characteristics, initial performance levels, and the broader educational context. Kayır and Akyol's [20] study with preschool children also suggested that environmental learning supported by digital storytelling tools may be associated with environmental attitudes and awareness. Because that study involved a different age group, a different digital tool, and a controlled design, its findings should be regarded as similar in direction rather than directly equivalent.

The two students who reported no marked change because they had already been environmentally sensitive before the intervention provide an important counterexample to the positive change reported by the majority. The intervention may have produced little perceived change for these students, or their initially high attitudes may have created a possible ceiling effect. Because individual baseline attitude distributions were not examined for this purpose, however, a ceiling effect could not be tested directly.

Increases in scale scores and students' self-reports do not by themselves demonstrate that pro-environmental behaviors became enduring. Although environmental knowledge and positive attitudes are important, behavior is influenced by multiple personal, social, and contextual variables [23]. Meta-analytic evidence suggests that the relationship between environmental attitudes and pro-environmental behavior is often influenced by factors such as behavioral intentions, perceived behavioral control, and personal norms [4]. Therefore, students' statements about practices such as recycling, conserving resources, and reducing noise can provide useful insights into how they understood and interpreted their learning experiences. However, whether these attitudes lead to actual behavioral changes and remain consistent across different settings cannot be determined from the present findings alone. Addressing this issue would require delayed follow-up measurements and direct observation of students' environmental behaviors.

4.3 Social skills and group processes

A substantial within-group increase in social skills was observed following the intervention, and 22 students reported that group work contributed positively to the quality of their products or to the success of their groups. The researcher journal also documented gradual improvements in role allocation, listening, communication, and presentation. This pattern is in line with previous research highlighting the contribution of structured participatory activities to social development [22], the importance of role sharing and interdependence in cooperative learning [34], and the inherently social nature of environmental learning [41].

Social interdependence theory suggests that simply placing students in groups does not automatically lead to effective cooperation. Productive group work requires conditions such as positive interdependence, individual accountability, promotive interaction, social skills, and group processing to be deliberately established [18]. In the present study, the shared task of designing a digital poster and presenting it to the class may

have provided a common goal and created task interdependence among group members. Likewise, dividing responsibilities for inquiry, information selection, visual organization, and presentation required students to communicate, coordinate their efforts, and contribute to a common product.

Conversely, three students reported within-group disagreement, some responsibilities were not completed, and Group 5 obtained lower observation scores than the other groups. These negative and divergent cases indicate that bringing students together around a shared product does not automatically generate effective collaboration. Clear roles, rotating leadership, monitoring of individual accountability, conflict management, and sustained teacher guidance are therefore important in group-based digital production.

The structured observation scores combined group functioning with the digital poster production process and therefore cannot be treated as independent external validation of the Social Skills Scale results. The two forms of evidence also operated at different levels: the scale assessed a relatively broad student-level construct, whereas the structured observations and journal entries captured context-specific behaviors within particular collaborative classroom situations. Agreement across these sources therefore does not imply that they measured the same phenomenon in the same way. Rather, the process evidence provides complementary context for understanding how broader changes in students' social-skills scores were expressed, and in some cases not expressed, within group interaction.

4.4 Canva use and implementation conditions

Students generally evaluated Canva positively. However, both the interviews and the researcher journal showed that the initial difficulties students experienced were not limited to Canva itself. Some students also had limited experience with basic computer operations, including using the mouse and keyboard and managing files. This distinction is consistent with research emphasizing the roles of perceived ease of use, digital competence, and self-efficacy in digital learning processes [8, 16, 31].

Being exposed to digital technologies from an early age does not necessarily mean that students have the skills needed to use educational digital tools effectively. Research challenging the "digital native" assumption suggests that familiarity with technology should be distinguished from the ability to search for and evaluate information, create digital content, and use digital tools for learning [21]. The initial difficulties observed in the present study similarly suggest that students' digital skills should not be inferred solely from their age or previous exposure to technology.

Canva was used as one component of a structured instructional process involving online inquiry, collaborative digital poster creation, presentation, and feedback. The findings therefore do not imply that the tool is inherently motivating or effective; rather, they suggest that Canva may support environmental education when integrated with appropriate instructional activities, adequate access, and teacher guidance. Providing two computers to each five-student group may have encouraged collaborative production, but limited device access may also have reduced some students' direct participation time. This possibility could not be tested because individual computer-use time was not recorded. Similarly, because baseline digital literacy was not measured, the contribution

of differences in computer use to product quality or learning outcomes could not be evaluated quantitatively.

These findings support the use of a brief diagnostic activity to assess basic digital skills before technology-supported classroom interventions and the continued provision of support for file management, keyboard and mouse use, reliable information searching, and visual organization. Such support can help the digital tool mediate students' investigation, organization, and communication of environmental knowledge rather than becoming an additional barrier to learning.

4.5 Integration of quantitative and qualitative findings

The joint display showed broad convergence between the quantitative and qualitative findings. The increase in academic achievement was broadly consistent with students' reports that they had learned new environmental information and with journal evidence of information searching, note taking, and increasing attention to information accuracy. Students' reports reflected perceived learning rather than a second measure of achievement and were therefore used to contextualize, rather than verify, the test results. Changes in environmental attitudes were consistent with most students' reports of greater attention to environmental problems, while the increase in social skills was consistent with predominantly positive evaluations of collaborative work and improved group communication over time.

The qualitative evidence also revealed important differences that could not be captured by the quantitative results alone. Some students were already environmentally sensitive before the intervention; groups experienced disagreements and unequal sharing of responsibility; students differed in basic computer use; and teacher support remained necessary. These conditions showed that the positive change in class means was not experienced uniformly. The qualitative and observational findings were therefore interpreted as complementary evidence explaining how change was experienced and under which conditions it varied, rather than as independent confirmation of the quantitative change.

The integrated result is more than an increase across three scale scores. Changes occurred within a recurring learning cycle of content instruction, inquiry, collaborative production, presentation, and feedback. Within this cycle, selecting and explaining information may have supported academic learning, generating solutions to environmental problems may have supported attitudinal engagement, and responsibility for a shared product and presentation may have supported social interaction. These are explanatory meta-inferences derived from considering the quantitative and qualitative findings together, not directly tested mediating mechanisms.

Convergence across data sources does not remove the limitations of the one-group design. Interviews, observations, and journal entries were generated in the same implementation context and largely by the same researcher, meaning that these sources were not fully independent. The joint display therefore does not establish the independent causal effect of the Canva-supported intervention; it provides a more integrated yet context-dependent explanation of classroom change, possible processes underlying that change, and implementation conditions.

5 Limitations

The findings should be considered in light of several limitations. First, the study involved a small convenience sample of 25 fourth-grade students from a single public school. Statistical generalization to other schools, regions, and student populations is therefore limited. The purpose was to explain change and implementation within a specific classroom context rather than to achieve statistical generalization.

Second, the absence of a control group and random assignment limits causal inferences that the observed changes resulted from the intervention. Familiarity with the tests, maturation, teacher attention, and other classroom experiences could not be excluded as alternative explanations. Moreover, because the intervention combined several instructional components, Canva's contribution could not be separated from content instruction, inquiry, group work, presentation, and feedback.

Third, the same researcher served as implementer, observer, journal writer, and interviewer, which may have introduced expectancy effects, participant reactivity, and social desirability. No independent observer was used for the structured observations, and interobserver agreement was not calculated. The 91.2% agreement reported for the qualitative analysis represents intrarater consistency between coding and recoding by the same researcher one month apart, not agreement between independent coders. In addition, the Structured Observation Form combined group-work and Canva-production criteria within a single composite score. The resulting score therefore cannot distinguish whether the chronological pattern primarily reflected changes in group functioning, increasing familiarity with digital production, or a combination of the two. Similarly, the broad construct assessed by the Social Skills Scale does not correspond directly to the context-specific collaborative behaviors documented through classroom observations and journal entries.

Fourth, environmental attitudes and interview data were based largely on students' self-reports. Although these data provide insight into students' perceptions and experiences, they do not directly indicate whether pro-environmental behaviors were actually practiced across different settings or maintained over time. Since no delayed posttest or follow-up observation was conducted, the persistence of changes in academic achievement, environmental attitudes, and social skills cannot be determined.

Finally, students' baseline digital literacy was not assessed, and access to computers and individual participation time were not systematically recorded. Therefore, the potential effects of basic computer skills, shared device use, and prior experience with Canva on the study outcomes could not be examined.

6 Recommendations

6.1 Recommendations for practice

Based on the findings of the study, the following recommendations are offered for educational practice:

- Canva and similar Web 2.0 tools should be integrated into environmental education through carefully planned, pedagogically grounded activities rather than being used as standalone technological additions.
- Prior to digital design-based learning activities, students should be supported in developing basic computer skills and digital literacy to ensure equitable participation.

- Group work should be structured through clear role distribution and teacher-guided scaffolding to support effective collaboration and reduce potential conflicts.
- Digital environmental education activities should be complemented with nature-based and experiential learning opportunities to strengthen real-world connections.

6.2 Recommendations for future research

Future research may extend the present study in several ways:

- Similar studies can be conducted with different grade levels and a wider range of environmental topics.
- Experimental or quasi-experimental designs incorporating control groups can be employed to further examine causal effects.
- Long-term and longitudinal studies can investigate the sustainability of observed changes in environmental knowledge, attitudes, and behaviors.
- Further research may explore the relationship between students' digital literacy levels and the effectiveness of digital design-based learning in environmental education.

Author contributions
This study was derived from A.Y.'s master's thesis conducted under the supervision of R.S. R.S. and A.Y. designed the study. A.Y. collected the data and performed the analyses. R.S. wrote the manuscript text and prepared the figures. All authors reviewed and approved the final manuscript.

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Data availability
The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request. The data are not publicly available due to privacy and/or ethical restrictions.

Declarations

Ethical approval
Ethical approval was obtained from the Gazi University Ethics Committee (No. 2023 – 1387; November 24, 2023), and implementation permission was obtained from the Kastamonu Provincial Directorate of National Education.

Consent to participate
Written informed consent was obtained from parents or legal guardians, and assent was obtained from the students. Consent and assent included audio-recording of the individual interviews. Participation was voluntary, and students were informed that they could withdraw without adverse consequences.

Consent for publication
Not applicable. The manuscript contains no identifiable participant information or images.

Competing interests
The authors declare no competing interests.

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